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Carbon footprint and energy use of transport in the supply chain of pulses for Swedish human consumption

– Klimatavtryck och energianvändning av transport av baljväxter för svensk humankonsumtion

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Abstract

Transport play a key role in the global economy. Through international trade characterized by large scale, long distances and complex distribution systems, consumers have access to a wide range of products from all over the world. Transport is associated with use of fossil energy and climate impacts and to lower the emissions from foods, a holistic perspective of product's life cycles is of large importance.

The aim of this study was to quantify the energy use and carbon footprint for transport of imported and domestic dry and industrially cooked (canned) pulses from origin to a grocery store in Stockholm, Sweden. Thus, to begin with, origin, typical transport modes and routes were mapped for 100 products found in Swedish grocery store in 2020. Information was obtained through contact with 12 food actors who market prevailing brands in Swedish grocery stores as well as contact with several other actors within the supply chain of pulses such as sourcing and traffic managers. Energy use and carbon footprint was calculated for 38 routes based on the most frequently stated transport routes from six countries including Swedish products. The tool *NTMCalc Advanced 4.0* was used to calculate emissions and energy use for transport by truck, container ships, ro-ro ships, electrical and diesel trains. Furthermore, a literature study was carried out to compare energy use and carbon footprint of transport with the cultivation stage in the supply chain to further discuss the role of transport.

The result showed that the Swedish consumption of pulses is heavily dependent on long-distance supplies from China followed by USA, Canada, Turkey and Italy. Typical routes for pulses to be sold canned were transport via Italy to Sweden whereas dry produce was often transported to the Netherlands, Denmark, Germany or England. Trucking was the most common stated mode of vehicle for transports within Europe for both canned and dry pulses. Canned produce was shipped more frequently by boat and train to Sweden compared to dry produce. Transport of pulses from China and USA canned in Italy had the highest carbon footprint and energy use whereas dry domestically produced Swedish beans and lentils had the lowest contribution. The carbon footprint from transport varied from 0.014-0.49 kg CO_2e and 0.20-7.0 MJ per kg cooked product. Large variations depended on whether the product was transported dry or canned and which mode of transport that was used. Fairly small distances on mainland, in relation to the whole distance from origin to point-of-sale, can contribute significantly to the greenhouse gas emissions and energy demand. Therefore, a shift towards less polluting vehicles (*e.g.* trains) can make a large difference for the total impacts of a route. Other important measures for reducing the impact of current distribution system were: consolidated shipments, collaboration between actors, vehicles with large loading capacity, high vehicle utilization (weight and volume) and the usage of rectangular shapes of primary cartons to increase space utilization. Moreover, the most important measure for less impacts in terms of carbon footprint and energy use from transport is short efficient transport of dry pulses from origin to point-of-sale and thus, local sourcing of pulses is by far the most efficient way to lower the impacts of transport.

Keywords: transport, pulses, carbon footprint, energy use

Sammanfattning

Transport spelar en nyckelroll i den globala ekonomin. Genom internationell handel som kännetecknas av stor utbredning, långa avstånd och komplexa distributionssystem har konsumenter tillgång till ett brett utbud av produkter från hela världen. Transport är förknippad med användning av fossil energi och miljöpåverkan och för att minska utsläppen från livsmedel är ett helhetsperspektiv av produkters livscykel av stor betydelse.

Syftet med denna studie var at kvantifiera energianvändningen och koldioxidavtrycket för transport av importerade och inhemska torra och industriellt kokta (konserverade) baljväxter från odling till en livsmedelsbutik i Stockholm, Sverige. Till att börja med kartlades ursprung, typiska transportmedel och rutter för 100 existerande produkter i svenska livsmedelsbutiker 2020. Denna information erhölls genom kontakt med 12 livsmedelsaktörer som marknadsför ledande varumärken i svenska livsmedelsbutiker samt kontakt med flera andra aktörer inom värdekedjan för baljväxter såsom inköps- och trafikchefer. Energianvändning och koldioxidavtryck beräknades för 38 rutter baserat på de vanligaste transportvägarna från sex länder inklusive svenska produkter. Verktyget *NTMCalc Advanced 4.0* användes för att beräkna utsläpp och energianvändning för transport med lastbil, containerfartyg, färjor, elektriska tåg och dieseltåg. Vidare genomfördes en litteraturstudie för att jämföra energianvändning och koldioxidavtryck från transporter med odlingen i värdekedjan för att diskutera transportens roll.

Resultatet visade att den svenska konsumtionen av baljväxter är starkt beroende av långväga transport från Kina följt av USA, Kanada, Turkiet och Italien. Typiska transportvägar för konserverad vara transporterades via Italien till Sverige medan torr vara ofta transporterades till Nederländerna, Danmark, Tyskland och England. Lastbil var det vanligaste angivna transportmedlet inom Europa för både konserverad och torr vara. Konserverade produkter transporterades oftare med båt och tåg till Sverige jämfört med torra produkter. Transport av baljväxter från Kina och USA som konserverades i Italien utgjorde högst koldioxidavtryck och energianvändning medan svenskodlade torra bönor och linser hade lägst andel. Koldioxidavtrycket varierade från 0.014-0.49 kg CO_2e och 0.20-7.0 MJ per kg kokad vara. Stora variationer berodde på om produkten transporterades torr eller konserverad och vilket transportmedel som användes. Relativt små avstånd på fastlandet, i relation till hela avståndet från odling till butik, bidra väsentligt till växthusgasutsläppen och energianvändningen. Därför kan en övergång till mindre förorenande fordon (*t.ex.* tåg) göra stor skillnad för den total miljöpåverkan från en transportväg. Andra viktiga åtgärder för att minska miljöpåverkan av det nuvarande distributionssystemet var: konsoliderade transporter, samarbete mellan aktörer, transporter med hög lastningskapacitet, hög fordonsutnyttjande (vikt och volym) och användning av rektangulära former av primärkartonger. Den viktigaste åtgärden för mindre miljöpåverkan i form av koldioxidavtryck och energianvändning för transporter är dock korta effektiva transporter av torkad vara från odling till butik och därmed är inköp av svenskodlade baljväxter det överlägset mest effektiva sättet att minska transporters klimatpåverkan.

Nyckelord: transport, baljväxter, klimatavtryck, energianvändning

Popular science summary

Today consumers have access to a wide range of cheap goods and services thanks to international trade. This would not have been possible without a well-developed international transport system. As all human activities, transport comes with climate impact and food transports are expected to increase in the future along with globalization, increased welfare and a growing population. Many different solutions are needed to meet the challenges of reducing greenhouse gases into the atmosphere. One of the solutions in Western societies is a dietary transition towards more plant-based foods. To lower the impacts even further for plant-based products, different stages in the supply chain needs to be scrutinized.

This study focused on the carbon footprint and energy use of transport of pulses for Swedish human consumption. How and from where are pulses transported to Sweden? Carbon footprint and energy use from transports was quantified with a calculating tool from the Network for Transport Measures, NTM. A total of 100 products was studied of imported and domestic dry and canned pulses. External actors in the supply chain were contacted to get a deeper understanding of the transport system.

The supply of beans in the Swedish grocery store was found to be transported far distances from mostly China and all products to be purchased canned were transported via Italy to Sweden whereas dry pulses were transported mostly to the Netherlands and Germany. Lentils were mainly originating from Turkey and Canada and chickpeas from Italy. The dominant vehicle mode for transports within Europe was by truck and large variations in terms of climate impact depended on if the product was transported dry or canned and what type of vehicles that was used. The results showed that transport emissions from dry imported pulses were 3-4 times lower on average compared to transport of canned produce and thus, transport of dry produce is a large mitigation option to lower the climate impacts along with high vehicle utilization, higher vehicle capacities (larger vehicles or containers/trailers) consolidated shipment and collaboration between actors. Least climate impact came from domestic produced Swedish pulses purchased dry and thus, local sourcing of Swedish pulses is a great option for lowering the impact of transport in the supply chain of pulses.

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1. Introduction

Over the last century, a global food distribution system has been built that allows products to be transported all over the globe. More than 5 000 container ships and 20 million container boxes circulates between continents, serviced by road, rail and inland barges (Martin *et al.* 2019) and some food travels thousands of miles before reaching its end consumer (Weber & Matthews, 2008; Wakeland *et al.* 2012).

Today's food supply chain accounts for approximately 1/4 of the world's greenhouse gas (GHG) emissions caused by human activity, causing detrimental changes of terrestrial and marine ecosystems (Poore & Nemecek 2018; Willett *et al.* 2019). Nevertheless, transports are often brought up as a fairly small contributor of a product's total emissions as other stages in the supply chain, particularly from land use change and processes at the farm, commonly has a higher climate impact for many food products (Weber & Matthews 2008; Eady *et al.* 2011; Clune *et al.* 2017). Meat has for example large shares of emissions coming from the production which makes the share from transport rather low (10–20%) of its total carbon footprint whereas production of vegetables and fruits requires less resources and therefore have a higher share (40-70%) in terms of transport emissions (Weber & Matthews 2008; Knudsen *et al.* 2011; Wakeland *et al.* 2012). However, emissions from transports do not only depend on product category and its transport distance but also how efficient the transports are in term of loadings and mode of transport. Plant-based diets are brought up as sustainable dietary options with 10-50 times less carbon footprint compared to animal-based products (Röös *et al.* 2017; Poore & Nemecek 2018) but yet, the climate impact of vegetable's full supply chain is far from being completely scrutinized (Frankowska *et al.* 2019). To attain a sustainable food system, a dietary shift towards more plant-based proteins is important (Röös *et al.* 2017). Pulses play an important part in such transition, being a good source of protein with several health and environmental benefits (Röös *et al.* 2018; Willett *et al.* 2019). Plants of the legume family have the ability to fix nitrogen (N) from the air via soil bacteria, reducing the total need of N fertilisation (Jensen *et al.* 2012, 2020; Kumar *et al.* 2020) but also stimulates the productivity of next coming crop as it increases N in the soil (MacWilliam *et al.* 2014; Preissel *et al.* 2015). Hence, legumes have the potential to improve the environmental sustainability of cropping systems.

In Sweden, the sales of pulses has increased during the past decade (Amcoff *et al.* 2012; The Swedish Food Retailers Federation 2016) and the current supply origin from many different continents. However, the climate impact of pulses of these origins for the Swedish market is not covered in existing studies (Fuentes *et al.* 2006; González *et al.* 2011). As consumption patterns changes over time, there is a need of an update. Against this background, this study is giving an updated snap shot of existing products in Swedish grocery stores, their cultivation sites and the major geographical routes of imported pulses to Sweden, in order to estimate the carbon footprint and energy use for these transports.

1.1. Aim

The aim of the study was to quantify energy use and carbon footprint of transport for common imported and domestic pulses for human consumption in Sweden by mapping origin, typical routes and transport modes. Furthermore, the aim was to compare the impacts of transport with the cultivation stage in the supply chain and discuss important actions for more sustainable transport.

2. Background

This chapter introduces the role of pulses within the food system and the transport system that makes it possible to import products from overseas. Furthermore, an overview of the climate impacts from different stages in the supply chain is presented with focus on transport operations, cultivation and production of packaging material.

2.1. Consumption of pulses

Pulses plays an essential role in the diet of millions of people, not least in low-income countries where they can be an important protein source in an otherwise cereal-based diet (Nedumaran *et al.* 2015; Del Borghi *et al.* 2018). The term *Pulses* refers to dry edible seeds for human consumption from plants in the legume family excluding seeds for oil extraction (FAO 2020). G*rain legumes* is another common term for dry edible seeds but includes seeds from oil plants *i.e.* soy beans and groundnuts (MacWilliam *et al.* 2014). There exists about 1300 species of legumes of which only 20 types of legumes are commonly consumed by humans *i.e.* peas (*Pisum sativum*), common beans (*Phaseolus vulgaris*), lentils (*Lens culinaris*), soybeans (*Glycine max*), peanuts (*Arachis hypogaea*) and chickpeas (*Cicer arietinum*) (Reyes-Moreno *et al.* 1993). According to FAO, there has been a slow and steady decline of the global intake of pulses in both developed and developing countries, remaining around 7 kg per person/year on average in the world (FAO 2016). However, as an interest for sustainable and healthy foods as well as vegetarian and vegan diets have taken form (The Nielsen Company 2016), especially in the Global North, a positive trend with higher intakes of pulses can be expected (Schneider 2002; Röös *et al.* 2018). The largest consumer of pulses is the Indian subcontinent whereas the lowest consumption takes place in Europe and the EU where Spain, France and the UK consumes more than 50% of the total consumption in the EU (Schneider 2002). There are various ways in how pulses are consumed which depends on regional food habits, traditions and market supply in each country. The sale within Europe generally dominates by industrially cooked and packaged products (hereafter referred to as *canned*) (Ibid.).

In Sweden, the average consumption of pulses in a large survey made 2010-2011 was 12 gram per person per week (Amcoff *et al.* 2012). Today, one could assume an increase of the average Swedish intake as data from Swedish grocery stores reveals an increase of 34% for dried peas and beans and an 27% increase for canned beans during the period 2011-2016 (The Swedish Food Retailers Federation 2016). Of these products, many come from China, Canada and Turkey (Ekqvist *et al.* 2019).

2.2. Major cultivation regions of pulses

Between 2017-2018, the largest producing countries of beans, peas, chickpeas and lentils in the world were India, Canada, Australia, Brazil, China and Russia (FAOSTAT, 2020). According to Statistics Sweden (2019), Sweden imports large quantities from The Netherlands, Belgium, UK and Turkey, even though cultivation of pulses only covers less than 2% of the agricultural land in Europe (Watson *et al.* 2017). The reason for this somewhat contradicting information partly has to do with imbalanced registrations of cargoes. For example, some foreign containers that are shipped and reloaded at the port of Rotterdam are listed as import from The Netherlands in Swedish statistics (Oker-Blom 2019). Furthermore, Turkey and other countries import *e.g.* lentils for processing to export (Yadav, 2007). Hence, Swedish statistics do not tend to give a correct overview of the origin of the imported product.

In Sweden, pulses were grown on approximately 1.5% of the total area of cropland in 2019, represented by mainly faba beans (18 000 ha) and yellow dry peas (20 000 ha) (Statistics Sweden 2019a; b). Large quantities are used as animal feed (80%) whereas pulses for human consumption accounts for 20% where only 3% goes to Swedish human consumption and the rest for export (New Legume Foods 2020). The area of cultivation of common beans is mainly restricted to Öland (an Island in the Baltic Sea) where brown beans have been traditionally grown for a long time (KÖTP 2020). Fairly recently, other common bean varieties *i.e.* kidney beans, black beans and borlotti beans are also grown in the area of Öland whereas lentil cultivations has been introduced in the south part of Sweden (Skåne county) and the island of Gotland. Peas are grown in several places, mostly in the middle and the south parts of Sweden, *e.g.* around the area of Öland, Gotland, Skåne and Östergötland county. About 40 growers on Öland delivers beans to Kalmar-Öland trädgårdsprodukter (KÖTP), which is the largest Swedish association owned by farmers handling common beans in Sweden. Most of the Swedish production of pulses is handled by KÖTP (mostly beans) and Lantmännen Cerealia (mostly peas). In addition, in 2016 a smaller actor (Nordisk Råvara) entered the market, offering unusual varieties of mostly organic lentils and peas to the catering industry as well as private customers.

2.3. Food distribution

Today's food system includes transportation of products by water, rail, road and air. The scale is massive of which the food transportation system operates on and products are distributed far distances globally and nationally (Wood *et al.* 2018). The distribution chain is often a complex network of multiple actors. However, three collaborating key roles enables the distribution (Swahn *et al.* 2019). These are (1) *the shipper* who request the transport (2) the *logistic service provider/forwarding agent* who plan the logistics and (3) the *carrier* who performs the physical transport *i.e.* haulers, train operators and other shipping companies. To better understand the transport system for food, a brief background history and a few important terms are presented below in 2.3.1-2.3.4.

2.3.1. Integrated transport systems and containerization

A thorough description of the development and performance of the global transport system is given by Rodrigue (2020). It was not until the mid-20th century that separate transport systems all over the world started to integrate, laying the ground for the global transportation system of today. Improved technology, coordination of new relationships among freight forwarders and operational and regulatory changes gave rise to an intermodal transport system where passengers and goods could be shipped by several different transport modes linked from point A to point B. The transport system was built around a standard unit of 20 or 40 feet metal containers which could be used on *e.g.* inland barges, trucks, ships and trains. Rodrigue (2020) further describes that the container not only protects the goods during transport, it also reduces labor and packaging costs, as the same container could easily be used by vehicles at different international sea ports around the world. The intermodal transport system and the global use of the standardized containers (containerization) paved the way for the present large-scale cross-border trade according to Rodrigue (2020) and today, 90% of all non-bulk products on the global market are transported in standardized containers. Also in the future, the trend of containerization is expected to grow.

2.3.2. Regulation on weights and dimensions of trucks

Each country has its own national laws for maximum authorized truck dimensions and weights to make sure that infrastructure such as roads and bridges are not damaged (Schmidt *et al.* 2018). Within the European countries, directives for international traffic are given by the European Parliament and European Council but each country has the responsibility to transfer the directives into suitable national laws. Hence, regulations can vary between countries.

The maximum gross vehicle weight (the total weight of the truck and its total load) given by Directive 96/53/EC and Directive (EU) 2015/719 for trucks driving on European roads is 40-46 ton depending on length, number of axles and distance between axles on the truck (European Commission 1996, 2015). Sweden stands out among the European countries, permitting a total of 60 ton gross vehicle weight on 95% of the public road network (The Swedish Transport Administration 2020). The current regulated maximum weight is 64 ton in Sweden but some roads (mostly in the north for the forestry industry) allows 74 tons gross weight. Trucks with trailers distributing food products from *e.g.* Italy to Sweden typically have a cargo weight around 24-24.5 ton to not exceed the general European limit of approximately 40 ton gross vehicle weight while cargos shipped by rail have a cargo weight up to 29 ton (Jönsson 2020, pers. comm. 14 April).

2.3.3. Food distribution within Sweden

The majority of groceries coming from abroad is transported to the colonial storages of the three main retailers in Sweden which are ICA, Axfood and COOP (Oker-Blom 2019). These storages are located in the south and the middle part of Sweden around Helsingborg, Gothenburg and Västerås. Import of fresh fruits and vegetables which require cold storage usually arrive at Port of Helsingborg whereas colonial goods *i.e.* coffee and pulses often arrive at port of Gothenburg. Hence, the most frequent routes for imported food products are Helsingborg/Gothenburg to Västerås/Mälardalen. Of these transport operations, food products are transported mainly by truck (95%) followed by rail (3%) and boat (2%) (Ibid.).

2.4. Climate impacts of transport

2.4.1. Carbon footprint and energy use

Life cycle assessment (LCA) is a widely used tool for valuing and communicating the ecological burdens of chosen impact categories throughout the life span of a product or process (Baumann 2004; Poore & Nemecek 2018). Eutrophication, acidification, particles and noise are examples of impact categories in LCA in terms of transport. Chosen impact categories in this study are energy use and the carbon footprint.

Carbon footprint calculates the emissions from an activity and is commonly expressed in the amount of carbon dioxide or its equivalent in other GHGs. Carbon dioxide equivalents (CO_2e) takes into account that different GHGs have different abilities to contribute to global warming. Hence, CO_2e represent the sum of the climate gases CO_2, methane (CH_4) and nitrous oxide (N_2O) where each gas is weighed in relation to CO_2 according to its effect on the climate during a defined time period (Penman *et al.* 2000), also referred to as Global Warming Potential. For example, emissions for moving a specific weight of cargo over a certain distance can be expressed in kg CO_2e per ton-km.

Energy use involves the transition of energy to machines from solid, liquid and gas energy sources (Rodrigue, 2020). In LCA, energy use is often expressed in energy demand in MJ.

2.4.2. Climate impacts of different modes of transport

The climate impact in terms of energy consumption and CO_2 emissions, varies for different modes of transport (Knudsen *et al.* 2011; Wakeland *et al.* 2012; Behdani *et al.* 2014). Type of vehicle, its size and the power source are crucial factors which affects the environmental burdens during transport. The energy demand and carbon intensities of some of the different types of vehicles used in this study are given in Table 1. Of these types of vehicles, emissions from trucks (34-40 ton) are about four times higher compared to large containerships (international waters) carrying the same export/import container. Transport by rail and water have the lowest contributions. Emissions from electrical trains depends on what type of feedstock that is used *e.g.* coal, uranium, oil, gas, biomass and wind and hydropower. European mix of energy is based on weighted average production among EU countries and the Swedish energy mix has lower emissions compared to the EU mix according to NTM. Furthermore, energy consumption includes energy for production, transmission and distribution of fuel (well to tank) and energy for vehicle consumption of the fuel (tank to wheel).

Table 1. Energy (MJ) and emissions (CO_2e) per ton kilometer by Network for Transport Measures

Type of vehicle	kg CO_2e per ton-km	MJ per ton-km
Containership, 160 000 dwt	0.017	0.22
Containership, 40 000 dwt	0.023	0.29
Truck, 14-20 ton[a]	0.123	1.77
Truck, 34-40 ton[b]	0.073	1.07
Truck, 50-60 ton[c]	0.068	0.98
Train, electric EU[d]	>0.015	0.31
Train, electric SWE[e]	0.00023	0.11
Train, diesel[f]	0.015	0.22

[a]Average road type, Euro 6 motor, Diesel B7 – SWE fuel type
[b]Motorway road type, Euro 4 motor, Diesel B5 – EU fuel type
[c]Average road type, Euro 6 motor, Diesel B7 – SWE fuel type
[d]European railways supply mix electricity source EU 27
[e]Swedish railways supply mix electricity source
[f]Diesel B0 – EU fuel type with no biodiesel added

2.4.3. Empty containers and cargo load factor

Two key factors which affects the efficiency of transport are the utilization of space inside the container (cargo load factor) and transportation of empty containers (also referred to as backhaul). Transport of empty containers occurs because of structural imbalances in the circulation of containers when for example more fully loaded containers come to Western Europe from China than fully loaded containers return to China (Swahn 2020). Transport of empty containers is a large issue in the shipping industry (Palmer *et al.* 2018; Shi & Taylor 2018; Swahn 2020) and numerous of reports have been carried out to propose measures for reducing empty backhaul rates within the food sector (The Swedish Transport Agency 2011; Shi & Taylor 2018; Oker-Blom 2019). According to Palmer *et al.* (2018), the amount of empty vehicles has hardly changed over a recently measured 10 years period ranging from 24-28% empty running road vehicles within the EU. Transportation of empty containers is a waste of energy and even though fully loaded containers requires more fuel compared to nearly empty ones – the majority of energy goes to moving the actual vehicle rather than its cargo (Wakeland, 2012). This links with the term *cargo load factor*, which represents the percentage of the volume or weight that is actually utilized inside the transporting vehicle or a container. To fully make use of a vehicle, its maximum weight load and volume capacity needs to be utilized. Within the EU, utilization by weight is around 54-57% according to Palmer *et al.* (2018).

2.5. Climate impacts of different stages in the supply chain of pulses

This study focused on the carbon footprint and the energy use of the transport stage. However, it is crucial to remember that each stage in the supply chain contributes to additional environmental burdens *i.e.* land use occupation, biodiversity loss, aquatic, ecological and human toxicity etc. In order to ease the comparison for latter discussion in this thesis, energy use and carbon footprint will be focused upon in the following chapter when introducing the remaining stages in the supply chain of pulses and its climate impacts.

Farm production

Energy use and GHG emissions from the production stage are linked with activities such as manufacture of inputs *e.g.* production of machinery, seed, fertilizer, pesticides etc. and fossil energy consumption for field operations, irrigation systems and storage. These practices lead to varying burdens depending on *e.g.* growing conditions, production system (organic/conventional growing principles), seed varieties etc. (Abeliotis *et al.* 2013; Krüger Persson 2019). As for many other field-grown vegetable crops, common hotspots in the production of pulses in terms of GHG emissions are N_2O from field applications of manure, plant residues and synthetic fertilizers as well as CO_2 emissions from fossil energy used by field machineries (Abeliotis *et al.* 2013; Röös *et al.* 2018; Broekema & Smale 2011) and irrigation systems in dry cultivation sites (Abeliotis *et al.* 2013; Del Borghi *et al.* 2018).

GHG emissions for producing one kg dry pulses within Europe is in general much less than 1 kg CO_2e/kg product (Table 2). Compared to other protein sources, the carbon footprint from on-farm production is approximately 30, 10 and 13 times higher for Swedish conventional feedlot beef, pork and packed cheese respectively, compared to conventional brown beans cultivated in Sweden including transport from farm gate to Port of Gothenburg for all mentioned products (González *et al.* 2011). The following table show greenhouse gas emissions and energy use for cultivation of dried pulses. GHG emissions from pulse cultivation ranges from 0.26 kg CO_2e/kg for lentils to 0.80 kg CO_2e/kg for chickpeas. The energy use varies from 1.6 MJ/kg for lentils to 2.9 MJ/kg for beans.

Table 2. Energy demand and GHG emissions arising on the farm using organic (org.) or conventional (conv.) growing principles

Commodity	**GHG kg CO_2 e/kg product**	**Energy used MJ/kg**	**Cultivation site**	**Reference**
Common beans	0.41	2.9	Sweden, conv.	Krüger Persson, 2019
Lentils	0.26	2.1	Sweden, org.	Krüger Persson, 2019
Chickpeas	0.45	1.6	Italy, conv.	Del. Borghi et al. 2017
Beans	0.58	1.9-2.0	Italy, conv.	Del. Borghi et al. 2017
Plake beans	0.30		Greece, conv.	Abeliotis et al. 2013
Plake beans	0.44		Greece, org.	Abeliotis et al. 2013
Field peas	0,40		Australia, conv.	Eady et al. 2011
Beans	0.61		Europe, conv.	Audsley et al. 2010
Chickpeas	0.77		Europe, conv.	Audsley et al. 2010
Chickpeas	0.80		World, conv.	Audsley et al. 2010

Processing

Pulses undergo several processing steps before taking its final form which the consumer buys (Yadav, 2007; Rawal, 2019). Some of the processing activities takes place early in the supply chain *i.e.* winnowing, drying, color sorting, cleaning, splitting and polishing whereas other activities come about later *i.e.* soaking and boiling/cooking. All procedures require its own mechanical equipment that are run by non-renewable or renewable energy sources (Del Borghi *et al.* 2018). Furthermore, different types of pulses require different amount of resources *e.g.* water and electricity for processing etc. Hence, environmental burdens of processing of different pulses can be much varying, depending on type of pulse, energy source that is used. For example, a study carried out by Del Borghi *et al.* (2017) includes impacts from cradle to factory gate plus disposal within Italy. The distribution of GHG emissions and non-renewable energy demand (NRED) is presented in Figure 1 for canned borlotti beans cultivated in Italy packed in 400 g tin-plated steel containers. The diagrams show that impacts from the processing stage is small in relation to the packaging stage, in terms of total impact when transport is not included.

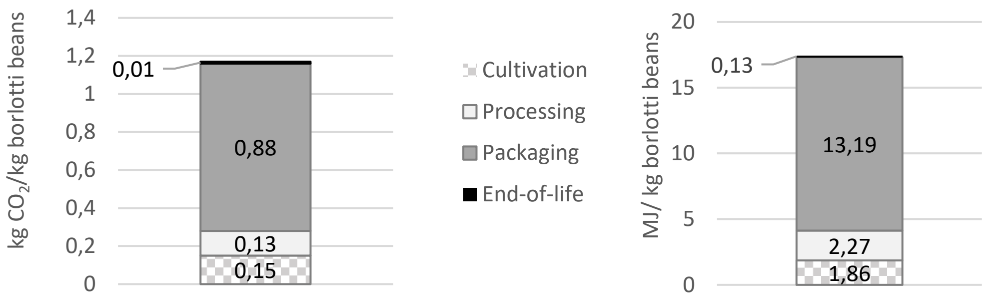

Figure 1. GHG emissions and NRED for canned (in 400 g tin-plated steel cans) borlotti beans cultivated in Italy

During the canning process, pulses are first soaked, blanched in hot water or by using steam heat and thereafter packed in containers together with a canning medium commonly based on water, salt, sugar and ascorbic acid (Clark *et al.* 2014; Del Borghi *et al.* 2018). Lastly, filled containers are sterilized at high temperatures to kill off potential pathogenic organisms and spores which require heat resisting packaging materials. For two centuries, glass jars and metal cans were the only materials that could withstand the heat and steam of sterilization (Tetra Pak 2020). However, during the last two decades, new technologies have made it possible also for paper-based containers to be used such as the Tetra Recart® carton which tolerates high temperatures due to thin layers of polypropylene, aluminum foil and a printing coat of lacquer (Magnusson 2005). The Tetra Recart® carton is a characteristic feature among modern processing techniques on industrial level as it allows pulses to be cooked inside the carton at high temperatures up to 130 °C. (Magnusson 2005; Holdsworth *et al.* 2008). Moreover, the processing requires less heat to achieve food sterility and less cooking time compared to canning in metal cans, adding up to significant energy savings (Holdsworth *et al.* 2008) which is presented in next paragraph.

Packaging production

Packaging serves multiple purposes in terms of portioning, protecting and communicating marketing information (Baldwin 2015). Lots of material needs to be produced as transport of many food products (including pulses) do not only require a primary packaging (material in direct contact with the food) but also secondary packaging (*e.g.* tray corrugated cardboards holding a set of packages together) and tertiary packaging materials (transport materials *e.g.* pallets and stretch foil). The material production includes energy-demanding activities *i.e.*

harvesting, extraction and processing of materials (Baldwin, 2015). For example, mining operations of metal ore for metal cans associates with land conversion, habitat desolating, great water use, pollution and toxic releases (Ibid.). Production of glass and metal are of those materials which are more energy-intensive compared to paper and plastic according to Frankowska *et al.* (2019), even though paper relates to deforestation and plastic relates to high consumption of fossil fuels for plastic formation.

The Tetra Recart® paper based carton show significantly lower climate impact compared to steel cans and glass jars for processed food with 2,5 times lower energy use and around six times lower GHG emissions compared to steel cans and glass jars (Table 3) (Markwardt & Wellenreuther 2017).

Table 3. Total primary energy use (TPE), Non-renewable primary energy (NonRPE) and GWP for production and recycling of packaging material corresponding to 1 liter of tomatoes produced at a plant factory in Italy. Calculations included material recycling based on recycling rates from Germany using a 50% allocation factor for open-loop-recycling

Packaging material	**TPE (MJ/L)**	**NonRPE (MJ/L)**	**GWP (kg CO2e/L)**
Tetra Recart®	2.52	1.94	0.08
Steel can	6.36	5.83	0.46
Glass jar	6.76	6.46	0.50

Packaging formation

Packaging is an important factor when estimating the overall climate impact of a product. However, not only the material, its manufacturing process and waste management needs to be considered but also the package's shape, weight, volume and stability to efficiently be transported. Especially the volume of the package plays an important role in food transport as *e.g.* the truck load is often limited by volume rather than weight. For example, the shape of cylindrical metal cans and glass jars leads to unutilized space as they require 30% more space per tray than the rectangular Tetra Recart® (Tetra Pak 2020). The transport work per ton-km is also higher for materials with high density *i.e.* glass, where lots of energy goes to moving the packaging material rather than its foods. Furthermore, how well the package protects the food from causing food waste during transport need to be considered as well as food scrapes left in the carton after usage. In fact, food waste of the actual product can have larger climate impact than the packaging material itself, according to Wallman & Nilsson (2011).

Consumer phase and waste management

Transportation from retail to kitchen (known as the "last mile") is also a factor which needs to be considered when estimating climate impacts along a products life cycle. Distance and mode of transport for this route can be varying and therefore difficult to estimate. However, in a study from 2005, as much as 80% of Swedish households went by car to the supermarket (Sonesson *et al.* 2005). Forty percent of the households had a distance of 1-5 km to a supermarket but the majority of the consumers drove much further, combining food shopping with other errands, adding up to a typical total distance between 6 and 30 km. Furthermore, as customers are likely to buy several different products at the store, allocation is needed to calculate the specific impacts from the package of pulses.

In terms of household preparation for dry pulses, energy for boiling needs to be considered. Energy use can vary for different types of stoves *i.e.* ceramic hot plates, gas stoves etc. as well as boiling time depending on type of pulses (Sonesson *et al.* 2003).

All packaging materials used for pulses can be recycled. For example, fibers in a paper-based carton can be reused 5–7 times before disposed. By using recycled wood fibers for new cartons, up to 70% of the energy for production is saved (The Swedish Packaging and Newspaper Collection Service 2020). The energy savings for using recycled metals are up to 75% for steel and 95% for aluminum whereas 20% less energy is used when producing glass from recycled glass containers (Ibid). Hence, metal and glass containers are valuable materials in terms of recycling but requires more energy for production compared paper based cartons.

3. Materials and methods

This chapter describes how this study was carried out and methods used including a description of the system boundaries, the functional unit and how the calculations of carbon footprint and energy use were made.

3.1. Scope of the study

Scope and system boundaries

This study focused on outbound logistics, meaning the transport from farm to point of purchase. Last transport distance from grocery store to kitchen (known as "the last mile") was not included due to highly varying fallouts in terms of distance and mode of transport used by end consumers.

Transport calculations of carbon footprint and energy use have been based on typical routes and modes of vehicles found in this study (Table 13-17 in Appendix) from origin of cultivation via sea ports and canning factories to Stockholm (Table 18 in Appendix). The products were assumed to be transported to a colonial storage in Västerås and thereafter transported (110 km) by 14-20 ton rigid trucks to a grocery store in central of Stockholm. Västerås was chosen based on the actual storage location of the largest Swedish food actor (ICA).

Energy use in this study represents the primary energy consumption including energy for the production, transmission and distribution of fuel (well to tank) and energy for vehicle consumption of the fuel (tank to wheel). Excluded elements were energy use for production, maintenance and disposal of infrastructure and vehicles.

Functional unit

The functional unit (FU) was the amount of dry pulses corresponding to 1 kilogram of cooked produce. The product was assumed to be purchased canned in Tetra Pak (380 g) or dry to be cooked and consumed by an end consumer in Stockholm. The unit was chosen as it is a convenient unit for comparison between different products.

3.2. Data collection and literature studies

Primary data collection

Information about land of origin, region of cultivation, mode of transport and geographical transportation route was collected from 12 food actors who is marketing prevailing brands available in leading grocery chains in Sweden. Gathered information is presented in Table 13, 14 and 15 in Appendix. Data was compiled by phone or through email contact with customer service for each of the food actor marketing the product. The study included a total of 100 dried or canned products of common beans (*Phaseolus vulgaris*), lentils (*Lens culinaris*) and chickpeas (*Cicer arietinum L.)* found in the Swedish grocery store during spring 2020. The products were purchased dry or canned packaged in Tetra Pak, metal cans, cardboard boxes or thin plastic bags. A total of 44 dry and 56 canned products were studied.

To better understand how and where these products were transported over the world, two international enterprises in the food industry were contacted (Di luca & Di Luca AB and Paulig Group) as well as one logistic service provider/carrier (DB Schenker), three grower associations (Pulse Canada, American Pulse Association, Kalmar-Ölands trädgårdsprodukter) and two American bean exporting companies (Chippewa Valley bean Co. and Bayside Best Beans). All people consulted in this study are listed in Table 12 in Appendix.

A literature study was made to compile data of energy demand and GHG emissions for cultivation to compare with transport. Furthermore, overall information regarding processing, packaging and the consumer phase (presented in the background section) were gathered to understand the role of transport.

3.3. Calculations of carbon footprint and energy use

Selection of common routes

Energy use and carbon footprint was calculated for a total of 38 different routes based on the most frequently stated transport routes from 6 countries including transport of Swedish pulses. These routes are listed in Table 16 and 17 in Appendix and specific cultivation sites and seaports are listed in Table 18 in Appendix. Fifteen of the total 38 routes were chosen to illustrate the carbon footprint in a diagram presented in the result section. These represents common routes for the most frequently stated countries of origin in this study.

Network for Transport Measures

The Network for Transport Measures (NTM) is a non-profit organization offering environmental data and calculation tools for transport operations. The environmental performance calculator *NTMCalc Advanced 4.*0 was used to calculate carbon footprint and energy use for transport by truck, container ships, ro-ro ships, cars, electrical and diesel trains.

Transport distances were obtained using NTM's calculation program as well as a website of an international freight broker (searate.com). The majority of routes were divided into sections, due to change of vehicle mode. For every section in the transport route, a set of parameters was taken into account when calculating emissions and energy use. Important parameters were type of vehicle, degree of cargo load factor, regional/international waters, road type as well as topography, cargo type and train size for travels by rail. These parameters were either left unchanged using default values or changed to match the specific transportation route. Exact information and description of these parameter settings are found in Table 19-21 in Appendix.

Ten types of vehicles were chosen. Based on information from Port of Gothenburg Authority (Minnhagen 2020, pers. comm. 10 August), smaller container ships (40 000 dwt) were chosen for routes by water from North America to Europe as well from Italy and Turkey. Large container ships (160 000 dwt) were chosen for ships departing from China to Europe. The selection of type of truck was based on information about the total cargo weight, gross vehicle weight given by food actors, suppliers, carriers, shippers, bean exporting companies or growers associations (listed in Table 12 in Appendix) for different routes in different countries. For all vehicles, cargo load factors were based on default values given by the calculation program itself, including travels by empty containers. Default values for cargo load factors among the chosen vehicles are presented in Table 4.

Table 4. Types of vehicles chosen for calculations in NTM for travels by road, rail and sea

Type of vehicle	**Gross vehicle weight (ton)**	**Typical cargo capacity (ton)**	**Cargo load factor (%)**
Rigid truck	14 - 20	12	40
Truck with trailer	20 - 28	16	40
Truck with trailer	28 - 34	22	50
Truck with trailer	34 - 40	26	50
Truck with trailer	50 - 60	40	50
	Ship size (dwt)		
Container ship	160 000		70
Container ship	40 000		70
Ro-Ro ship	10 000		70
	Train size		
Diesel cargo train	Heavy		60
Electrical cargo train	Heavy		60

Conversion factors for dry to boiled pulses

Energy use and carbon footprint for transports were recalculated from 1 kg dry product to 1 kg boiled product. The conversion factor for these recalculations was based on data by Durlinger *et al.* (2017) for processing 1 kg dried product in the Netherlands. Table 5 show the amount of required dried pulses (with different dry matter content) to produce 1 kg of canned pulses.

Table 5. The amount of dried product to produce 1 kg of canned product

Type of pulses	**Amount (kg)**
Bean	0.349
Chickpea	0.379
Lentil	0.259
Peas	0.349

3.4. Assumptions and limitations

Information regarding land of origin, region of cultivation, mode of transport and geographical transportation route was collected for products packaged in Tetra Pak (a paper based carton), metal cans, thin plastic bags and cardboard boxes. However, the calculations focused on canned produce in 380 grams Tetra Pak containers. This decisions was made not only because of Tetra Pak being the major type of container found on the shelf in the store, but as metal cans are gradually being phased out from the supply of some prevailing brands, according to information from two Swedish retailers.

Furthermore, trains and trucks were assumed to be transported by Ro-ro ferries from Germany over to Denmark from either Puttgarden–Rødbyhavn (for trucks coming from northeast of Europe) or Rostock–Gedser/Trelleborg (for trains and trucks coming from South of Europe). These are frequently used ferries for transport of goods to Sweden according to C. Jönsson (2020) when interviewed on 14 April 2020.

4. Results

The following chapter presents major countries of origin and cultivation sites for the studied products, their transportation routes, carbon footprint and energy use.

4.1. Origin

Origin for the studied products is shown in Table 6. These origins give a snapshot of available products in Swedish grocery store during spring 2020 as origin of a product can vary depending on season etc. The major countries of origin for the 91 imported pulses products were China (39%), USA (17%), Canada (12%), Turkey (10%) and Italy (9%). These countries of origin will be focused upon when presenting carbon footprint and energy use in section *4.3*.

Table 6. Number of times a country was stated as the land of origin for a total of 100 dry or canned products, sectioned in type of pulse, organic and conventional products. Several countries of origin was sometimes stated on one product

Country	Total	Bean	Lentil	Chickpea	Organic	Conventional
Argentina	4	2		2	1	1
Canada	14	7	6	1	6	8
China	50	46	4		38	12
France	1			1		1
India	1		1		1	
Italy	12	4		8	10	2
Mexico	2			2		2
Poland	5	5			2	3
Russia	1		1		1	
South America	1	1			1	
Tanzania	1	1			1	
Turkey	14	1	11	2	13	1
USA	21	17	2	2	13	8
Sweden	9	8	1		1	8

All responding food actors could state the country of origin for their products but far from all actors revealed region within country. Whereas some staff working with customer service could state the origin of cultivation for all their products, others responded that they did not have access to the information or could not forward the information. Common replies from non-respondents were "*we have limited* *resources to support school related projects*", "*to find out origin of cultivation we need to contact our suppliers or do a thorough research in our documents which is too time consuming*", "*we do not prioritize your request of information due to other prioritizations in times of the Corona pandemic*". Table 7 show the regions of cultivation stated by customer service complemented by information from sourcing managers, growing associations and bean exporting companies contacted in this study.

Table 7. Common regions of cultivation for common beans, chickpeas and lentils

Country	**Region of cultivation**
Canada	Ontario (beans), Saskatchewan (lentils, chickpeas), Manitoba (lentils, beans), Alberta (chickpeas)
China	HeilongJiang, Tongliao, Liaoning, Shaanxi, Tianjin, Yunnan, Guizhou, Xinjiang, Hebei, Chongqing, Gansu, Jilin, Shanxi, Sichuan, Shandong (beans), Henan, Shanxi, Shaanxi, Gansu, Xinjiang, Inner Mongolia (lentils), Gansu, Xinjiang, Inner Mongolia, Yunnan (chickpeas)
Italy	Emilia-Romagna, Tuscany, Marche, Sardegna, Puglia Silicy (chickpeas), Calabria, Basilicata, Puglia (organic chickpeas)
Turkey	Batman province (lentils), Konya, Karaman, Corum, Antalya, Kutahya Usak (Chickpeas), South Eastern and Central Anatolia (lentils), Mediteranian and Western Anatolia (beans)
USA	Wisconsin, Minnesota, Michigan (beans), North Dakota (beans, lentils, chickpeas), Idaho, Washington, Montana (lentil, chickpeas)

4.2. Mode of transport and distances

All food actors shared overall information about transportation route and transport mode for their products. However, more detailed information regarding load weight, gross vehicle weight and which seaports that were used etc. was difficult to get from customer service. Most often, the staff had to contact their suppliers who handled the procurement of pulses as well as the transport. Direct contact with the supplier was not possible as the customer service staff did not reveal the name of the supplier due to confidentiality. Only a few suppliers assisted the customer service staff with detailed information regarding sea ports, load weight, gross vehicle weight etc.

The average distance by road, sea and rail from each of the major countries of origin to a grocery store in Stockholm is presented in Table 8. All products from outside of Europe arrived by boat in 20 or 40 feet shipping containers to mainly Italy (60%), Denmark, (9%), the Netherlands (8%), England (6%) and Germany (5%).

Table 8. The average distance by road, sea and rail for dried and canned pulses transported to Stockholm, Sweden

Country of origin	**Total (km)**	**Road (km)**	**Sea (km)**	**Rail (km)**
Canada, lentils (dry)	12 670	1 770	8 310	1 810
Canada, common beans (canned)	13 930	1 420	8 590	3 920
China, common beans (dry)	22 790	1 160	20 610	
China, common beans (canned)	20 020	2 840	16 440	720
Italy, chickpeas (chickpeas)	2 940	2 300	80	560
Sweden, lentils (dry)	990	870	120	
Sweden, common beans (dry)	470	470		
Sweden, common beans (canned)	4 500	4 380	120	
Turkey, lentils (dry)	7 470	2 250	4 880	340
Turkey, chickpeas (dry)	8 720	1 850	6 870	
USA, common beans (canned)	13 260	1 710	9 130	2 420
USA, chickpeas (canned)	21 340	2 900	17 610	840

Imported pulses to be bought dry were transported to Sweden via mostly The Netherlands (25%) followed by Denmark (23%), Germany (17%) and England (15%) whereas all pulses purchased canned were transported via Italy. The total number of times a transport mode was stated for the majority of the distance driven within Europe to Sweden is illustrated in Figure 2. The most common vehicle for transports within Europe of dry products was by truck (87%), boat (7%) or train (4%) whereas canned products was transported by trucks (44%), boats (31%) and trains (24%). One food actor did not state the mode of transport for two products.

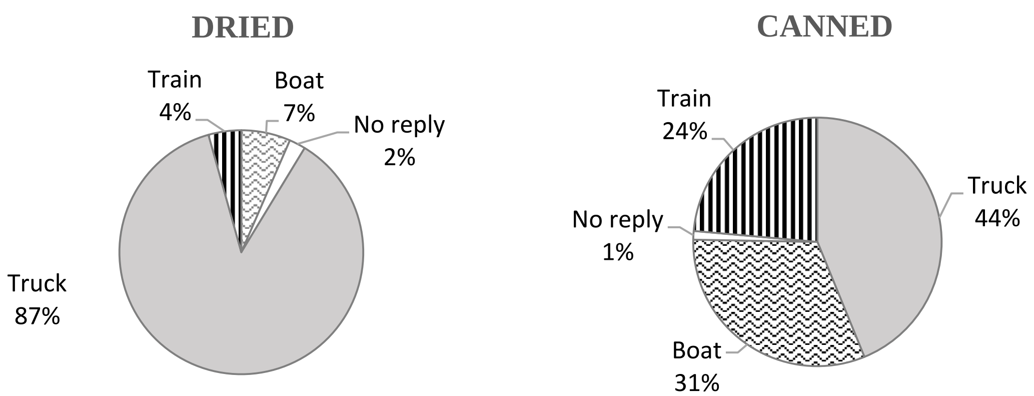

Figure 2. Transport mode for the majority of distance within Europe for imported dried (left) and canned (right) pulses to Sweden. Percentages illustrate the total number of times one mode of vehicle was stated. Customer service sometimes stated several mode of transports.

4.3. Typical shipping routes

Figure 3 illustrates the major shipping routes based on the studied products in this study. A detailed list of all stated routes is found in Appendix 16 and 17. The two most stated transport routes were China/USA – Italy – Sweden. These transport routes are focused upon in the following subchapters 4.3.1 - 4.3.3 to give examples of how grain legume products are transported to Sweden.

Figure 3. Typical shipping routes for pulses imported to Sweden

4.3.1. Italy to Sweden

All canned products as well as some of the dry products in this study were transported via Italy to Sweden. A typical geographical route from Italy to Sweden can be exemplified by products transported by DB Schenker, one of the world's leading actors in the field of logistics and transportation. DB Schenker is the forwarding agent and the carrier for one of the largest food actors in Sweden whose products are processed in Campania region in the south. In Italy, mainly two freight stations are used by DB Schenker. These are located in Verona in the north and in Domodossola in the northwest (Jönsson 2020, pers. comm. 17 April) of which Verona freight station is the one most frequently used. To Verona, products are received from all parts of Italy to be loaded onto electrical trains directly to Rostock in Germany without any stops (Ibid.). A common route through Europe, not only for DB Schenker's trains but for other actor's carriers in this study, is via the Brenner Pass in the alpine mountain rage on the northeast Italian boarder to Austria. Containers can be filled with goods by various shippers (consolidated shipment) or one customer can book a whole train on the condition that the customer can fill the train both to and back between Verona to Rostock (Ibid.). In Rostock, trailers are removed from the train to be put on a Ro-Ro ship to Trelleborg in Sweden where the trailers are redistributed by trains and trucks onwards.

4.3.2. China to Italy

Most of the stated regions of cultivation for beans in this study are located in the northeast of China. From these regions, beans are most likely to be transported to the nearest sea port in 40 feet containers hauled by trucks, having a bean load weight of approximately 20-25 ton (Linell 2020, pers. comm. 26 April). For example, organic beans ordered by one large food actor is cultivated in Inner Mongolia in the Tongliao prefecture. These beans (kidney beans, black beans, white small and large beans) are transported by truck to Dalian to be rinsed and packed in 25 kg bags before being shipped from Dalian seaport in 40 feet containers to Italy. The containerships are usually of a larger sizes around 160 000 dwt (Minnhagen 2020, pers. comm. 10 August). Other common areas for cultivation is Shanxi (shipped from Port of Xingang), Tianjin (shipped from Port of Tianjin) and Yunnan region in South of China.

4.3.3. USA to Italy

Of the products studied, kidney beans made up the largest share of pulses from USA, followed by black beans and borlotti beans. Kidney beans and borlotti beans that are shipped from USA to Italy are commonly cultivated in Wisconsin, Minnesota, North Dakota and Michigan (McClellan 2020, pers. comm. 16 April). From these states, beans are usually transported by railcar in 20 feet containers or partly transported by truck and diesel train to Port of Montreal in Canada. At the sea port, beans are loaded onto vessels bound for Naples, Salerno or Livorno sea ports (Ibid.). For example, North America’s largest processor and exporter of Kidney beans, Chippewa Valley Bean Co., handles large quantities of beans that are transported to Italy (Soppeland 2020, pers. comm. 15 April). From Menomonie in Wisconsin, kidney beans are transported (~45 km) to Minneapolis in Minnesota transported by a 34–36 ton (gross vehicle weight) trailer hauled by a truck, carrying a net weight of kidney beans of approximately 20 ton. In Minneapolis, containers are loaded onto a diesel train to be railed (~260 km) to Chicago, Illinois. In Chicago, containers are transferred to another diesel train and are further railed (~1370 km) to the Port of Montreal. The beans are thereafter shipped on a vessel to Italy where the majority of kidney beans arrives into the Port of Salerno in southwest of Italy. Port of Livorno and Naples is sometimes used. The beans are transported in the same container (20 feet) from Menomonie to Italy, packed in 10-1000 kg poly super sacks that are stacked on pallets, leaving about 15 cm gap between stack and container ceiling. According to Soppeland (2020, pers. comm. 15 April), most of the space in the container is utilized, adding up to a cargo load factor of 95%.

Departing containerships from North America’s east coast to Europe are usually of a smaller size around 40 000 dwt or somewhat larger but much less than 160 000 dwt (Minnhagen 2020, pers. comm. 10 August). These ships usually have high goods density and departures more often than large ships from *e.g.* Montreal to Salerno.

4.3.4. Transport of Swedish beans and lentils

Swedish bean transports

Almost all Swedish common beans for human consumption are produced around the region of Kalmar and Öland. The beans are delivered from each farm mostly by tractors or by trucks ordered from local haulage contractors (Zedig 2020, pers. comm. 30 March). Each delivery weighs 15–40 ton and is transported an average distance of 30-40 km from farm to the factory in Färjestaden, Öland. At the factory, beans are dried (if necessary), rinsed, marked with origin and packed for wholesaler and restaurants. Large quantities are thereafter transported to a packaging factory in Linköping (~240 km) to one of KÖTP’s largest customer (Lantmännen Cerealia). To Linköping, dry produce is transported in 800 or 900 kg bags by large trucks with a weight load of ~35 ton (Ibid.). From Linköping, beans to be sold canned are transported to Italy (~1 800 km) in rigid trucks with 22.8 ton load weight (Lantmännen Cerealia 2020, pers. comm. 31 March).

Swedish lentil transports

The majority of Swedish lentils are produced on Gotland and in Skåne County. In this study, two growers were contacted located on Gotland (an Island in the Baltic sea) and northeast of Kristianstad in Skåne county. Both growers deliver lentils to Nordisk Råvara, a small actor mentioned in the background chapter of this study. At the time, four lentil growers are located on Gotland (Håkansson 2020, pers. comm. 8 April). From farms on Gotland, lentils are transported on average 20-40 km by tractor to one of the farms to be dried and separated from oats. Thereafter, lentils are packed in 800 kg bags and are further shipped by truck with trailer loaded with 6-8 ton of lentils per loading combined with other goods (consolidated shipment). The truck is shipped by a ferry from Visby to Oskarshamn and further on to Nordisk Råvara’s temporary packaging factory in Nol in Gothenburg (Backman 2020, pers. comm. 24 April). Lentils from Gotland and Skåne County packed in Nol are further transported 130 km in 30-60 ton trucks with trailers to a storage in Götene. In the future, Götene will be the location for both packaging and storage, according to (Backman 2020).

4.4. Carbon footprint and energy use of transport

Table 9 show the primary energy use and carbon footprint for transporting pulses to Stockholm from major countries of origin for products found in the Swedish grocery store during spring 2020 and number of routes considered in the calculations. Pulses from USA and China canned in Italy have the highest carbon footprint and energy use whereas domestically produced Swedish lentils and beans purchased dry have the lowest contributions. Mapped routes for Canadian, Chinese and American beans and Italian chickpeas represents large variation in energy use and carbon footprint for different transport routes to Sweden. Large variations highly depends on whether the pulses are transported dry or canned and what mode of vehicle that is used. For example, beans from Canada, China, and USA that are processes in Italy and thereafter transported by 34-40 tons trucks to Sweden have 40-45% less total impact if transported by train from Italy to Sweden. In this particular case, large variation is due to the energy mix used for Swedish trains on the section from the Swedish boarder to Stockholm which has significantly lower climate impact compared to trucks, as shown in Table 1. Furthermore, transport of dry beans have approximately five times lower carbon footprint and energy use when carried by a 34-40 ton truck through Europe compared to canned beans. The explanation for such high variation between dry and canned produce is that less weight is being transported, as dried pulses does not contain additional weight from absorbed water from the canning process nor extra weight from liquid medium for preservation. The variation for Canadian beans and lentils is somewhat larger as container ships are usually smaller than *e.g.* ships from China, according to Minnhagen (senior manager at Port of Gothenburg Authority) when contacted on the 10 August 2020. Therefore, transport by sea from North America contribute to slightly higher carbon footprint and energy use.

Table 9. Energy use and carbon footprint per FU for transporting canned (c) pulses in Tetra Pak 380 g or dried (d) pulses from origin of cultivation to a grocery store in Stockholm, Sweden. Large variations depends on if the product is transported dry or canned and mode of transport

Land of origin	Carbon footprint (kg CO_2e)	Energy use (MJ)	Number of routes
CAN, lentils (d)	0.075–0.135	1.03–1.80	4
CAN, common beans (c)	0.168–0.431	2.65–6.20	7
CHN, common beans (d)	0.170–0.202	2.27–2.74	3
CHN, common beans (c)	0.273–0.488	4.05–6.98	7
ITA, chickpeas (c)	0.166–0.360	2.66–5.28	3
SWE, lentils (d)	0.020	0.28	1
SWE, common beans (d)	0.014	0.20	1
SWE, common beans (c)	0.360	5.42	1
TUR, lentils (d)	0.079–0.082	0.78–1.19	5
TUR, chickpeas (d)	0.110–0.115	1.50–1.58	2
USA, common beans (c)	0.230–0.434	4.69–6.78	4

The carbon footprint for 15 common routes to Sweden is shown in Figure 4. Canned products transported by truck stands out as the largest contributor of GHG emissions. Pulses are transported 2850-4400 km by truck for the five most polluting routes (ITA 3, SWE 3, CAN 3, USA 2, CHN 3). A route description for each bar in the bar chart is presented on the next page in Table 10. For example, transport of dry beans from China (CHN 1) to Germany have significantly lower carbon footprint than Chinese beans to be purchased canned transported by train (CHN 2) or truck (CHN 3) from Italy to Sweden. Transport emissions of Swedish beans to be purchased dry (SWE 1) are approximately 25 times less than Swedish canned beans (SWE 3), due to transport by truck back and forth to Italy for processing.

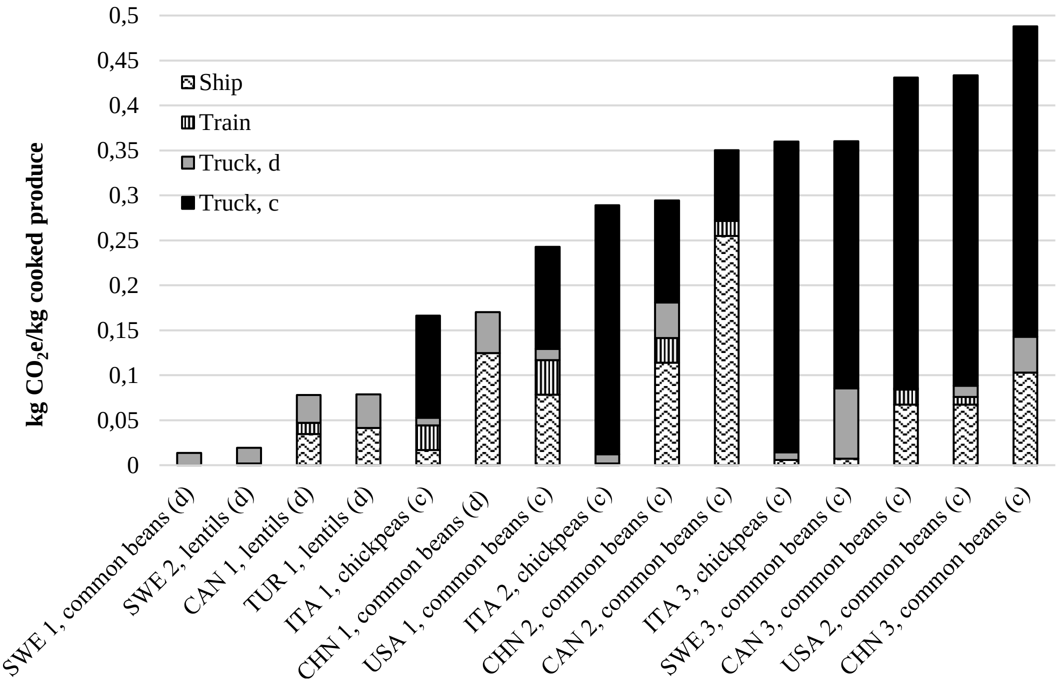

Figure 4. Carbon footprint per FU for canned (c) pulses in 380 g Tetra Pak and dried (d) pulses transported to Stockholm, Sweden. Route description from each country is listed in Table 10

Table 10. Route description for each bar in figure 4 from cultivation site (bold) to Stockholm, Sweden

Label	Route
CAN 1	**Saskatchewan** - Montreal - Rotterdam (NLD) - Stockholm
CAN 2	**Saskatchewan** - Montreal - Salerno (ITA) - Gothenburg (SWE) - Stockholm
CAN 3	**Saskatchewan** - Montreal - Salerno (ITA) - Verona - Stockholm
CHN 1	**Tongliao** - Dalian - Hamburg (DEU) - Stockholm
CHN 2	**Helijongjang** - Dalian - Salerno (ITA) - Stockholm
CHN 3	**Helijongjang** - Dalian - Salerno (ITA) - Stockholm
ITA 1	**Puglia** - Napels - Verona – Rostock (DEU) - Trelleborg (SWE) - Stockholm
ITA 2	**Marche** - Piacenza - Stockholm
ITA 3	**Puglia** - Napels - Rostock (DEU) - Gedser (DNK) - Stockholm
SWE 1	**Öland** - Linköping - Stockholm
SWE 2	**Gotland** - Göteborg - Götene - Stockholm
SWE 3	**Öland** - Linköping - Ferrara (ITA) - Stockholm
TUR 1	**Batman province** - Mersin Port - Aarhus (DNK) - Mariager - Stockholm
USA 1	**Wisconsin** - Montreal (CAN) - Salerno (ITA) - Stockholm
USA 2	**Wisconsin** - Montreal (CAN) - Salerno (ITA) - Stockholm

4.5. Emissions of transport in comparison to cultivation

Energy use and carbon footprint from transport of studied pulses are much varying, ranging from 0.014 kg CO_2e and 0.20 MJ per FU for Swedish dry lentils to 0.49 kg CO_2e and 7.0 MJ for canned common beans from China (Table 11). In comparison to the cultivation stage, impact of pulses (presented in Table 2, paragraph 2.5) ranges from 0.067-0.30 kg CO_2e per FU and 0.54-1.0 MJ when converted from dry to cooked produce using conversion factors in Table 5. Thus, impacts from transport can be less than the cultivation stage but also larger depending on origin and modes of vehicles used. Especially in terms of energy demand, which according to this study's calculations can be seven times larger for transport (for canned Chinese beans) compared to the cultivation stage.

Table 11. Carbon footprint and energy use for the cultivation and transport stage

Stage in the supply chain	Carbon footprint CO_2e per FU	Energy use MJ per FU
Transport	0.014-0.49	0.20-7.0
Cultivation	0.067-0.30	0.54-1.0

5. Discussion

5.1. Origin and transportation routes

The major countries of origin declared for the 91 imported pulses in this study was China (which was most frequently stated), USA, Canada, Turkey and Italy. The result confirms the study by (Ekqvist *et al.* 2019) reporting that China was the most frequently stated country for beans and peas whereas imported lentils originated from Canada and Turkey. In this study, only 31 of the 100 products had an origin in Europe and nine in Sweden. Thus, it is clear that the Swedish consumption of pulses is heavily dependent on long-distance supplies. Moreover, the supply of existing products on the Swedish market does not seem to reflect the increasing interest for locally sourced and plant-based foods among consumers in the global north (Eklöf *et al.* 2012; Joosse & Hracs 2015).

According to information compiled from customer service, canned pulses were transported by truck (44%), boat (31%) and train (24%) from Italy to Stockholm. However, according to Jönsson (2020, pers. comm. 14 April), food retailers seldom have the whole and accurate picture of the specific transport route and what vehicles that has been used. The specific percentages in terms of the frequency of different vehicles used must therefore be interpreted with care. What can be read from these numbers is however that trucking is very common for transports. As the data collection constitutes for some uncertainties, contacts with sourcing managers, supply chain managers and traffic managers have been of large importance regarding the specific routes and vehicles used for the 91 imported products. It was found that mode of vehicles plays a crucial role for the emissions and energy use of transport of pulses and this is further discussed in the following paragraph.

5.2. Type of vehicle more important than food miles

In this study, one mode of vehicle was usually stated for driving the whole distance from Italy to Sweden by customer service. However, in some cases, products can also be assumed to be transported by several different modes and types of vehicles along its route, depending on planned courses and different locations for loading sites used by different carriers. For example, if a canned product originating from Saskatchewan is transported by train from Verona (Italy) to Trelleborg (Sweden) and is thereafter reloaded onto a 34-40 ton truck instead of a Swedish train for the lasting 630 km to a loading site in Eskilstuna, total emissions from transport would be increased by approximately 30%. Hence, what could be seen as a fairly small distance (630 km by truck or 580 km by train) of a total distance (~13 500 km), still plays an important part for the total emissions depending on what vehicle used. Moreover, as described in the background, lager trucks (50-60 ton) are commonly used in Sweden, as the regulated maximum weight is higher than many other European countries. If the 34-40 ton truck would be replaced by a 50-60 ton truck on the section from the Swedish boarder (Trelleborg) to Eskilstuna, emissions would instead be increased by 20% compared to transport by train.

In summary, fairly small distances in relation to the whole distance (food miles), can add significant emissions depending on what modes and types of vehicles that are used within the Swedish border. Therefore, one can assume that there are opportunities for lowering the total emissions and energy use of transport by replacing trucking with Swedish trains or tranship cargos onto larger trucks. Unfortunately, transhipment of goods onto e.g. larger trucks are rare and foreign trucks and chauffeurs often drive the whole distance from *e.g.* Verona to Eskilstuna as transshipment at terminals along the route comes with high expenses according to Jönsson (2020, pers. comm. 6 August). However, attention should be paid to the last transport within Sweden to lower the total emissions from transport. Especially as the Swedish government aims to reduce GHG emissions from domestic transport by 70 % by 2030 compared to 2010 (The Ministry of Environment and Energy 2018).

An interesting aspect found in this study is that dry produce is more likely to be transported longer distances by containerships to harbours closer to Sweden (located in The Netherlands, Denmark, England, Germany etc.). Thereby, the distance driven on mainland is shorter compared to canned produce transported from Italy. However, a long distances driven by a vehicle with low impacts (*i.e.* containership) is not a guarantee for low total transport emissions of a whole route. Instead, an advantage with container ships is that many containers can be shipped in one go. One could therefore assume that transport by containership is less polluting per shipping container, even though emissions from *e.g.* electrical trains (which usually carries a maximum of 25 trailer) are slightly less per ton-km than containerships. Nevertheless, dry products in this study were all transported by truck from the seaport to Sweden. If these transports could be replaced by train, emission would be even lower for dry produce.

As expected for this study, transport of dry domestically produced pulses had the lowest carbon footprint and energy use compared to imported products. The average impact of dry Swedish pulses (beans and lentils) was 0.02 kg CO_2e per FU and 0.24 MJ whereas canned Swedish beans accounted for 0.36 kg CO_2e per FU and 5.42 MJ. Thus, transport of dry pulses are 21 times less polluting than canned beans and require 23 times less energy. Such high impacts of Swedish canned beans is due to trucks used back and forth to Italy as no trains are used for Swedish transport of beans, according to Lantmännen Cerealia. In fact, transport of Swedish canned beans has slightly higher impacts per FU than the average impact (0.33 kg CO_2e and 4.9 MJ) of transport from imported canned pulses in this study. For example, the processing of the Swedish beans is assumed to take place in northern Italy in the region of Emilia-Romagna. For Italian chickpeas, that are processed in Emilia-Romagna region (and cultivated in Marche region a bit further south), transport accounts for 0.29 kg CO_2e and 4.24 MJ per FU when transported to Sweden by 30-34 ton truck. Thus, transport of canned Italian chickpeas is less polluting in comparison to Swedish canned beans and emissions would be even lower if vehicles with lower impacts were used for Italian chickpeas. If Swedish pulses were to be processed locally though, large improvements in terms of reduced impacts can be expected which is further discussed in next paragraph.

5.3. Local production and processing of pulses

As introduced previously in the background section, industrial processing of pulses accounts for a fairly small share of the total carbon footprint and energy use in the supply chain of pulses. However, *where* the processing takes place and thus *how far* canned products are transported has large effect on the total impacts of transport. Today, one of the challenges for expanding the local production of Swedish pulses stated by Olsson (2017) lies within solving the issue of economical investments for facilities and machinery needed for processing. Nevertheless, if local processing of domestic and imported dry pulses were feasible within Sweden, transport emissions would be significantly reduced. Hence, an establishment of Swedish processing facility would not only gain the market for local farmers by adding values linked to the increasing trend of plant-based and locally produced foods, but would also be a step in the right direction towards reaching the SDGs to lower the emissions of GHG as well as the emissions from domestic transport, set by the Swedish Ministry of Environment and Energy (2018).

5.4. Impact of transport in relation to cultivation

As previously described, impacts from transport for imported pulses can be less than the cultivation stage but also larger, according to this study. This is in agreement with Knudsen *et al.* (2011) who state that transport of imported plant-based products accounts for large shares (40-70%) of the carbon footprint when transported by ship and/or truck. However, more information regarding cultivation is needed for a more reliable comparison of energy consumption as only few articles were found which stated the energy use for the cultivation stage of pulses (Table 2). Furthermore, it should be considered that the conversion factor for lentils (0.259) is smaller compared to beans (0.349) and chickpeas (0.379) as less amount of dry lentils is required to produce 1 kg of canned produce, according to Durlinger *et al.* (2017). Calculations for lentils therefore result in somewhat lower carbon footprint and energy use compared to beans and chickpeas. Whether lentils should be compared to beans and chickpeas is therefore questionable. Perhaps, it would be fairer to compare lentils in a separate group e.g. by protein content. It should also be considered that impacts from cultivation can be much varying as described in the background part, with more or less intensive systems etc. Unfortunately, few studies gives a full explanation of how transports have been calculated, using standard freight transport distances and does not state what types of vehicles that have been assumed nor their weight capacities (Fuentes *et al.* 2006; Frankowska *et al.* 2019).

Transport in relation to remaining stages in the supply chain

As addressed in the background section, production of packaging material was of large importance for a product's total emissions while the share from waste management was very low (Del Borghi *et al.* 2018). Round shaped glass and metal containers required more energy for production as well as space and energy (due to higher density) compared to rectangular paper-based cartons (Markwardt & Wellenreuther 2017; Tetra Pak 2020). Thus, packaging material and as well as its formation are important factors for more sustainable transports.

5.5. Sustainability challenges of transport

The awareness of climate impacts of transports is high among all actors contacted in this study. The forwarding agents and other third party logistic service providers have a big responsibility in making sure that container and trailers are loaded to its maximum capacity, utilizing both weight and volume in the container or trailer. However, there are some things that forwarders are not able to control. For example, numerous of sea ports lack connecting railroad systems and organized waterways (Fan *et al.* 2019). Container trucking has so become the foremost common mode of vehicle for distribution to and from seaports within Europe despite the ambition of European commission's Transport White Paper to replace trucking by half with other modes of vehicles *i.e.* rail by 2050 (European Commission 2016). Not only is trucking the most polluting mode of vehicle found in this study (Table 1) but trucking also causes traffic congestion (Fan *et al.* 2019).

To reduce the climate impacts of container transport, several studies bring to light some fairly simple but important opportunities for handling road freight transport (Palmer *et al.* 2018; Fan *et al.* 2019). By consolidating cargoes to even larger containers, moving from 20 and 40 feet maritime containers to 45 feet (fitting 26 standard pallets) or 53 feet trailers (30 pallets), less containers would be used and hence decrease impacts in terms of less running empty containers and less traffic congestion. In this study, typical transport routes have revealed that 20 feet and 40 feet containers are commonly used for transport of pulses from land of origin to Europe. Only two actors mentioned that their products were transported in larger containers and trailers carrying between 32-36 pallets. Hence, one could assume that there are opportunities for decreasing the climate impacts if larger containers and trailers could be applied, if the infrastructure allows it along with national transport regulations. Furthermore, collaboration between shippers, forwarding companies and carriers is an important feature to achieve higher vehicle utilization as forwarders can combine goods for multiple customers (Wakeland *et al.* 2012; Palmer *et al.* 2018). Due to a broad customer base, forwarders are also likely to obtain less empty returns if goods can be shipped both ways (Wakeland *et al.* 2012). An interesting example of collaboration on regional level can be exemplified by the Danish food distribution system where political decisions have led to a so called "open distribution system". That involves a distribution system where competitors can transport each other's goods and thus increase intermodal transport, leading to economic and environmental benefits (Oker-Blom 2019). However, on global level, the synchronizing of goods from several companies is already in use and competitor's products often share transport (Jönsson 2020, pers. comm. 22 August). Nevertheless, according to this study, transportation routes often varies for different food actor's products. Thus, competitor's products are likely to travel separately within Europe, depending on what forwarding agent that has been hired and the loading sites it uses. Whether transports are shared between competitor's should however not matter from a sustainability viewpoint as products are always consolidated with other types of goods, filling the whole transport unit resulting in high loading rates.

Nevertheless, efficient transports that fulfills all measures mentioned above might not be the solution for more sustainable transport in the long-term perspective. In 2017, the Swedish Parliament agreed upon the government's proposal that includes no net emissions of GHG into the atmosphere by 2045. Furthermore, the Swedish government appointed an investigation in December 2019 for how and when to phase out fossil fuels and ban the sale of new petrol and diesel cars (Government Offices 2019). Thus, even though existing transport can be more efficient in terms of vehicle utilization and well planned consolidated shipments etc. – it is not enough to reach the climate goals. Other solutions for more sustainable transports in the future are combinations of high capacity transports which are currently tested on Swedish ground with longer (32 meter) and heavier (80 ton) trucks (DB Schenker 2020) as well as new innovative heavy-duty battery electric trucks which have recently been introduced in the food distribution system in Norway (Elfordon.se 2020). However, local sourcing of pulses is the most efficient mitigation option to reduce the climate impact from transport.

6. Conclusion

The major countries of origin for the imported pulses in this study was China (39%), USA (17%), Canada (12%), Turkey (10%) and Italy (9%). Typical routes for products to be sold canned were transport via Italy to Sweden whereas dry pulses were often transported to the Netherlands, Denmark, Germany or England. The dominant mode of vehicle for transports within Europe for dry imported products was by truck (almost 90%), while boat or train transport was used less frequently. Also canned products were mainly driven by truck (44%), but the share of boat and train was higher than for dry pulses.

Pulses from China, USA and Canada canned in Italy had the highest carbon footprint and energy use whereas domestically produced Swedish lentils and beans purchased dry had the lowest contributions. Large variations were found due to two main factors (1) whether the product was transported dry or canned and (2) if the route contained large distances driven by truck. Fairly short distances driven by truck can have large effects on the total emissions from transport and significant reductions can be expected if trucking is replaced by train, especially for transport within the Swedish boarder.

Comparison of the transport and the cultivation phase showed that energy use and carbon footprint from transport can be higher and lower than the cultivation depending on origin and modes of vehicles used. Thus, transport can have a much larger impact than addressed in earlier publications that includes transport of pulses.

Important measures for more sustainable transport were high vehicle capacity and utilization (in terms of weight and volume) where consolidated shipment and collaboration between actors can improve the efficiency of transports. Moreover, imports should entirely include transport of dry pulses that are transported short distances and an establishment of a Swedish processing facility would enhance opportunities to lower the emissions from transport. Thus, local sourcing of domestically produced Swedish pulses is an important mitigation option to reduce climate impacts of transport in the supply chain of pulses.

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Appendix

Table 12. List of people which have been contacted during this study

Name	Profession, company name	Content of information
Customer Service	ICA, COOP, Axfood, Risenta, Zeta, Saltå Kvarn, Midsona, Citygross, Lidl, Lantmannen Ceralia, Nordisk Råvara, Sevan	Information regarding country of origin, origin of cultivation, transportation route, mode of transport
Catharina Jönsson	Traffic manager Central Europe, Schenker AB	Transports within Europe, common transport modes with focus on transport routes from Italy to Sweden
Micaela Wahrén	Supply chain manager Di luca & Di Luca AB	Transport of Zeta's products, common shipping routes, cargo load factors, shipping methods etc.
Peter Linell	Sourcing Manager, head of raw material Paulig	Origin of cultivations, common transport/shipping routes in the world etc.
Jacob Minnhagen	Senior Manager at Port of Gothenburg Authority	Information regarding containerships (weights, routes etc.) from Canada/China/Italy to southern Europe
Matt Soppeland	Logistics and Documentation Manager at Chippewa Valley Bean Co. in the US	Export of beans from the US to Italy
David McCellan	Regional Representative, USA Dry Pea & Lentil Council	Export of beans, lentils and chickpeas from the US to Italy
Rob Chandonnet	General Manager/Marketing director, Bayside Best Beans	Export of beans from the US to Italy
Magnus Swahn	Operation Manager, NTM	Calculation programe *NTMCalc Advanced 4.0* , empty containers, cargo load factor etc.
Oskar Zedig	Responsible for production, Kalmar-Öland trädgårdsprodukter	Transport and production of Swedish pulses
Gunnar Backman	Founder Nordisk Råvara	Transport and packaging of Swedish lentils
Tomas Isaksson	VD, Kalmar-Ölands trädgårdsprodukter	Overview of the market of Swedish pulses, transport of Swedish pulses
Mari Håkansson	Lentil grower, Mickelgårdens Lantbruk, Gotland	Transport of Swedish lentils produced on Gotland
Per Modig	Lentil grower, Fagraslätt, Skåne county	Transport of Swedish lentils produced in Skåne county

Table 13. Specific data for pulses found in this study (1/3). The list continues on the next page

Food actor	Variety	Dried	Canned	Packaging materi	Route	Distance 1	Distance 2	Place of processing	Place of packaging
A	Red lentils	x		Plastic bag	Canada/Turkey - Belgium - Sweden	Boat	Truck	Canada/Turkey, Belgium	Stockholm
	Green lentils	x		Plastic bag	USA - England - Sweden	Boat	Truck	USA, England	Stockholm
	Black lentils	x		Plastic bag	Canada - England - Sweden	Boat	Truck	Canada, England	Stockholm
	Black beans	x		Plastic bag	China - England - Sweden	Boat	Truck	China, England	Stockholm
	Kidneybeans	x		Plastic bag	China/USA - England - Sweden	Boat	Truck	China/USA, England	Stockholm
	Navy beans	x		Plastic bag	USA - England - Sweden	Boat	Truck	USA, England	Stockholm
	Large white beans	x		Plastic bag	Poland/China - England - Sweden	Truck/Boat	Truck	Poland/China, England	Stockholm
	Chickpeas	x		Plastic bag	France - Belgium - Sweden	Truck	Truck	France, Belgium	Stockholm
B	Black beans*		x	Aluminium can	China - Italy - Sweden	Boat	Truck	China, Italy	Italy
	Borlotti beans*		x	Aluminium can	China - Italy - Sweden	Boat	Truck	China, Italy	Italy
	White large beans*		x	Aluminium can	China - Italy - Sweden	Boat	Truck	China, Italy	Italy
	Black beans*	x		Plastic bag	China - Denmark - Sweden	Boat	Truck	China, Denmark (Mariager)	Denmark,Mariager
	Kidneybeans*	x		Plastic bag	China - Denmark - Sweden	Boat	Truck	China, Denmark (Mariager)	Denmark,Mariager
	Black lentils*	x		Plastic bag	Canada - Denmark - Sweden	Boat	Truck	China, Denmark (Mariager)	Denmark,Mariager
	Red lentils*	x		Plastic bag	Turkey - Denmark - Sweden	Boat	Truck	Turkey, Denmark (Mariager)	Denmark,Mariager
	Green lentils*	x		Plastic bag	Turkey - Denmark - Sweden	Boat	Truck	Turkey, Denmark (Mariager)	Denmark,Mariager
	Chickpeas*	x		Plastic bag	Turkey/Italy - Denmark - Sweden	Boat	Truck	Turkey/Italy, Denmark	Denmark,Mariager
	Navy beans*	x		Plastic bag	Turkey/Italy - Denmark - Sweden	Boat	Truck	Turkey/Italy, Denmark	Denmark,Mariager
C	Black beans		x	Tetra pac	Argentina/China - Italy - Sweden	Boat	Truck	Argentina/China, Italy (Emilia Romagna/Puglia/Sicily)	Italy (Emilia Romagna/Apulia/Sicily)
	Kidneybeans		x	Tetra pac	USA/China - Italy - Sweden	Boat	Truck	USA/China, Italy (Emilia Romagna/Puglia/Sicily)	Italy (Emilia Romagna/Apulia/Sicily)
	Kidneybeans*		x	Tetra pac	USA/China - Italy - Sweden	Boat	Truck	USA/China, Italy (Emilia Romagna/Puglia/Sicily)	Italy (Emilia Romagna/Apulia/Sicily)
	Chickpeas		x	Tetra pac	Mexico/Italy - Italy - Sweden	Boat	Truck	Mexico, Italy (Emilia Romagna/Puglia/Sicily)	Italy (Emilia Romagna/Apulia/Sicily)
	Chickpeas*		x	Tetra pac	Italy - Sweden		Truck	Italy (Emilia Romagna/Puglia/Sicily)	Italy (Emilia Romagna/Apulia/Sicily)
D	Black beans*		x	Tetra pac	China - Italy - Sweden	Boat	Truck/boat	China, Italy (Campania)	Italy (Campania, Sarno)
	Kidneybeans*		x	Tetra pac	China - Italy - Sweden	Boat	Truck/boat	China, Italy (Campania)	Italy (Campania, Sarno)
	Borlotti beans*		x	Tetra pac	China - Italy - Sweden	Boat	Truck/boat	China, Italy (Campania)	Italy (Campania, Sarno)
	Red lentils*		x	Tetra pac	China - Italy - Sweden	Boat	Truck/boat	China, Italy (Campania)	Italy (Campania, Sarno)
	Green lentils*		x	Tetra pac	China - Italy - Sweden	Boat	Truck/boat	China, Italy (Campania)	Italy (Campania, Sarno)
	Navy beans*		x	Tetra pac	China - Italy - Sweden	Boat	Truck/boat	China, Italy (Campania)	Italy (Campania, Sarno)
	White large beans*		x	Tetra pac	China - Italy - Sweden	Boat	Truck/boat	China, Italy (Campania)	Italy (Campania, Sarno)
	Chickpeas*		x	Tetra pac	Italy - Sweden	Boat	Truck/boat	Italy (Campania)	Italy (Campania, Sarno)
	Green lentils*	x		Plastic bag	Turkey - Denmark - Sweden	Boat	Truck	Turkey	Denmark,Mariager
	Red lentils*	x		Plastic bag	Turkey - Denmark - Sweden	Boat	Truck	Turkey	Denmark,Mariager

*Organic

Blank rows in section *place of processing* means that origin for processing has not been given by the producer/has not been found on the package. Processing refers to drying, rinsing, boiling process. Distance 1 refers to the transport section from continent of origin to Europe. Distance 2 refers to the transport section within Europe.

Table 14. Specific data for pulses found in this study (2/3). The list continues on the next page

Food actor	Variety	Dried	Canned	Packaging materi	Route	Distance 1	Distance 2	Place of processing	Place of packaging
E	Black beans*		x	Tetra pac	China - Italy - Sweden	Boat	Truck	China, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Kidneybeans*		x	Tetra pac	China - Italy - Sweden	Boat	Truck	China, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Brown Lentils*		x	Tetra pac	China - Italy - Sweden	Boat	Truck	China, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Chickpeas*		x	Tetra pac	Italy - Sweden		Truck	Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Borlotti beans*		x	Tetra pac	USA - Italy - Sweden	Boat	Truck	uSA, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
F	Borlotti beans		x	Aluminium can	Italy - Sweden	Boat		Italy	Italy
	Borlotti beans	x		Plastic bag	China - Turkey - Sweden	Boat		Turkey	Turkey
G	Black beans		x	Tetra pac	Argenitina/China - Italy - Sweden	Boat	Train	Argentina/China, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Black beans*		x	Tetra pac	USA/China -Italy - Sweden	Boat	Train	USA/China, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Kidneybeans*		x	Tetra pac	USA/China - Italy - Sweden	Boat	Train	USA/China, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Cannelini*		x	Tetra pac	Argentina/China - Italy - Sweden	Boat	Train	Argentina/China, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	White large beans		x	Tetra pac	China/Poland - Italy - Sweden	Boat/Truck	Train	China/poland, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	White large beans*		x	Tetra pac	China/Poland - Italy - Sweden	Boat/Truck	Train	China/poland, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Chickpeas		x	Tetra pac	Mexico - Italy - Sweden	Boat	Train	Mexico, Italy (Emilia-Romagna)	Italy (Emilia-Romagna)
	Red Lentils*	x		Plastic bag	India/Turkey - Italy - Sweden	Boat/Truck	Boat/Truck	India/Turkey, Italy (Campania/Puglia)	Italy (Campania/Puglia)
	Green lentils*	x		Plastic bag	Russia/Turkey/Canada - Italy - Sweden	Boat/Truck	Boat/Truck	Russia/Turkey/Canada, Italy (Campania/Puglia)	Italy (Campania/Puglia)
	Kidney beans	x		Plastic bag	China - Italy - Sweden	Boat	Train	China, Italy (Campania/Puglia)	Italy (Campania/Puglia)
	Navy beans*	x		Plastic bag	China - Italy - Sweden	Boat	Train	China, Italy (Campania/Puglia)	Italy (Campania/Puglia)
H	Chickpeas*	x		Cardboard box	Turkey - Germany - Sweden	Boat	Truck	Turkey, Adıyaman	Sweden (Malmö)
	Green lentils*	x		Cardboard box	Turkey - Germany - Sweden	Boat	Truck	Turkey, Adıyaman	Sweden (Malmö)
	Red lentils*	x		Cardboard box	Turkey - Germany - Sweden	Boat	Truck	Turkey, Adıyaman	Sweden (Malmö)
	Kidneybeans	x		Cardboard box	China - Germany - Sweden	Boat	Truck	China, Dailan	Sweden (Malmö)
	Navy beans*	x		Cardboard box	China - Germany - Sweden	Boat	Truck	China, Dailan	Sweden (Malmö)
	White large beans*	x		Cardboard box	China - Germany - Sweden	Boat	Truck	China, Dailan	Sweden (Malmö)
	Black beans*	x		Cardboard box	China - Germany - Sweden	Boat	Truck	China, Dailan	Sweden (Malmö)
	Borlotti beans*		x	Aluminium can	USA - Italy - Sweden	Boat	Truck/Train	Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Navy beans*		x	Aluminium can	USA - Italy - Sweden	Boat	Truck/Train	Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Chickpeas*		x	Aluminium can	Italy - Sweden		Truck/Train	Italy, Campania (Neapel)	Italy, Campania (Neapel)
I	Black beans	x		Cardboard box	Sweden (Öland) - Linköping	Truck		Sweden (Öland)	Sweden (Linköping)
	Borlotti beans	x		Cardboard box	Sweden (Öland) - Linköping	Truck		Sweden (Öland)	Sweden (Linköping)
	Kidneybeans	x		Cardboard box	Sweden (Öland) - Linköping	Truck		Sweden (Öland)	Sweden (Linköping)
	Navy beans	x		Cardboard box	Sweden (Öland) - Linköping	Truck		Sweden (Öland)	Sweden (Linköping)
	Black beans		x	Tetra pac	Sweden (Öland) - Linköping - Italy - Sweden	Truck		Sweden (Öland), Italy	Italy
	Borlotti beans		x	Tetra pac	Sweden (Öland) - Linköping - Italy - Sweden	Truck		Sweden (Öland), Italy	Italy
	Kidneybeans		x	Tetra pac	Sweden (Öland) - Linköping - Italy - Sweden	Truck		Sweden (Öland), Italy	Italy
	Navy beans		x	Tetra pac	Sweden (Öland) - Linköping - Italy - Sweden	Truck		Sweden (Öland), Italy	Italy

*Organic

Blank rows in section *place of processing* means that origin for processing has not been given by the producer/has not been found on the package. Processing refers to drying, rinsing, boiling process. Distance 1 refers to the transport section from continent of origin to Europe. Distance 2 refers to the transport section within Europe.

Table 15. Specific data for pulses found in this study (3/3)

Food actor	Variety	Dried	Canned	Packaging materi	Route	Distance 1	Distance 2	Place of processing	Place of packaging
J	Lentils*	x		Plastic bag	Sweden (Gotland/Skåne county) - Gothenbourg (Nol)	Truck/Boat		Sweden (Gotland/Skåne county), Sweden (Nol)	Sweden (Nol)
K	Black beans	x		Plastic bag	Canada - The Netherlands - Sweden	Boat	Truck	Canada, The Netherlands	The Netherlands
	Red lentils	x		Plastic bag	Canada - The Netherlands - Sweden	Boat	Truck	Canada, The Netherlands	The Netherlands
	Green lentils	x		Plastic bag	Canada - The Netherlands - Sweden	Boat	Truck	Canada, The Netherlands	The Netherlands
	Red lentils*	x		Plastic bag	Turkey - The Netherlands - Sweden	Boat	Truck	Turkey, The Netherlands	The Netherlands
	Green lentils*	x		Plastic bag	Turkey - The Netherlands - Sweden	Boat	Truck	Turkey, The Netherlands	The Netherlands
	Black lentils	x		Plastic bag	USA - The Netherlands - Sweden	Boat	Truck	USA, The Netherlands	The Netherlands
	Borlotti beans*	x		Plastic bag	China - The Netherlands - Sweden	Boat	Truck	China, The Netherlands	The Netherlands
	Kidney beans*	x		Plastic bag	China - The Netherlands - Sweden	Boat	Truck	China, The Netherlands	The Netherlands
	Navy beans*	x		Plastic bag	China - The Netherlands - Sweden	Boat	Truck	China, The Netherlands	The Netherlands
	White large beans*	x		Plastic bag	China - The Netherlands - Sweden	Boat	Truck	China, The Netherlands	The Netherlands
	Black beans		x	Tetra pac	China/North america - Italy - Sweden	Boat	Boat/Truck/Train	China/North America, Italy	Italy
	Kidney beans		x	Tetra pac	Canada/USA -Italy - Sweden	Boat	Boat/Truck/Train	Canada/USA, Italy	Italy
	Chickpeas		x	Tetra pac	USA/Canada/Argentina - Italy - Sweden	Boat	Boat/Truck/Train	USA/Canada/Argentina, Italy	Italy
	Large white beans		x	Tetra pac	Poland - Italy - Sweden	Boat	Boat/Truck/Train	Poland, Italy	Italy
	Black beans*		x	Tetra pac	China/North america - Italy - Sweden	Boat	Boat/Truck/Train	China/North america, Italy	Italy
	Canellini beans*		x	Tetra pac	China/North america - Italy - Sweden	Boat	Boat/Truck/Train	China/North america, Italy	Italy
	Kidneybeans*		x	Tetra pac	China/North america - Italy - Sweden	Boat	Boat/Truck/Train	China/North america, Italy	Italy
	Chickpeas*		x	Tetra pac	Italy - Sweden	Boat	Boat/Truck/Train	Italy	Italy
	Borlotti beans*		x	Tetra pac	Italy - Sweden	Boat	Boat/Truck/Train	Italy	Italy
	Kidney beans		x	Aluminium can	China - Italy - Sweden	Boat	Boat/Truck/Train	China, Italy (Campania)	Italy (Campania)
	Chickpeas		x	Aluminium can	Italy - Sweden	Boat	Boat/Truck/Train	Italy	Italy
L	Black beans*		x	Tetra pac	China - Italy - Sweden	Boat	Boat	China, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Canellini beans*		x	Tetra pac	China - Italy - Sweden	Boat	Boat	China, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Green lentils*		x	Tetra pac	China - Italy - Sweden	Boat	Boat	China, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Borlotti beans*		x	Tetra pac	Canada/USA/Italy/China - Italy - Sweden	Boat	Boat	Canada/USA/China, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Kidney beans*		x	Tetra pac	USA/China - Italy - Sweden	Boat	Boat	USA/china, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Kidney beans*		x	Aluminium can	China/Tanzania/USA- Italy - Sweden	Boat	Boat	China/Tanzania/USA, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Chickpeas*		x	Aluminium can	Italy/USA/Argentina - Italy - Sweden	Boat	Boat	USA/Argentina, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	Black beans*		x	Aluminium can	South america/China - Italy - Sweden	Boat	Boat	South America/China, Italy, Campania (Neapel)	Italy, Campania (Neapel)
	White large beans*		x	Aluminium can	Poland - Italy - Sweden	Truck	Boat	Poland, Italy, Campania (Neapel)	Italy, Campania (Neapel)

*Organic

Blank rows in section *place of processing* means that origin for processing has not been given by the producer/has not been found on the package. Processing refers to drying, rinsing, boiling process. Distance 1 refers to the transport section from continent of origin to Europe. Distance 2 refers to the transport section within Europe.

Table 16. Number of times a route was stated for a total of 91 imported dry or canned (in 380 g Tetra Pak) beans, lentils and chickpeas found in the Swedish Supermarket 2020. One product sometimes stated several countries of origin. Routes used for calculations in this study are marked in bold

ROUTE	TOTAL
Argentina - Italy - Sweden	4
Canada - Belgium - Sweden	1
Canada - Denmark - Sweden	1
Canada - Italy - Sweden	**8**
Canada - England - Sweden	**1**
Canada - The Netherlands - Sweden	**3**
Canada - Turkey - Sweden	1
China - Denmark - Sweden	**2**
China - England - Sweden	3
China - Germany - Sweden	**4**
China - Italy - Sweden	**36**
China - The Netherlands - Sweden	**4**
China - Turkey - Sweden	1
France - Belgium - Sweden	1
India - Italy - Sweden	1
Italy - Denmark - Sweden	2
Italy - Sweden	**10**
Mexico - Italy - Sweden	2
Poland - Italy - Sweden	4
Poland - England - Sweden	1
Russia - Italy - Sweden	1
South america - Italy - Sweden	1
Tanzania - Italy - Sweden	1
Turkey - Belgium - Sweden	1
Turkey - Denmark - Sweden	**6**
Turkey - Germany - Sweden	**3**
Turkey - Italy - Sweden	**2**
Turkey - The Netherlands - Sweden	**2**
USA - England - Sweden	3
USA - Italy - Sweden	**17**
USA - The Netherlands - Sweden	1
Sweden (Öland) - Linköping	4
Sweden (Öland) - Linköping - Italy - Sweden	4
Sweden (Gotland) - Gothenburg	1

Table 17. Number of times a route was stated for a total of 91 imported dried or canned beans, lentils and chickpeas found in the Swedish Supermarket 2020. One product sometimes stated several countries of origin. Routes used for calculations in this study are marked in bold

IMPORTED BEANS	
Argentina - Italy - Sweden	2
Canada - Italy - Sweden	**6**
Canada - The Netherlands - Sweden	1
canada - Turkey - Sweden	1
China - Denmark - Sweden	**2**
China - England - Sweden	3
China - Germany - Sweden	**4**
China - Italy - Sweden	**32**
China - The Netherlands - Sweden	**4**
China - Turkey - Sweden	1
Italy - Denmark - Sweden	1
Italy - Sweden	2
Poland - England - Sweden	1
Poland - Italy - Sweden	4
south america	1
Tanzania - Italy - Sweden	1
Turkey - Denmark - Swedem	1
USA - England - Sweden	2
USA - Italy - Sweden	**15**

IMPORTED LENTILS	
Canada - Belgium - Sweden	1
Canada - Denmark - Sweden	1
Canada - Italy - Sweden	1
Canada - England - Sweden	**1**
Canada - The Netherlands - Sweden	**2**
Canada - Turkey - Sweden	1
China - Italy - Sweden	4
India - Italy - Sweden	1
Russia - Italy - Sweden	1
Turket - Belgium - Sweden	1
Turkey - Denmark - Sweden	**4**
Turkey - Germany - Sweden	**2**
Turkey - Italy - Sweden	**2**
Turkey - The Netherlands - Sweden	**1**
USA - England - Sweden	1
USA - The Netherlands - Sweden	1

IMPORTED CHICKPEAS	
Argentina - Italy - Sweden	2
Canada - Italy - Sweden	1
France - Belgium - Sweden	1
Italy - Denmark - Sweden	1
Italy - Sweden	**7**
Mexico - Italy - Sweden	2
Turkey - Denmark - Sweden	**1**
Turkey - Germany - Sweden	**1**
USA - Italy - Sweden	2

Table 18. Regions of cultivation and seaports used to determine distances. Represents the most frequently mentioned cultivation sites and seaports by contacted actors in this study

Land of origin	**Types of pulses**	**Region of cultivation**	**Sea port**
Canada	Lentils	Saskatchewan, Manitoba	Port of Montreal, Vancouver
	Common Beans	Saskatchewan, Manitoba	Port of Montreal
China	Common Beans	Tongliao, HeilongJiang, Sichuan	Port of Dalian, Port of Shenzhen
USA	Common beans	Wisconsin, Michigan	Port of Montreal
Turkey	Lentils	District of Kozluk, Batman province	Port of Mersin
Italy	Chickpeas	Marche, Puglia	Port of Salerno, Port of Napels
Sweden	Common Beans	Öland	Beans are not passing a sea port
	Lentils	Gotland, Skåne county	Ferry from Visby to Oskarshamn

Table 19. Input data (1/3) for calculations in Network for transport measures (NTM)

Type of vehicle	Input data	NTMs Parameter description
Rigid truck 14-20 t		
Cargo carrier capacity	12 tonne	*Maximum weight load capacity of the vehicle
Cargo load factor - weight	40	*The percentage of the maximum weight load capacity that is actually utilized.
Euro class	6	*The emission standard of the vehicle, as defined by European Union directives.
Fuel	Diesel B7 - SWE	*Type of fuel used to power the vehicle. Options for input data e.i. pure diesel or diesel with 5 or 7 % biodiesel purchased within Sweden or EU.
Fuel consumption	0.211 l/km	*The actual fuel consumption based on the selected road type, fuel type, euroclass, gradient and load factor.
Road gradient	± 2 %	*The average road gradient, uphill (+) and downhill (-), for bi-directional traffic.
Road type	Average road type	*A road mix which is typical for a transport within Sweden
Truck with trailer 20-28 t		
Cargo carrier capacity	16 tonne	*Maximum weight load capacity of the vehicle
Cargo load factor - weight	40	*The percentage of the maximum weight load capacity that is actually utilized.
Euro class	6	*The emission standard of the vehicle, as defined by European Union directives.
Fuel	Diesel B7 - SWE	*Type of fuel used to power the vehicle. Options for input data e.i. pure diesel or diesel with 5 or 7 % biodiesel purchased within Sweden or EU.
Fuel consumption	0.259 l/km	*The actual fuel consumption based on the selected road type, fuel type, euroclass, gradient and load factor.
Road gradient	± 2 %	*The average road gradient, uphill (+) and downhill (-), for bi-directional traffic.
Road type	Motorway	*A main road for fast-moving traffic, having limited access and separate carriageways for vehicles travelling in opposite directions
Truck with trailer 28-34 t		
Cargo carrier capacity	22 tonne	*Maximum weight load capacity of the vehicle
Cargo load factor - weight	50	*The percentage of the maximum weight load capacity that is actually utilized.
Euro class	4	*The emission standard of the vehicle, as defined by European Union directives.
Fuel	Diesel B5 - EU	*Type of fuel used to power the vehicle. Options for input data e.i. pure diesel or diesel with 5 or 7 % biodiesel purchased within Sweden or EU.
Fuel consumption	0.291 l/km	*The actual fuel consumption based on the selected road type, fuel type, euroclass, gradient and load factor.
Road gradient	± 2 %	*The average road gradient, uphill (+) and downhill (-), for bi-directional traffic.
Road type	Motorway	*A main road for fast-moving traffic, having limited access and separate carriageways for vehicles travelling in opposite directions
Truck with trailer 34-40 t		
Cargo carrier capacity	26 tonne	*Maximum weight load capacity of the vehicle
Cargo load factor - weight	50	*The percentage of the maximum weight load capacity that is actually utilized.
Euro class	4	*The emission standard of the vehicle, as defined by European Union directives.
Fuel	Diesel B5 - EU	*Type of fuel used to power the vehicle. Options for input data e.i. pure diesel or diesel with 5 or 7 % biodiesel purchased within Sweden or EU.
Fuel consumption	0.330 l/km	*The actual fuel consumption based on the selected road type, fuel type, euroclass, gradient and load factor.
Road gradient	± 2 %	*The average road gradient, uphill (+) and downhill (-), for bi-directional traffic.
Road type	Motorway	*A main road for fast-moving traffic, having limited access and separate carriageways for vehicles travelling in opposite directions

Table 20. Input data (2/3) for calculations in Network for transport measures (NTM)

Truck with trailer 50-60 t		
Cargo carrier capacity	40 tonne	*Maximum weight load capacity of the vehicle
Cargo load factor - weight	50	*The percentage of the maximum weight load capacity that is actually utilized.
Euro class	6	*The emission standard of the vehicle, as defined by European Union directives.
Fuel	Diesel B7 - SWE	*Type of fuel used to power the vehicle. Options for input data e.i. pure diesel or diesel with 5 or 7 % biodiesel purchased within Sweden or EU.
Fuel consumption	0.510 l/km	*The actual fuel consumption based on the selected road type, fuel type, euroclass, gradient and load factor.
Road gradient	± 2 %	*The average road gradient, uphill (+) and downhill (-), for bi-directional traffic.
Road type	Average road type	*A road mix which is typical for a transport within Sweden
Container ship 40 000 dwt		
Cargo load factor - weight	70	*The percentage of the maximum weight load capacity that is actually utilized. **Factor 70 was used for all grain legumes transported by ship was assumed to be dry product.**
Nox emission compliance	Tier I	*Compliance with the IMO NOx emission standards. Applies to ships with construction date after 1 January 2000.
RO 2,7 % S, fuel share	100% weight	*Share in % weight of RO 2.7%S (residual oil with 2.7 % sulphur).
Shipment weight	1 ton	*The weight of the shipment that is subject of the transport. **1 tonne was used as a default value for all distances.**
Ship size	40 000 dwt	*The ship size measured by its carrying capacity in deadweight tonnes (dwt) which includes cargo, fuel, fresh water, ballast water, provisions, passengers and crew.
Type of waters	Ocean	*Depending on type of waters selected, a typical ship size was selected by the calculation tool itself and used as default value for the field "Ship size". ***Ocean*** **was used for all distances to Europe except from China.**
Container ship 160 000 dwt		
Cargo load factor - weight	70	*The percentage of the maximum weight load capacity that is actually utilized.
Nox emission compliance	Tier I	*Compliance with the IMO NOx emission standards. Applies to ships with construction date after 1 January 2000.
RO 2,7 % S, fuel share	100% weight	*Share in % weight of RO 2.7%S (residual oil with 2.7 % sulphur).
Ship size	160 000 dwt	*The ship size measured by its carrying capacity in deadweight tonnes (dwt) which includes cargo, fuel, fresh water, ballast water, provisions, passengers and crew.
Type of waters	Ocean large	*Depending on type of waters selected, a typical ship size was selected by the calculation tool itself and used as default value for the field "Ship size". ***Ocean large*** **was used for distances from China to Europe.**
Ro-Ro ship		
Cargo load factor - weight	70	*The percentage of the maximum weight load capacity that is actually utilized.
Nox emission compliance	Tier I	*Compliance with the IMO NOx emission standards. Applies to ships with construction date after 1 January 2000.
RO 2,7 % S, fuel share	100% weight	*Share in % weight of RO 2.7%S (residual oil with 2.7 % sulphur).
Ship size	10 000 dwt	*The ship size measured by its carrying capacity in deadweight tonnes (dwt) which includes cargo, fuel, fresh water, ballast water, provisions, passengers and crew.
Type of waters	Regional	*Depending on type of waters selected, a typical ship size was selected by the calculation tool itself and used as default value for the field "Ship size". **Regional water was used for distances from Germany to Denmark/Sweden.**

Table 21. Input data (3/3) for calculations in Network for transport measures (NTM)

Eletric cargo train		
Cargo load factor - weight	60%	*The percentage of the maximum weight load capacity that is actually utilized.
Cargo type	Average	*Freight train cargo types. *Average* describes a general cargo transporting consumer goods etc. (not bulk).
Empty positioning factor	0.50	*The portion of the transport distance that the train, on average, will run empty due to unbalances in cargo flows. If the factor, for example, is set to 0.5, and the transport distance is 100 km, then the train will run empty for an extra 50 km in connection to the transport.
Fuel	EU 27 mix/Swedish supply mix	*Type of fuel used to power the vehicle. ***EU 27 mix*** is a mix of energy feedstock e.g. coal, uranium, oil, gas, biomas as well as wind and hydro power, based on weighted average production among EU countries. ***Swedish railways supply mix*** is a mix of energy feedstock supplied by the Swedish Transport Administration at swedish railways.
Max payload:Gross weight ratio	73 % weight	
Topography	Hilly	*The hilliness of the landscape which the train travels through. Hilly was chosen (neutral slope factor 100%, typical areas are France, Germany, Finland, Polen (except regions in these countries where flat or mountainious conditions dominate).
Train size	Heavy	*Small/medium/large/heavy
Train weight	2 000 tonne	*Train gross weight including engine, wagons and cargo.
Transmission losses	0.15	*Energy losses during transmission and voltage/frequency transformation between the powerplants(s) and the engine.
Diesel cargo train		
Cargo load factor - weight	60%	*The percentage of the maximum weight load capacity that is actually utilized.
Cargo type	Average	*Freight train cargo types. *Average* was choicen as it describes a general cargo transporting consumer goods etc. (not bulk).
Empty positioning factor	0.50	*The portion of the transport distance that the train, on average, will run empty due to unbalances in cargo flows. If the factor, for example, is set to 0.5, and the transport distance is 100 km, then the train will run empty for an extra 50 km in connection to the transport.
Fuel	Diesel B0 - EU	*Type of fuel used to power the vehicle. Two options diesel B0 - EU or diesel B0 - Swe
Max payload:Gross weight ratio	73 % weight	
Topography	Hilly	*The hilliness of the landscape which the train travels through. Hilly was chosen (neutral slope factor 100%, typical areas are France, Germany, Finland, Polen (except regions in these countries where flat or mountainious conditions dominate).
Train size	Heavy	*Small/medium/large/heavy
Train weight	2 000 tonne	*Train gross weight including engine, wagons and cargo.

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