School of Business, Economics and Law
GÖTEBORG UNIVERSITY

SIR-C Swedish Intermodal Transport Research Centre

Rail freight costs

Some basic cost estimates for intermodal transport

Jonas Flodén

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Jonas Flodén
Department of Business Administration
School of Business, Economics and Law
University of Gothenburg
P.O. Box 610
SE 405 30 Göteborg
Sweden

E-mail: jonas.floden@handels.gu.se
http://www.handels.gu.se/fek/logistikgruppen
http://www.sir-c.se
Telephone: +46-(0)31-786 51 31

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1 Introduction

A number of rail cost calculations has been performed as a part of providing general input data for the Heuristics Intermodal Transport model (HIT-model). A summary of the input data has been presented in the report *Suggested input data*, written by Flodén (2011). This report intends to provide more information regarding rail cost calculations. The cost data is for the year 2010, unless otherwise stated. All costs are in Swedish kronor, kr (SEK).

Freight rail cost calculations are generally considered relatively challenging, due to the reluctance of rail companies to share cost data. The number of rail haulage companies, maintenance companies, equipment manufacturers etc. in the market is still fairly low, which limits the number of data sources from which to obtain information. The newly deregulated market also makes companies careful about sharing data for competitive reasons. In comparison, the road haulage market consists of a very high number of haulage firms using similar equipment, with a large number of equipment and service providers. Thus, road cost data is well known, while there is a lack of good rail cost data. This report will openly show cost calculations, input data and sources. The calculations are also available as an attached Excel file and can be obtained by contacting the author.

The cost data will focus on Swedish conditions and analyses aimed at a strategic level. The data presented is production costs. There is a difference between cost and price. The cost is the cost necessary to produce a service, while price is what a customer will have to pay to use a service, and can be affected by many more factors than the actual cost of transport.

1.1 Some important aspects of rail freight transport calculation

Cost calculation is not an exact science, and the types of costs included and their estimation can vary between different calculations. The intention of this chapter is not to instruct the reader on how to make basic calculations, but rather to highlight some important characteristics of rail freight calculations.

1.2 Cost structure

The cost structure in the transport industry can, as in most other industries, be divided into fixed costs and variable costs. The division into fixed and variable costs is completely dependent on the time period over which the system is studied. Rent for a terminal area is, for example, a fixed cost on a day-to-day basis, but a variable cost over a 20-year period, where a choice may be made to close the terminal. Similarly, if a decision has been made to operate a train according to a certain timetable during the next year, the cost of operating the train can be considered a fixed cost during that year. The fixed costs are, thus, really variable costs that can be considered fixed for the chosen time period. Many of the fixed costs are also shared costs, e.g. general administration, which either have to be considered jointly for the entire business or allocated to suitable cost units, e.g. lorries.

The variable costs can be further subdivided into costs variable by time and distance transported. Commonly mentioned time-dependent costs are financial costs, salary costs, vehicle taxes and insurance. Commonly mentioned distance dependent costs are tires, fuel, maintenance, kilometre taxes, and rail infrastructure fees. As mentioned above, some of these costs are regarded as fixed costs in many calculations, depending on the time frame.

The division in fixed, variable, time and distance-dependent costs might sometimes appear arbitrary. For example, the capital cost of a piece of equipment can be considered a fixed cost for a year, but can also be allocated into a cost per time or cost per distance, if the yearly utilisation is known. The principle is then to choose the allocation that gives the fairest representation of the real costs, and matches the way in which the output from the calculation is to be used.

1.3 Depreciation

Expensive equipment that is purchased for use over a long period of time is normally depreciated over its service life. This means that the initial cost is allocated over several years in the company's bookkeeping. This is also done when calculating the running costs. Calculations often separate economic life and technical life. Technical life is how long the assets can technically be used, while economic life is how long it is economically meaningful to use it. The economic life is often shorter than the technical life, since new inventions and increasing maintenance costs make it unprofitable to continue using the assets.

Production cost calculations should assume that the cost of an investment is allocated to the period of use, i.e. that the cost is divided over its entire economic life. However, many companies use a shorter depreciation time for accounting purposes, e.g. for tax reasons or that the economic life became longer than was expected when the equipment was purchased. The easiest, and perhaps most common, method of allocating the costs is to use linear depreciation, i.e. the same sum is depreciated each year.

1.4 Overhead costs

All operations also include certain costs that are difficult to allocate to a specific activity in the company, e.g. general administration, some insurance, advertising costs etc. These are very much dependent on the specific conditions in the organization, and therefore make it hard to obtain general estimates. Most calculations include these overhead costs as a percentage surcharge to the other costs. The underlying cost is then a general cost driver for the overhead costs. This practice might create some unintended effects in calculations with very high fixed costs, as is the case in transport cost calculations. It can be argued that a new, expensive rail engine will not require more administration than an old low-cost engine operating in exactly the same transport system, but that rather the opposite may be the case, since the number of breakdowns, etc., are likely to be smaller for the new engine. Also, the amount of necessary administration might be significantly different between a small company and a large company. However, unless the specific administrative costs are known, it is recommended to use a percentage surcharge. A general estimate of 10-15% can be used. This percentage surcharge could be lower if equipment with high capital costs is used, as the general administration costs are not likely to increase only because the equipment is more expensive.

1.5 Level of detail

Perhaps the most important thing to know about cost calculations is that they will never be completely correct. This is particularly true when trying to estimate the costs of equipment that will be used for 35 years. Of course, one should always try to make the calculations as accurate as possible, but it is also important to realise that the right level of detail must be used, and the same level of detail should be used in all aspects of the calculation. For example, it is not necessary to calculate the specific tax effects for the pension fees included in the salary, while at the same time only using a rough estimate of the actual salary paid. The level of detail in the calculations should match the quality of the input data and the intended use of the output data.

1.6 External costs and social valuation

Apart from the direct operating costs, transport also incurs substantial external costs. External costs are caused by external effects which occur when (Button, 1993, p. 93)

> *the activities of one group affect the welfare of another group without any payment or compensation being made.*

Note that external effects, by definition, can be both positive and negative. Many of these external effects can be attributed to environmental pollution but there are also many other external effects (Button, 1993), such as noise, visual intrusion (e.g. destroying a beautiful view), risk of accidents, and the barrier effects of a road. Button makes a division between technological externalities and pecuniary externalities. Technological externalities are effects caused directly by production or consumption, e.g. building a road destroys a beautiful view, while pecuniary effects are indirect effects, e.g. when traffic diverted to the new road takes potential customers away from a garage on the old road, causing a reduced income for the garage. A further distinction can be made between pollution and congestion, where pollution is an external factor that affects actors external to the medium, e.g. plants killed by exhaust fumes. Congestion is when the external effect affects actors that are also using the medium, e.g. private motorists are caught in queues caused by lorries.

The notion of external effects is also closely linked to the social cost perspective and valuation of costs. The social cost perspective aims at (Bohm, 1996, p. 12)

> *taking into consideration all individuals' appraisals of, in principal, everything produced or consumed / used, i.e. not only the purely material aspects*

Society, from this perspective, includes not only the government and public sectors, but all citizens and companies in society. Social cost valuations of transport are commonly made, particularly in conjunction with infrastructure investments and as a part of political decision processes. The valuations aim at including the external effects in the decision process, where the external effects are included in monetary estimation[1]. Naturally, it is very difficult to find a fair way to valuate these aspects. For example, if building a new road will destroy the local habitat of a small frog threatened by extinction, how can this loss be valued? The effects occur on three levels: local, regional and global. Local effects are health effects, contamination (dirt) and corrosion. Regional effects include damage to the environment and health effects. Global effects are the green house effect and reduction of the ozone layer (SIKA, 2002). Some general values for social costs have been decided by the Swedish Institute for Transport and Communications Analysis (SIKA)[2] (SIKA, 2008)), to be used for Swedish national transport planning. These values are used in this report.

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[1] Social cost valuation can, of course, also be non-monetary, but the general aim is to include as much factors as possible as monetary. A division can be made between social cost calculation, where everything is included at monetary values, and social analysis where none-monetary values are included.

[2] Recently renamed the Swedish Agency for Transport Policy Analysis (TrafikAnalys).

2 Train operations

Freight trains are operated either as block trains, wagon groups or wagon loads. A block train is a full train in which all the wagons are being sent between the same origin and destination. A wagon group is a group of wagons that are being sent between the same origin and destination. The wagon group is shunted between trains. A wagon load is a single wagon. The wagon is sent in the wagon load system, where the trains exchange wagons at central marshalling yards. The most efficient transport is the block train, followed by wagon groups and the last wagon load.

Intermodal freight transport in Sweden today almost exclusively operates with the use of block trains. Block trains are assumed in these calculations.

2.1 Rolling stock

The equipment used in the Swedish railway sector is still largely influenced by the equipment used by the former state railway, SJ, before the deregulation in 2001, since the former state railway and its privatised elements still dominate the rail sector. The long technical life of rail equipment means that the equipment from before the deregulation has only recently begun to be replaced.

2.1.1 Engines

SJ used a standard type RC electrical engine for almost all their electrical trains, both passenger and freight. Diesel engines type T44, was used for the diesel line haul and some shunting. The RC engines were built by ASEA between 1967 and 1988, and exist in a number of different versions (RC 1 to RC7). An RC engine weighs 78 tonnes and can pull trains of about 1600 tonnes. This engine still remains the most common electrical engine in Sweden. Recently, this type has started to be replaced by more modern engines from Bombardier’s TRAXX-family and the SIEMENS Eurosprinter. These engines weigh about 84 tonnes and can pull trains of about 2000 tonnes.

Figure 1 Two RC4 engines (Picture: Flodén)

Diesel line haul is not that common in Sweden, since most lines are electrified. The type T44, manufactured between 1968 and 1987, is still the most common diesel engine, although a limited number of modern engines are starting to appear. The T44 weighs 76 tonnes and can pull trains of about 900 tonnes in a line haul, but is heavier when shunting. Other common types are the old TMY, TMX and TMZ engines purchased from the Danish railways. Only a few modern diesel engines are operated in Sweden.

Figure 2 A TMY diesel engine (Picture: Wikipedia)

More information about the different engines types currently used in Sweden can be found on the Lokguiden (the Engine Guide) homepage[3].

The technical life of a rail engine might be very long. 50-year-old engines, such as the diesel TMY and TMX, are still used in the Swedish rail network, although in limited numbers. A more normal (Nelldal, 2011)economic life expectancy for a rail engine is about 35 years[4]. The economic life can also be extended by upgrades and modernisations. Green Cargo recently ordered an upgrade of their 35-40 year old type RC2 and RC3 electrical engines. This is expected to prolong their service life by 15-20 years (Green Cargo, 2007) at a cost of about 25 million SEK each[5] (Green Cargo, 2010)

The oldest engines tend to be used by smaller independent operators, due to their relatively low purchase price. An old RC engine can be valued at about 10 million SEK (depending on its age and exact type[6]) as compared to a new TRAXX engine at about 35 million SEK (Nelldal, 2011). A new operator starting its business is likely to prefer a less expensive engine (but with higher operating costs), in order to reduce the initial need for capital. One particular problem with the rail engine market is the different technical standards in different countries. In most cases, it is not possible to move an engine from one country to another without having to adapt that country's signalling system, electricity system, certificates and approval, etc., to the local standards, a process which might be expensive. This limits the market for second-hand engines. Leasing a modern engine is also an option for an operator who wants access to modern equipment without the high investment costs, although this is more expensive than using an old engine. The availability of leasing engines that are technically adapted to smaller markets, such as the Swedish market, might also be limited.

2.1.2 Wagons

Several different rail wagons and wagon manufacturers exist. However, all manufacturers classify their wagons according to a classification system laid out by the UIC (International Union of Railways), where letters are used to identify the characteristics of a wagon. For example, an Lgns wagon is a flat wagon with separate axels (L) used for container transport (g), with a max load of at least 30 tonnes (n) and suitable for speeds up to 100 km/h (s). Thus, two Lgns wagons from different

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[3] http://www.jarnvag.net/index.php/lokguide
[4] Bark states 25-30 years and Nelldal states 35 years.
[5] 42 engines modernised at a total cost of 1.1 billion SEK.
[6] The RC engines are between 43 and 22 years old and exist in several versions.

manufacturers might have a slightly different design and set of technical specifications, but they share the same classification.

The most common types of wagons for intermodal transport in Sweden are Lgns, Sgns and Sdggmrss.

A two-axle standard container Lgns wagon weighs 12.5 tonnes and has a length of 17.1 meters. The wagon can carry two 20’ containers/swap bodies or one 40´container, and can load 33 tonnes (gross weight of containers). This is, in essence, a flat wagon with pins to fasten the containers together. This is an older type of wagon that can be purchased second-hand for about 100 000 SEK, with an expected service life of 15 years. Maintenance costs are about 0.10 SEK/km (Nelldal, 2011).

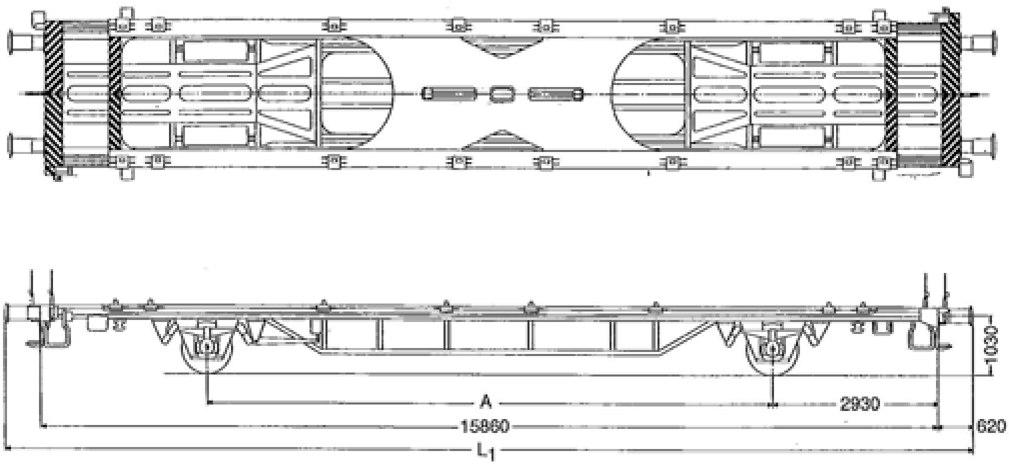

Figure 3 Lgjns wagon (source: Green Cargo homepage)

The Sgns wagon is a four-axel wagon weighing 20 tonnes. The wagon can carry three 20’ containers/swap bodies or combinations of 20’, 30’ and 40’containers/swap bodies. The wagon length is 19.6 meters and it can load 70 tonnes (Green Cargo, 2011). The cost of purchasing a wagon is about 700 000 kr, with an expected service life of 50 years. Maintenance costs are about 0.15 SEK/km (Nelldal, 2011).

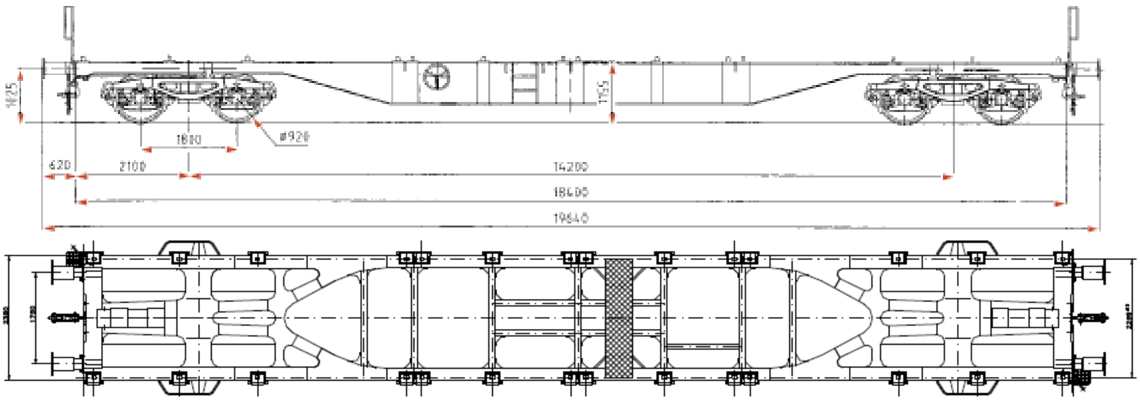

Figure 4 Sgns wagon (source: Green Cargo homepage)

Trailers are normally transported in sdggmrss wagons, which are equipped with “pockets” to accommodate the wheels of the trailer. These are longer six-axle wagons (34.2 meters) which can carry two trailers or four 20’ containers/swap bodies, or combinations thereof. Tara weight is 34.8

tonnes and maximum load is 100 tonnes. The cost to purchase a wagon is currently about 1.3 million SEK with an expected service life of 30-35 years (Nelldal, 2011, Oehrstroem, 2005). Maintenance costs are about 0.25-0.30 SEK/km (Oehrstroem, 2005). It is more expensive than other wagon types, but this multipurpose wagon can carry all common load unit types.

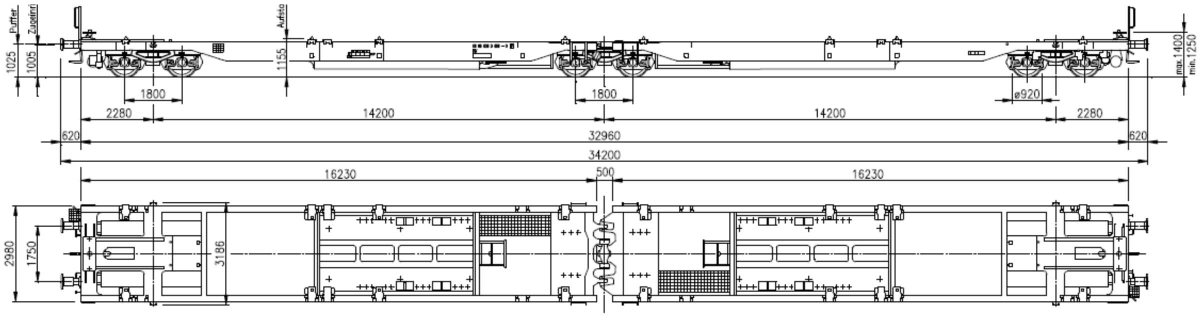

Figure 5 Sdggmrss wagon (source: Green Cargo homepage)

When operating a train service, more wagons are needed than those that are actually installed on each train. A number of spare wagons is needed when other wagons are in for maintenance, repairs etc. The necessary number of wagons is difficult to estimate. A large operator will obtain scale effects and can share the reserve wagons between several train services, which is not possible for a small operator.

2.2 Utilisation

A key factor influencing the cost of operating a train is the utilisation of the equipment. Due to the high fixed costs associated with engines and wagons, it is important to utilise the equipment as much as possible in order to keep the fixed costs per km as low as possible. A train operating on a 500km shuttle service each week night and staying idle during the day will have a total utilisation (excl. holidays, maintenance etc.) of roughly 120 000 km per year (500*5*48). If the same train could run twice per day, every day of the week, the utilisation would be 364 000km (500*2*7*52), or almost three times as often. However, the fixed costs concerning the cost of capital would stay the same.

Official statistics show that Sweden has 316 electrical engines available for freight transport, which performed 43 678 000 train kilometers in 2008. This would provide an average utilisation of 138 000 km per engine (SIKA, 2009). However, the individual variations are very large; some old engines are used very little, mainly as backup or for shunting. Thus, the median utilisation is larger. The same calculations for a diesel engine are not meaningful, as they result in unrealistic low utilisations, probably caused by the fact that most diesel engines are used for shunting[7].

The utilisation of the rail wagons is normally lower than that of the engines. The standard procedure for intermodal transport begins when an engine delivers a number of rail wagons to a terminal and then leaves to perform other haulage. The wagons are left at the terminal, where they are unloaded and re-loaded for a couple of hours. A rail engine then returns to pick up the wagons. As for engines, it is very hard to estimate an average utilisation. Statistics show that the average Swedish freight rail

[7] 222 diesel engines performs 3 940 000 trainkm.

wagon travels about 71 000km per year[8]. It is likely that intermodal wagons, often operating in shuttle trains, have a higher utilisation. Nelldal (2011) estimates a utilisation of 110 000 km per year for a Lgs wagon and 220 000 km per year for a Sgns/Sddgmrs wagon.

If known, it is obviously recommended that the planned utilisation of the train system under calculation be used, since these costs are highly dependent on the design of the specific train system, and will in many cases be a decisive factor in the profitability of a system.

The length of the train and the number of wagons might also differ. Generally, a maximum train length of 630 meters can be used in Sweden, which equals about 18 sdggmrs wagons, 20 sgns or 36 lgns wagons. The maximum train length depends on a number of factors, such as train weight, type of engine, breaks, terrain etc., but most often, the limiting factor is the length of the side tracks used for meeting other trains on a single track line. However, the Swedish rail traffic regulations stipulates a maximum train length of 730 meter or 880 meters depending on the breaks, but also states that the infrastructure will generally not allow such long trains (Trafikverket, 2010b).

A typical intermodal train in Sweden, according to data from one of the large operators, (Bäckström, et al., 2009) is 410 meters with 20 Sgns wagon and 60 TEU capacity. The train weight is 806 tonnes (excl. engine) and the loaded weight on the train was 398 tonnes, consisting of 45 TEU, of which 18 TEU were empty units. The average load per wagon is 19.9 tonnes. Looking at the freight train in general, the average freight train in Sweden has a weight of 490 net tonnes (Nelldal, et al., 2005), i.e. approximately 15 wagons.

The average speed of a freight train in Sweden is about 70km/h. This assumes a, more or less, continuously running block train, a speed which might drop substantially, e.g. if shunting and marshalling is required. This is particularly noteworthy in a European context where wagon load traffic can have substantial waiting times at congested marshalling yards.

2.2.1 Personnel costs

Wages can vary between operators. The largest freight train operator in Sweden, Green Cargo, pays their engine drivers 28 000 kr per month, 12 months per year, after two years working experience (Green Cargo, 2009a, Green Cargo, 2009b). Added to this is a holiday pay (0.8% of the monthly pay per day on holiday) and other surcharges, such as overtime pay, overnight allowances and on call time. Most notably, night work between 7 p.m. and 6 a.m. is paid 37.20 extra per hour. Most freight trains are run during the night. According to national statistics from Statistics Sweden, the average salary of an engine driver (both passenger and freight), including surcharges, is 29 000 kr (SCB, 2009). Added to this are taxes paid by the employer, currently 31.42% in Sweden (Skatteverket, 2011), and other charges such as collective insurances and extra pension fees agreed on with the union. These other charges can vary between different employers but is normally around 7.5%, of which 4.5% is pension fees. The working time is 36 hours per week for employees that work at night and 40 hours for employees that work during the day. The workers have 25 days of vacation per year plus national holidays, such as Christmas, Easter etc.(Green Cargo, 2009a). This provides a total number of working

[8] Calculated based on SIKA (2009). Total transport tonnekm (weight of all goods transported) subtracted from total wagontonnekm (weight of all goods and wagons) to get wagontonkm excl. goods (22.8 milliongrosstonkm). Average weight of a rail wagon in Sweden (20.5 tonnes) calculated by using the number of wagons (15 623 total) of each type and an average weight per type. From this, the average km per wagon can be calculated.

hours per year of about 1 600 hours for nighttime workers. About 75% of this time is spent actually driving a train (Nelldal, 2011).

2.3 Infrastructure use

Rail infrastructure (tracks, etc.) is publicly owned in Sweden and each railway operator pays a fee to use the infrastructure. The fee is divided into one fixed fee part for the train and one flexible element that changes depending on train weight/length. Note that this might be different in other parts of Europe. The current infrastructure fees in Sweden for 2011 are:

Train path for a freight service	SEK 0.27/train-kilometre, (1.67 on high standard lines)
Track charge	SEK 0.0036/gross tonne-kilometre
Accident charge	SEK 0.81/train-kilometre
Emission charge, diesel-powered engine	SEK 0.87/litre of diesel fuel

Table 1 Infrastructure charges

There are further fees to use marshalling yards, “parking fees,” use of stations, etc. in Sweden. Some parts of the network with higher standards also have higher train path fees for trains using that part of the network. This applies for the main lines between Stockholm, Gothenburg and Malmö and some other lines. A large share of intermodal trains in Sweden can be expected to, at least partly, use the high-standard part of the network, as these are the lines with the highest demand for freight transport (excluding iron ore). There is also an extra passage charge for passing certain congested points, e.g. Stockholm main central, at certain times of the day, of 150 kr per passage (Banverket, 2010, Trafikverket, 2010b)

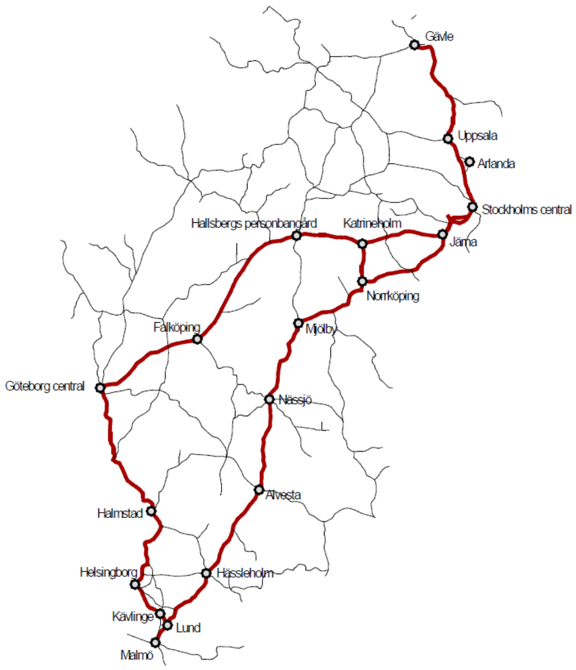

Figure 6 High level fee network marked in bold red on the map (Banverket, 2010, p.10)

All fees can be found in the Network Statement available on the infrastructure managers' homepages. In the case of Sweden: www.trafikverket.se See alsohttp://www.railneteurope.com for fees from other countries. Note that infrastructure charges in Sweden are likely to be raised in the coming years.

2.4 Energy consumption

The energy consumption from a train can vary depending on many factors, such as train weight, air resistance, terrain and the driver's skills. The drag created by the wagons often has a huge impact on consumption. An empty flat wagon between two loaded wagons might, for example, drastically increase consumption. Empty timber wagons with a large number of poles are known to create a great deal of drag. Some operators report that, under extreme circumstances, they might even have more energy consumption on an empty train than on a full one.

In calculations, the energy consumption of a freight train is often assumed to be linear, i.e. one extra tonne adds X in energy consumption. This is not used because it is clearly true, but because it is the best approximation that can be made without any detailed study of the specific train service. This is also used by infrastructure providers to charge train operators for their electricity consumption. On a deregulated market, such as the Swedish market, all rail operators must pay the rail administration for their electricity consumption. The Swedish rail administration (Trafikverket) charges intermodal trains 0.0212 kwh/grosstonnekm (Trafikverket, 2010b). Charges for other trains vary from 0.0112 kwh/grosstonnekm for iron ore trains and 0.0189 kwh/grosstonnekm for general freight trains, to 0.0327 kwh/grosstonnekm for freight trains faster than 130km/h[9]. The EcoTransIT project has calculated the energy consumption for general freight trains depending on the train weight. They estimate the consumption of a 500 tonnes train at 0.024 kwh/grosstonnekm, for a 1000 tonnes train at 0.017 kwh/grosstonnekm and 0.014 kwh/grosstonnekm for a 1500 tones train (IFEU, 2008). Bäckström, et al. (2009) has collected data from an intermodal transport operator and estimated the consumption at 5.84 kWh/train km plus 0.0147 kWh/grossetonnekm, including 15% transmission losses.

However, Trafikverket's consumption estimates are the most appropriate to use for cost calculations, since electricity is charged according to their model. The rail administration includes conversions and transmission losses in the price and considers power feedback, resulting in different prices for different engine types. The current price (forecasted price for 2011) for an RC engine is 0.7315kr/kWh (25% transfer loss) and 0.6807kr/kWh (16% transfer loss) for a TRAXX engine (Trafikverket, 2010a). The price will vary for each month, depending on the current market price on electricity.

Diesel line haul faces similar problems in determining the fuel consumption. Bäckström, et al. (2009) reviews the fuel consumption and emission data from diesel hauling and concludes that it is difficult to obtain good consumption and emission data, in particular for shunting. Bäckström et al. presents an equation based on ARTEMIS data where fuel consumption = 1.89 *trainkm + 0.0053 * grossetonkm. A modern engine is expected to have 20% lower fuel consumption, resulting in: fuel consumption = 1.51 *trainkm + 0.00424 * grossetonkm. The cost of diesel is 5.18 SEK/litre (SPI, 2011). Note that rail traffic in Sweden does not pay fuel taxes.

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[9]Note that the real electricity consumption will be charged for engines with electricity meters installed. Only engines without electricity meters will be charged according to these generalised estimated.

When comparing the cost and emissions between diesel and electric line hauling using the cost estimates in this report, it should be noted that the energy consumption is allocated differently to engines and wagons. The electric line haul uses linear energy consumption, i.e. assuming that each added tonne consumes the same amount of energy. The diesel line haul uses a two-step consumption where a fixed consumption is assigned to the train (i.e. the engine in the calculations below), followed by a linear consumption for each added tonne. Thus, the different representations affect how the total consumption is allocated among the components of the train. Different representations are chosen to more correctly represent the true costs. The diesel fuel model more closely represents the real fuel consumption, i.e. the real fuel costs, while the electricity method is chosen since it is the model used by the rail administration to charge electricity costs.

3 Business Economic Costs

Three different cost levels have been calculated for rail costs in order to reflect how the costs can be substantially different, depending on the equipment used and its utilization. The low-cost alternative represents transport that uses old second-hand equipment with a high utilisation. The medium cost alternative represents modern equipment with medium utilisation. The high cost alternative represents top-of-the-line equipment with a low utilisation.

	Low	**Medium**	**High**
Engine type, electric line haul	Second hand RC4 engine	New TRAXX engine	New TRAXX engine with dual voltage system and ERTMS
Engine type, diesel haul	Second hand T44, TMZ or similar	New Vossloh Euro 4000	New Vossloh Euro 4000
Utilisation	High	Medium	Low
Wagon type	Lgjs	Sgns	Sdggmrs
Load carriers	Swap body, containers	Swap body, containers	Swap body, containers, trailers
TEU per wagon	2	3	4

Table 1 Train types

Costs have been calculated on three levels: the cost of the engine, the cost of a new rail wagon, and the cost of using a rail wagon. The cost of the engine represents the costs associated with starting a new train, such as driver salary, engine costs and infrastructure charges related to the engine and train. The cost of a new rail wagon includes cost for the wagon and energy consumption, and infrastructure charges related to the weight of the empty wagon. The cost of using a wagon includes the costs of energy consumption and infrastructure charges of the freight loaded onto the wagon.

This report will present data for each train type. Note that it is not possible to “change” wagons, e.g. by taking the summary cost from the Sdggmrs-wagon and using it with engine data from the T44 engine, since the energy consumption for the wagon is based on the engine type used. However, these “change” calculations can easily be performed in the separate Excel-file, with cost calculations that are available with this report or that can be obtained from the author. The calculations are also included in the appendix.

3.1 Engine costs

The engine cost includes the cost of the engine, energy consumption of the engine, maintenance, track charges for the train service and the gross weight of the engine and the personnel cost.

The calculations will assume an economic life of 35 years for the rail engines, as this is when an operator will probably have to replace or modernise the engines. No salvage value is included in the calculations, as this value would probably be rather low and difficult to estimate. A linear depreciation will be used during the entire economic life, i.e. the same cost is allocated to each year, as the utilisation of the engine is expected to be the same during each year of its service life.

The capital costs are higher when the asset is new and is reduced when the depreciations are made. The real cost of capital can be used when it is known, but for general calculations an average cost of capital is used. Mot operators also have a mix of old and new assets, which makes an average cost realistic.

It is assumed that the engine can find other uses while the wagons are loaded/unloaded. Thus, the utilisation of the engine is higher than that of the wagons.

		Low	**Medium**	**High**
Electric train	**Time-dependent SEK/hour**	739	1299	1871
	Distance dependent SEK/km	11.60	10.40	12.05
Diesel train	**Time-dependent SEK/hour**	783	1093	1436
	Distance dependent SEK/km	33.15	23.25	24.40

Table 2 Engine line haul costs

3.2 Empty wagon costs

The wagon cost includes the cost of the wagon, energy consumption, maintenance and track charges by gross weight. This is the cost for using an empty wagon, which is represented by using the empty weight to calculate energy consumption.

The cost refers to the time wagons run in a train. Wagons are also tied up at terminals for a large part of the day; however, the costs for waiting have been included in the costs presented here. Thus, no extra cost should thus be allocated for waiting time when this data is used. This can be changed in the Excel sheet by changing the field “Time in traffic” to include waiting time.

The cost of reserve wagons, i.e. spare wagons to use when wagons are out of service for maintenance, repairs etc., is not included.

		Low	Medium	High
Electric train	Time dependent SEK/hour	7.26	13.45	46.31
	Distance dependent SEK/km	0.39	0.56	1.07
Diesel train	Time dependent SEK/hour	33.15	23.25	24.40
	Distance dependent SEK/km	7.26	13.45	46.31

Table 3 Empty wagon costs

3.3 Using wagon costs

This is the cost of transporting something on the rail wagon. This includes the added energy consumption and track charges by the new weight. However, all capital costs are already allocated to the empty wagon. The calculations assume a fill rate of about 40% in each load unit.

These costs are rather low and many other cost calculations do not separate between empty and full wagons. Instead they use an average load factor of the train, e.g. 75% of the wagons are loaded, and include this in an average wagon cost.

		Low	Medium	High
Electric train	Time dependent SEK/hour	-	-	-
	Distance dependent SEK/km	0.46	0.64	0.71
Diesel train	Time dependent SEK/hour	-	-	-
	Distance dependent SEK/km	0.86	1.04	1.14

Table 4 Using wagon costs

3.4 A typical train

Transport costs are often referred to as cost per tonnekm or trainkm. The numbers have therefore been calculated for an average type of train with 60 TEU, 75% loaded wagons and 20% spare wagons. The number of wagons, train weight and train length are different across the trains, since they use different equipment, including different load units. Other train types can easily be calculated from the data above or the Excel file.

		Low	Medium	High
Number of wagons		30	20	15
Train lenght, meters		529	411	532
Load units per wagon		2 * 20’	1*20’ and 1*40’	2*trailer
TEU positions		60	60	60
Share of loaded wagons		75%	75%	75%
Number of TEU on the train		45	45	44
Number of load units on the train		45	30	22
Train weight, tonnes		927	948	991
Net weight on train, (excluding load units tara weight)		473	465	383
Electric train cost, SEK	per train km	47.96	54.96	74.68
	per gross tonne km	0.05	0.06	0.08
	per net tonne km	0.10	0.12	0.20
	per TEU km	1.07	1.22	1.66
Diesel train cost, SEK	per train km	86.29	76.03	91.66
	per gross tonne km	0.09	0.08	0.09
	per net tonne km	0.18	0.16	0.24
	per TEU km	1.92	1.69	2.04

Table 5 Typical train costs

The cost difference between the train types can also be shown as a percentage. Note that the difference in net tonne cost is largely dependent on the trailer being used as the load unit for that train. The difference would be smaller if containers where used; however, the use of trailers shows a large cost span that exists within rail transport. It is interesting to note that the medium cost diesel train provides a lower total cost, due to its reduced fuel consumption compared to that of an older engine.

		Low	Medium	High
Electric train cost, SEK	**per train km**	100%	115%	156%
	per gross tonne km	100%	120%	160%
	per net tonne km	100%	120%	200%
	per ITU km	100%	114%	155%
Diesel train cost, SEK	**per train km**	100%	88%	106%
	per gross tonne km	100%	89%	100%
	per net tonne km	100%	89%	133%
	per ITU km	100%	88%	106%

Table 6 Typical train costs in percentage of the low cost train

The costs can also be divided into different cost components for the train[10]. The electricity costs and capital cost of the engine are the largest expenses, except for low-cost trains with old second-hand engines.

	Share of cost per train type		
Cost component	**Low**	**Medium**	**High**
Electricity	30%	25%	19%
Cost of capital, engine	6%	18%	23%
Over-head costs	13%	13%	13%
Salary	13%	12%	9%
Maintenance, engine	16%	11%	9%
Infrastructure fee	9%	9%	8%
Cost of capital, wagons	7%	7%	14%
Maintenance, wagons	6%	5%	6%

Figure 7 Share for each cost component for electric powered train

[10] The reason that the over-head cost is not 15% as used in the calculations, is that it is used as a surcharge, i.e. 15% of the underlying value. The table shows the share of the total cost, including the over-head costs.

4 Environment

Freight trains in Sweden only purchase electricity from renewable sources, which produce very low levels of emissions when the electric line haul is used. However, it can easily be argued that it is not possible to buy only some of the electricity on the market, and that the emissions should be estimated according to the national mix of energy sources. The electricity mix can also be substantially different in other countries with fewer renewable energy sources. However, emissions in these calculations are based on the electricity mix purchased by the Swedish rail administration and contain only renewable energy sources, mainly hydropower. The calculations are based on emission data from Bäckström, et al (2009).

	Gram emission per enginekm or wagonkm	Low	Medium	High
Engine	CO2	0.164	0.200	0.200
	NOx	0	0	0
	HC	0.00060	0.00073	0.00073
	CO	0.00431	0.00525	0.00525
	PM	0.000072	0.000088	0.000088
	SO2	0	0	0
	Energy, MJ	8.67	10.56	10.56
	Emission costs, SEK	0.21	0.21	0.21
Empty wagon	CO2	0.026	0.048	0.084
	NOx	0	0	0
	HC	0.00010	0.00018	0.00031
	CO	0.00068	0.00127	0.00221
	PM	0.000011	0.000021	0.000037
	SO2	0	0	0
	Energy, MJ	1.37	2.55	4.45
	Emission costs, SEK	0.00004	0.00008	0.00014
Wagon in use	CO2	0.044	0.075	0.082
	NOx	0	0	0
	HC	0.00016	0.00027	0.00030
	CO	0.00115	0.00196	0.00215
	PM	0.000019	0.000033	0.000036
	SO2	0	0	0
	Energy, MJ	2.30	3.95	4.33
	Emission costs, SEK	0.00007	0.00006	0.00011

Table 7 Electric line haul emissions

For diesel line hauls, there is a large difference between old and new engines. A modern engine might produce, for example, almost half the emissions of NO_x, HC and PM compared with an old engine (Banverket and SIKA, 2002). The calculations are based on emission data from Bäckström, et al (2009). Note that emission data for rail engines are difficult to obtain. The emissions are therefore based on data for new and modernised T44 diesel engines.

	Gram emission per enginekm or wagonkm	Low	Medium	High
Engine	CO2	6424.44	5134.48	5156.00
	NOx	148	34	35
	HC	6.13	0.97	0.98
	CO	12.00	5.73	5.75
	PM	4.23	0.85	0.85
	SO2	1.03	0.82	0.83
	Energy, MJ	3.71	2.96	2.98
	Emission costs, SEK	20.00	10.25	10.29
Empty wagon	CO2	168.14	215.22	376.64
	NOx	3.9	1.4	2.5
	HC	0.16	0.04	0.07
	CO	0.31	0.24	0.42
	PM	0.11	0.04	0.06
	SO2	0.027	0.035	0.060
	Energy, MJ	0.10	0.12	0.22
	Emission costs, SEK	0.52	0.42	0.74
Wagon in use	CO2	282.48	333.59	365.88
	NOx	6.5	2.2	2.5
	HC	0.27	0.06	0.07
	CO	0.53	0.37	0.41
	PM	0.19	0.06	0.06
	SO2	0.045	0.054	0.059
	Energy, MJ	0.16	0.19	0.21
	Emission costs, SEK	0.87	0.09	0.06

Table 8 Diesel line haul emissions

5 Social economic costs

Social economic cost estimates can be carried out by adding societal costs to business economic costs. Cost estimates for emissions, noise and accidents are added according to SIKA (2008). The most important external factor is the environmental consequences of transport. The effects occur on three levels: local, regional and global. Local effects are health effects, contamination (dirt) and corrosion. Regional effects include damage to the environment and health effects. The global effects include the greenhouse effect and reduction of the ozone layer (SIKA, 2002). For local emissions it is assumed that 20% of the transport takes place within an average size city and 80% in the countryside. SIKA (2004) calculated the population density along six selected transport links in Sweden, and found that about 80-90% of the transport occurred in rural areas. The calculations are further explained in Flodén (2007).

		Low	Medium	High
Engine	Time dependent SEK/hour	739	1 299	1 871
	Distance dependent SEK/km	11.82	10.61	12.26
Empty wagon	Time dependent SEK/hour	7.26	13.45	46.31
	Distance dependent SEK/km	0.39	0.59	1.07
Wagon in use	Time dependent SEK/hour	-	-	-
	Distance dependent SEK/km	0.46	0.64	0.71

Table 9 Societal electric line haul costs

		Low	Medium	High
Engine	Time dependent SEK/hour	783	1 093	1 436
	Distance dependent SEK/km	53.15	33.50	34.68
Empty wagon	Time dependent SEK/hour	7.26	13.45	46.31
	Distance dependent SEK/km	1.21	0.69	0.89
Wagon in use	Time dependent SEK/hour	-	-	-
	Distance dependent SEK/km	1.82	0.42	0.18

Table 10 Societal diesel line haul costs

6 Terminal costs

The cost of loading and unloading at a terminal can vary substantially depending on the type of terminal. The terminal activities normally consist of shunting of the train and terminal handling, where the load units are loaded on to and unloaded off the train.

6.1 Shunting

Shunting is, roughly, the operation in which the train is moved into the terminal from the main line. Shunting is normally performed by diesel engines, since a normal terminal cannot have overhead electric lines, as the handling equipment lifts the load units from the top. When shunting, the electric line-haul engine hands over the train to a diesel shunting engine that moves the train into the terminal. The process is reversed when the train leaves the terminal. Some terminal designs and/or handling equipment allows for the shunting to be performed by the electric line-haul engine, but these terminals are rare.

A rough estimate of shunting time is 30 minutes to enter and 30 minutes to exit the terminal, but this might vary depending on the terminal layout and number of wagons. A rough estimate is to calculate one minute per wagon on the train (Nelldal, 2011). Bäckström, et al. (2009) surveyed the shunting at a number of Swedish terminals and found that the time for shunting ranged from 20 minutes to 1 hour, or between 0.625 to 1.58 minutes per load unit.

A brake test is also sometimes needed before the train can depart, e.g. if the engine has been decoupled from the wagons. This can be estimated at roughly 30 minutes or 1 minute per wagon (Nelldal, 2011) and is performed by using the line haul engine. There is also some administrative work to be done when the train departs, which takes about 30 minutes. All this will require the presence of the engine driver or the person operating the shunting engine. Shunting engine drivers have a salary that adds up to about 80% of the line haul driver’s salary (Green Cargo, 2009b).

The costs for shunting are the salary costs of the persons involved and the operating costs of the shunting locomotive. Added costs are also empty repositioning costs if the line haul engine leaves the terminal during the day, or if the shunting engine is not located at the terminal.

There are several different types of diesel shunting engines. Heavy shunting engines such as the T44 are the most commonly used, but smaller engines, such as the type V5 or Z65, are used at some terminals.

Figure 8 A type T44 diesel engine (Picture: Wikipedia)

Fuel consumption is hard to estimate, and different sources estimate the consumption of a shunting T44 to fall between 17 litres per hours when idle, to 45 litres during heavy shunting. The average consumption is between 35-45 litres per hour. Bäckström, et al. (2009) calculated the fuel consumption during an average one hour shunting at 37 litters, or 0.82 litres per load unit. This amount would be less with a more modern engine. The smaller Z65 engines consumes 16 litres per hour (Bäckström, et al., 2009). The cost of diesel is 5.18 SEK/litre (SPI, 2011). Note that rail traffic in Sweden does not pay fuel taxes.

Figure 9 A type Z65/ Z70 diesel engine (Picture: Wikipedia)

6.1.1 Shunting costs

Due to the short distances involved in shunting, all costs are estimated as time dependent costs. The cost below includes the shunting engine driver. Note that the division into low, medium and high refers to the costs, and not necessarily the size of the terminal.

	Low	**Medium**	**High**
Engine type	Smaller 2-axel engine	G4 Vossloh	Used T44
Utilisation, hours/year	3 500	2 900	3 300
Time dependent SEK/hour	1 021	1 152	1 129

Table 11 Shunting costs

6.1.2 Shunting emissions

The shunting emissions can be calculated using emission data from Bäckström, et al. (2009). This estimates the emissions per hour shunting as:

Gram emission per hour shunting	Low	Medium	High
CO2	40 608	73 602	93 906
NOx	400	493	2168
HC	17.8	13.9	89.5
CO	52.8	82.1	175.4
PM	5.3	12.2	61.8
SO2	6.5	11.8	15.1
Energy, MJ	23.45	42.50	54.22
Emission costs, SEK	87.47	143.85	289.18

Table 12 Shunting emissions

6.1.3 Shunting societal costs

Social economic costs can be calculated according to the same principles as the rail transport.

	Low	Medium	High
Time dependent SEK/hour	1 108	1 296	1 418

Table 13 Societal shunting costs

6.2 Terminal handling

Terminal handling includes the loading and unloading of load units from the train and the handling of arriving and departing trucks and their load units. Normally, a reach stacker is used to lift materials on or off of the unit load, but gantry cranes and other equipment might also be used.

Figure 10 A reach stacker (Picture: Green Cargo)

Unloading for a load unit takes only 3 minutes, but considering that a full train might carry 70 TEU and most terminals only have one or two reach stackers, a full train takes 3-4 hours to load/unload. This also includes the consideration that the reach stackers must spend some time lifting TEUs on or off trucks, since the trucks often are not available to lift the TEU directly from the train to the truck. Often, the load unit is put down on the ground first. Approximately 50% of the load units are handled twice at a terminal (Woxenius, 2003). Bäckström, et al. (2009) estimates that a container takes 2-4 minute to unload with a total handling time for the reach stacker of 4-7 minutes, including repositioning the reach stacker for the next load unit, etc. The same handling time for a trailer/ swap body is 3-6 and 4-12 minutes.

6.3 Terminal costs

Terminal costs can vary greatly depending on the terminal design. Several studies indicate a cost of about 200-300kr per handled load unit (Flodén, 2007, Nelldal, 2011, Sommar, 2010). The cost will vary with the size of terminal, equipment used and type of load units. This report will not go into detail on terminal costs and emissions as this has been studied in detail by Sommar (2010) and Bäckström, et al. (2009) for Swedish conditions.

Sommar (2010) calculates the costs for four types of terminals per handled unit. A small terminal is assumed to handle 25 000 TEU annually, a medium terminal handles 50 000 TEU annually, a large terminal handles 100 000 TEU annually and a line terminal is assumed to handle 15 000 TEU annually. Note that Sommar's shunting costs are based on different assumptions than the shunting cost calculations in chapter 6.1.1.

	Small terminal	**Medium terminal**	**Large terminal**	**Line terminal**
Cost per load unit, SEK, including shunting	320	268	239	257
Cost per load unit, SEK, excluding shunting	256	182	166	257

Table 14 Terminal handling costs

A liner terminal is a smaller terminal where the trains stop along the line to tranship some of their load units before continuing to the next terminal, much like a passenger train stopping at stations. This is different from conventional terminals where the entire train is unloaded at one terminal. Sommar's cost calculation for a line terminal is based on the "Dalkullan" line train concept tested in Sweden, where a fork lift truck accompanies the train on a separate wagon. At each stop, the train engine driver drives the truck of the train and performs the transhipments. Only swap bodies are handled. For more information see Bärthel and Woxenius (2003, 2004). It should be noted that liner trains are a new concept, and a large number of alternative transhipments methods have been suggested with very different cost structures.

The terminal handling costs can also be expressed in relation to the total cost of a train. When examining the typical train from chapter 3.4 and adding the terminal handling costs of a medium size terminal, one can see that the terminal handling constitutes a large share of the total rail costs. Note that overhead costs are not separated out from the terminal costs.

	Share of cost per train type		
Cost component	**Low**	**Medium**	**High**
Terminal costs	50%	37%	24%
Electricity	15%	16%	15%
Cost of capital, engine	3%	11%	17%
Overhead costs	7%	8%	10%
Salary	7%	7%	7%
Maintenance, engine	8%	7%	7%
Infrastructure fee	5%	6%	6%
Cost of capital, wagons	3%	5%	11%
Maintenance, wagons	3%	3%	5%

Figure 11 Share for each cost component for electric powered train

6.4 Environment

The emissions from terminal handling mostly come from shunting and the diesel powered handling equipment at the terminal. Bäckström, et al. (2009) estimates the emissions from terminals. His calculation includes shunting, empty running, multiple lifts etc. at the terminals. Note that the assumptions are not identical to the assumptions in the terminal cost calculations by Sommar (2010) in chapter 6.3. However, it is not possible to calculate emissions based on Sommar's data, or to calculate costs based on Bäckström's data. The emission costs have been calculated based on the data from Bäckström using the cost estimates according to SIKA (2008) explained in chapter 0.

Gram emission per terminal handling of a load unit	Small terminal	Medium terminal	Large terminal
CO2	5 367	6 163	8 286
NOx	56	61	76
HC	22	23	25
CO	35	39	47
PM	2,4	2,8	3,8
SO2	0.000017	0.000020	0.000027
Energy, MJ	74	85	114
Emission costs, SEK	12.62	14.22	18.56

Table 15 Terminal handling emissions

6.5 Social economic costs

Social economic costs can be calculated according to the same principles as for the rail transport. The calculations are based on costs from Sommar and emissions estimations from Bäckström et al.

	Small	Medium	Large
Cost per lift, SEK	333	282	258
Cost per lift, SEK, excluding shunting	269	196	185

Table 16 Societal terminal handling costs

7 Rail cost uncertainties

Rail cost calculations are very dependent on the specific case being calculated, e.g. how the transport system is designed. Some cost factors are also difficult to estimate, for example, maintenance and overhead costs.

However, the impact on the total costs from most of the cost factors is small. A sensitivity analysis can be performed by varying some key variables. Using the figures for the typical train from chapter 3.4, a number of tests can be performed to show how changes will impact the cost per tonnekm. A 50% cost increase has been assumed in all input variables. The changes have been calculated one by one.

50% increase in	Low	Medium	High	Comment
Electricity consumption	17%	14%	11%	Cost exactly known as charging made according to exact formula. However, true consumption difficult to estimate
Electricity price	17%	14%	11%	Exactly known today, but difficult to estimate for the future.
Over-head costs	13%	13%	13%	Difficult to estimate.
Engine purchase price	3%	10%	13%	Well know for new engines. Harder to determine for used engines.
Interest rate	3%	8%	11%	Well known today, but difficult to estimate for the future.
Salary costs	8%	7%	5%	Basic salaries well know, but total costs are very dependent on the specific system design and staff planning.
Engine utilisation km	-2%	-7%	-9%	Well known if the transport system design is known. Otherwise hard to estimate.
Engine maintenance	9%	6%	5%	Difficult to get data.
Wagon purchase price	4%	4%	8%	Well know for new wagons. Harder for used wagons.
Wagon maintenance	4%	3%	3%	Difficult to get data.
Engine depreciation period	-1%	-3%	-4%	Hard to determine exactly due to the long service life of an engine
Wagon utilisation km	-3%	-3%	-5%	Well known if the transport system design is known. Otherwise hard to estimate.
Wagon depreciation period	-2%	-1%	-2%	Hard to determine exactly due to the long service life of a wagon.

Table 17 Changes in cost per grosstonnekm from a 50% cost increase in one factor

A 50% change in an input variable is a very large change, and it is not likely that the differences between different system designs and data sources are that large. Even then, the impact on total costs in most cases is just a few percentage points. The key factors here are the price and consumption of electricity, which create a change of 14% for a medium cost train. For this factor, the price charged by the infrastructure provider is public and well known. Electricity consumption is, as discussed above, difficult to estimate precisely. However, Trafikverket charges trains according to a linear mathematical equation based on train weight. When doing cost calculations, the question of whether or not consumption estimates are exact is not relevant, as long as the calculations use the same estimates as Trafikverket uses for charging the operator. This might change in the future as more engines are equipped with electricity meters, and thus are charged for their true consumption. However, with an installed electricity meter, the true consumption should not be difficult to estimate. The errors in the estimated electricity consumption will impact the emission calculations.

The overhead costs are also an important factor. Unfortunately, this factor is very difficult to estimate. It can only be emphasized that care must be taken in trying to estimate the overhead cost as accurately as possible, and not use a general percentage surcharge if other information is available.

Other important factors are the purchase price of the engine and the utilisation and maintenance costs. The purchase prices can be considered to be fairly well-known, at least for new engines. However, it is often difficult to get good cost estimates from maintenance costs. Utilisation is very much dependent on the specific system layout, as discussed above. It is therefore important to use utilisation data that is as specific as possible in order to get a good result.

8 Conclusion

It can be concluded that the costs of operating a freight train can vary substantially depending on the equipment used and the system design. However, the total cost is fairly robust for changes in individual input factors. It is important to consider the whole system for the rail transport and not just focus on a single transport when calculating costs. The individual cost factors in rail cost calculations are relatively well-known; however, the ways in which the total rail transport system is designed and in which the equipment is used have a great impact on the total cost. The largest contributions to cost are made by electricity consumption and the capital cost of the engine.

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Appendix A – Electric Train Costs

General data		Comment	Source
Interest rate	6,5%	Difficult to estimate and will vary over time. The average interest rate in Sweden during the last 10 years is 7.5%	
Overhead costs	8%	General administration etc.	Nelldal, 2011
Unexpected costs	7%	Margin to cover unexpected events.	Nelldal, 2011
Sum OH costs	15%	Could be different depending on the size of the company. A lower value can be used if high cost equipment is used.	
Profit margin	0%	Not included if a cost calculation is intended. Othervise, 10% is appropriate.	Nelldal, 2011

	A low cost train with high usage.						A high cost train with low usage.			
Electric haul **Railway engine cost estimate**										
	Low	*Comment*	*Source*	*Medium*	*Comment*	*Source*	*High*	*Comment*	*Source*	*General comment*
Purchace price	10 000 000 kr	Used engine type RC	Nelldal, 2011	35 000 000 kr	New TRAXX-engine or equivalent	Nelldal, 2011	38 000 000 kr	TRAXX with ERTMS (2 000 000 kr) and dual voltage system (1 000 000 kr)	Nelldal, 2011	
Service life, years	20		Nelldal, 2011	35	Nelldal, 2011	Nelldal, 2011	35	Same service life for ERTMS and dual voltage	Nelldal, 2011	
Depreciation, years	20			35			35			Depreciation can also be made over a shorter time period for accounting and tax reasons.
Weight, tonnes	79		Diehl & Nilsson, 2003	83		Green Cargo, 2009	83		Green Cargo, 2009	
Length, meters	15,5			18,9			18,9			
Electricity consumption, kWh per grosstonkm	0,0212			0,0212			0,0212		Trafikverket, 2010b	This can be varied between 0,019 to 0,024 depending on total train weight. A heavier train has lower consumption per grosstonkm.
Maximum traction, tonnes	1600		Nelldal, 2011, Bark, 2005	2000		Nelldal, 2011	2000		Nelldal, 2011	Numbers refers to normal conditions. Total train weight might be limited by other factors, such as track gradient, etc.
Price (SEK) per kWh elec	0,7315 kr	type RC	Trafikverket, 2010a	0,6807 kr	type TRAXX	Trafikverket, 2010a	0,6807 kr	type TRAXX	Trafikverket, 2010a	Conversions and transmission losses included in the price. Price depends therefore on engine type.
Running distance per year, km	300 000	type RC		220 000	Assuming same utlisation as the waggons.		138 000	Statistical average.	Based on SIKA, 2009	
Average speed	70	km/h	CargoNet, 2006	70	km/h	CargoNet, 2006	70	km/h	CargoNet, 2006	
Time in traffic	4286	hours		3143	hours		1971	hours		
Maintenence costs per km	7,50 kr	type RC	Nelldal, 2011	6,00 kr	type TRAXX	Nelldal, 2011	6,50 kr	type TRAXX with ERTMS och dual voltage.	Nelldal, 2011	
Infrastructure charges										
Train path charge, per train km	0,27 kr	Base level fee for the general network.	Trafikverket, 2010b	0,74 kr	Assuming 1/3 on high quality network and 2/3 on general nework.	Trafikverket, 2010b	1,67 kr	High level fee for using high quality parts of the network.	Trafikverket, 2010b	
Accident charge, per train km	0,81 kr		Trafikverket, 2010b	0,81 kr		Trafikverket, 2010b	0,81 kr		Trafikverket, 2010b	
Track charge, per gross tonne km	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	

Calculations per year										
Average cost of capital	325 000 kr			1 137 500 kr			1 235 000 kr			Average capital tied up during the depreciation period * interest rate. Assuming linear depreciation.
Depreciation	500 000 kr			1 000 000 kr			1 085 714 kr			Linear depreciation.
Overhead costs	*123 750 kr*			*320 625 kr*			*348 107 kr*			
Profit margin	*- kr*			*- kr*			*- kr*			
Fixed costs	*948 750 kr*			*2 458 125 kr*			*2 668 821 kr*			
per km	*3,16 kr*			*11,17 kr*			*19,34 kr*			
or per hour	***221,38 kr***			***782,13 kr***			***1 353,75 kr***			
Maintenence costs	2 250 000 kr			1 320 000 kr			897 000 kr			
Electricity costs (engine only)	367 535 kr			263 507 kr			165 291 kr			
Infrastructure fees	409 320 kr			406 003 kr			383 474 kr			Train related charges (train path and accident) and weight charges related to the engine.
Overhead costs	*454 028 kr*			*298 426 kr*			*216 865 kr*			
Profit margin	*- kr*			*- kr*			*- kr*			
Variable costs	*3 480 883 kr*			*2 287 936 kr*			*1 662 630 kr*			
per km	***11,60 kr***			***10,40 kr***			***12,05 kr***			
Total costs	*4 429 633 kr*			*4 746 061 kr*			*4 331 451 kr*			
per km	*14,77 kr*			*21,57 kr*			*31,39 kr*			
Waggon costs, empty wagon										
Purchase price	100 000 kr	used type Lgjs	Nelldal, 2011	700 000 kr	Type Sgns	Nelldal, 2011	1 300 000 kr	Type Sdggmrs	Nelldal, 2011, Oehrstroem 2005	
Service life, years	15		Nelldal, 2011	50		Nelldal, 2011	35		Nelldal, 2011	
Depreciation, years	15			50			35		Nelldal, 2011	
Tara weight, tonnes	12,5		GreenCargo, 2011	20		GreenCargo, 2011	35		AAE, 2005	
TEU per wagon	2			3			4			
Length, meters	17,1			19,6			34,2			
Running distance per year, km	110 000		Nelldal, 2011	220 000		Nelldal, 2011	138 000	Assuming the same utilisation as for the engine.		
Average speed	70			70			70			
Time in traffic	1571	hours		3143	hours		1971	hours		Wagons are also tied up at the terminals for loading and unloading.
Maintenence costs per km	0,10 kr		Nelldal, 2011	0,15 kr		Nelldal, 2011	0,30 kr		Oehrstroem 2005	
Infrastructure charges										
Track charge, per gross tonne km	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	Only charges per tonnekm are relevant. Cost associated to trainkm has been assigned to the engine.
Calculations per year and wagon										
Average cost of capital	3 250 kr			22 750 kr			42 250 kr			
Depreciation	6 667 kr			14 000 kr			37 143 kr			
Overhead costs	*1 488 kr*			*5 513 kr*			*11 909 kr*			
Profit margin	*- kr*			*- kr*			*- kr*			
Fixed costs	*11 404 kr*			*42 263 kr*			*91 302 kr*			
per km	0,10 kr			0,19 kr			0,66 kr			
or per hour	**7,26 kr**			**13,45 kr**			**46,31 kr**			
Maintenence costs	11 000 kr			33 000 kr			41 400 kr			
Electricity costs (wagon only)	21 323 kr			63 496 kr			69 701 kr			

Infrastructure charges	4 950 kr			15 840 kr			17 388 kr			
Overhead costs	*5 591 kr*			*16 850 kr*			*19 273 kr*			
Profit margin	- kr			- kr			- kr			
Variable costs	*42 864 kr*			*129 186 kr*			*147 762 kr*			
per km	**0,39 kr**			**0,59 kr**			**1,07 kr**			
Total costs	*54 268 kr*			*171 449 kr*			*239 064 kr*			
per km	0,49 kr			0,78 kr			1,73 kr			
Waggon costs, loaded wagon										
Weight loaded , tonnes	21	2 20' container		31,0	1 20' and 1 40'		34,0	2 trailers		Gross weight loaded, including load unit. 40% fill rate in each load unit.
Fixed costs	- kr			- kr			- kr			All fixed costs carried by the empty wagon
per km	**- kr**			**- kr**			**- kr**			
Maintenence costs	- kr			- kr			- kr			Slightly dependent on the weight, but very hard to estimate.
Electricity costs (freight only)	35 823,02 kr			98 418,33 kr			67 709,50 kr			
Infrastructure charges	8 316 kr			24 552 kr			16 891 kr			Charged per tonnekm
Overhead costs	*6 620,85 kr*			*18 445,55 kr*			*12 690,11 kr*			
Profit margin	- kr			- kr			- kr			
Variable costs	*50 759,87 kr*			*141 415,88 kr*			*97 290,81 kr*			
per km	**0,46 kr**			**0,64 kr**			**0,71 kr**			
Personell costs										
Salary	341 600 kr		Green Cargo, 2009a,b	341 600 kr		Green Cargo, 2009a,b	341 600 kr		Green Cargo, 2009a,b	Salary for class F10 driver (27 120kr) inlcuding holiday pay (0,08%) per vacation day.
Night surcharges, per hour	37,20 kr		Green Cargo, 2009	37,20 kr		Green Cargo, 2009	37,20 kr		Green Cargo, 2009	For work between 7 p.m. and 6 a.m.
Share of night work	50%		Green Cargo, 2009	50%		Green Cargo, 2009	50%		Green Cargo, 2009	Intermodal trains are often run during the night. No driver should work more than a total of 1/3 totalt night time per work scheduling period (10 p.m. to 6 a.m.), exlcuding travel time. Note that this definition of night is different from the salary surcharge times.
Working hours per year	1600		Green Cargo, 2009	1600		Green Cargo, 2009	1600		Green Cargo, 2009	Can vary depening on the share of night work, number of holidays worked etc. 36 hours per week for night time workers.
Night cost	29 760 kr			29 760 kr			29 760 kr			
Other surcharges, %	5%			5%			5%			On call time, allowances during travel, overtime pay etc. and other added suppliments to the salary. Included as a general percentage as the exact amount will depend och the specific schedule for the driver.
Other surcahges, SEK	17 080 kr			17 080 kr			17 080 kr			
Salary costs	388 440 kr	32 370 kr		388 440 kr			388 440 kr			
Taxes, %	31,42%		Skatteverket, 2011	31,42%		Skatteverket, 2011	31,42%		Skatteverket, 2011	
Taxes, SEK	122 048 kr			122 048 kr			122 048 kr			

Collective insurances, pension etc.%		7,5%			7,5%			7,5%		Based on agreements with the union. The amount will vary depending on the employeer and union and increases with a higher salary.
Collective insurances, pension etc.SEK		29 133 kr			29 133 kr			29 133 kr		
Total cost		*539 621 kr*			*539 621 kr*			*539 621 kr*		
Cost per hour		337,26 kr			337,26 kr			337,26 kr		
Share of worktime driving a train		75%	Nelldal, 2011		75%	Nelldal, 2011		75%	Nelldal, 2011	
Cost per train hour		449,68 kr			449,68 kr			449,68 kr		
Overhead costs		80 943 kr			80 943 kr			80 943 kr		
Profit margin		- kr			- kr			- kr		
Other costs		*80 943 kr*			*80 943 kr*			*80 943 kr*		
per train hour		*67,45 kr*			*67,45 kr*			*67,45 kr*		
Total cost		*620 564 kr*			*620 564 kr*			*620 564 kr*		
per train hour		*517,14 kr*			*517,14 kr*			*517,14 kr*		
Input to the HIT-model										
Engine	Used RC			TRAXX			Full TRAXX			
Time dependant costs, kr		739 kr			1 299 kr			1 871 kr		
Distance dependant costs		11,60 kr			10,40 kr			12,05 kr		
Empty rail wagon	used Lgjs			Sgns			Sdggmrs			
Time dependant costs, kr		7,26 kr			13,45 kr			46,31 kr		
Distance dependant costs		0,39 kr			0,59 kr			1,07 kr		
Used rail wagon										
Time dependant costs, kr		- kr			- kr			- kr		
Distance dependant costs		0,46 kr			0,64 kr			0,71 kr		
A typical train										
Number of wagons in the train		30			20			15		Number of waggons selected to give the same loading capacity in TEU on all trains.
Loading capacity TEU		60			60			60		
Share of loaded wagons		75%			75%			75%		
Weight loaded on train, tonnes		473			465			383		
Train weight, tonnes		927			948			991		
Train lenght, meters		529			411			532		
Reserve wagons, %		20%			20%			20%		Not all wagons can be in service all the time. Extra wagons needed during repairs, maintenance etc. Time dependent cost.
Total number of waggons		36,0			24,0			18,0		
Distance, km		500,0			500,0			500,0		
Average speed, km/h		70,0			70,0			70,0		
Running time, hours		7,1			7,1			7,1		
Engine and salary costs		11 077 kr			14 480 kr			19 387 kr		
Empty waggon costs		7 711 kr			8 177 kr			13 985 kr		
Used wagon costs		5 191 kr			4 821 kr			3 966 kr		
Total cost per train		23 979 kr			27 479 kr			37 338 kr		
per trainkm		47,96 kr			54,96 kr			74,68 kr		
per grosstonnekm		0,05 kr			0,06 kr			0,08 kr		

per nettonnekm	0,10 kr	0,12 kr	0,20 kr	Including tara weight of load units
per ITUkm	1,07 kr	1,22 kr	1,66 kr	

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Appendix B – Diesel Train Costs

General data		Comment	Source
Interest rate	6,5%	Difficult to estimate and will vary over time. The average interest rate in Sweden during the last 10 years is 7.5%	
Overhead costs	8%	General administration etc.	
Unexpected costs	7%	Margin to cover unexpected events.	
Sum OH costs	15%		
Profit margin	0%	Not included if a cost calculation is intended. Otherwise, 10% is appropriate.	Nelldal, 2011

Diesel haul Railway engine cost estimate	*Low* A low cost train with high usage.	*Comment*	*Source*	*Medium*	*Comment*	*Source*	*High* A high cost train with low usage.	*Comment*	*Source*	*General comment*
Purchace price	10 000 000 kr	Used engine type TMZ or similar	Nelldal, 2011	30 000 000 kr	New Euro 4000 engine or equivalent	Nelldal, 2011	30 000 000 kr	New Euro 4000 engine or equivalent	Nelldal, 2011	
Service life, years	15		Nelldal, 2011	50	Nelldal, 2011	Nelldal, 2011	50		Nelldal, 2011	
Depreciation, years	15			50			50			Depreciation can also be made over a shorter time period for accounting and tax reasons.
Weight, tonnes	121			121			123			
Length, meters	21			21			23			
Diesel consumption, litre per train (start value)	1,89	Old T44 engine	Bäckström et al 2009	1,51	Modernised T44 engine		1,51			Added to this is the consumption per grosstonkm.
Diesel consumption, litre per grosstonkm	0,0053		Bäckström et al 2009	0,00424		Bäckström et al 2009	0,00424		Bäckström et al 2009	
Maximum traction, tonnes	2000		Nelldal, 2011	2000		Nelldal, 2011	2000		Nelldal, 2011	Numbers refers to normal conditions. Total train weight might be limited by other factors, such as track gradient, etc.
Price (SEK) per litre diesel	5,18 kr		SPI, 2011	5,18 kr		SPI, 2011	5,18 kr		SPI, 2011	Rail traffic do not pay fuel taxes in Sweden.
Running distance per year, km	300 000			220 000	Assuming same utlisation as the waggons.		138 000	Statistical average for electric engines.	Based on SIKA, 2009	
Average speed, km/h	70		CargoNet, 2006	70		CargoNet, 2006	70		CargoNet, 2006	
Time in traffic, hours	4286			3143			1971			
Maintenence costs per km	12,00 kr	Type TMZ	Nelldal, 2011	6,00 kr	Euro 4000	Nelldal, 2011	6,00 kr	Euro 4000	Nelldal, 2011	
Infrastructure charges										
Train path charge, per train km	0,27 kr	Base level fee for the general nework.	Trafikverket, 2010b	0,74 kr	Assuming 1/3 on high quality network and 2/3 on general nework.	Trafikverket, 2010b	1,67 kr	High level fee for using high quality parts of the network.	Trafikverket, 2010b	
Accident charge, per train km	0,81 kr		Trafikverket, 2010b	0,81 kr		Trafikverket, 2010b	0,81 kr		Trafikverket, 2010b	
Track charge, per gross tonne km	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	
Emission charge, per litre diesel	0,87 kr		Trafikverket, 2010b	0,87 kr		Trafikverket, 2010b	0,87 kr		Trafikverket, 2010b	
Deisel conspumption per year, engine only, litres	759 390			445 069			280 350			
<u>Calculations per year</u>										
Average cost of capital	325 000 kr			975 000 kr			975 000 kr			Average capital tied up during the depreciation period * interest rate. Assuming linear depreciation.
Depreciation	666 667 kr			600 000 kr			600 000 kr			Linear depreciation.
Overhead costs	*148 750 kr*			*236 250 kr*			*236 250 kr*			
Profit margin	*- kr*			*- kr*			*- kr*			
Fixed costs	*1 140 417 kr*			*1 811 250 kr*			*1 811 250 kr*			
per km	*3,80 kr*			*8,23 kr*			*13,13 kr*			
or per hour	***266,10 kr***			***576,31 kr***			***918,75 kr***			
Maintenence costs	3 600 000 kr			1 320 000 kr			828 000 kr			
Diesel costs (engine only)	3 933 640 kr			2 305 456 kr			1 452 212 kr			
Infrastructure fees	1 115 349 kr			823 309 kr			647 251 kr			Train related charges (train path and accident) and weight charges related to the engine.
Overhead costs	*1 297 348 kr*			*667 315 kr*			*439 119 kr*			
Profit margin	*- kr*			*- kr*			*- kr*			
Variable costs	*9 946 338 kr*			*5 116 080 kr*			*3 366 582 kr*			
per km	***33,15 kr***			***23,25 kr***			***24,40 kr***			

Total costs	*11 086 755 kr*			*6 927 330 kr*			*5 177 832 kr*			
per km	*36,96 kr*			*31,49 kr*			*37,52 kr*			
Waggon costs, empty wagon										
Purchace price	100 000 kr	used type Lgjs	Nelldal, 2011	700 000 kr	Type Sgns	Nelldal, 2011	1 300 000 kr	Type Sdggmrs	Nelldal, 2011, Oehrstroem 2005	
Service life, years	15		Nelldal, 2011	50		Nelldal, 2011	35		Nelldal, 2011	
Depreciation, years	15			50			35		Nelldal, 2011	
Tara weight, tonnes	12,5		GreenCargo, 2011	20		GreenCargo, 2011	35		AAE, 2005	
TEU per wagon	2			3			4			
Length, meters	17,1			19,6			34,2			
Running distance per year, km	110 000		Nelldal, 2011	220 000		Nelldal, 2011	138 000	Assuming the same utilisation as for the engine.		
Average speed, km/h	70			70			70			
Time in traffic, hours	1571			3143			1971			Wagons are also tied up at the terminals for loading and unloading.
Maintenence costs per km	0,10 kr		Nelldal, 2011	0,15 kr		Nelldal, 2011	0,25 kr		Nelldal, 2011	
Infrastructure charges										
Track charge, per gross tonne km	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	Only charges per tonnekm are relevant. Cost associated to trainkm has been assigned to the engine.
Emission charge, per litre diesel	0,87 kr		Trafikverket, 2010b	0,87 kr		Trafikverket, 2010b	0,87 kr		Trafikverket, 2010b	
Deisel conspumption per year, wagon only, litres	7 288			18 656			20 479			
Calculations per year and wagon										
Average cost of capital	3 250 kr			22 750 kr			42 250 kr			
Depreciation	6 667 kr			14 000 kr			37 143 kr			
Overhead costs	*1 488 kr*			*5 513 kr*			*11 909 kr*			
Profit margin	- kr			- kr			- kr			
Fixed costs	*11 404 kr*			*42 263 kr*			*91 302 kr*			
per km	0,10 kr			0,19 kr			0,66 kr			
or per hour	**7,26 kr**			**13,45 kr**			**46,31 kr**			
Maintenence costs	11 000 kr			33 000 kr			34 500 kr			
Diesel costs (wagon only)	37 749 kr			96 638 kr			106 082 kr			
Infrastructure charges	11 290 kr			32 071 kr			35 205 kr			
Overhead costs	*9 006 kr*			*24 256 kr*			*26 368 kr*			
Profit margin	- kr			- kr			- kr			
Variable costs	*69 045 kr*			*185 965 kr*			*202 155 kr*			
per km	**0,63 kr**			**0,85 kr**			**1,46 kr**			
Total costs	*80 449 kr*			*228 228 kr*			*293 457 kr*			
per km	0,73 kr			1,04 kr			2,13 kr			
Waggon costs, loaded wagon										
Weight loaded , tonnes	21,0	2 20' container		31,0	1 20' and 1 40'		34,0	2 trailers	Gross weight loaded, including load unit. 40% fill rate in each load unit.	
Fixed costs	- kr			- kr			- kr		All fixed costs carried by the empty wagon	
per km	**- kr**			**- kr**			**- kr**			
Infrastructure charges										
Track charge, per gross tonne km	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	0,0036 kr		Trafikverket, 2010b	Only charges per tonnekm are relevant. Cost associated to trainkm has been assigned to the engine.
Emission charge, per litre diesel	0,87 kr		Trafikverket, 2010b	0,87 kr		Trafikverket, 2010b	0,87 kr		Trafikverket, 2010b	
Deisel conspumption per year, freight only, litres	12 243,00 kr			28 916,80 kr			19 894,08 kr			
Maintenence costs	- kr			- kr			- kr		Slightly dependent on the weight, but very hard to estimate.	
Diesel costs (freight only)	63 418,74 kr			149 789,02 kr			103 051,33 kr			
Infrastructure charges	18 967 kr			49 710 kr			34 199 kr		Charged per tonnekm	
Overhead costs	*12 357,92 kr*			*29 924,80 kr*			*20 587,56 kr*			
Profit margin	- kr			- kr			- kr			
Variable costs	*94 744,07 kr*			*229 423,44 kr*			*157 837,94 kr*			
per km	**0,86 kr**			**1,04 kr**			**1,14 kr**			

Personell costs							
Salary	341 600 kr	Green Cargo, 2009a,b	341 600 kr	Green Cargo, 2009a,b	341 600 kr	Green Cargo, 2009a,b	Salary for class F10 driver (27 120kr) inlcuding holiday pay (0,08%) per vacation day.
Night surcharges, per hour	37,20 kr	Green Cargo, 2009	37,20 kr	Green Cargo, 2009	37,20 kr	Green Cargo, 2009	For work between 7 p.m. and 6 a.m.
Share of night work	50%	Green Cargo, 2009	50%	Green Cargo, 2009	50%	Green Cargo, 2009	Intermodal trains are often run during the night. No driver should work more than a total of 1/3 totalt night time per work scheduling period (10 p.m. to 6 a.m.), exlcuding travel time. Note that this definition of night is different from the salary surcharge times.
Working hours per year	1600	Green Cargo, 2009	1600	Green Cargo, 2009	1600	Green Cargo, 2009	Can vary depening on the share of night work, number of holidays worked etc. 36 hours per week for night time workers.
Night cost	29 760 kr		29 760 kr		29 760 kr		
Other surcharges, %	5%		5%		5%		On call time, allowances during travel, overtime pay etc. and other added suppliments to the salary. Included as a general percentage as the exact amount will depend och the specific schedule for the driver.
Other surcahges, SEK	17 080 kr		17 080 kr		17 080 kr		
Salary costs	388 440 kr	32 370 kr	388 440 kr		388 440 kr		
Taxes, %	31,42%	Skatteverket, 2011	31,42%	Skatteverket, 2011	31,42%	Skatteverket, 2011	
Taxes, SEK	122 048 kr		122 048 kr		122 048 kr		
Collective insurances, pension etc.%	7,5%		7,5%		7,5%		Based on agreements with the union. The amount will vary depending on the employeer and union and increases with a higher salary.
Collective insurances, pension etc.SEK	29 133 kr		29 133 kr		29 133 kr		
Total cost	*539 621 kr*		*539 621 kr*		*539 621 kr*		
Cost per hour	337,26 kr		337,26 kr		337,26 kr		
Share of worktime driving a train	75%	Nelldal, 2011	75%	Nelldal, 2011	75%	Nelldal, 2011	
Cost per train hour	449,68 kr		449,68 kr		449,68 kr		
Overhead costs	80 943 kr		80 943 kr		80 943 kr		
Profit margin	- kr		- kr		- kr		
Other costs	*80 943 kr*		*80 943 kr*		*80 943 kr*		
per train hour	*67,45 kr*		*67,45 kr*		*67,45 kr*		
Total cost	*620 564 kr*		*620 564 kr*		*620 564 kr*		
per train hour	*517,14 kr*		*517,14 kr*		*517,14 kr*		
Input to the HIT-model							
Engine	Used TMZ, T44		Euro 4000		Euro 4000		
Time dependant costs, SEK per hour	783 kr		1 093 kr		1 436 kr		
Distance dependant costs, SEK per km	33,15 kr		23,25 kr		24,40 kr		
Empty rail wagon	used Lgjs		Sgns		Sdggmrs		
Time dependant costs, SEK per hour	7,26 kr		13,45 kr		46,31 kr		
Distance dependant costs, SEK per km	0,63 kr		0,85 kr		1,46 kr		
Used rail wagon							
Time dependant costs, SEK per hour	- kr		- kr		- kr		
Distance dependant costs, SEK per km	0,86 kr		1,04 kr		1,14 kr		
A typical train							
Number of wagons in the train	30		20		15		Number of waggons selected to give the same loading capacity in TEU on all trains.
Loading capacity TEU	60		60		60		
Share of loaded wagons	75%		75%		75%		
Weight loaded on train, tonnes	473		465		383		
Train weight, tonnes	969		986		1031		
Train lenght, meters	534		413		536		
Reserve wagons, %	20%		20%		20%		Not all wagons can be in service all the time. Extra wagons needed during repairs, maintenance etc. Time dependent cost.
Total number of waggons	36,0		24,0		18,0		
Distance, km	500,0		500,0		500,0		
Average speed, km/h	70,0		70,0		70,0		

Running time, hours	7,1	7,1	7,1	
Engine and salary costs	22 172 kr	19 438 kr	22 454 kr	
Empty waggon costs	11 281 kr	10 758 kr	16 941 kr	
Used wagon costs	9 690 kr	7 821 kr	6 434 kr	
Total cost per train	43 143 kr	38 017 kr	45 829 kr	
per trainkm	86,29 kr	76,03 kr	91,66 kr	
per grosstonnekm	0,09 kr	0,08 kr	0,09 kr	
per nettonnekm	0,18 kr	0,16 kr	0,24 kr	Including tara weight of load units
per ITUkm	1,92 kr	1,69 kr	2,04 kr	

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Appendix C – Electric emissions

Electric railway engine emissions estimate										
	Low	*Comment*	*Source*	*Medium*	*Comment*	*Source*	*High*	*Comment*	*Source*	*General comment*
	Used engine type RC			New TRAXX-engine or equivalent			TRAXX with ERTMS and dual voltage system			
Emission, grams per kWh									Bäckström et al 2009	
CO2	0,098			0,113			0,113			
NOx	0			0			0			
HC	0,00036			0,00042			0,00042			
CH4	0			0			0			
CO	0,00257			0,00298			0,00298			
PM	0,000043			0,000050			0,000050			
SO2	0			0			0			
Energy, MJ	5,18			6,00			6,00			
Engine										
Electricity consumption, kWh per grosstonkm	0,0212			0,0212			0,0212		Trafikverket, 2010	
Weight, tonnes	79			83			83			
Energy consumption, kWh/enginekm	1,6748			1,7596			1,7596			
Emission, grams per enginekm										
CO2	0,164			0,200			0,200			
NOx	0			0			0			
HC	0,00060			0,00073			0,00073			
CH4	0			0			0			
CO	0,00431			0,00525			0,00525			
PM	0,000072			0,000088			0,000088			
SO2	0			0			0			
Energy, MJ	8,67			10,56			10,56			
Empty wagon										
	Used type Lgjs			Type Sgns			Type Sdggmrs			
Weight, tonnes	12,5			20			35			
Energy consumption, kWh/wagonkm	0,265			0,424			0,742			
Emission, grams per km										
CO2	0,026			0,048			0,084			

NOx	0	0	0
HC	0,00010	0,00018	0,00031
CH4	0	0	0
CO	0,00068	0,00127	0,00221
PM	0,000011	0,000021	0,000037
SO2	0	0	0
Energy, MJ	1,37	2,55	4,45
Loaded wagon			
Weight, tonnes	21	31	34
Energy consumption, kWh/wagonkm	0,4452	0,6572	0,7208
Emission, grams per km			
CO2	0,044	0,075	0,082
NOx	0	0	0
HC	0,00016	0,00027	0,00030
CH4	0	0	0
CO	0,00115	0,00196	0,00215
PM	0,000019	0,000033	0,000036
SO2	0	0	0
Energy, MJ	2,30	3,95	4,33

Sources

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Appendix D – Diesel emissions

Diesel railway engine emissions estimate	*Low*	*Comment*	*Source*	*Medium*	*Comment*	*Source*	*High*	*Comment*	*Source*	*General comment*
Type	Used engine type TMZ			Euro 4000			Euro 4000			
Emission, grams per litre diesel			Bäckström et al 2009			Bäckström et al 2009			Bäckström et al 2009	
CO2	2538	Data for old T44		2538	Data for modernised T44		2538	Data for modernised T44		
NOx	58,6			17,0			17,0			
HC	2,42			0,48			0,48			
CO	4,74			2,83			2,83			
PM	1,67			0,42			0,42			
SO2	0,41		Ahlvik, 1996	0,41		Ahlvik, 1996	0,41		Ahlvik, 1996	
Energy, MJ	1,47		SPI, 2011	1,47		SPI, 2011	1,47		SPI, 2011	
Engine										
Diesel consumption, litre per train (start value)	1,89		Bäckström et al 2009	1,51		Bäckström et al 2009	1,51		Bäckström et al 2009	
Diesel consumption, litre per grosstonkm	0,0053			0,00424			0,00424			
Weight, tonnes	121			121			123			
Diesel consumption, litre/enginekm	2,5313			2,02304			2,03152			
Emission, grams per enginekm										
CO2	6424,44			5134,48			5156,00			
NOx	148			34			35			
HC	6,13			0,97			0,98			
CO	12,00			5,73			5,75			
PM	4,23			0,85			0,85			
SO2	1,03			0,82			0,83			
Energy, MJ	3,71			2,96			2,98			
Empty wagon										
	Used type Lgjs			Type Sgns			Type Sdggmrs			
Weight, tonnes	12,5			20			35			
Diesel consumption, diesel/wagonkm	0,06625			0,0848			0,1484			
Emission, grams per km										
CO2	168,14			215,22			376,64			
NOx	3,9			1,4			2,5			
HC	0,16			0,04			0,07			
CO	0,31			0,24			0,42			
PM	0,11			0,04			0,06			
SO2	0,027			0,035			0,060			
Energy, MJ	0,10			0,12			0,22			
Loaded wagon										
Weight, tonnes	21			31			34			
Diesel consumption, liter/wagonkm	0,1113			0,13144			0,14416			
Emission, grams per km										

CO2	282,48	333,59	365,88
NOx	6,5	2,2	2,5
HC	0,27	0,06	0,07
CO	0,53	0,37	0,41
PM	0,19	0,06	0,06
SO2	0,045	0,054	0,059
Energy, MJ	0,16	0,19	0,21

Sources

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Appendix E – Electric Societal costs

Electric haul, societal costs Railway engine cost estimate	Low	Comment	Source	Medium	Comment	Source	High	Comment	Source	General comment
Railway engine										
	Used engine type RC			New TRAXX-engine or equivalent			TRAXX with ERTMS and dual voltage system			
Running distance, km per year	300 000			220 000			138 000			
Fixed costs	948 750 kr			2 458 125 kr			2 668 821 kr			
per km	3,16 kr			11,17 kr			19,34 kr			
or per hour	**221,38 kr**			**782,13 kr**			**1 353,75 kr**			
Maintenence costs	2 250 000 kr			1 320 000 kr			897 000 kr			
Electricity costs (engine only)	367 535 kr			263 507 kr			165 291 kr			
Infrastructure fees	409 320 kr			406 003 kr			383 474 kr			
Overhead costs	454 028 kr			298 426 kr			216 865 kr			
Emission costs per year										
Local effects										
Societal cost NOx	- kr			- kr			- kr			
Societal cost SO2	- kr			- kr			- kr			
Societal cost HC	0,16 kr			0,15 kr			0,09 kr			
Societal cost PM	3,32 kr			2,97 kr			1,86 kr			
Noise	63 564 kr			46 614 kr			29 240 kr			
Regional effects										
Societal cost NOx	- kr			- kr			- kr			
Societal cost SO2	- kr			- kr			- kr			
Societal cost HC	6 kr			5 kr			3 kr			
Global effects										
Societal cost CO2	73,67027 kr			65,84194 kr			41,30086 kr			
Emission costs, total	63 647,08 kr			46 687,80 kr			29 285,98 kr			
per km	*0,21 kr*			*0,21 kr*			*0,21 kr*			
Variable costs	3 544 530 kr			2 334 624 kr			1 691 916 kr			
per km	**11,82 kr**			**10,61 kr**			**12,26 kr**			
Empty wagon										
	Used type Lgjs			Type Sgns			Type Sdggmrs			
Running distance per year	110 000			220 000			138 000			
Fixed costs	11 404,17 kr			42 262,50 kr			91 301,79 kr			
per km	0,10 kr			0,19 kr			0,66 kr			

or per hour	**7,26 kr**	**13,45 kr**	**46,31 kr**
Maintenence costs	11 000 kr	33 000 kr	41 400 kr
Electricity costs (wagon only)	21 323 kr	63 496 kr	69 701 kr
Infrastructure charges	4 950 kr	15 840 kr	17 388 kr
Overhead costs	5 591 kr	16 850 kr	19 273 kr
Emission costs per year			
Local effects			
Societal cost NOx	0	0	0
Societal cost SO2	0	0	0
Societal cost HC	0,0094	0,0350	0,0384
Societal cost PM	0,19	0,72	0,79
Regional effects			
Societal cost NOx	0	0	0
Societal cost SO2	0	0	0
Societal cost HC	0,32	1,21	1,32
Global effects			
Societal cost CO2	4,27	15,87	17,42
Emission costs, total	4,80	17,82	19,56
per km	*0,00004 kr*	*0,00008 kr*	*0,00014 kr*
Variable costs	42 869 kr	129 204 kr	147 782 kr
per km	**0,39 kr**	**0,59 kr**	**1,07 kr**
Loaded wagon			
Fixed costs			
per km	- kr	- kr	- kr
or per hour	- kr	- kr	- kr
Maintenence costs	- kr	- kr	- kr
Electricity costs (freight only)	35 823 kr	98 418 kr	67 710 kr
Infrastructure charges	8 316 kr	24 552 kr	16 891 kr
Overhead costs	6 621 kr	18 446 kr	12 690 kr
Emission costs per year			
Local effects			
Societal cost NOx	- kr	- kr	- kr
Societal cost SO2	- kr	- kr	- kr
Societal cost HC	0,02 kr	0,03 kr	0,03 kr
Societal cost PM	0,32 kr	0,55 kr	0,61 kr
Regional effects			
Societal cost NOx	- kr	- kr	- kr
Societal cost SO2	- kr	- kr	- kr
Societal cost HC	0,55 kr	0,93 kr	1,02 kr
Global effects			

Societal cost CO2	7,18 kr		12,30 kr		13,49 kr		
Emission costs, total	8,07 kr		13,81 kr		15,15 kr		
Per km	*0,00007 kr*		*0,00006 kr*		*0,00011 kr*		
Variable costs	50 767,94 kr		141 429,69 kr		97 305,96 kr		
per km	**0,46 kr**		**0,64 kr**		**0,71 kr**		
Personell costs							
per train hour	517 kr		517 kr		517 kr		Same as business economic costs
Input to the HIT-model							
Engine	Used RC		TRAXX		Full TRAXX		
Time dependant costs, kr per hour	739 kr		1 299 kr		1 871 kr		
Distance dependant costs, kr per km	11,82 kr		10,61 kr		12,26 kr		
Empty rail wagon	used Lgjs		Sgns		Sdggmrs		
Time dependant costs, kr per hour	7,26 kr		13,45 kr		46,31 kr		
Distance dependant costs, kr per km	0,39 kr		0,59 kr		1,07 kr		
Used rail wagon							
Time dependant costs, kr per hour	- kr		- kr		- kr		
Distance dependant costs, kr per km	0,46 kr		0,64 kr		0,71 kr		

References

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Statens institut för kommunikationsanalys, SIKA PM 2005:16, Stockholm

Appendix F - Diesel societal costs

Diesel haul, societal costs Railway engine cost estimate										
	Low	*Comment*	*Source*	*Medium*	*Comment*	*Source*	*High*	*Comment*	*Source*	*General comment*
Railway engine										
	Used engine type TMZ			Euro 4000			Euro 4000			
Running distance, km per year	300 000			220 000			138 000			
Fixed costs	1 140 417 kr			1 811 250 kr			1 811 250 kr			
per km	3,80 kr			8,23 kr			13,13 kr			
or per hour	**266,10 kr**			**576,31 kr**			**918,75 kr**			
Maintenence costs	3 600 000 kr			1 320 000 kr			828 000 kr			
Diesel costs (engine only)	3 933 640 kr			2 305 456 kr			1 452 212 kr			
Infrastructure fees	1 115 349 kr			823 309 kr			647 251 kr			
Overhead costs	1 297 348 kr			667 315 kr			439 119 kr			
Emission costs per year										
Local effects										
Societal cost NOx	24 041 kr			4 088 kr			2 575 kr			
Societal cost SO2	1 393 kr			817 kr			514 kr			
Societal cost HC	1 654,69 kr			192,36 kr			121,17 kr			
Societal cost PM	194 575,18 kr			28 680,22 kr			18 065,73 kr			
Noise	63 564 kr			46 614 kr			29 240 kr			
Regional effects										
Societal cost NOx	2 759 016 kr			469 103 kr			295 489 kr			
Societal cost SO2	6 498 kr			3 809 kr			2 399 kr			
Societal cost HC	56 969 kr			6 623 kr			4 172 kr			
Global effects										
Societal cost CO2	2 890 997,73000 kr			1 694 376,92160 kr			1 067 291,53632 kr			
Emission costs, total	5 998 709,62 kr			2 254 301,22 kr			1 419 866,45 kr			
Per km	*20,00 kr*			*10,25 kr*			*10,29 kr*			
Variable costs	15 945 048 kr			7 370 381 kr			4 786 448 kr			
per km	**53,15 kr**			**33,50 kr**			**34,68 kr**			
Empty wagon										
	Used type Lgjs			Type Sgns			Type Sdggmrs			
Running distance per year	100 000			700 000			1 300 000			
Fixed costs	11 404,17 kr			42 262,50 kr			91 301,79 kr			
per km	0,10 kr			0,19 kr			0,66 kr			
or per hour	**7,26 kr**			**13,45 kr**			**46,31 kr**			
Maintenence costs	11 000 kr			33 000 kr			34 500 kr			
Diesel costs (wagon only)	37 749 kr			96 638 kr			106 082 kr			

Infrastructure charges	11 290 kr	32 071 kr	35 205 kr
Overhead costs	9 006 kr	24 256 kr	26 368 kr
Profit margin			
Local effects			
Societal cost NOx	210	545	1772
Societal cost SO2	20	169	344
Societal cost HC	14,4357	25,6550	83,3787
Societal cost PM	1697,49	3825,16	12431,76
Regional effects			
Societal cost NOx	24070	62565	203338
Societal cost SO2	56,6934375	507,9732	1650,9129
Societal cost HC	497,01	883,28	2870,65
Global effects			
Societal cost CO2	25221,38	225983,52	734446,44
Emission costs, total	51787,11	294504,99	956936,43
Per km	*0,52 kr*	*0,42 kr*	*0,74 kr*
Variable costs	120 832 kr	480 470 kr	1 159 092 kr
per km	**1,21 kr**	**0,69 kr**	**0,89 kr**
Loaded wagon			
Fixed costs			
per km	- kr	- kr	- kr
or per hour	- kr	- kr	- kr
Maintenence costs	- kr	- kr	- kr
Diesel costs (freight only)	63 419 kr	149 789 kr	103 051 kr
Infrastructure charges	18 967 kr	49 710 kr	34 199 kr
Overhead costs	12 358 kr	29 925 kr	20 588 kr
Emission costs per year			
Local effects			
Societal cost NOx	352,36 kr	120,72 kr	132,40 kr
Societal cost SO2	20,42 kr	24,11 kr	26,45 kr
Societal cost HC	24,25 kr	5,68 kr	6,23 kr
Societal cost PM	2 851,79 kr	847,00 kr	928,97 kr
Regional effects			
Societal cost NOx	40 437,52 kr	13 853,78 kr	15 194,46 kr
Societal cost SO2	95,24 kr	112,48 kr	123,36 kr
Societal cost HC	834,97 kr	195,58 kr	214,51 kr
Global effects			
Societal cost CO2	42 371,91 kr	50 039,21 kr	54 881,71 kr
Emission costs, total	86 988,46 kr	65 198,56 kr	71 508,09 kr
Per km	*0,87 kr*	*0,09 kr*	*0,06 kr*
Variable costs	181 732,53 kr	294 621,99 kr	229 346,04 kr
per km	**1,82 kr**	**0,42 kr**	**0,18 kr**
Personell costs			

per train hour	517 kr	517 kr	517 kr	Same as business economic costs
Input to the HIT-model				
Engine	Used RC	TRAXX	Full TRAXX	
Time dependant costs, kr per hour	783 kr	1 093 kr	1 436 kr	
Distance dependant costs, kr per km	53,15 kr	33,50 kr	34,68 kr	
Empty rail wagon	used Lgjs	Sgns	Sdggmrs	
Time dependant costs, kr per hour	7,26 kr	13,45 kr	46,31 kr	
Distance dependant costs, kr per km	1,21 kr	0,69 kr	0,89 kr	
Used rail wagon				
Time dependant costs, kr per hour	- kr	- kr	- kr	
Distance dependant costs, kr per km	1,82 kr	0,42 kr	0,18 kr	

References

SIKA, 2002, *Luftföroreningar : Delrapport ASEK* , SIKA Rapport 2002:12, Stockholm
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Appendix G – Shunting costs

General data			
		Comment	Source
Interest rate	6,5%	Difficult to estimate and will vary over time.	
Overhead costs	8%	General administration etc.	Nelldal, 2011
Unexpected costs	7%	Margin to cover unexpected events.	Nelldal, 2011
Sum OH costs	15%		
Profit margin	0%	Not included if a cost calculation is intended. Othervise, 10% is appropriate.	Nelldal, 2011

Low, medium and high referes to the cost level and not the size or type of terminal.

Shunting engine cost estimate	*Low*	*Comment*	*Source*	*Medium*	*Comment*	*Source*	*High*	*Comment*	*Source*	*General comment*
Purchace price	15 000 000 kr	Smaller 2-axel engine	Nelldal, 2011	20 000 000 kr	Engine type G4 Vossloh or GM	Nelldal, 2011, Sweeley, 2005	10 000 000 kr	Used T44		
Service life, years	50		Nelldal, 2011	50			15		Nelldal, 2011	
Depreciation, years	50			50			15			Depreciation can also be made over a shorter time period for accounting and tax reasons.
Diesel consumption, litre per hour	16	Type V5	Bäckström, et al., 2009	29	Modernised T44 engine	Bäckström, et al., 2009	37	Type T44	Bäckström, et al., 2009	Average value per hour. Momentarily, the consumption might be much higher. Will also differe depending on the weigth of the train.
Price (SEK) per litre diesel	5,18 kr		SPI, 2011	5,18 kr			5,18 kr		SPI, 2011	Rail traffic do not pay fuel taxes in Sweden.
Utlisation, hours per year	2 500		Nelldal, 2011	2 900			3 300		Nelldal, 2011	
Maintenence costs per hour	130,00 kr		Nelldal, 2011	130,00 kr		Nelldal, 2011	130,00 kr		Nelldal, 2011	
<u>Calculations per year</u>										
Average cost of capital	487 500 kr			650 000 kr			325 000 kr			Average capital tied up during the depreciation period * interest rate. Assuming linear depreciation.
Depreciation	300 000 kr			400 000 kr			666 667 kr			Linear depreciation.
Overhead costs	*118 125 kr*			*157 500 kr*			*148 750 kr*			
Profit margin	*- kr*			*- kr*			*- kr*			
Fixed costs	*905 625 kr*			*1 207 500 kr*			*1 140 417 kr*			
per hour	*362,25 kr*			*416,38 kr*			*345,58 kr*			
Maintenence costs	325 000 kr			377 000 kr			429 000 kr			
Diesel costs	207 200 kr			435 638 kr			632 478 kr			
Overhead costs	*79 830 kr*			*121 896 kr*			*159 222 kr*			
Profit margin	*- kr*			*- kr*			*- kr*			
Variable costs	*612 030 kr*			*934 534 kr*			*1 220 700 kr*			
per hour	*244,81 kr*			*322,25 kr*			*369,91 kr*			
Total costs	*1 517 655 kr*			*2 142 034 kr*			*2 361 116 kr*			
per hour	***607,06 kr***			***738,63 kr***			***715,49 kr***			
Personell costs										
Line haul engine driver, per hour	517,14 kr			517,14 kr			517,14 kr			
Shunting eninge driver, per hour	413,71 kr			413,71 kr			413,71 kr			

Total cost including driver, per hour	1 020,77 kr	1 152,34 kr	1 129,20 kr

References

Bäckström, S. & Bohlin, M. & Franzen, U. & Jonsson, P., 2009, *Miljökalkyler för intermodala transportkedjor - Detaljerad beräkningsmetodik och relevanta schablonvärden*,
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Appendix H – Shunting societal costs

Railway engine cost estimate	Low	Comment	Source	Medium	Comment	Source	High	Comment	Source	General comment
Shunting engine cost estimate, societal costs										
	Smaller 2-axel engine			Engine type G4 Vossloh or GM			Used T44			
Utlisation, hours per year	*2500*			*2900*			*3300*			
Fixed costs	905 625 kr			1 207 500 kr			1 140 417 kr			
or per hour	362 kr			416 kr			346 kr			
Maintenence costs	325 000 kr			377 000 kr			429 000 kr			
Diesel costs	207 200 kr			435 638 kr			632 478 kr			
Overhead costs	79 830 kr			121 896 kr			159 222 kr			
Emission costs per year										
Local effects										
Societal cost NOx	540 kr			772 kr			3 865 kr			
Societal cost SO2	73 kr			154 kr			224 kr			
Societal cost HC	39,98 kr			36,35 kr			266,05 kr			
Societal cost PM	2 025 kr			5 419 kr			31 285 kr			
Noise	- kr			- kr			- kr			
Regional effects										
Societal cost NOx	62 000 kr			88 641 kr			443 614 kr			
Societal cost SO2	342 kr			720 kr			1 045 kr			
Societal cost HC	1 376 kr			1 251 kr			9 160 kr			
Global effects										
Societal cost CO2	152 280 kr			320 169 kr			464 835 kr			
Emission costs, total	218 678 kr			417 164 kr			954 294 kr			
Emission cost per hour	87,47 kr			143,85 kr			289,18 kr			
Variable costs	830 708 kr			1 351 697 kr			2 174 994 kr			
per hour	**332,28**			**466,10**			**659,09**			
Total costs	1 736 333 kr			2 559 197 kr			3 315 410 kr			
per hour	694,53 kr			882,48 kr			1 004,67 kr			
Total cost including driver, per hour	1 108,24 kr			1 296,19 kr			1 418,38 kr			

Appendix I – Shunting emissions

Diesel railway engine shunting emissions estimate										
	Low	*Comment*	*Source*	*Medium*	*Comment*	*Source*	*High*	*Comment*	*Source*	*General comment*
	Smaller 2-axel engine			Engine type G4 Vossloh or GM			Used T44			Diffcult to get emission datafor all types of enigne. The availible data has been used. See Bäckström et al 2009. The types used high might be different for the types used in the cost calculations.
Emission, grams per litre diesel			Bäckström et al 2009			Bäckström et al 2009			Bäckström et al 2009	
CO2	2538			2538			2538			
NOx	25,0			17,0			58,6			
HC	1,11			0,48			2,42			
CO	3,30			2,83			4,74			
PM	0,33			0,42			1,67			
SO2	0,41		Ahlvik, 1996	0,41		Ahlvik, 1996	0,41		Ahlvik, 1996	
Energy, MJ	1,47		SPI, 2011	1,47		SPI, 2011	1,47		SPI, 2011	
Engine										
Diesel consumption, litre per hour	16			29			37			
Emission, grams per hour										
CO2	40 608			73 602			93 906			
NOx	400			493			2168			
HC	17,8			13,9			89,5			
CO	52,8			82,1			175,4			
PM	5,3			12,2			61,8			
SO2	6,5			11,8			15,1			
Energy, MJ	23,45			42,50			54,22			

Sources

Ahlvik, P., 1996, *Exhaust emissions from a 2-stroke locomotive engine*, AB Svensk Bilprovning, Motortestcenter, 1996:4 MTC 9410A, Haninge
Bäckström, S. & Bohlin, M. & Franzen, U. & Jonsson, P., 2009, *Miljökalkyler för intermodala transportkedjor - Detaljerad beräkningsmetodik och relevanta schablonvärden*, WSP Analys & Strategi, SIR-C Swedish Intermodal Transport Research Centre Rapport nr. 2009:6,
SPI, 2011, Homepage, http://spi.se/, Accessed March 2 2011

Appendix J – Terminal handling costs

Terminal costs	Small terminal	Comment	Source	Medium terminal	Comment	Source	Large terminal	Comment	Source	Line terminal	Comment	Source	General comment
Cost per handling													
Truck costs	192 kr			128 kr			106 kr			195 kr			Truck refers to the handling equipment on the terminal, and not the lorry.
Investment costs	64 kr			54 kr			60 kr			62 kr			
Shunting costs	64 kr			86 kr			73 kr			- kr			Based on an average train size. Note that the calculations are not the same as the shunting cost calculations in this Excel-sheet.
Sum, cost per lift	***320 kr***			***268 kr***			***239 kr***			***257 kr***			Note that these are costs per lift and not per TEU.
Cost per lift, excl. shunting	*256 kr*			*182 kr*			*166 kr*			*257 kr*			

Sources

Sommar, R., 2010, *Utvärdering av intermodala transportkedjor - kostnadsmodeller* TFK, KTH, SIR-C Swedish Intermodal Transport Research Centre

Appendix K – Terminal handling societal costs

Terminal societal costs	Small terminal	Comment	Source	Medium terminal	Comment	Source	Large terminal	Comment	Source	Line terminal	Comment	Source	General comment
Cost per handling													
Truck costs	192			128			106			195			Truck refers to the handling equipment on the terminal, and not the lorry.
Investment costs	64			54			60			62			
Shunting costs	64			86			73			0			Based on an average train size. Note that the calculations are not the same as the shunting cost calculations in this Excel-sheet.
Emission costs											Using the same emissions as for a small terminal.		
Local effects													
Societal cost NOx	0,030 kr			0,033 kr			0,041 kr			0,030 kr			
Societal cost SO2	0,000000077 kr			0,000000090 kr			0,00000012 kr			0,000000077 kr			
Societal cost HC	0,020 kr			0,021 kr			0,023 kr			0,020 kr			
Societal cost PM	0,37 kr			0,43 kr			0,58 kr			0,37 kr			
Regional effects													
Societal cost NOx	3,47 kr			3,78 kr			4,71 kr			3,47 kr			
Societal cost SO2	0,00000036 kr			0,00000042 kr			0,00000057 kr			0,00000036 kr			
Societal cost HC	0,68 kr			0,71 kr			0,78 kr			0,68 kr			
Global effects													
Societal cost CO2	8,05 kr			9,24 kr			12,43 kr			8,05 kr			
Emission costs, total	12,62 kr			14,22 kr			18,56 kr			12,62 kr			
Sum, cost per lift	***333 kr***			***282 kr***			***258 kr***			***270 kr***			
Cost per lift, excl. shunting	*269 kr*			*196 kr*			*185 kr*			*270 kr*			

Sources

Sommar, R., 2010, *Utvärdering av intermodala transportkedjor - kostnadsmodeller* TFK, KTH, SIR-C Swedish Intermodal Transport Research Centre

Appendix L – Terminal handling emissions

Terminal Handling Emissions

	Small terminal	Comment	Source	Medium terminal	Comment	Source	Large terminal	Comment	Source	General comment
Emission, grams per handling										
CO2	5 367			6 163			8 286			
NOx	56			61			76			
HC	22			23			25			
CH4	0			0			0			
CO	35			39			47			
PM	2,4			2,8			3,8			
SO2	0,000017			0,000020			0,000027			
Energy, MJ	74			85			114			

All data are recommended values from Bäckström et al (2009)

The data represents all activites included in handling a load unit at a terminal.
Includes all handling activites, including multiple lifts, empty running etc.
Note that the emissions also **includes** diesel shunting

Sources

Bäckström, S. & Bohlin, M. & Franzen, U. & Jonsson, P., 2009, *Miljökalkyler för intermodala transportkedjor - Detaljerad beräkningsmetodik och relevanta schablonvärden* ,
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