Comparing Freight Transport Emissions by Mode

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Abstract

In New Zealand, moving domestic freight by rail and coastal shipping is widely regarded as using less energy, and emitting less greenhouse gas emissions, per tonne-km than road freight. While the evidence appears to support this view in general, the data that would tell us how much reduction in energy use and emissions we could expect if more freight were diverted from road to rail or coastal shipping has been quite limited.

This paper reviews the evidence on freight emissions by mode in New Zealand. We consider each of the three modes—coastal shipping, rail, and road transport. For each mode, we look at the New Zealand-specific evidence, then compare this to overseas evidence. A particular challenge in comparing emissions by mode is that rail and coastal shipping compete mainly with large linehaul trucks. Since large linehaul trucks are considerably more energy-efficient per tonne-km than urban delivery trucks, a simple comparison of rail and coastal shipping with an average truck would be misleading for estimating emission changes from mode shifts. We, therefore, use a unique dataset obtained from EROAD to estimate emissions per tonne-km separately for linehaul and urban delivery trucks.

We conclude with some recommendations regarding reasonable assumptions about average emissions per tonne-km by mode and some suggestions for further research.

Introduction

In New Zealand, moving domestic freight by rail and coastal shipping is widely regarded as using less energy, and emitting less greenhouse gas emissions, per tonne-kilometre than road freight. While the evidence appears to support this view in general (see, for example, IPCC 2014, NZ Gov 2020, MoT 2020) the data that would tell us how much reduction in energy use and emissions we could expect if more freight were diverted from road to rail or coastal shipping is quite limited.

This paper reviews the evidence on freight emissions by mode in New Zealand. We consider each of the three modes—coastal shipping, rail, and road transport—in separate sections. Within each section, we look at the New Zealand-specific evidence, then compare this to overseas evidence. We conclude with some recommendations regarding reasonable assumptions about average emissions per tonne-km and some suggestions for further research.

Consistent with the approach used by Ministry for the Environment in measuring greenhouse gas emissions (MfE, 2020a, p. 11), we seek to estimate 'tank-to-wheels' emissions, based on the emissions from fuel combustion only, without considering the 'well-to-tank' emissions involved in producing, processing, and transporting the fuel. The latter can vary greatly depending upon the supply chain for the fuel, and estimating well-to-tank emissions for New Zealand fuel is beyond the scope of this paper.

All of the results presented here give emissions in CO_2-equivalent, thereby considering all greenhouse gases emitted, not just CO_2. The difference between CO_2 and CO_2-equivalent for transport emissions is, however, generally inconsequential—about 1.6% for transport diesel fuel, for example, according to the Ministry for the Environment (MfE, 2020b, Fuel 2020 tab). Even this may be an overestimate; as-yet unpublished results from the Ministry of Transport's non-CO_2 emissions modelling indicate that non-CO_2 emissions make up only about 1% of total greenhouse gas emissions for the New Zealand road vehicle fleet.

All of results presented here are also designed to reflect real-world operating conditions, including actual loadings and empty movements.

Sources for Overseas Evidence

The authors have identified four overseas sources of authoritative guidelines for calculating emissions by mode in freight transport, whose estimates are presented in the sections of this paper discussing overseas evidence. These guidelines were prepared either by government agencies (the United Kingdom and France) or by industry-sponsored consortiums with broad stakeholder involvement (the Netherlands and Sweden). All of them provide estimates of CO_2-e emissions/tonne-km for a variety of modes and, in most cases, vehicle types/sizes. The sources for the guidelines are as follows:

United Kingdom (BEIS/DEFRA) – The United Kingdom Department for Business, Energy & Industrial Strategy (BEIS) and the Department for Environment Food and Rural Affairs (DEFRA) of the UK jointly publish a spreadsheet of *UK Government GHG Conversion Factors for Company Reporting* (UKBEIS, 2020a), which includes freight emissions per tonne-km. The methodology is described in an accompanying paper (UKBEIS, 2020b). Data are drawn from a variety of mostly-official sources, including government transport statistics, the UK Greenhouse Gas Inventory, and vehicle fuel efficiency surveys. Emission factors are provided for a variety of road vehicles and types of ships, but only an overall average figure is given for rail freight. The emission factors should reflect actual loadings and actual driving conditions. Emission factors exclude upstream (well-to-tank) emissions in producing and transporting the fuel to the vehicle.

Netherlands (STREAM) - Consulting firm CE Delft in Delft, the Netherlands, has produced the *STREAM Freight Transport 2016 handbook* (CE Delft, 2017) providing fleet average freight emissions per tonne-kilometre. This handbook was produced under the sponsorship of Topsector Logistiek, which is an organisation that promotes public-private partnerships in the logistics sector in the Netherlands (Topsector Logiistiek,2021). Most of the emission factor calculations appear to be bottom-up, starting with fuel consumption for specific vehicles. Emission factors can therefore be provided separately for bulk freight and containers, for a variety of vehicle types, and, for trucks, by road type (urban, rural, motorway). There is also a high level summary of representative emission factors by mode. The calculations are designed to reflect the real-world of the Netherlands, including typical load factors and empty moves. Emission factors are given on a both well-to-wheels and tank-to-wheels basis. We use the latter.

France (MEDDE/ADEME) – The Ministère de l'Écologie du Développement durable et de l'Énergie (Ministry of Ecology, Sustainable Development and Energy) and the Agence de l'Environnement et de la Maîtrise de l'Energie (Environment and Energy Management Agency) of France have jointly produced *GHG information for transport services* (MEDDE, 2019). Emission factor calculations are bottom-up, starting with the fuel consumption for various vehicle types. The data are presumably drawn from official sources, although the document does not provide much information on this. Data are provided for a variety of vehicle types and, for rail, by density of the commodity being shipped. The calculations are designed to reflect the real-world of France, including typical load factors and empty moves. Transport emission factors include upstream (well-to-tank) emissions. The report does, however, show well-to-tank and well-to-wheels emission factors for each specific fuel (emissions per unit of fuel), which allowed the authors to back out the well-to-tank component in the figures quoted here.

Sweden (NTM) – Sweden's Network for Transport Measures, NTM, is a non-government research organisation (NTM, 2020). They publish on their website a set of benchmark data for calculating transport emissions, including freight emissions per tonne-km (NTM, 2018). NTM appears to have broad industry participation, with data coming from participating carriers. Data are provided for a variety of vehicle types and world regions. The calculations are designed to reflect the real-world, including typical load factors and empty moves. Emission factors are given mainly on a well-to-wheels basis. For consistency, we have used the MEDDE, 2020 data discussed above to back out the well-to-tank component in the figures quoted here in cases where tank-to-wheels data were not provided.

Domestic Coastal Shipping

New Zealand-Specific Data

New Zealand customers wishing to move containers by domestic coastal shipping often have a choice of using an international carrier or a domestic carrier. Unlike many countries, New Zealand law does allow international carriers to carry domestic coastal cargo under certain conditions, the most significant being that the carriage of the domestic cargo is incidental to the carriage of international cargo (New Zealand Legislation, 2021). This arises when a container ship travelling on an overseas routing stops at two or more ports in New Zealand and has spare capacity between those ports. Statistics from the Ministry of Transport's Freight Information Gathering System (FIGS) (MoT, 2021, FIGS Containers->Coastal Movements (N5)) indicate that domestic movements by international carriers make up a large majority of domestic coastal container shipments. For example, in 2020, about 357,906 coastal traffic containers were handled by international carriers, while only 145,597 were handled by domestic carriers (for 11,210 containers, the carrier was not known).

Given that this domestic carriage of containers by international carriers is incidental to their international operations, it is impossible to estimate their emissions per tonne-km, but it is arguably close to zero; the ships are going to operate between New Zealand ports with or without the domestic freight. Although this sounds like an environmentally attractive alternative, it is unclear the extent to which use of international carriers for domestic container shipping could be expanded, as the capacity available is determined by the carrier's international operations. Also, this service is available only on certain origin-destination pairs, may operate on an irregular schedule, and that schedule may be subject to disruption due to problems overseas. So using an international carrier is likely to be an attractive alternative only for a limited set of customers.

Customers desiring domestic coastal container shipping with greater range of offerings and greater reliability can use a New Zealand domestic coastal container carrier, of which there is only one, Pacifica Shipping. There are several other domestic carriers that engage in coastal shipping of oil products and dry bulk commodities, such as cement. Unfortunately, there are no regularly-published statistics on either fuel use or tonne-kilometres for any of these carriers. Hence, it is not possible to directly calculate New Zealand-specific emission factors for domestic coastal shipping.

The Ministry of Business, Innovation and Employment (MBIE) does regularly publish tables showing oil use in 'domestic navigation' (MBIE, 2020) from which one could calculate emissions. However, it is not clear what is included in these figures. They may include some fishing and recreational vessels, and would definitely include the Cook Strait ferries and coastal shipping. The Cook Strait ferries are more than just freight carriers. Furthermore, from the perspective of this paper, the Cook Strait ferries probably should not be considered domestic coastal shipping, since the Cook Strait ferries do not provide an alternative to road or rail transport. Our understanding is that, due to confidentiality restrictions, MBIE cannot provide a break-out of coastal shipping oil use or emissions alone.

Overseas Data

New Zealand's domestic coastal shipping fleet is small and consists of small ships. The New Zealand Shipping Federation publishes a fact sheet that includes a list of New Zealand coastal ships as of 2019 (NZSF, 2019). There are 14 ships listed, however, two of these are research vessels and five are Cook Strait ferries. As mentioned above, the authors would not regard Cook Strait ferry operations as domestic coastal shipping, at least from the perspective of this paper, as they do not provide an alternative to road or rail transport. One more, the container ship Spirit of Canterbury, is no longer in the New Zealand fleet[1].

That leaves six true coastal shipping ships, as follows (all data from Marine Traffic, 2021):

Bulk Ships:
Anatoki – bulk cargo – 447 tonnes deadweight
Aotearoa Chief – cement carrier – 8024 tonnes deadweight
Buffalo - cement carrier – 9092 tonnes deadweight

Tankers:
Kokako – oil product tanker – 49218 tonnes deadweight
Matuku – oil product tanker – 50143 tonnes deadweight

Container Ships:
Moana Chief – container ship -- 1740 TEUs (containers) capacity – 23305 tonnes deadweight

Table 1 shows the data for comparable ships from our four overseas sources.

[1] An updated version of the Fact Sheet provided by NZSF Executive Director Annabel Young via e-mail on 19 April 2021 shows a list of ships that is identical to the list in the 2019 version available on the NZSF website, except for the deletion of the Spirit of Canterbury.

small bulk cargo ships		
United Kingdom	bulk carrier, 0-9999 tonnes deadweight	29.6 g CO_2-e/tonne-km (BEIS, 2020a)
Netherlands	bulk carrier, feeder, 3341 tonne load capacity	28 g CO_2-e/tonne-km (CE Delft, 2017, Table 25)
France	handysize bulk carrier - deadweight tonnage of less than 40,250 tons	9.6 g CO_2-e/tonne-km (MEEDE, 2019[2])
Sweden	bulk carrier, coastal – no size given	9.1 g CO_2-e/tonne-km (NTM, 2018[3])
medium oil products tankers		
United Kingdom	oil products tanker, 20,000-59,999 tonnes deadweight	10.4 g CO_2-e/tonne-km (BEIS, 2020a)
Netherlands	oil tanker, 20,000-60,000 tonnes deadweight	15 g CO_2-e/tonne-km (CE Delft, 2017, Table 25)
France	handy oil product tanker - deadweight tonnage between 26 500 and 68 499 tonnes	16.1 g CO_2-e/tonne-km (MEEDE, 2019)
Sweden	NA	
small container ships		
United Kingdom	container ship, 1000-1999 TEU	32.6 g CO_2-e/tonne-km (BEIS, 2020a)
Netherlands	container ship (handysize like), 1500 TEU capacity, medium weight containers	21 g CO_2-e/tonne-km (CE Delft, 2917, Table 27)
France	container ship - 1 200-1899 TEU	18.9 g CO_2-e/tonne-km (MEEDE, 2019)
Sweden	Container feeder, 1000 TEU	18.1 g CO_2-e/tonne-km (NTM, 2018)

Table 1 – Comparison of overseas estimates of emission factors for coastal shipping

Comparing the available figures for small bulk cargo ships, the French and Swedish figures are lower than the UK and Netherlands numbers, probably because they are considering ships that are much larger (up to 40,240 tonnes in the case of France) than the three New Zealand bulk cargo ships. The other two suggest an appropriate estimate for the New Zealand ships might be 28-30 g CO_2-e/tonne-km.

Looking at oil products tankers, the United Kingdom number appears to differ from the other two. The authors have no explanation as to why this should be as the ships considered by all three sources should be comparable. Taken together, the three numbers suggest an appropriate estimate for New Zealand would be in the range of 10-16 g CO_2-e/tonne-km.

Finally, looking at container ships, the United Kingdom's number again appears to be an outlier

[2] All figures in this table for MEDDE, 2019 are from Table 16, adjusted to a tank-to-wheels basis for heavy fuel oil using the fuel emission factors shown in Table 14, which indicated a multiplication by a factor of 0.86.

[3] All figures in this table for NTM, 2018 are adjusted to a tank-to-wheels basis for heavy fuel oil using the fuel emission factors shown in MEEDE, 2019, Table 14, which indicated a multiplication by a factor of 0.86, and use the figure given for travel at design speed (not slow steaming),

compared to the other sources, but this time in the opposite direction. Again, it is not clear why this should be, as the ships considered by all four sources should be comparable. We will base our estimates for the Moana Chief on the other three sources, but cannot rule out the possibility that the United Kingdom figure would be more appropriate.

Rail

New Zealand-Specific Data

Table 2 shows Kiwirail emissions per net tonne-kilometre (ntkm), based on data kindly supplied by Kiwirail. All figures relate to rail freight services only. Kiwirail operates both diesel- and electric-hauled freight trains, so emission factors are calculated separately for diesel- and electric-hauled trains, as well as an average for all freight trains.

Fiscal Year (Ending 30 June)	2015-16	2016-17	2017-18	2018-19	2019-20
Diesel Litres/Diesel ntkm[4]	0.0115	0.0113	0.0105	0.0106	0.0107
Electricity kWh/Electricity ntkm	0.0526	0.0530	0.0559	0.0553	0.0628
g CO_2-e/Litre Diesel (MfE, 2020b,'Fuel 2020' tab)	2,694	2,694	2,694	2,694	2,694
g CO_2-e/kWh Electricity[5]	104.3	120.8	110.1	110.1	110.1
g CO_2-e/ntkm Diesel	31.0	30.5	28.2	28.6	28.7
g CO_2-e/ntkm Electric	5.5	6.4	6.2	6.1	6.9
g CO_2-e/ntkm Average	28.4	28.5	27.0	27.6	28.2

Table 2 – Emission factor calculations for Kiwirail[6]

Table 3 compares the average emissions on the bottom line of Table 2 to the numbers published in Kiwirail's Integrated Annual Report (Kiwirail, 2021). The small differences are explained by Kiwirail's use of slightly different emission factors.

Fiscal Year (ending 30 June)	g CO_2-e/ntkm	
	Kiwirail Reported	From Table 2
2015-16	28.83	28.4
2016-17	28.82	28.5
2017-18	27.32	27.0
2018-19	27.51	27.6
2019-20	28.13	28.2

Table 3 – Comparison of reported freight emissions per net tonne-kilometre (ntkm)

Overseas Data

Table 4 shows the data for rail freight from our four overseas sources. For the Netherlands, we

[4] Kiwirail data were supplied to the author by the Kiwirail Sustainability Team in an e-mail dated 19 February 2021.

[5] From MfE, 2020b, Factors shown equal transmission and distribution losses emission factors for the relevant year from the 'T & D losses 2020' tab plus electricity purchased energy emission factors for the relevant year from the 'Purchased energy 2020' tab. Since no data were supplied for years after 2018, the 2018 factors were used for 2019 and 2020.

[6] Calculated figures shown are from a spreadsheet using the exact numbers; results based on the rounded numbers shown here may be subject to small rounding errors. All emission factors are simple averages derived by dividing total in-scope emissions by total in scope ntkms.

show data for diesel trains of medium bulk freight and of medium-weight containers. We do not show the data for electric trains, as Europe would have a different mix of power sources from New Zealand, and the emissions would therefore not be comparable to New Zealand. In the UK, most freight trains would be diesel.

United Kingdom	freight train (generic)	25.6 g CO_2-e/tonne-km (BEIS, 2020a)
Netherlands	diesel, short-length train (935 tonnes), medium bulk freight	23 g CO_2-e/tonne-km (CE Delft, Table 12)
	diesel, medium-length train (1403 tonnes), medium bulk freight	18 g CO_2-e/tonne-km (CE Delft, Table 12)
	diesel, long-length train (1870 tonnes), medium bulk freight	15 g CO_2-e/tonne-km (CE Delft, Table 12)
	diesel, short-length train (935 tonnes), medium weight containers	36 g CO_2-e/tonne-km (CE Delft, Table 15)
	diesel, medium-length train (1403 tonnes), medium weight containers	27 g CO_2-e/tonne-km (CE Delft, Table 15)
	diesel, long-length train (1870 tonnes), medium weight containers	23 g CO_2-e/tonne-km (CE Delft, Table 15)
France	diesel, 1000 tonne train, goods <249 kg/cubic meter	28.7 g CO_2-e/tonne-km)[7]
	diesel, 1000 tonne train, goods 250-399 kg/cubic meter	22.3 g CO_2-e/tonne-km
	diesel, 1000 tonne train, goods >400 kg/cubic meter	19.2 g CO_2-e/tonne-km
Sweden	diesel freight train, tank-to-wheels, EU	21 g CO_2-e/tonne-km (NTM, 2018)
	Diesel freight train, tank-to-wheels, global	20 g $C0_2$-e/tonne-km (NTM, 2018)

Table 4 – Comparison of overseas estimates of emission factors for rail freight

These figures are, in general, a bit lower than the Kiwirail figures. This is what one would expect given New Zealand's more difficult topography and New Zealand's more lightly-constructed rail infrastructure, which would tend to have more curves and grades and, in some cases, lower axle loadings, than would be typical of Europe, even for similar terrain. The Kiwirail figures look reasonable in comparison to the overseas data.

Truck

New Zealand-Specific Data

Based on the New Zealand Ministry of Transport's Vehicle Fleet Emission Model (VFEM) (MoT, 2019b), emissions in calendar year 2017 (the latest year for which historical data on both emissions and tonne-kms are available[8]) for heavy trucks (>10,000 kg gross vehicle mass, as per MoT, 2019c, Table 1) were 3.115 billion kg CO_2-e, while emissions for 'medium trucks' (>3500 kg gross vehicle mass, as per MoT, 2019c, Table 1) were 0.463 billion kg CO_2-e, for total medium and heavy truck emissions of 3.578 billion kg CO_2-e. Based on estimates developed from truck road user charge (RUC) returns and the NZTA's truck weigh-in-motion statistics (MoT, 2019a, Tab 11.1,11.2), net tonne-kilometres in the same year were 24,887 million. Dividing the two gives 144 g CO_2-e / tonne-KM.

[7] All figures in this table for France are from MEDDE, 2019, Table 10, adjusted to a tank-to-wheels basis for non-road diesel fuel using the fuel emission factors in Table 8, which indicated a multiplication by a factor of 0.793.

[8] Updates to VFEM are currently under development, but results were not available at the time of this writing.

These figures for New Zealand should be reasonably credible. The VFEM historical year results have been carefully calibrated to give a total road fuel use which matches MBIE's road fuel sales figures. Each vehicle type is assigned a fuel use factor, which allowed VFEM to break out fuel use and emissions by vehicle type.

There is, however, an additional consideration when we wish to use these emission statistics to estimate the emissions savings that might be achieved by shifting freight between modes. The truck figures include a significant amount of freight that could not feasibly be diverted to coastal shipping or rail because of its small shipment size, short distance, or specialised equipment requirements. Much of this non-divertible freight moves in medium-size trucks. The freight for which road, coastal shipping, and rail compete would tend to move in large-size trucks, which would have lower than average emissions per tonne-km.

To address this data gap, the Ministry of Transport contracted with EROAD to provide anonymised data on fuel use for a sample of 10,000 trucks in New Zealand by road user charge (RUC) type. EROAD is a company that has devices installed in many trucks to help operators monitor their performance and automate the calculation of road user charges (EROAD, 2021). RUC type 2 trucks are generally straight trucks with only two axles, which would typically be used in local pickup and delivery service. They would not generally carry freight that could be moved by coastal shipping or rail. RUC types 6, 14, and 19 are generally tractor-trailer 'big rigs', having three or more axles, which would typically be used for linehaul operations. These are the trucks that might carry freight that could be diverted to coastal shipping or rail.

Based on the EROAD sample data, the authors were able to obtain estimates of mean and median fuel use per vehicle-kilometre by RUC type, which may be multiplied by an emission factor for the fuel[9] to give average emissions per vehicle-kilometre. Although EROAD was not able to provide data on tonne-kilometres or actual loadings, estimates of average payloads by RUC type can be obtained from Waka Kotahi/NZTA weigh-in-motion (WIM) data. The data are collected by roadside detectors which record the weight and RUC type of passing trucks. By subtracting this total weight from the average tare weight for the RUC type, which may be calculated from data in the Motor Vehicle Register, an estimate of the average payload for each RUC type may be obtained. Dividing mean or median emissions per vehicle-kilometre from the EROAD sample by average tonnes of payload per vehicle from the WIM data give an estimate of emissions per tonne-kilometre by RUC type. The results are shown in Table 5 below.

Survey Year	Urban Delivery (RUC Type 2)		Linehaul (RUC Types 6,14,19)	
	Mean	Median	Mean	Median
2015	384	342	108	106
2016	420	376	110	107
2017	434	391	111	108
2018	439	396	110	107

Table 5 – Emissions per Tonne-Kilometre by RUC Type (g CO_2-e / tonne-km) (Wang, 2019)[10]

Table 5 presents both mean and median emissions per tonne-kilometre. We present both because good arguments can be made for using either one. On the one hand, if the truck sample had encompassed the entire fleet, then multiplying the tonne-kilometres for each shipment by the mean emissions per tonne-kilometre and summing across all shipments would give total emissions, which is what we would expect. This argues for measuring modal emissions using mean values. On the other hand, the mean value is more prone to sampling errors than the median should there be a few trucks having exceptionally high emissions. As the EROAD truck sample was limited in size, this argues for measuring emissions for this sample using median values. In any case, the

[9] 2.694 kg CO_2-e/litre of transport diesel from MfE 2020b

[10] Figures in Wang 2019, slide 17, were in g CO_2 /tonne-km; they have been converted here to g CO_2-e / tonne-km by multiplying all figures by 1.0173. This is equal to 2.694 kg CO2-e per litre for transport diesel / originally-used 2.6482 CO_2 per litre for transport diesel.

differences between mean and median for linehaul trucks, which are the focus here, are small.

The results in Table 5 suggest that emissions for linehaul trucks in New Zealand, which would be the ones most likely to carry freight competitive with coastal shipping and rail, would be around 108 g CO_2-e/tonne-km. Splitting the difference between mean and median for urban delivery trucks would suggest emissions around 400 g CO_2-e/tonne-km.

United Kingdom	all diesel HGVs > 3.5 tonnes, average laden	106.5 g CO_2-e/tonne-km (BEIS, 2020a)
	All rigid > 3.5 tonnes, average laden	212.8 g CO_2-e/tonne-km (BEIS, 2020a)
	All articulated > 3.5 tonnes, average laden	79.4 g CO_2-e/tonne-km (BEIS, 2020a)
Netherlands	truck, <10 tonne, medium bulk freight (3 tonne load capacity)	336 g CO_2-e/tonne-km (CE Delft, Table 6)
	truck, 10-20 tonne, medium bulk freight (7.5 tonne capacity)	201 g CO_2-e/tonne-km (CE Delft, Table 6)
	tractor semi-trailer, light (15.7 tonne load capacity), medium bulk freight	134 g CO_2-e/tonne-km (CE Delft, Table 6)
	tractor semi-trailer, heavy (29.2 tonne load) capacity), medium bulk freight	64 g CO_2-e/tonne-km (CE Delft, Table 6)
France	straight truck with a gross vehicle weight of 7.5 tonnes, miscellaneous goods	613 g CO_2-e/tonne-km[11]
	straight truck with a gross vehicle weight of 12 tonnes, miscellaneous goods	334 g CO_2-e/tonne-km
	semi-trailer truck with a gross combination weight of 26 tonnes, large volumes	128 g CO_2-e/tonne-km
	semi-trailer truck with a gross combination weight of 40 tonnes, miscellaneous goods/regional	68 g CO_2-e/tonne-km
Sweden	rigid truck <7.5 tonnes gross weight, operating in EU	177 g CO_2-e/tonne-km[12]
	rigid truck 7.5-12 tonnes gross weight, operating in EU	176 g CO_2-e/tonne-km
	rigid truck 20-26 tonnes gross weight, operating in EU	83 g CO_2-e/tonne-km
	truck with trailer, 34-40 tonnes gross weight, operating in EU	55 g CO_2-e/tonne-km
	Truck with trailer, 50-60 tonnes gross weight, operating in EU	48 g CO_2-e/tonne-km

Table 6 – Comparison of overseas estimates of emission factors for road freight

Overseas Data
Table 6 above shows a selection of data for trucks from our four overseas sources.

[11] All figures in this table for France are from MEDDE, 2019, Table 19, adjusted to a tank-to-wheels basis for pumped road diesel fuel using the fuel emission factors in Table 17, which indicated multiplication by a factor of 0.794.
[12] All figures in this table for Sweden are from NTM, 2108. Only well-to-wheels figures are presented; these were adjusted to a tank-to-wheels basis using the fuel emission factors shown in MEEDE, 2019, Table 17, which indicated multiplication by a factor of 0.794.

While not entirely consistent with each other, the main message presented by the overseas estimates in Table 6 is that road freight emissions per tonne-km can vary widely depending primarily on the size of the truck. Large trucks have considerably lower emissions per tonne-km than smaller trucks.

The New Zealand-specific data for trucks discussed above looks reasonable compared to the overseas data. As discussed further below, truck emissions per tonne-km for New Zealand would appear to be at the high-end of the range of overseas data, although it is difficult to draw any conclusions given the wide dispersion of the overseas data.

Conclusions and Recommendations

The results presented in this paper suggest that estimating emissions per tonne-km for freight is a complex issue, which can depend upon the type of freight being carried (bulk vs. containers, high density vs. low-density), the size of the vehicle used (especially for trucks), the fuel source (especially diesel vs. electric for rail), as well as vehicle load factors and repositioning requirements, among other factors. The overseas data reviewed in this paper can help guide these distinctions. However, for all three modes considered here, New Zealand probably tends to have higher emissions per tonne-km than would be typical of most developed countries due to its small domestic coastal ships, difficult topography for rail and road, and more lightly-constructed rail and road infrastructure.

The results presented here do, however, suggest some typical New Zealand averages that could be used as a starting point for estimating freight emissions by mode. The authors recommend the following assumptions based on the New Zealand-specific discussions in this paper:

road (average) – 144 g CO_2-e/tonne-km

road (straight truck/urban delivery) – 400 g CO_2-e/tonne-km

road (tractor-trailer/linehaul) – 108 g CO_2-e/tonne-km

rail (diesel) – 29 g CO_2-e/tonne-km

rail (electric) – 7 g CO_2-e/tonne-km

rail (average) – 28 g CO_2-e/tonne-km

coastal shipping (container freight) – 20 g CO_2-e/tonne-km

coastal shipping (oil products) – 15 g CO_2-e/tonne-km

coastal shipping (other bulk) - 29 g CO_2-e/tonne-km.

The results do confirm that rail and coastal shipping have significantly lower average emissions per tonne-km than road freight. The low emissions of electric rail freight especially stands out.

Regarding directions for future research, our top priority suggestion would be to collect better primary data on emissions in freight transport. This is especially true for coastal shipping, where there is essentially no New Zealand data available on fuel use and very limited data on tonne-kilometres. More regular collection of real-world fuel-use data by type of truck would also improve our understanding of the determinants of road freight emissions. Given better data, it would also be possible to model the emissions involved in handling different types of shipments (commodities, densities, shipment sizes, and distances) by the three modes in New Zealand, as the overseas sources cited here are already doing to a limited degree. Finally, many shipments by rail or coastal shipping require a truck movement from the actual origin to the rail terminal or port, and/or from the rail terminal or port to the actual destination. Some consideration should probably be given to the emissions impact of these 'last mile' truck movements on the overall emission factors for rail and coastal shipping.

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Samuelson – Gathered and compiled the overseas data, Kiwirail data, and New Zealand ship data; wrote initial draft of paper.

Wang – Gathered and compiled New Zealand-specific truck data, including WIM data on average loadings and EROAD data on truck fuel use; contributed edits and revisions to the text.

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