Chapter 4

Transport Sector

January 2021

This chapter should be cited as

Study team (2021), 'Transport Sector', in Mongolian Energy Institute and ERIA (eds.), *Mongolia's Energy Efficiency Indicators 2019.* ERIA Research Project Report FY2020 no. 17, Jakarta: ERIA, pp.30-44.

Chapter 4

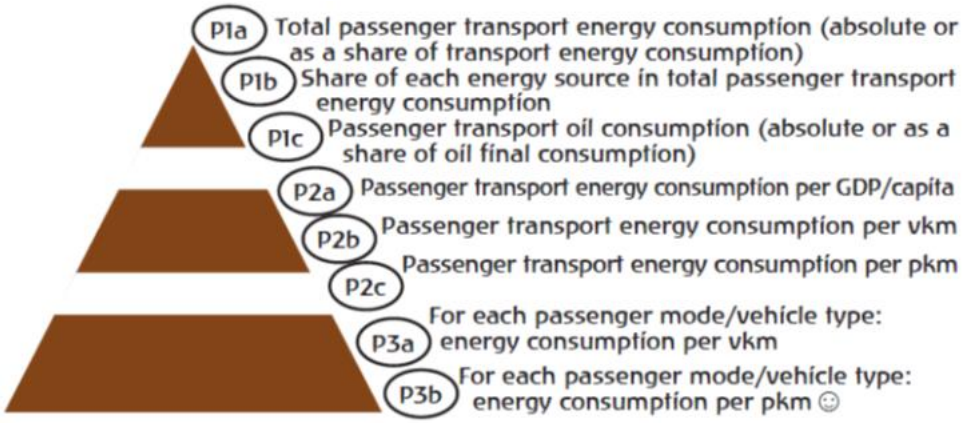
Transport Sector

1. Energy Efficiency Indicators in the Transport Sector

Like other sectors, energy efficiency indicators (EEIs) in transport are in principle results of dividing energy consumption by the sector's activity. Based on type of activity, the transport sector is broken down into freight and passenger transport (Figure 4-1 and Figure 4-2).

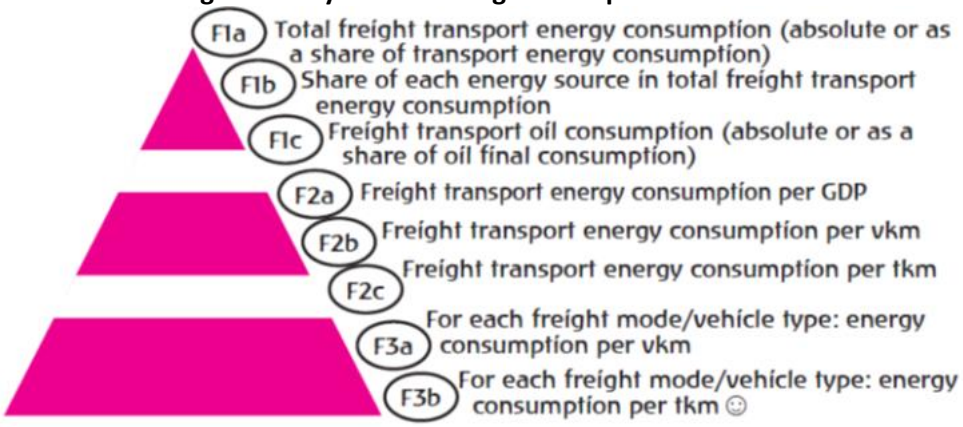
For each activity type, we estimate the indicators in a bottom-up manner. Based on the survey results, we estimate the EEIs starting from the vehicle type. For example, in passenger road transport, we start estimating the indicators for road vehicles with sedans, buses, and taxis whilst for freight road, we start with trucks.

Figure 4-1 Pyramid of Passenger Transport Indicators



Source: IEA (2014b).

Figure 4-2 Pyramid of Freight Transport Indicators



Source: IEA (2014b).

For passenger transport, EEIs are calculated in gigajoules/passenger-km (GJ/pass-km). For freight transport, the indicators are given in gigajoules/ton-km (GJ/ton-km). For both passenger and freight transport, calculation results of EEIs are in terms of GJ/vehicle-km.

Multiplying the estimated EEIs with transport demand in terms of vehicle-km, passenger-km (for passengers), and ton-km (for freight), we can move up to the higher level of the pyramid to calculate the total energy consumption of the transport sector, i.e. in totality as well as by modes.

Finally, we also calculate transport efficiency or intensity that relates energy consumption with the economy of the country. For passenger transport, the indicator is energy consumption per GDP/capita whilst that for freight, it is energy consumption per GDP.

2. Effective Sampling Survey

The research team collected 203 questionnaires on the road and transport sector from 871,350 registered vehicles, 138 locomotives, 34 aircraft, and 60 ships using random sampling. In July 2019, the joint working group, which included experts from ERIA, decided to exclude ship research, so the remaining 200 sampling surveys were considered useful.

3. Transport Sector Characteristics

The transport sector is one of the most important sectors for the economy of Mongolia, considering the country's relatively sparsely settled populations and wide steppes. Mongolia has 3,423 business entities and organisations operating in four main modes, which is land (road, rail), air, and water (shipping) transport, 48.7% of which are operating regularly.

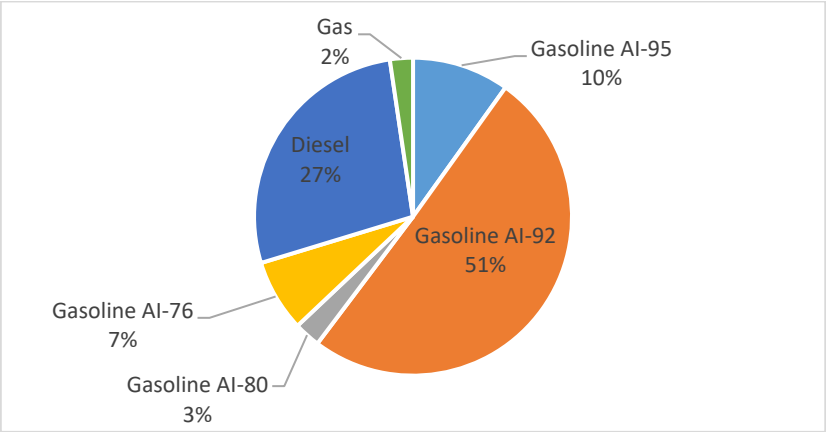
3.1. Road transport mode statistics

Road transport in Mongolia consists of sedans, taxis, trucks, buses, and special purpose vehicles. In 2018, the total number of registered road vehicles was 871.3 thousand, an increase of 56.3 thousand or 6.9% from 2017.

Of those registered in Mongolia, 53.2% are right-hand drive vehicles (i.e. the steering wheel is on the right side) and 46.8% are left-hand driven. Road vehicles aged 10+ years comprise 75.9%; those aged 7–9 years, 14.03%; those aged 4–6 years, 6.3%; and those aged 0–3 years, 3.74%. In terms of engine capacity, 32.77% have up to 1,500 cm^3; 38.04% have 1,501–2,500 cm^3; 14.16% have 2,501–3,500 cm^3; 4,18% have 3,501–4,500 cm^3; and 10.85% have 4,501 cm^3 and above.

Road transport vehicles run on the following types of fuel: 31.86%, on AI-92 gasoline; 9.89%, on AI-95; 2.67%, onAI-80; 7,34%, on A-76; 27.36%, on diesel fuel; 2.34%, on gas; and 0.02%, on electricity.

Figure 4-3. Share of Fuel Type Used by Road Vehicles (%)



Source: MEEI.

Of the total registered road vehicles in Mongolia, 67.2% passed through governmental technical inspection in 2018. Cars that did not pass through governmental technical inspection were not excluded from the state registration database.

Table 4-1 shows the total number of registered and those that passed through governmental technical inspection vehicles in provinces, in the capital, and in regions. Ulaanbaatar has the highest number of road vehicles; it comprises more than 57% of the total registered road vehicles in Mongolia and around 68% road vehicles that passed through technical inspection. Amongst the road vehicles that passed through technical inspection in Ulaanbaatar in 2018, 72.8% or 309.8 thousand are passenger cars (sedans); 57.2% or 75.3 thousand are trucks; 55.5% or 10.3 thousand are buses; and 69.4% or 6.4 thousand are special purpose vehicles.

Table 4-1. Total Number of Registered Road Vehicles and Those that Passed through Governmental Technical Inspection (2018)

Provinces/Capital	Registered	Passed through Governmental Technical Inspection
Western region	**75,935**	**44,988**
Bayan-Ulgii	17,501	17,941
Gobi-Altai	12,557	4,545
Zavkhan	14,424	5,037
Uvs	13,958	9,452
Khovd	17,495	8,013
Khangai region	**122,062**	**54,783**
Arkhangai	14,717	6,135
Bayankhongor	19,969	4,986
Bulgan	12,743	7,896
Orkhon	25,994	19,226
Uvurkhangai	23,917	5,346
Khuvsgul	24,722	11,194
Central region	**129,450**	**67,905**
Gobisumber	3,557	2,311
Darkhan-Uul	24,133	8,941
Dornogobi	19,554	11,909
Dundgobi	10,829	2,818
Umnugobi	28,521	22,700
Selenge	25,038	11,219
Central region	17,818	8,007
Eastern region	**41,969**	**15,962**
Dornod	15,565	6,121
Sukhbaatar	12,052	6,083
Khentii	14,352	3,758
Ulaanbaatar	**501,934**	**401,725**
Total	**871,350**	**585,363**

Source: National Statistics Office of Mongolia (2018a).

Table 4-2. Types of Vehicles that Passed through Technical Inspection (2018)

Types	2016	2017	2018
Bus	18,912	18,550	18,570
Truck	111,431	120,751	131,573
Car	360,513	388,448	426,065
Special	8,296	8,650	9,155
Total	**499 152**	**536 399**	**585,363**

Source: National Statistics Office of Mongolia (2018a).

According to the National Statistics Office of Mongolia (2018b), in 2018, there were around 196.6 million passengers, and passenger turnover was 2.125 billion passengers- km. The number of passengers from 2017 decreased by 15.3 million or 7.3% whilst turnover increased by 84.8 million passengers-km or 4.2%.

Total cargo transported in 2018 was 441,389,000 tons, which increased by 12,926,000 tons or 41.4% from 2017. Cargo turnover reached 6.8 billion tons-km in 2018, which increased by 1.083 billion tons-km or 19% from the previous year.

3.2 Statistics on railway sector

In 2018, the total railway length nationwide was 1,920 km, which means a density of 1.22 km/km^2. In 2018, government and private companies provided freight and passenger services with 138 locomotives; 3,571 freight wagons; and 608 passenger wagons.

According to the National Statistics Office of Mongolia (2018a), in 2018, railway transport carried 2.6 million passengers, which decreased by 578,000 persons or 2.2% from 2017. Of the total number, 2.5 million people or 95.4% travelled domestically and 1,182,000 or 4.6% travelled abroad. The number of international passengers increased by 0.6% over the previous year, and local passengers decreased by 0.6%. Railway turnover reached 993.7 million passengers-km in 2018, which increased by 20.5 million passengers-km or 2.11% from 2017.

The same statistics source shows that 25.763 million tons of freight were transported by railway, which increased by 3.0 million tons or 13.2% from the previous year. International freight transport by railway was 59.9% and locally transported freight was 40.1%. From the total number of freights transported internationally by railway, exports comprised 60.1% or 9.3 million tons; imports comprised 18.1% or 2.8 million tons; and transit transport comprised 21.8% or 3.4 million tons. The freight turnover of railway reached 15.3 billion tons-km, which increased by 1.8 billion tons-km or 13.5% from 2017. From these, 2.9 billion tons-km or 18.7% are local, 7.3 billion tons-km or 47.7% are exports, 1.4 billion tons-km or 9.2% are imports, 3.7 billion tons-km or 24.4% are transit freight.

3.3 Aircraft statistics

The number of aircraft registered in Mongolia is 34. In 2018, the number of certified aircraft was 18, with a total of 8 large aircraft, 6 medium-sized aircraft, and 4 small aircraft.

The National Statistics Office of Mongolia (2018a) shows that the aircraft sector transported a total of 1.4 million passengers in 2018: an increase of 1.707 million people or 13.6% over the previous year.

The number of passengers by domestic flight reached 4.016 million people, increased by 7.657 million passengers or 23.5% compared to 2017. International flights were taken by 1.02 million people, an increase of 9.415 million people or 10.16% over the previous year.

Table 4-3. Main Indicators of Auto Transport

Indicator	2015	2016	2017	2018
Auto transport				
Number of passengers, million	256.5	260.7	212.2	196.9
Turnover of passengers, million passengers-km	1,940.5	1,959.9	2,040.9	2,125.7
Transported freight, million tons	13,043.7	20,406.2	31,212.9	44,138.9
Freight turnover, million tons-km	2,374	4,236.2	5,661.3	6,744.9
Transport revenue, billions ₮	345.1	467.2	506.4	627.83
Railway transport				
Number of passengers, million	2.79	2.64	2.63	2.57
Turnover of passengers, million passengers-kilometres	996.7	955.5	973.2	993.7
Transported freight, million tons	19,150.8	19,989.1	22,765	25,763.3
Freight turnover, million tons-kilometres	11,462.6	12,371	13,493.3	15,315.3
Transport revenue, billions ₮	387.9	441.8	530	616.48
Air transport [a]				
Number of passengers, million	0.9	1	1.2	1.42
Turnover of passengers, million passengers-kilometres	1,123.3	1,156.5	1,363.2	1,573.5
Transported freight, million tons	4.7	4.8	5.3	5.7
Freight turnover, million tons-kilometres	7.7	8.1	7.8	7.8
Transport revenue, billions of MNT	254.3	287.3	385.5	442.2

₮ = Mongolian currency *tugrik.*

[a] Information from Civil Aviation Authority of Mongolia.

Source: Ministry of Road and Transport Development (2018).

4. Calculation of Fuel Consumption and Efficiency Indicators

4.1 Road modes

For road freight and road passenger modes, fuel consumption is calculated using the following equation:

$$FC_{veh} = FCF_{veh}.DEM_{veh}.EC_{fuel}.10^4 \quad \text{(i)}$$

Where

FC_{veh} = fuel consumption (megajoule or MJ)

FCF_{veh} = fuel consumption factor (litre/ 100 km)

DEM_{veh} = transport demand (millions of vehicles-km)

EC_{fuel} = energy content (MJ/litre)

veh are all vehicle types included in the survey, i.e. passenger road vehicles (cars or sedans, buses, taxis) and freight road vehicles (trucks).

Table 4-4. Fuel Types in Relation to Road Vehicle Types

Fuel Type	Vehicle Type
Gasoline	Cars (sedans), taxi
Diesel	Buses, trucks, rail passenger, rail freight

Source: Authors' elaboration.

Table 4-5. Energy Content of Each Fuel Type

Fuel Type	Energy Content (MJ/litre)
Gasoline	35.2
Diesel	37.3

Source: Authors' elaboration.

The fuel consumption factor (FCF_{veh}) is calculated based on the vehicle survey results of the Mongolian Energy Economics Institute (MEEI) (Table 4-6).

The average technical norm consumption of gasoline of cars (sedans) is 10.3 litres/ 100 km whilst that of buses is 35.4 litres/100 km. For trucks, the sample survey was taken from 70 trucks, of heavy-carrying capacity diesel engines, from Nord Benz, Howo and Beiben of China, which are widely used in Mongolia. Trucks included in the survey have an average technical norm consumption of 62.1 litres/100 km, and aged 0–15 years.

Table 4-6. Calculated Average Fuel Economies (Fuel Consumption Factors)

Mode		Vehicle Type	Fuel Consumption Factor (litres/100 km)
Road passenger		Cars	10.3
		Buses	35.4
		Taxis	8.0
Road freight		Trucks	62.1

Source: Authors' calculation.

Road transport demand (DEM_{veh}) in millions of vehicles-km is calculated by the following equation.

$DEM_{veh} = NB_{veh}.DIST_{veh}.UR_{veh}.10^{-6}$ (ii)

NB_{veh} = number of vehicles which is taken from data (Table 4-2)

$DIST_{veh}$ = average yearly distance (km/vehicle)

UR_{veh} = average fleet utilisation rate

The survey conducted by the MEEI gives some information on the average annual distance travelled by each vehicle type ($DIST_{veh}$) (Table 4-7). A study conducted by Batjargal and Matsumoto (2017) also provide information on the average annual distance of some vehicle types in Mongolia. Each information shows some differences.

For passenger cars, the MEEI survey shows an average mileage of nearly 23,700 km/year whilst Batjargal and Matsumoto's (2017) value is 12,000 km. The latter value was selected as the study focused on road emission in Ulaanbaatar and should give more precise estimate of the annual distance (in kilometres) than the MEEI survey.

Table 4-7. Average Trip Distance of Vehicles based on MEEI Survey

Vehicle Type	Assumed Fuel	Average Distance of Trip (km/vehicle)		
		Per day	Per month	Per year
Cars (sedans)	Gasoline	49	1,974	23,690
Buses	diesel	241	5,712	68,545
Taxis	Gasoline	234	7,450	89,400
Trucks	diesel	292	3,288	39,458

Source: Authors' calculation.

Furthermore Amarsaikhan (2016) stated that around 60% of all motor vehicles were registered in Ulaanbaatar, which confirmed statistics shown in the section 0.

For taxis, the values of both sources do not differ much. For the same reason as for passenger cars, the value of Batjargal and Matsumoto (2017), i.e. 73,000 km, was selected.

The two resources show different values for trucks' yearly distance travelled. Calculating transport demand and using Batjargal and Matsumoto's (2017) value of 12,000 km and comparing it to the transport demand data – i.e. 6.775 billion tons-km (section 0) – would give an average carried load of 10.7 tons per truck. MEEI survey results would give an average carried load of 1.8 tons per truck, which is relatively too low. Herewith, 12,000 km was selected as the average yearly distance travelled (in kilometres) of trucks.

For buses, the values from both sources differ quite a lot: 39,458 km per MEEI survey and 6,000–12,000 km per Batjargal and Matsumoto (2017). An old study from JICA (1994) mentioned that in the early 1990s, buses' average mileage in Mongolia was around 317 km/day or around 116,000 km/year. Using that information, the value of MEEI results, i.e. 86,546 km, was chosen.

Table 4-8. Annual Average Mileage for Road Vehicles

Vehicle Type	Annual Distance per Vehicle (km)		
	MEEI survey (2019)	Batjargal and Matsumoto (2017)	Selected value
Cars	23,690	12,000	12,000
Taxis	89,400	73,000	73,000
Trucks	39,458	6,000–12,000	12,000
Buses	68,546	6,000–15,900	68,546

Source: Authors' elaboration.

The average utilisation rate (UR_{veh}) is the ratio of vehicles in active operation to the total number of vehicles in the fleet. There is no data on Mongolian utilisation rates of road transport modes. Even if this aspect is understudied in Asia, this study tried to look for some available references to be used as inputs for Mongolia.

The World Bank (2005) estimated that between 2000 and 2003, the utilisation rates of buses in Chennai, India are 78%–81% whilst for Bangalore the rates are 95%–96%. Karali et al. (2019) concluded that in India, the utilisation rates of buses nationwide are about 90% for the last decade whilst for trucks, the rates are much lower, 55%– 70%.

For passenger road modes, we assume that utilisation rates in Mongolia are significantly lower than those of India. Departing from that assumption, we used the total road passenger transport turnover of 2,126 passengers-km (see section 0) as the benchmark to calculate a reasonable road passenger transport demand (DEM_{veh}) in millions of vehicles-km and found the following utilisation rates reported in Table 4-9.

Table 4-9. Assumed Road Vehicle Fleet Utilisation Rates

Vehicle Type	Fleet Utilisation Rate
Cars	0.1
Buses	0.3
Taxis	0.3
Trucks	0.4

Source: Authors' elaboration.

Finally, the total energy efficiency for road passenger modes (road pass) in terms of MJ/passenger-km is calculated as follows:

$$EE_{roadpass} = (FC_{sedans} + FC_{buses} + FC_{taxis}).10^{-6}/TO_{roadpass} \quad \text{(iii)}$$

Where $TO_{roadpass}$ is road passenger transport turn-over (million passengers-km) from section 0 .

For trucks, the calculation is as follows:

$$EE_{roadfreight} = (FC_{trucks}).10^{-6}/TO_{roadpass} \quad \text{(iv)}$$

4.4.2 Rail modes

For road freight and road passenger modes, fuel consumption is calculated using the following equation:

$$FC_{veh} = FCF_{veh}.DEM_{veh}.EC_{fuel}.10^{-2} \text{ (v)}$$

Where

FC_{veh} = fuel consumption (megajoule or MJ)

FCF_{veh} = fuel consumption factor (litre per 100 km)

DEM_{veh} = transport demand (vehicles-km)

EC_{fuel} = energy content (MJ/litre) of diesel fuel, i.e. 37.3

veh or vehicle in rail transport in this study is in fact the sets of trains consisting of locomotive and their tracked wagons. *veh* consists of two modes, i.e. rail freight and rail passenger.

Transport demand DEM_{veh} is calculated by multiplying the number of vehicles, the average yearly kilometre, and the fuel consumption.

$$DEM_{veh} = NB_{veh}.(\frac{RAILCAR_{veh}}{\sum_{veh} RAILCAR_{veh}})DIST_{veh}.UR_{veh} \qquad \text{(vi)}$$

Where

$RAILCAR_{veh}$ = the number of railcars for each used, i.e. freight and passenger.

Table 4-10. Results of Vehicles Survey (Average Value)

Vehicle Type	Assumed Fuel	Norm l/100 km	Distance of Trip/Km		
			Per day	Per month	Per year
Railway locomotives	diesel	2,125	336	3,583	42,990

Source: MEEI.

We assume a value of 0.9 as the utilisation rate of both rail freight and rail passenger modes.

EEIs are calculated the same way as in the road modes (section 0).

4.3 Air passenger modes

For air passenger mode, fuel consumption is calculated using the following equation:

$FC_{veh} = FCF_{veh}.DEM_{veh}.EC_{fuel}.10^4$ (vii)

Where

FC_{veh} = fuel consumption (megajoule or MJ)

FCF_{veh} = fuel consumption factor (kg per vehicle-km)

DEM_{veh} = transport demand (millions of vehicles-km)

EC_{fuel} = energy content which is assumed to be 43 MJ/kg jet fuel.

Passenger air transport demand (DEM_{veh}) in vehicles-km is calculated in the same way as in the road modes, i.e. multiplying the number of aircraft with the average annual distance (kilometres per aircraft) and the assumed utilisation rate of the fleet (assumed to be 0.95).

The fuel consumption factor (FCF_{veh}) in terms of kilogram of fuel per vehicle-km is calculated as the fuel consumption weighted average of the aircraft types included in the survey performed by the MEEI. However, as we used external sources of information on aircraft fuel consumption and cruising speed, i.e. Purwanto et al. (2017), the MEEI results show some inconsistencies.

Table 4-11. Average Aircraft Fuel Consumption Factors

Type of Aircrafts Surveyed	Average Fuel Consumption (kg/hour)	Average Cruising Speed (km/h)
B737	3,340	605
B767	6,449	639
B767	6,449	639
B737	3,340	605
F-50	1,011	321
10-360L2A	916	271
ERJ-145	2,360	444
B767-300	6,449	639
Forcer-50	1,011	321
B767-300	6,449	639
B767-300	6,449	639

Source: Purwanto et al. (2017).

5. Calculation Results

5.1 Energy efficiency

Table 4-12 to Table 4-16 show the results of transport sector EEIs. For passenger transport, the EEIs are calculated in gigajoules/passenger-km (GJ/pass-km); for freight transport, the indicators are given in gigajoules/ton-km (GJ/ton-km).

For both passenger and freight transport, the calculation results of EEIs in terms of GJ/vehicle-km are given (Table 4-12).

Table 4-12. Calculation Results of Road Passenger Mode

Vehicle Type	Number of Vehicles	Average yearly (km)	Average Fuel Consumption Factors (litre/100 km)	Assumed Utilisation Rate	Transport Volume (million vehicles-km)	Assumed Fuel Type	Assumed Energy Content (MJ/litre)	Fuel Consumption (GJ)	Road Passenger Turnover (million passengers-km)	Energy Efficiency (GJ/passengers-km) indicators (GJ/pass-km)	Energy Efficiency Indicators (GJ/vehicle-km) (GJ/veh-km)
Sedans	426,065	12,000	10.3	0.1	511.278	gasoline	35.2	1,852,875			0.0036
Buses	18,570	16,000	35.4	0.3	89.136	diesel	37.3	1,177,720			0.0132
Taxis	800	73,000	8.0	0.3	17.52	gasoline	35.2	49,585			0.0028
Road Passenger					617.934			3,080,180	2,125.70	0.0014	0.0050

Source: Authors' calculation.

Table 4-13. Calculation Results of Roadc Freight Mode (Trucks)

Vehicle Type	No. of Vehicles	Average Yearly Distance (km)	Average Fuel Consumption (litre/100 km)	Assumed Utilisation Rate		Transport Volume (vehicles-km)	Assumed Fuel	Assumed Energy Content (MJ/litre)	Fuel Consumption (GJ)	Freight Turnover (million tons-km)	Energy Efficiency Indicators (GJ/ton-km)	Energy Efficiency Indicators (GJ/vehicle-km)
Trucks	13,1573	12,000	12.0	0.4		631,550,400	diesel	37.3	14,625,887	6,744.9	0.0021	0.0231

Source: Authors' calculation.

Table 4-14. Calculation Results of Rail Passenger Mode

Vehicle Type	Total no. of Locomotives	No. of Passenger Wagons	Average Annual Distance (km)	Utilisation rate	Average Fuel Consumption Factor (litre/100 km)	Transport Volume (locomotives-km)	Assumed Fuel	Assumed Energy Content (MJ/litre)	Fuel Consumption (GJ)	Passenger Turnover (million passengers-km)	Energy Efficiency Indicators (GJ/passengers-km)
Locomotives	138	608	42,990	0.9	2,215	776,820	diesel	37.3	641,775	993.70	0.00065

Source: Authors' calculation.

Table 4-15. Calculation Results of Rail Freight Mode

Vehicle Type	Total no. of Locomotives	No. of Freight Wagons	Average Annual Distance (km)	Utilisation Rate	Average Fuel Consumption Factor (litre/100 km)	Transport Volume (Locomotives-km)	Assumed Fuel	Assumed Energy Content (MJ/litre)	Fuel Consumption (GJ)	Freight Turnover (million tons-km)	Energy Efficiency Indicators (GJ/tons-km)
Locomotives	138	3,571	42,990	0.9	2,215	4,562,538	diesel	37.3	3,769,374	15,315.30	0.00025

Source: Authors' calculation.

Table 4-16. Calculation Results of Air Passenger Mode

Vehicle Type	No. of Vehicles	Average Annual Distance (km)	Average Fuel Consumption Factor (kg fuel/vehicle hour)		Assumed Utilisation Rate (kg fuel/vehicle-km)	Transport Volume (vehicles-km)	Assumed Fuel	Assumed Energy Content (MJ/kg fuel)	Fuel Consumption (MJ)	Fuel Consumption (GJ)	Passenger Turnover (million passengers-km)	Energy Efficiency Indicators (GJ/passengers-km)
Air passenger	18	510,327.27	5,022	8.16	0.95	8,726,596	jet fuel	43	3,062,454,294	3,062,454	1,573.50	0.0019

Source: Authors' calculation.

Table 4-17 compares the results of the international study on energy efficiency in the transport sector.

Table 4-17. Comparison of Energy Efficiency of the Transport Sector

Research	Road Passenger MJ/pkm	Road Freight MJ/tkm	Air Passenger MJ/pkm	Rail Passenger MJ/pkm	Rail Freight MJ/tkm	Car MJ/vkm	Bus MJ/vkm	Taxi MJ/vkm
Mongolia - 2018	**1.44**	**2.17**	**1.95**	**0.65**	**0.25**	**3.62**	**13.21**	**2.83**
IEA - Japan - 2005		7		0.2	0.12			
IEA - Japan - 2015		5		0.18	0.1			
IEA - Korea - 2005		4.1		0.3	0.6			
IEA - Korea - 2015		3.2		0.2	0.05			
PWC - Europe - 2005	1.45			0.46				
ECF EU28 - 2015			2	0.3		3	17	
IEA/ESTSAP 2010 - China				0.2	0.3			
IEA/ESTSAP 2010 - India				0.3	0.2			
Non-OECD Asia 2015				1.3	1.3			
France - 2010						1.87		
IEA			3.1	0.17				

ESTSAP = Energy Technology Systems Analysis Program, IEA = International Energy Agency, OECD = Organisation for Economic Co-operation and Development, PWC = PriceWaterhouse and Coopers.
Source: Various sources (Authors' elaboration).

There is certain comparability of the results of Mongolia's rail transport EEIs that we have calculated to those produced in the studies of Japan, Korea, China, and India. The high values of rail passenger and freight in Mongolia indicate that the development of modern vehicles (locomotives) have not yet penetrated the country and more outdated technology is still in use in Mongolia.

It is not easy, however, to find studies on other modes from other Asian countries. Nevertheless, comparing the transport EEIs of the world, the European region, and some European countries such as France, with the results shown for Mongolia indicates that the methodology we used in this study is in the right direction. Some improvements need to be conducted, however, especially in the quality of survey results and in validating the process of data collection. These improvements should result in more reliable and robust efficiency indicators' values for Mongolia to be compared with those of other countries or regions.

5.2 Total energy consumption

Table 4-18. Estimated Energy Consumption of the Transport Sector (GJ and %)

Transport Mode	Fuel Consumption (GJ)	Share (%)
Road passenger	3,080,180	12.2
Road freight	14,625,887	58.1
Rail passenger	641,775	2.5
Rail freight	3,769,374	15
Air passenger	3,062,454	12.2

Total transport	25,179,671	100

Source: Authors' calculation.

According to the estimation results (Table 4-18), 58% of the total fuel consumption in the transport sector goes to road freight mode, i.e. trucks, and 15% goes to rail freight modes. Air and road passenger modes consume around 12% each, and rail passenger mode consumes around 2.5%.

5.3 Energy intensity: relating energy consumption to the economy

Based on IEA (2014b) using the nominal GDP per capita 2018 data for Mongolia of 4,122 US$/capita and the calculated total energy consumption in passenger transport of 6,784,409 GJ, the passenger transport energy intensity in Mongolia is calculated at 1,646 GJ/US$ per capita. This means that for each US dollar per capita, Mongolia needs to consume energy in terms of its passenger transport activity of around 1,646 GJ or about 39 tonnes of oil equivalent (toe) by.

For freight transport, Brunel (2005) and IEA (2014b) define transport intensity as the ratio between the number of tons-km realised in a country by freight vehicles and the value of the GDP of this country. It represents the number of transport units (ton-km) made by freight vehicles necessary to produce one unit of output, i.e. GDP (US$1.00).

For Mongolia, with the 2018 industry GDP of about US$4,970 and a total freight transport turnover of 22,060 million ton-km, the freight transport intensity is around 0.004 ton-km/US$. This means that in 2018 Mongolia needed 4 kg-km of goods to be transported by freight vehicles to produce US$1.00 of GDP.

As the total freight transport in Mongolia consumed about 18.4 million GJ in 2018, then the freight transport energy intensity of Mongolia was estimated at 3.7 kJ/US$ or around 0.103 litre of diesel fuel/US$. This signifies that, in 2018, Mongolia's freight transport needed to consume around 0.103 litres of diesel fuel to produce US$1.00 of GDP.