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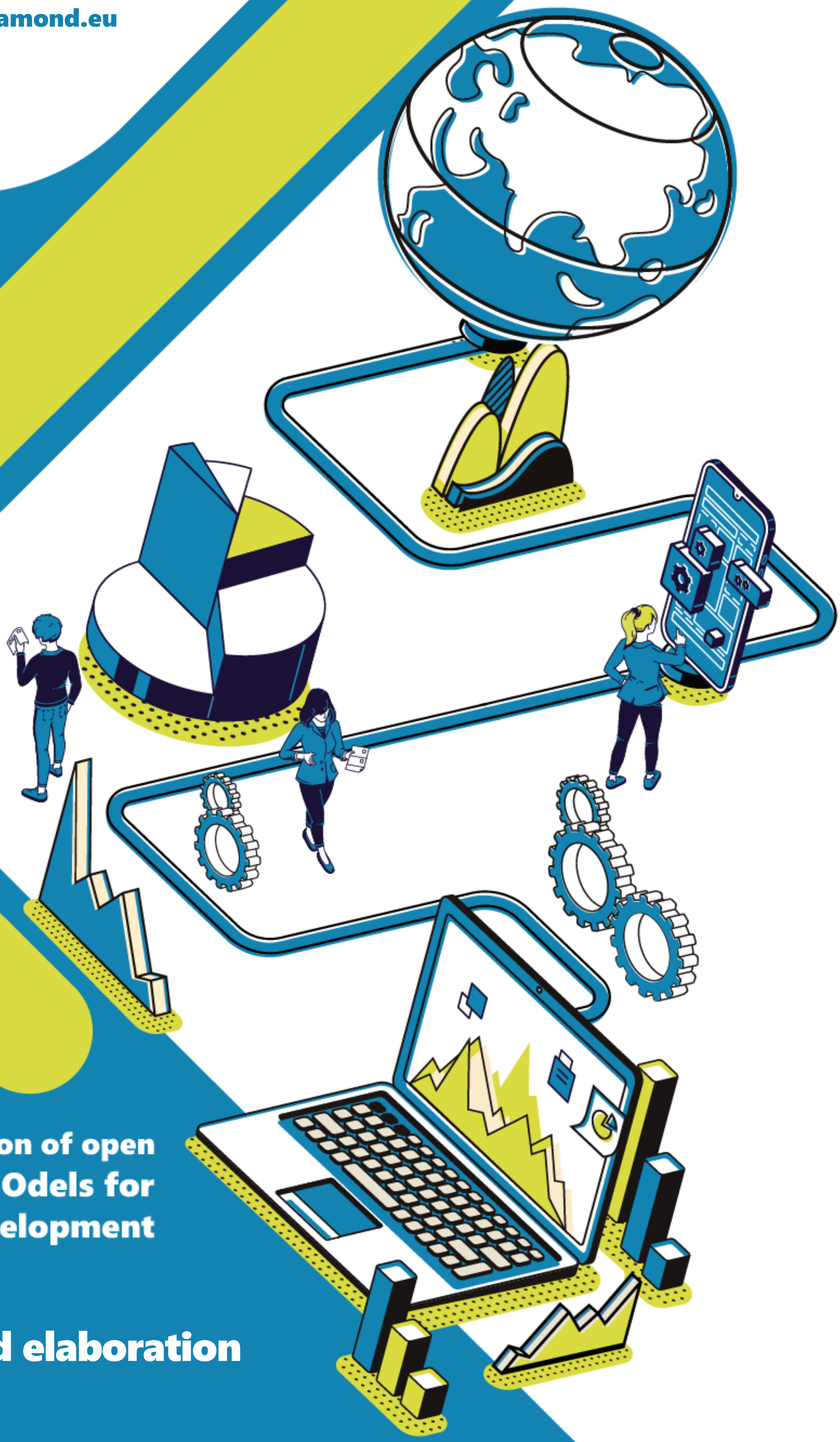

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OMNIA Data input and elaboration

Transport sector

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Short summary

This report outlines the adaptations and improvements made to transition from the transport sector's representation of the TIMES-GEO model, a TIMES global energy consumption model, to the residential sector's representation of the OMNIA model—an enhanced, more detailed, and flexible version. The TIMES-GEO model's input spreadsheet was revised to meet OMNIA's specific requirements. This report details these improvements and explains how they enhance the model's functionality and usability.

Model files Attachment

This report refers to the files with codes and data inputs in the OMNIA Github repository for the transport sector, VT_OMNIA_TRA. Also, in the same repository, in the folder OMNIA_RES_SRV_TRA there are the respective subfolders that include the documentation documents in the structure shown in Figure 0.1*, and the codes and data for the residential and transport sector respectively. This documentation also refers to the input of TIMES_GEO model, an older TIMES model, which can be found in the GitHub repository https://github.com/MaREI-EPMG/TIMES-GEO.*

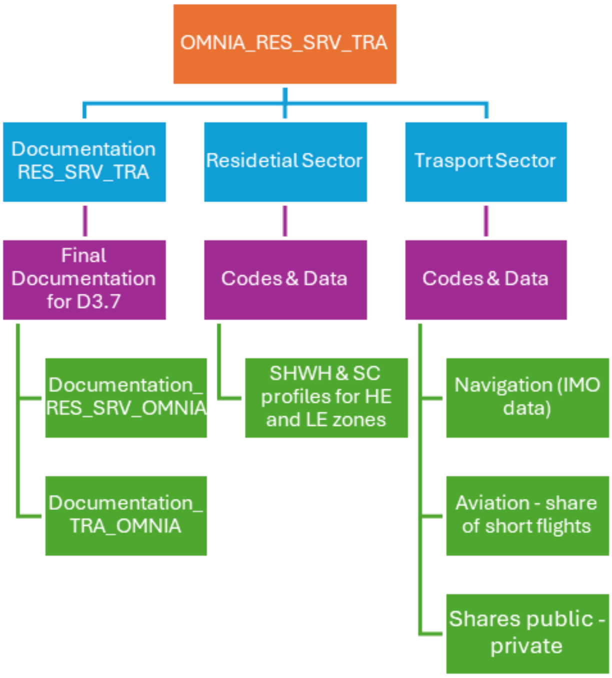

Figure 0.1 Figure illustrate the repository structure that includes the documentation of the OMNIA's transport and residential sector and the data ad codes used to developed the input files.

File name	*Type*	*Description & Location in directory of Figure 0.1*
Shares public-private based on cities.xlsx	*Excel doc*	*Excel file where calculations were done to estimate that share between public and private road transport in African regions. Can be found in OMNIA_RES_SRV_TRA >Transport Sector > Codes & Data > Shares Public transport*
short_flights_domestic_international.py	*Python file*	*Python file used to estimate the share between short and long, domestic and international flights.* *OMNIA_RES_SRV_TRA >Transport Sector > Codes & Data >*

		Aviation- share of short flights
IMO_stats_calculations.xlsx	*Excel doc*	*Excel file where calculations were made to estimate the shares between long, short, passenger – domestic and banker navigation.* *OMNIA_RES_SRV_TRA >Transport Sector > Codes & Data > Navigation (IMO data)*

Contents

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1 Improvements and enhancements of the new design

The key improvements made in the representation of the transport sector of OMNIA versus the TIME-GEO transport sector are as follows:

1) Type of transport vehicle Breakdown by Fuel: The share of energy consumption for different types of vehicles (e.g., cars, buses etc) by fuel type was detailed according to modeler sense/assumptions, the TIMES-GEO workbook of the transport sector (VT_GEO_TRA), and by using of a chart that presents the shares of different transport types for different cities worldwide. (**Section 2.1.1**).

2) Technologies for Aviation and Shipping: 2020 EU Reference scenario data were used to provide the technoeconomic values for technologies for aviation and shipping including future fuels. For the fuels that didn't exist in the database some assumptions were made. **(Section 2.1.2**).

3) Share of long and short and passenger navigation for domestic and banker: Another improvement made is that the navigation is now split in short long trips and passenger trips for both domestic and international navigation. This is because, the use of electric shipping technology is most likely to be used for smaller ships and shorter trips, and domestic passenger trips. Data from the IMO (International Marine Organisation) ('MEPC 76-6-1 - 2019 report of Fuel Oil Consumption Data submitted to the IMO Ship Fuel Oil Consumption Database in GISIS') report for the year 2019 allowed to extract the shares of the global share between long trips with large ships, short trips with small ships, and passenger ships trips which were used together with assumptions, to create the energy consumption shares between different types of shipping globally. **Section 2.1.3**.

4) Short and long flights: The aviation from the Energy balance was split into domestic and international flights. The aviation was further disaggregated into long and short flights for both domestic and international flights to allow the model to choose technologies in a disaggregated way. The aviation is now split in short and long flights for both domestic and international flights. This was done since in the future, there is potential use of different technologies depending if the flight is short or long. For example, long flights are unlikely to be fully battery electric, or hydrogen use, whereas short flight can be as presented in **Section 2.1.5** and the resulted shares are provided in Table 8.

5) High Speed Electric Rail: High speed rail was included in the model, since this sector differentiates significantly in the efficiency. Logical assumptions were made for the rate of electric trains which are high speed, versus total electric powered trains. Then, the technoeconomic values of high speed rail were introduced in the model. (Section 2.1.4.)

2 Data requirements

2.1 Assumptions and input data used

This section presents in detail the improvements and enhancements done in the OMNIA model for the transport sector. **Section 2.1.1** presents some assumptions made for producing the energy share assumptions for road transport in Table 2, **Section 2.1.2** presents the steps for producing the disaggregation shares of the aviation domestic and international flights into long and short flights, Section **2.1.3** presents how the assumptions for the disaggregation of the navigation sector were done, into long, short and passenger trips. Finally, Section 2.1.5 presents how the inputs for the input tables for the technoeconomic values of aviation, navigation and rail were created.

2.1.1 Update of Energy Shares by Road Transport Type for African Regions in OMNIA

Here are presented some of the energy share assumptions by road-mode transport type which can be found in the VT_OMNIA_TRA excel document, in the spreadsheet "Key Inputs 1_BY EB" sheet, in Table 2. The calculations are demonstrated in the Excel file entitled "Shares public-private based on cities", and one can be guided through the respective README file in the same folder.

2.1.1.1 Scope

The goal was to ensure reasonable assumptions for the shares of the public and private transport in road demand, particularly for African regions. These adjustments are important because for the demand projections, the shares between public (buses) and private (cars / motorbikes) road transport, from in the VT_OMNIA_TRA excel document, in the Key Inputs 2_BY Road sheet, in Table 17 were used to project future shifts in future public-private transport demands.

2.1.1.2 Methodology followed

1. **Source data extraction**:

The Figure in page 35 form the report, **Global Monitor 2022** ('Global Monitor 2022 (MobilisedYourCity)') was used which shows road transport modal splits for various cities in multiple regions worldwide. The source image was digitised to extract the data using PlotDigitizer.

2. **Selection of relevant modes**:

From the figure the data extracted were:

1. Private vehicles (cars + others)
2. Paratransit
3. Formal public transport

Walking and cycling were excluded.

3. **Data handling and transformation**:

The units in the original figure were not explicitly mentioned. However, it was assumed they represent passenger-km (which is standard practice in transport analyses). The extracted shares were adjusted so they reflected energy shares rather than passenger-km shares, by multiplying the rates, with efficiency values for the energy used per passenger-km for the different forms of transportation.

Table 1 Efficiency values for the energy used per passenger-km for the different forms of transportation.

Transport type	Energy efficiency values [MJ/pass-km]
public transport	0.8
Paratransit	2
Car	3

4. **Regional aggregation**:

Each African city in the dataset was mapped to the corresponding OMNIA regions. When there was more than one city per region, the population-weighted averages were used to estimate an average share for that region.

5. **Implementation into VT_OMNIA_TRA**:

The shares for the African regions in Table 2 of the VT_OMNIA_TRA input, were adopted to match the calculated energy shares from the Excel file "Shares public-private based on cities". Finally, to ensure that the assumption in Table 2 matches the MobiliseYourCity data a trial and error adjustment was done to ensure that the final private vs public split (cars + motorcycles vs buses) in Table 17, measured in billion passenger-kilometres (Bpkm), matches the shares from the Excel file "Shares public-private based on cities".

2.1.1.3 Files and References

- **VT_OMNIA_TRA**
- **Shares public-private based on cities.xlsx** (Go to folder "shares public private" in Figure 0.1)
- **MobiliseYourCity** Modal Split Figure in page 35 of the report ('Global Monitor 2022 (MobilisedYourCity)')

2.1.1.4 Further Notes and Assumptions

- Energy shares and passenger-km shares are not the same. Passenger-km shares were adjusted into energy shares because private vehicles usually have higher energy intensity (MJ/passenger-km) compared to public transport.
- Only African cities were used to update African regions (Casablanca, Dakar, Addis Ababa, Douala, etc.).
- Assumptions made:
    - "Others" category combined with "cars" to represent private transport.
    - Paratransit and public transport were assumed to represent the general category of Buses for the African cities OMNIA regions.

2.1.2 Aviation: Disaggregate Domestic and International flights, into Short and Long Flights

Here be found how the shares between AVDL, AVDS, AVBL and AVBS were calculated in the VT_OMNIA_TRA excel document, in the spreadsheet "Key Inputs 1_BY EB" sheet, in Table 8. The calculations are done using the developed PYTHON programs which can be found in the folder "shares of short flights" and one can be guided on how to run the programs through the respective README file in the same folder.

2.1.2.1 Scope of disaggregation

The aviation sector, was already split from the UN energy balance (UNITED NATIONS DEPARTMENT FOR ECONOMIC AND SOCIAL AFFAIRS, 2022) into domestic and international (banker) flights. To further disaggregate the sector, the domestic and international flights were further split into short and long flights for each category, and each OMNIA region. This disaggregation was made since short flight aircrafts have a potential to be replaced by electricity and hydrogen technologies in the future.

The differentiation between domestic and international routes allows OMNIA to account for the share of flights which are short (<500 km) in both domestic (within a region) and international (between regions) aviation, and allow only those short flights to be substituted by low-carbon future technologies such as electric and hydrogen-powered aircrafts (see section **Error! Reference source not found.**).

2.1.2.2 Methodology

To disaggregate aviation into long and short flights, a 2014 flight database was used [https://openflights.org/data.php], that provides data of flights for over 10,000 airports globally. The database was processed through a Python programme that calculates for the flights that belong in each OMNIA region, the percentages of flights that have short distance (<500 km in total) or long distance (>500 km in total) for both domestic and international flights.

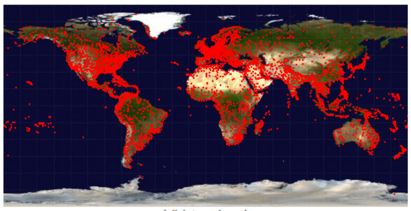
Database description: The database includes data for the departure and arrival airport of each flight, and covers a significant number of flights globally covering all OMNIA regions with hundreds or thousands flights per region, allowing for reliable statistical estimations/outcomes for each OMNIA region.

Code function: The information included in the database can be sufficient to evaluate the share between long and short flights. The code first allocates which flight belong in each region based on the departure airport, and given the departure and arrival airports, an additional database called "airports.dat" from [https://openflights.org/data.php], is used that provides the coordinates of each airport worldwide, allowing it to evaluate the distance between the airports. Given that distance, it splits in each region the short and long flights, for domestic and international flights.

The python program "short_flights_domestic_international.py" pursues the following steps:

- The 3-letter codes for the airports of departure and arrival were used, together with the "airports.dat" database that provides the coordinates for each airport (*OpenFlights: Airport and airline data*, 2014). This allowed, to calculate the distances between the two airports, assuming that the routes are approximately arches on the spherical earth, in order to categories them in short and long flights.
- Also, the flights were allocated to the different OMNIA regions based on the departure airport and calculated the percentage of flights that are short.
- Then, given that the percentage of kilometres done through short flights is known, it is assumed that this percentage is approximately equal to the share of fuel used for short flights respectively that is the required input of Table 8 in the VT_OMNIA_TRA workbook).

Airport database



(click to enlarge)

As of January 2017, the OpenFlights Airports Database contains **over 10,000** airports, train stations and ferry terminals spanning the globe, as shown in the map above. Each entry contains the following information:

Airport ID	Unique OpenFlights identifier for this airport.
Name	Name of airport. May or may not contain the **City** name.
City	Main city served by airport. May be spelled differently from **Name**.
Country	Country or territory where airport is located. See Countries to cross-reference to ISO 3166-1 codes.
IATA	3-letter IATA code. Null if not assigned/unknown.
ICAO	4-letter ICAO code. Null if not assigned.
Latitude	Decimal degrees, usually to six significant digits. Negative is South, positive is North.
Longitude	Decimal degrees, usually to six significant digits. Negative is West, positive is East.
Altitude	In feet.
Timezone	Hours offset from UTC. Fractional hours are expressed as decimals, eg. India is 5.5.
DST	Daylight savings time. One of E (Europe), A (US/Canada), S (South America), O (Australia), Z (New Zealand), N (None) or U (Unknown). *See also:* *Help: Time*
Tz database timezone	Timezone in "tz" (Olson) format, eg. "America/Los_Angeles".
Type	Type of the airport. Value "airport" for air terminals, "station" for train stations, "port" for ferry terminals and "unknown" if not known. *In airports.csv, only type=airport is included.*
Source	Source of this data. "OurAirports" for data sourced from OurAirports, "Legacy" for old data not matched to OurAirports (mostly DAFIF), "User" for unverified user contributions. *In airports.csv, only source=OurAirports is included.*

Figure 2.1 Screenshot describing the database used to disaggregate the aviation sector (*OpenFlights: Airport and airline data*, 2014).

2.1.2.3 Data sources used

- **OpenFlights Route Data (2014)**:
  https://openflights.org/data.html (Figure 2.1)
  Provides global flight routes including source and destination airport codes.
- **Airport Coordinates Dataset**:
  Used to calculate great-circle distances (approximated as spherical arcs) between airports (the airport.dat file in https://openflights.org/data.html).

2.1.2.4 Programmes developed for input calculations

In order to produce the shares of AVDS, AVBS, AVBL and AVDL for Table 8 in the VT_OMNIA_TRA workbook, the user needs to go in the folder "share of short flights" repository, and run the file "short_flights_domestic_international.py". The folder includes README file with more details on how to run the programme and how the programme functions.

2.1.2.5 Steps followed in the code

The methodology followed is described below:

Step 1: Data Preparation

- Loaded flight route data and airport coordinates from the file airports.dat.
- Calculated **flight distance in kilometers** between origin and destination airports.
- Added **country** and **OMNIA region** information for both source and destination airports.
- Classified each flight as:
  - **Domestic**: source and destination regions are the same.
  - **International**: source and destination regions differ.

Step 2: Classification of Flights

- **Short Flights**: Routes with distance < 500 km.

- **Long Flights**: Routes with distance ≥ 500 km.

Step 3: Regional Aggregation

- Grouped routes by **source OMNIA region** and **flight type** (Domestic/International).
- For each group:
    - Calculated the **total flight distance**.
    - Calculated the **total short-flight distance (<500 km)**.
    - Derived the **percentage of short vs long flight distances**.
    - Computed the **share of domestic vs international flight kilometers** within each region.

2.1.2.6 Program output

The output is saved as a CSV file: flight_type_stats_by_region.csv in the format of Table 2, and is presented like the sample output of Table 3.

Table 2 Format of the programme output CSV file flight_type_stats_by_region.csv:

Column	Description
region	OMNIA region code
flight_type	Domestic or International
share_of_total_km	% of total flight kilometers from the region in this type
short_km_pct	% of flight kilometers from this type that are short (<500 km)
long_km_pct	% of flight kilometers from this type that are long (≥500 km)

Table 3 Sample output of the CSV file flight_type_stats_by_region.csv:

Region	flight_type	share_of_total_km	short_km_pct	long_km_pct
EUM	Domestic	26.85	63.12	36.88
EUM	International	73.15	18.94	81.06
USA	Domestic	39.45	54.32	45.68
USA	International	60.55	11.20	88.80

2.1.2.7 Further notes and assumptions:

Assumptions:

- Distances are approximated using circle arcs over a spherical Earth model.
- The rate of distance covered, by each flight category is assumed to be equal to the rate of fuel used for each respective flight category.

Notes:

- The analysis is based on 2014 data but it is assumed that the results can be assumed to be similar for the following years, since it is assumed that the resulted shares would remain approximately the same for the year 2019 which is the base year for OMNIA.
- The categorization of flights is based on the assumption that short-haul routes are more likely to adopt electric/hydrogen alternatives due to range limitations.

2.1.3 Navigation: Disaggregate between Short, Long and Passenger trips in Domestic and International Navigation

The navigation, originally already split into Domestic and International from the Energy Balance (UNITED NATIONS DEPARTMENT FOR ECONOMIC AND SOCIAL AFFAIRS, 2022), was further disaggregated into long, short and passenger trips for each category to achieve better disaggregation and technologies representation. Therefore, now there exist 6 categories for navigation (NADS, NADL, NADP, NABS, NABL, NABP) (see section **Error! Reference source not found.**).

In Table 2 of the 2019 report ('MEPC 76-6-1 - 2019 report of Fuel Oil Consumption Data submitted to the IMO Ship Fuel Oil Consumption Database in GISIS', 2019) for energy use in navigation (to be provided) of the IMO data and split the different ship categories into the 3 main categories for disaggregation: long short and passenger. The shares of energy use for the global navigation sector were 85%, 11% and 4% for long, short and passenger respectively.

Then by doing some calculations in the file "IMO_stats_calculations.xlsx" of the Marine_efficiencies folder in the Marine (IMO data) folder, a reasonable split for the 3 categories of navigation for domestic and bunkers was identified that when summed up to evaluate the total long total short and total passenger, it resulted the desired 85%, 11% and 4% respectively with accurate agreement since the assumed shares were calculated with trial and error. The assumed split is shown in Table 2.4 was applied for all the regions. The steps followed to calculate these rates are presented in the respective README file in the folder "Navigation – IMO data" (Figure 0.1).

Table 2.4 assumed split for the shipping categories to meet the evaluated total shares from IMO data 85%, 11% and 4% for long short and passenger respectively.

Domestic Long	67.54%
Domestic Short	28.18%
Domestic Passenger	4.28%
SUM Domestic	100.00%
Bunker Long	90.43%
Bunker Short	6.42%
Bunker Passenger	3.15%
SUM Banker	100.00%

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2.1.4 High Speed Electric Rails

To estimate the share of high-speed trains within total electric rail activity across OMNIA regions, indicative assumptions were initially provided by expert desk research based on public information about infrastructure, investment, and rail development. These served as a starting point for regional differentiation. Then based on modeler's judgement, these rates were further adopted, by assigned a share of zero in the regions without high-speed rail infrastructure. All estimates were subsequently reviewed and adjusted by the modeler to reflect expert judgment and ensure consistency with OMNIA's broader transport assumptions.

2.1.5 Techno economics inputs improvement for Aviation, Navigation and Rail.

Improvements, versus the TIME-GEO Veda input were done in the technoeconomic values of aviation, navigation and rail included in Table 22 for the energy efficiencies, and Table 24 for the CAPEX and OPEX in the spreadsheet Key Inputs_NT Non-Road in the VT_OMNIA_TRA model input file. Specifically, the EU reference scenario 2020 (*EU Reference Scenario 2020 - European Commission*, no date, p. 2) for technology assumptions was used to evaluate the techno-economic values for aviation, navigation and rail.

The efficiencies of the technology provided were measured in toe/Bpkm (tonnes of oil equivalent per billion passenger – kilometer) for passenger transport technologies, or toe/Btkm (tonnes of oil equivalent per billion tonne – kilometer) for freight technologies and had to be converted to Bpkm/PJ (billion tonne – kilometer per Peta joule) or Btkm/PJ (billion passenger – kilometer per Peta joule), while the CAPEX value provided was measured in euro2015 and had to be converted to USD2021.

To convert the given efficiency values into Btkm/PJ, the following calculation was applied:

$$\boldsymbol{Efficiency\ (Btkm/PJ) = 41.868 \times 10^{6} / Efficiency\ (toe/Btkm)}$$

For currently existing technologies, the database provided tables like the example provided in Figure 2.2, while for future technologies, the database provided data in the format of the example provided in Figure 2.3.

Freight Inland Navigation/National maritime

Reference values for conventional diesel/ fuel oil freight inland navigation

2015		
Energy consumption	toe/Mtkm	10.7
Capital cost	Million Euro'15	7

Reduction of specific energy consumption relative to 2015 (%)	Capital cost of diesel/fuel oil freight inland navigation/national maritime vessel in Million Euro'15			
	2020	2030	2040	2050
5%	8.6	8.2	8.2	8.2
10%	9.1	8.3	8.3	8.3
15%	9.5	8.4	8.4	8.4
18%	11.8	9.2	8.8	8.8
20%	14.1	9.9	9.1	9.1
25%	16.5	10.7	9.4	9.4
27%	18.8	11.4	9.7	9.7

Figure 2.2 Example of data for a navigation existing technology in the EU2020 database. The highlighted values, are the sets of efficiencies improved and Capex values used for the ordinary, improved and advanced technologies respectively.

Reduction of specific energy consumption relative to 2015 (%)	Capital cost of Hybrid Aircraft in Million Euro'15		
	2030	2040	2050
14%	121	119	119
23%	126	124	124
30%	130	128	128
35%	134	132	132
40%	146	141	141
45%	166	146	146
50%	188	151	151
55%	215	162	162

Figure 2.3 Example of data for an aviation future technology in the EU2020 database.

For existing technologies the CAPEX tables were provided for the years 2020, 2030, 2040, and 2050, for a range of expected improvements in the efficiency of the existing technologies versus the reference value from 2015 (Figure 2.2). Different rates of improvement (representing gradual technological advancement) were assumed for the period 2020–2040. For each selected improvement rate, the corresponding CAPEX value was used to represent the cost of the technology in that specific year as highlighted in Figure 2.2. The selected rates of improvement and CAPEX values highlighted in Figure 2.2, similarly were applied for all other technologies provided in the EU 2020 reference database.

The assumed rate of technology improvement was also used to evaluate the expected changes in energy efficiency for the years 2020, 2025, and 2040, respectively in Table 22 of the VT_OMNIA_TRA workbook.

For technologies that do not currently exist, such as in the example in Figure 2.3, the efficiency and CAPEX values were provided starting from the year 2030. In such cases, the reported technology years in the VT_OMNIA_TRA spreadsheet in Table 22 and Table 24 of the VT_OMNIA_TRA were the years 2030, 2040, and 2050.

Finally, all CAPEX values were converted from Euro2015 to USD2021 by multiplying by:

$$\boldsymbol{CAPEX\ (USD2021) = CAPEX\ (Euro2015) \times Exchange\ Rate\ (Euro2015\ to\ USD2021) \times Inflation\ Factor}$$

or

$$\boldsymbol{CAPEX\ (USD2021) = CAPEX\ (Euro2015) \times 1.18 \times 1.07}$$

In navigation, there were some future technologies that were not provided in the EU 2020 Database. For those technologies missing from the Ref2020 database (such as ammonia-based shipping) assumptions were made regarding their efficiencies, as shown in the following Section 2.1.5.1.

2.1.5.1 Assumptions for relevant efficiency of navigation technologies compared to Diesel

Since efficiencies for alternative fuel technologies were not found in the EU2020 database, assumptions were made for the relevant efficiency of several navigation technologies compared to diesel. Specifically, for the technologies: Gasoline, Kerosene, Coal, LPG, LNG, Hydrogen, Ammonia the table below was used using the diesel values as reference values. The estimations were done through desk research.

Fuel Type	Energy Density (MJ/kg)	Engine Efficiency (%)	Energy Ratio (vs Diesel)	Efficiency Ratio (vs Diesel)	Expected Efficiency (Mtkm/PJ)	% Change vs Diesel	Sources
Diesel	42.8	50%	1	1	**2237.3**	**0% (Reference)**	- Energy Density: SEA-LNG Alternative Marine Fuels Study - Engine Efficiency: IEA Bioenergy Marine Biofuel Report
Ammonia	18.6	40%	0.435	0.8	**780**	**-65%**	- Energy Density: SEA-LNG Alternative Marine Fuels Study - Engine Efficiency: H2SHIPS Comparative Report on Alternative Fuels
Gasoline	44.4	40%	1.037	0.8	**1856.7**	**-17%**	- Energy Density: SEA-LNG Alternative Marine Fuels Study - Engine Efficiency: IEA

							Bioenergy Marine Biofuel Report
Kerosene	43	45%	1.005	0.9	**2023.9**	**-10%**	- Energy Density: SEA-LNG Alternative Marine Fuels Study - Engine Efficiency: IEA Bioenergy Marine Biofuel Report
Coal	24	35%	0.561	0.7	**877.7**	**-61%**	- Energy Density: SEA-LNG Alternative Marine Fuels Study - Engine Efficiency: IEA Bioenergy Marine Biofuel Report
LPG	46.1	38%	1.078	0.76	**1831.2**	**-18%**	- Energy Density: SEA-LNG Alternative Marine Fuels Study - Engine Efficiency: IEA Bioenergy Marine Biofuel Report

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