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Tourist Transportation Generated Carbon Dioxide (CO_2) Emissions in Latvia

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***Abstract* – The tourism has a close relation to the travel and tourism transport. Transport is the source of CO_2 emissions. The aim of the research was to inspect the tourist transportation (TT) CO_2 emissions caused by the tourist overnight trips, because any similar analysis up until now has not been made. For the determination of CO_2 emissions from the TT a hybrid (top-down and bottom up) approach, correlation, regression was used. The author's proposed algorithm for determining CO_2 emissions from the TT is useful in the circumstances when there is not sufficient statistical data. In the research of regions of Latvia (NUTS 3) from 2012 to 2017, it was determined that the TT overnight trips indicated a reduction of CO_2 emissions of 475 t/year. It is a positive approach in order to reach reduction of CO_2 emissions according to the EU criteria for 2030; however, it left a negative impact on the national GDP. Finding solution to this economical problem is the aim of the next researches.**

***Keywords* – CO_2 emissions; tourism; transportation**

1. INTRODUCTION

Transport vehicles, including passenger transport, are believed to be the main source of CO_2 pollution. "Globally, the transportation sector accounts for 21 % of all anthropogenic CO_2 emissions" [1]. Tourism itself relies on travelling, thus also the use of transport is obvious – 62 % of all EU citizens have made at least one trip in 2017 [2]. Tourism is one of the main leading forces behind anthropogenic global warming [3], [4], which should be channelled towards sustainable resource management [5], but the European low-emissions mobility strategy [6] has stated that until 2050 the amount of global warming causing gases has to be reduced by 60 % in comparison with the 1990. Considering that tourism has to be in terms of Kyoto protocol global warming effect mitigation systems, it is necessary to evaluate the CO_2 emissions of the transport involved in the tourism industry [7]. In line with the IPCC (Intergovernmental Panel on Climate Change) guidelines, each year countries have to prepare GHG (greenhouse gas) inventory, i.e., to evaluate the emissions and their sources, which cause the largest impact on emissions. In Latvia the data on CO_2 emissions is collected according to the sectors of the economy – the tourism sector is not specifically outlined. According to the guidelines, GHG emissions and CO_2 relation to the transport sector is

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calculated based on and separated into following: a) domestic aviation; b) road transportation; c) railway; d) domestic navigation and e) other transportation [8].

In one respect, such an approach to data compilation does not allow one to estimate CO_2 emissions from the tourism sector, while the lack of information undermines the possibilities to monitor and to reduce emissions in this particular sector [9]. Since CO_2 has long-term implications it is necessary to quantitatively monitor the tourism sector's share of emissions. Moreover, in Latvia no research has previously focused on estimating CO_2 emissions in the tourism sector. The lack of information caused the authors to propose the research aim: to investigate CO_2 emissions in tourist transportation in Latvia. In order to achieve this goal the following tasks were set: 1) to acquire information on the research approaches for determining of CO_2 emissions in case of limited amount of data; 2) to determine the data which could be used for estimation of CO_2 emissions in tourist transportation; 3) to determine overnight trip of Latvian residents in Latvia by destination regions; 4) to develop a methodology for determination of CO_2 emissions; 5) Description of processes and input data for calculations; 6) to carry out estimations on CO_2 emissions from the tourist transportation in NUTS 3 regions of Latvia.

Limitations: only emissions from the domestic transport used in tourism in Latvia were evaluated. This study calculates the CO_2 emissions for three tourist transportation (further on TT).

Car (car); buses (bus) and railway transportation (rail). The evaluation of the CO_2 emissions in this research does not attribute to the single day travellers but only to tourists. Only data on tourists travelling with their private or a rented car was taken into consideration, while the statistical data on the car was associated with the same place where the car rental company issues the car to customer in the first place. The lack of scientific research in the field of CO_2 emissions in TT studies in Latvia was the reason behind using mainly technical literature and sources for calculations and their justification. The lack of primary data, misalignment of statistical data units limited the variety of the scientific methods applied in the specific case.

The methods applied: The research is based on literature studies, the method of analysis as well as synthesis were used in the current study. The research methods are hybrid (top-down and bottom-up) approach to the estimation of the CO_2 emissions from the transport, correlation and regression.

1.1. CO_2 Emission Estimation Methods and the Used Data on Tourist Transportation

In terms of pursued research on CO_2 emissions from the perspective of tourist transportation in countries like China, India and Thailand, the research of which is mostly connected with the development of national economy, incl., and development of domestic tourism and CO_2 emissions. It should be noted that China was responsible for almost half of the annual increase in global CO_2 emissions in 2018. Meanwhile the estimations for 2018 showed that emissions of China grew, on average, by 4.7 % in the possible range of 2 % to 7.4 %. The railway transport emissions in China are relatively stable however; the road (TT) is the main source of CO_2 emissions (Table 1) [10].

In the case of Latvia, it is important to investigate the causes for CO_2 emissions, and more specifically those caused by transportation. It is ever more important in light of challenges that Latvian scientists are dealing with in terms of evaluation of CO_2 emissions, for example – tourism is not a sector of the national account system. In order to determine what the obstacles are in evaluating CO_2 emissions, the authors analysed scientific literature (Table 1), by refining scientific articles which are similar to this research.

It should be noted that there are two main approaches for evaluation of CO_2 emissions caused by TT, namely, top-down and bottom-up approach (Table 1).

In case of:

- Bottom-up approach (Table 1) the amount of emissions can be estimated with the help of the calculated or measured energy consumption while using a specific energy emission factor;
- In the top-down assessment method the emission amount is assessed based on changes of a chosen set of energy and emission indicators;
- The emission assessment method is determined by using changes to the chosen energy consumption and emissions describing indicators in the given period and energy consumption data;
- In different research (Table 1) when using margins that include local tourism consumption, incoming tourism consumption and internal tourism consumption related to outgoing travels and tickets, which are paid to transport service providers, the bottom-up approach is used. In order to evaluate the overall national CO_2 emissions from tourism, tourism satellite account is connected with the sectors input-output model. In addition CO_2 emissions (Table 1) are calculated on a national level, in scope of tourism sector (as direct and indirect emissions), in tourism transport in general and on average, as well as per one tourist, which uses transport [11]–[13].

TABLE 1. SUMMARY OF MAIN STUDIES ON CARBON DIOXIDE EMISSIONS FROM TOURISM TRANSPORTATION [11]–[13]

Authors, year	Country	Method	Research results for CO_2 emissions from tourism
Pu and Peihu, 2011 [10]	China	Bottom-up approach, literature research and mathematical statistics technology were also adopted	CO_2 emissions from tourism 51.34 Mt, accounting for 0.86 % of the total in China
Tang et al., 2015 [11]	China	This study estimated CO_2 emissions from tourism transport using bottom-up approach	Total tourism transport CO_2 emissions has increased from $13.1 \cdot 10^4$ t in 1978 to $224.17 \cdot 10^4$ t in 2012, based on the average growth indicator 9.47 % road transport was the main source of CO_2 emission sources in tourism industry
Jamnongchoba et al., 2017 [12]	Thailand	Bottom-up approach was observed by using questionnaire CO_2 emission from energy consumption by transportation was calculated following IPCC2006 guideline	Mean CO_2 emissions in tourist transportation by Thailand were 32 249.66 kg CO_2eq and 21.20 kg CO_2 person^{-1}
Weiqing et al., 2017 [13]	China	Bottom-up approach is used in order to evaluate the national dioxide emissions in tourism, by connecting tourism satellite accounts and productive industries input-output model	The total CO_2 of China tourism industry in 2002, 2005, 2007 and 2010 accounted for 111.49 mil. tonnes, while China's industry accounted for 141.88 mil. tonnes. Indirect CO_2 emissions in different spheres of tourism with exception of transport were 3–4 times larger than those of direct carbon emissions

Authors underline that the emission calculations were carried out based on methodology and parameters, which are based on the guidelines created by the IPCC [14].

However, there are situations when there are certain statistical data limitations. Authors are investigating what indicators better to use when evaluating CO_2 emissions from TT according to the following activity indicators:

- Fuel consumption;
- Number of cars;
- Number of cars by fuel and vehicle type;
- Distance travelled by cars by fuel and vehicle type;
- Fuel emission factors.

1.1.1. Fuel Consumption

Internationally recognized CO_2 emissions evaluation tool is *COPERT* IV (Table 2), which is a software for calculating emissions from the road-transport sector. This tool has been widely used for research purposes when it is necessary to calculate emissions on a national, regional and local scale, and which includes calculation pre-sets on all main pollutants: greenhouse gases, air pollutants and toxic substances.

In comparison to other *COPERT* models, *COPERT* IV calculates different types of emissions (thermal or physical, e.g. tyre wear emissions) for different types of vehicles, including those for 240 auto industry companies, including motorbikes, cars, high energy output vehicles, incl. vehicles adapted for tourism purposes, which is the main subject of this research as chosen by the authors. It should be noted that *COPERT* has a connection to *TREMOVE*, which is a policy planning and evaluation model, which helps evaluate emissions according to different types of transport and environment. Such a tandem can help evaluate the actions taken for reduction CO_2 emissions. Unfortunately, the emission factor provided by the model cannot be used because it is meant for estimation of CO emissions, which is not the aim of this research [15].

TABLE 2. ACTIVITY INDICATORS AND SOURCES USED FOR CARBON EMISSIONS CALCULATION IN ROAD TRANSPORT [11]–[14]

Activity indicators	Source of activity data	Remarks
Fuel consumption	Calculate consumption by *Copert* IV model	Calibrated with national statistics. Deviation less than 0.15 %
Number of cars	Road safety Directorate	For calculation the number of cars with permission to participate in traffic is used
Number of cars by fuel and vehicle type	Road Traffic Safety Directorate and calculation	Based on available data cars are grouped by fuel type, engine power, age and vehicle categories according to emission control system
Distance travelled by cars by fuel and vehicle type	Road Traffic Safety Directorate and calculation	Based on average data by cars classes it is modelled by fuel type, engine power, age and vehicle categories
Emission factors (EF)	Fuel specific for CO_2 emissions	CO_2 emissions factors is based on carbon content in fuel 1990–2008 EF gasoline is 68.6 kg/GJ, in – onwards EF gasoline is 71.18 kg/GJ

1.1.2. Number of Cars

The availability of Road Traffic Safety Directorate statistics data on the number of cars (Table 2) ensures the possibility to use this information in calculations, however it should be noted that, only data on such types of vehicles can be used that are accepted and the technical condition of which allows them to participate in the transportation of tourists. Authors have partial (indirect) access to this information and thus it can be used.

1.1.3. Number of Cars by Fuel and Vehicle Type

In the reviewed articles (Table 2), the acquired information on types of transport was separated by type of fuel, engine power, car age and transport, which was combined for determination of CO_2 emissions. The described distribution is acceptable in such research.

1.1.4. Distance Travelled by Cars by Fuel and Vehicle Type

The statistical data of the Road Traffic Safety Directorate (Table 2) was used when calculating the average amount of fuel spent during the travel distance dependent of the type of the car, power of engine, cars age, and category of transport. It should be taken into account that the average consumption of fuel was dependent of:

– The density of the fuel. The denser the fuel is (e.g. diesel), the more carbon it contains and thus emits more CO_2 emissions. Due to this fact, the gasoline and diesel CO_2 emissions differ radically. For instance, the differing amount of fuel bio-additives due to which each type of fuel has a different CO_2 emission factor and, CO_2 emission coefficients differ among countries. According to IPCC 2006 guidelines on the greenhouse gas emissions by the transport, they have to be applicable to the country in which the fuel is sold [16], [17];
– The power of engine and the type of transport, which is offered by the Vehicle Emissions Laboratories (VELA) of the European Commission Joint Research Centre (EC-JRC), located in Ispra (Italy) on different types of emissions of vehicles in terms of different driving cycle measurements [18];
– Meanwhile the producers of vehicles provide data on CO_2 emissions of newly produced vehicles according to the guidelines on CO_2 emissions of EU registered new passenger cars and light commercial vehicles according to the EU regulation (EC) No. 715/2007 [19];
– EURO standard which requires yearly improvements in terms of fuel efficiency in both the construction of the vehicles itself as well as its engine, and also the age of the car according to EURO 1, EURO 2, EURO 3, i.e., according to the year of the car's production [20].

However, the fuel consumption of a vehicle on a certain distance driven is dependent on multiple different factors, such as speed, driving manner, engine load, engine service situation, tyre pressure and the use of air conditioning. It is unlikely to acquire all of the impacting parameters, for every vehicle. Therefore, for the calculations on the distance travelled by cars the average indicators are used, which are based on variable fuel consumption rates for different types of transport groups. Such an approach can be used in this research.

1.1.5. Fuel Emission Factors

The use of CO_2 emissions factor (EF) as used in articles (Table 2) is based on data on the carbon footprint for gasoline, which in 1990–2008 was 68.6 kg/GJ, but after 2009 –

71.18 kg/GJ. As it was concluded CO_2 factor emissions are dependent on multiple factors, e.g., type of used fuel, load, engine revolution count, travel distance, ambient air temperature, temperature of cooling system, spark time, and engines maintenance, as well as the year of information collected, which is the reason for differences in emission factors.

Such data is available in many guidelines, publication of organizations in many countries and scientific literature, e.g., EPA Centre for Corporate Climate Leadership (United States Environmental Protection Agency), Emissions Factor Database (EFDB) and the National Atmospheric Emissions Inventory (NAEI) national reports reviews, Co-operative programme for monitoring and evaluation of long range transmission of air pollutants in Europe/European Environment Agency (EMEP/EEA) factor source handbook – air polluting emission inventory guidebook. In addition, one should consider that the average CO_2 emission factors of brand-new cars are annually altered based on "real world" correction, different engine power and vehicle weight indicators [21].

The CO_2 emission factors can be applied to different units. Both in the examples of (Table 2) as well as, EPA, EFDB, EMEP/EEA factor units are different. For example, passenger car CO_2 emissions is 0.343 kg/mile, passenger cars include: passenger car, minivans, SUVs, and pickups; bus – 0.0560 kg/mile; rail – 0.161 kg/mile. Commuter rail is a service between the centre of city and suburbs, also known as suburban rail [22], [23].

However, since for the use of the emission factor in determining CO_2 emissions the data was lacking, authors used a different evaluation approach. The literature analysis indicated the possibility to use the average emission per unit for estimation of the overall CO_2 emissions, which can be expressed in units g/km or kg/km [24].

1.2. Data on TT Used for Estimation of CO_2 in Latvia

For estimation of CO_2 emissions, it is first necessary to learn the profile of the tourists who are using transport. According to the Latvia Tourism Law [25], not every traveller is a tourist. In statistical data, a tourist is assumed to be a visitor who is spending time outside of his/her regular dwelling place for at least 24 hours, thereby statistical data was used on multiday travels. The statistical data in Latvia offers information about four main domestic overnight tourist means of transport: car, buses, rail and other types of transport. Due to lack of precise data on tourists who use other types of transport and due to their share being below 5 % of the total tourists, they were considered statistically insignificant. Thus, they were not included in the statistical analysis [26], as well as the research included travels with rented cars, which area of use was assumed the area where the service provider hands the vehicle to the visitor for the use, as well as private cars belonging to the tourists.

Thus, the tourists visiting all six NUTS 3 regions of Latvia (Riga region, LV006; Pieriga region, LV007; Vidzeme region, LV008; Kurzeme region, LV003; Zemgale region, LV009; and Latgale region, LV005), mainly use three types of transport:

- Car *(*car);
- Buses (bus);
- Train transport (rail) [27].

1.2.1. Data of TT by Car (Car)

In Latvia, it is possible to rent *Volvo*, *Ford*, *Peugeot*, *Volkswagen*, *Nissan*, *Toyota*, and other brands of cars, starting with small cars and ending with SUVs. The highest concentration of car rental business is in the Riga region and Pieriga region with the total number of rental vehicles at 124 and 296 per year, respectively. Car rental establishments provide vehicles with diverse class and power specifications, while the rental branches are situated throughout Latvia. Some exclusive vehicles are also available, with fuel consumption 12.3–13.8 l/km, such as, *Mercedes-Benz* E-Class and *BMW* 5 Series. Overall the fuel consumption for rental cars vary between 3.2 l/km and 13.8 l/km, which depends on the car's brand, model, power of engine, and engine volume as well as the year of production.

Authors based their analysis on data on cars which are in technically exploitable status as registered in Road Safety Directorate in Latvia (RTSD) in regions of Latvia [28], [29].

1.2.2. Data of TT by Buses (Bus)

In the period, 2012–2017 in Latvia tourists were serviced by from 410 to 431 licensed international transport operators and from 8 to 22 per year local operators [30].

Tourist transportation in Latvia is provided with buses of such brands as *Volvo*, *Scania*, *Solaris*, *Mercedes Benz*, *Nolan* and other and microbuses/minivans – *Mercedes Benz Sprinter*, *Iveco Daily*, *Renault* and others with the number of seats varying from 30 to 74 in buses and 8 to 19 in minivans accordingly [31], [32].

The division of transport according to international transport emission standards, which can provide passenger, including tourist transportation services, vary between from 30 % to 37 % EURO IV, from 37 % to 32 % EURO VI, from 14 % to11 % EURO III, from 40 % to 21 % EURO 0–EURO II (data on December 31th 2018). For instance, *Mercedes-Benz Intouro* during the wintertime can consume even 44 l/km, *Mercedes-Benz Sprinter* – 10 l/km. The fuel consumption for buses and microbuses varies between 44–35 l/km and 8–11 l/km for microbuses [30]. The number of buses is based on RTSD registered vehicles in the regions, which are in a good technical shape.

1.2.3. Data of TT Train Transports (Rail)

The passenger, incl. tourist, transportation by railway constitutes about 7 % of the total land-based transportation via rail, while in Riga suburbs regions it reaches 35 %. Local passenger rail cars are provided by the JSC "Pasazieru vilciens" and LLC "Gulbenes–Aluksnes banitis". The rail transport with diesel engines provide transport, thus also tourism transportation, services on three major lines: Riga–Valga, Riga–Daugavpils, Riga–Liepaja with additional routes Plavinas–Gulbene, Krustpils–Zilupe. LLC "Gulbenes–Aluksnes banitis" provides a popular for tourists on a narrow-gauge railway line Gulbene–Aluksne (the research did not include rail transportation with the steam train) [33].

All of the mentioned passenger transportation vehicle types produce CO_2 emissions, thus international experience on estimation of emissions concerning each type was analysed.

1.3. Overnight Trip of Latvian Residents in Latvia by Destination Regions

The overnight trips by Latvian residents within Latvia were analysed within the scope of NUTS 3 (Riga region; Pieriga region; Vidzeme region; Kurzeme region; Zemgale region and Latgale region) (Fig. 1). The largest quantity (2012–2017) was reached in Pieriga region in 2012 and 2014 – in a region where the vast majority of population is of a working age, highly educated and overall with high income [34]–[36].

In 2015, a reduction of number of trips was observed which made an impact on overnight trips, while the common amount of tourist trips increased due to an increase in the some-day trips.

2. METHODOLOGY

2.1. Method to Calculate the CO_2 Emissions of TT

This research included the hybrid approach (top-down and bottom-up approach). The analysis from the top-down perspective helps to evaluate tourism as a branch of economics. In the research, the method was used to calculate the relation between the total GDP and TT of the total CO_2 emissions in Latvia. The bottom-up approach was used to calculate CO_2 emissions from TT. The CO_2 emission factors for each type of fuel were used, as well the emissions were calculated based on travel attributes, for example, travelled distance [37]–[39]. The CO_2 emissions are calculated based on the consumed fuel and carbon content within the fuel, because it is well-defined [40]. For calculation of CO_2 emissions, the average emissions per one (unit) transport vehicle g/km or kg/km were used [39], based on *DEFRA* CO_2 emissions calculation methodology act Trial, the authors used the following equation to calculate CO_2 emissions:

$$C_{T_n;t;R_k} = \sum_{T_n=1}^{4} N_{T_n;t} \cdot \beta_{T_{n2};t} \cdot D_{T_n;t} \cdot T_{T_n;t} \, , \tag{1}$$

where

$C_{T_n;\,t;\,R_k}$	CO_2 caused by tourism transport in region R_k in time t by transport types T_n (car-gasoline, car-diesel, bus-diesel, rail-diesel);
$N_{T;t}$	Number of type of transport vehicles T_{n1} in region R in time t;
$\beta_{T_n;t}$	CO_2 emissions for the certain type of fuel for transport type T_n;
$D_{T_n;t}$	Distance driven by transport vehicle T_n in time t;
$T_{T_n;t}$	Number of trips with transport vehicle T_n in time t.

2.2. Description of Process and Input Data for Calculations

There was no clear information available on the transport vehicles participating in tourism activities, however data was available on the number of overnight trips from 2013 until 2017 by NUTS 3 regions. Taking that into consideration, authors calculated the needed data indirectly:

- Division number of type of transport;
- Division of trips by type of transport by fuel;
- Calculation number of trips with transport vehicle (gasoline and diesel);
- Division by consumption according to mean fuel consumption and CO_2 emissions per 100 km;
- Calculation of trip distance;
- CO_2 emissions for the certain type of fuel for transport type.

Division by fuel emissions of transport in the following procedural order.

The division by type of transport in regions NUTS 3 regions Latvia was calculated based on CSB data (T_{total}) and modes of transport used during the overnight trips around Latvia (koef$_n$): car – 80.6 %; bus –14.5 %; rail – 4.4 % [41]–[43].

2.2.1. Division Number of Type of Transport

Division number of type of transport equation:

$$N_{T_{n1};t} = N_{total} \cdot \text{koef}_{n1}, \tag{2}$$

where

$N_{T_{n1};t}$ Number of type of transport vehicles T_{n1} in region R in time t;

N_{total} Number of total transport vehicle T_{n1} in time t;

koef_{n1} Overnight trips by type of vehicles in Latvia, %.

2.2.2. Calculation Division Type of Transport by Fuel

Based on the data from RTSD, information on cars and buses with gasoline and diesel engines, a time series of the share of type of vehicles in the period 2010–2017 was estimated (Table 3) and was calculated based on Eq. (3):

$$N_{T_n;t} = N_{T_{n1};t} \cdot \text{koef}_{n2}, \tag{3}$$

where

$N_{T_n;t}$ Number of transport vehicles T_n in time t;

$N_{T_{n1};t}$ Number of type of transport vehicles T_{n1} in time t;

koef_{n2} Overnight trips by type of fuel of vehicles in Latvia, %.

TABLE 3. GASOLINE AND DIESEL CAR, BUS AND RAIL DISTRIBUTION IN LATVIA (2013–2017)

Year	Car		Bus		Rail
	Gasoline, %	Diesel, %	Gasoline, %	Diesel, %	Diesel, %
2010	74.0	26.0	34.3	65.7	97.7
2011	65.7	34.3	3.6	96.4	98.2
2012	62.2	37.8	2.3	97.7	98.6
2013	57.9	42.1	1.8	98.2	98.9
2014	53.6	46.4	1.4	98.6	99.1
2015	49.5	50.5	1.1	98.9	99.4
2016	46.0	54.0	0.9	99.1	97.7
2017	46.0	54.0	0.6	99.4	98.2

It was taken into account that tourists are travelling not only with rental cars, but also, as evident by the surveys, with their private cars. This was based on the data from "Latvia Tours Travel index" and the public opinion survey centre SKDS common study [44], [45]. Authors based their assumptions on data on cars and buses which are in a technically suitable condition and which were registered by RTSD in regions of Latvia (see chapter 1.2). In terms of transportation by bus (Table 3) and rail, the main fuel for combustion engines in the majority of cases was diesel, therefore in calculations no data on other types of fuel was considered.

2.2.3. Calculation of Number of Trips with Transport Vehicle by Fuel (Gasoline and Diesel)

Based on the acquired information and calculation, the overnight trips made in Latvia, by destination regions [46], were further divided according to the type of vehicle and fuel used, see (Table 3), the trip by car (gasoline), by car (diesel), by bus (diesel), and by rail (diesel) the overnight trips by Latvian residents within NUTS 3 Latvia regions from 2012 to 2017 were calculated based on the following equation:

$$T_{t_n;t} = T_{\text{total}} \cdot \text{koef}_{n2}\,, \tag{4}$$

where

$T_{t_n;t}$ Number of transport vehicles T_t in time t;

T_{total} Number of total transport vehicles T_{n1} in time t;

koef_{n2} Overnight trips by vehicle types in Latvia, %.

2.2.4. Division by Consumption According to Mean Fuel Consumption and CO_2 Emissions per 100 km (F)

Based on information in Latvia's RTSD handbook [44] for determination of CO_2 emissions, the following average fuel consumption values were used: for cars with gasoline engines per 100 km – 6.7 l/km; for diesel engine – 5.8 l/km, for bus – 35.4 l/km; for rail – 352 l/km [47]. Based on the information from the handbook on the CO_2 emissions of passenger vehicles available in Latvia's market from 2011 to 2017, authors used the average car-gasoline emission 169.36 g/km, car-diesel – 156.6 g/km. According to bus-diesel fuel emission – 76.4 g/km; rail-diesel – 19 g/km [45], [46].

2.2.5. Calculation of Trip Distance

The distances of trips by car and bus were determined based on the average distances between:

- Riga centre 0 km (coordinates of the geographical center of Riga: geographic latitude – 56°58'18.2" N, geographic length – 24°07'42.3" E) and further borders of the regions with roads or streets;
- Nearest and furthest towns of regions outside of Riga: Pieriga region (Riga–Jurmala, Riga–Ainazi); Vidzeme region (Riga–Sigulda, Riga–Valmiera, Riga–Aluksne); Kurzeme region (Riga–Talsi, Riga–Ventspils, Riga–Liepaja); Zemgale region (Riga–Jelgava, Riga–Jekabpils); Latgale region (Riga–Rezekne, Riga–Daugavpils) (Table 4), since they are the main tourist travel targets within the regions of Latvia [48], [49], which was backed by CSB statistics [50].

The average rail distances were calculated based on the infrastructure of Latvia's railway infrastructure length [51]. It took into consideration the average distances:

- In Riga between: the stations Riga-pass; Zemitanu; Ciekurkalns and Jugla;
- In the territory of Latvia further from Riga, the distances between the rail lines according to the (Table 4) NUTS 3 regions; i.e., resp., nearest and furthest towns of regions outside of Riga: Pieriga region (Riga–Olaine); Vidzeme region (Riga–Valmiera); Kurzeme region (Riga–Ventspils, Riga–Liepaja); Zemgale region (Riga–Jekabpils, Riga–Jelgava); Latgale region (Riga–Daugavpils) (Table 4).

TABLE 4. AVERAGE TRIP DISTANCES BY CAR AND BUS AND RAIL IN LATVIA BY REGIONS (2013–2017), KM

NUTS 3 regions	Average trip, km	
	Car and bus	Rail
Riga region	25	17
Pieriga region	67	40
Vidzeme region	119	122
Kurzeme Region	171	197
Zemgale region	114	83
Latgale region	236	212

2.2.6. Calculation CO_2 Emissions for Certain Types of Fuel by Transport Type

$$\beta_{T_n;t} = T_{T_n;t} \cdot F_n \,, \tag{5}$$

where

$\beta_{T_n;t}$ — CO_2 emissions for certain transport type T_n;

$T_{T_n;t}$ — Number of transport vehicles T_n in time t;

F_n — Overnight trips by type of vehicle in Latvia (percentage).

After determining the division of trips by type of transport, type of fuel [52]–[54], and after estimating the transportation distances, as well as the emissions of one litre of fuel (gasoline and diesel) depending on type of transportation, the authors calculated the CO_2 emissions by Eq. (1).

3. RESULTS AND DISCUSSION

The acquired results of TT generated CO_2 emissions in Latvia and NUTS 3 regions were discussed in the following order:

- Tourist transportation generated CO_2 emissions by transport types;
- CO_2 emissions of tourist transportation by Latvia's NUTS 3 regions and in Latvia and impact factors;
- Relation between the Total GDP of TT and Total CO_2 emissions from TT in Latvia.

3.1. Tourist Transportation Generated CO_2 Emissions in Latvia and by Latvian NUTS 3 Regions

The CO_2 emissions from TT were calculated by using a bottom-up approach and by developing an algorithm showing a step-by-step methodological approach proposed by the authors. Based on Eq. (1) TT total CO_2 emissions in Latvia calculations, it was determined that a decrease in CO_2 emissions can be observed when comparing 2012 with 2017, which decreased from 1202.86 tCO_2/year to 727.51 tCO_2/year accordingly.

In order to determine factors, which may have caused the difference at the amount of 475.35 tCO_2/year, the differences in CO_2 emissions in NUTS 3 regions of Latvia, and TT generated CO_2 emissions by types of vehicles were analysed.

3.1.1. Tourist Transportation Generated CO_2 Emissions by Transport Type

According to the descriptive statistics results on the arithmetic average (Table 5), each TT by type of fuel, indicated that the most CO_2 emissions in Latvia were generated by car and gasoline fuel, while the least by public transport – railway.

The dispersion indicator standard deviation (std. deviation) defines the specific variation of the certain attributes. Since the Std. deviation define the dispersion of values from their average value, then the std. deviation (Table 5) demonstrates the dominating sphere of effect of the car-gas on the amount of CO_2 emissions generated compared to other types of TT.

The difference between the maximum CO_2 emissions for a gasoline engine car and the minimum CO_2 emissions for a diesel run train (Table 5) are stunning – 551.17 tCO_2/year, which shows an overwhelming benefit and level of efficiency attributed to the use of rail for TT since the overall CO_2 outflow is smaller.

TABLE 5. DESCRIPTIVE STATISTICS BY CAR, BUS AND RAIL CO_2 EMISSIONS IN LATVIA (2012–2017), T/YEAR

CO_2 emissions	Minimum	Maximum	Mean	Std. deviation
Car-gas	261.06	667.67	435.20	157.67
Car-diesel	162.63	174.05	167.19	5.18
Bus-diesel	175.90	217.74	191.32	14.88
Rail-diesel	116.50	151.45	125.61	12.89
Total Latvia	728	1203	919.31	177.27

Authors underline that the resulting data (Table 5) on CO_2 emissions in TT from car and bus does not indicate a significant difference. However, if the possible number of total numbers of transported tourists would be taken into account, then the differences would be believed to be significant. For instance, if comparing the number of possible passengers per transport unit in *Volvo*, *Scania*, *Solaris*, *Mercedes Benz*, *Neoplan* and other buses and different brand microbuses/minivans, e.g., *Mercedes Benz Sprinter*, *Iveco Daily*, *Renault* and others, the number of seats, as previously defined vary from 30 to 74 in buses and 8 to 19 in minivans.

The amount of CO_2 emissions from type of TT shall be greater per passenger when comparing TT of a gasoline engine car and diesel engine train, which is an assumption to be investigated in further research. As observed, CO_2 emissions by type of tourism transportation for diesel bus vehicles has decreased from 218 tCO_2/year in 2012 to 176 tCO_2/year in 2017.

When comparing the generated CO_2 emissions by TT rail with diesel engine bus vehicles overall reduction of emissions was noticed as well. In comparison in 2012 diesel train TT generated CO_2 emissions were 151 tCO_2/year while in 2017 117 tCO_2/year which is by 34 tCO_2/year less. That can be explained by introduction of newer and in terms of CO_2 emissions, cleaner, buses by brands *Volvo*, *Scania*, *Solaris*, *Mecedes Benz*, *Neoplan* and others, as well as due to the reduction of the overall number of trips in 2017, as well as the assumption, that there are different factors affecting results that should be further investigated in the future. The reduction of CO_2 emissions was most pronounced in rail and bus categories in Vidzeme and Zemgale regions. The cause for such trends could be internal migration, incl., to the capital city of Riga, a downward trend of 1.7 % to 1.1 % in 2017 accordingly and based on the data by the RTSD due to the increasing number of cars. In order to challenge the assumption, whether the use of TT generates CO_2 emissions depending on the type of transport, authors carried out the research on the relation between the use of TT and the type of fuel.

3.1.2. CO_2 Emissions of Transportation by Latvia's NUTS 3 Regions and in Latvia overall

The calculations carried out within the research in certain years (Table 6) during the period 2012–2017 showed maximum indicator differences in the TT total CO_2 emissions from NUTS 3 in regions of Latvia.

TABLE 6. RESULTING INDICATORS OF CO_2 EMISSION CHANGES OF TT IN LATVIA AND LATVIA'S NUTS 3 REGIONS (2012–2017)

NUTS 3 regions						
Riga	Pieriga	Vidzeme	Kurzeme	Zemgale	Latgale	Latvia
Indicators, t/year						
–30.0	–344.97	–51.67	–19.64	–9.33	–63.44	–475.4

In a certain year, changes to the CO_2 emissions (Table 6) were taking place even by 335.64 t/year maximum difference in-between some NUTS 3 regions. When analysing results of the research, the authors determined the following set of causal-impact factors:

- Socioeconomic;
- Demographic;
- Increase in the quantity of new transport vehicles;
- Increase in the quantity of cars and buses with diesel engines;
- Use of more economical types of fuel.

Socioeconomic factor impacts (Table 6) to the changing CO_2 emissions can be observed throughout Latvia, however it is most pronounced in Latgale region where it is well portrayed in the constant TT CO_2 emissions, which are at the highest level in Latvia, and since 2014 on average account for emissions of CO_2 164 t/year. It is surprising that the CO_2 emissions in Zemgale region are also constantly relatively low which should be analysed in further research.

Demographic factors affect the whole country and affect changes of CO_2 emissions from TT. However, the results on the CO_2 emissions generated by the TT in NUTS 3 regions of Latvia indicate that in 2013, the Pieriga region was dominating with 38.4 % of the total CO_2 emissions in Latvia; meanwhile in 2017 it was 14.2 %. With ongoing increase in the wealth of the population of this region starting from 2015, according to the RTSD data, in the Garkalne, Babite, Adazi and Carnikava municipalities, the number of cars with reduced amount of CO_2 emissions, has increased significantly.

Increase of newer transport vehicles have a quality attribute. One of such is the EURO standard, which regularly requires improvements to fuel efficiency and outflow air quality, i.e. beneficial changes to the design of the construction of vehicles and their engines improves the CO_2 indicators which are connected with the age of the car, which indicates the overall amount of CO_2 emissions.

Data on the average CO_2 emissions of cars in Latvia was used in the research, incl. car-gas emission 169.36 g/km, car-diesel – 156.6 g/km. According to the consensus achieved on 17 December 2018 EC, European Parliament and European Council made a compromise in the form of EU regulation stating binding rules for future CO_2 emissions of passenger vehicles with set targets to be achieved until 2025 and 2030. According to the regulation, CO_2 emissions of new vehicles should be reduced on average by 15 % until 2025 and by 37.5 %

until 2030, compared to emissions in 2021. Thus, in comparison with the CO_2 emissions used in this research (95 g/km), the further goals could correspond to 81 g/km in 2025 and 59 g/km in 2030. The new microbuses/vans registered in the EU do not emit more than 175 grams of CO_2 per kilometre on average (in 2017). Thus, there is still space for further improvements

An increase of diesel engine and bus use can be observed as they become more popular also due to their lower amounts of produced CO_2 emissions. This trend is also to be seen in the TT in Latvia (Table 3) as well as in the UK (2017) where the proportion was 59.9 % for car-diesel and 95.7 % for diesel bus [38]. Despite the wide use of diesel cars in TT, the emissions in period 2012–2017 reached 166–174 tCO_2/year and that did not cause a significant increase, only 8 t in 2017 that resulted in a negative correlation of CO_2 emissions in TT total (Table 6). More efficient types of fuel are in use in Latvia as well as in a number of other European countries, including Germany, Sweden, Norway Denmark and Lithuania, where bio-fuel (regular fuel with bio-ethanol additives) has been introduced. Switch to fuel with bio-additive has been carried out according to the best experience of countries where the reduction of the overall amount of CO_2 emissions in order to tackle the effects of global warming has been given a priority. Until now, the regular fuel with added bio-ethanol (at 5 % quantity) has been included in the EU fuel quality standard (EN 228 for gasoline, EN 590 for diesel fuel).

Apart from these impact reducing factors affecting the CO_2 emissions from TT in this research, there are others, such as the choice of lower CO_2 intensity TT vehicles. In this light, increase in the number of tourist trips taking place with rail-diesel transport as one of the most efficient of traditional types of public transport should be further encouraged in the future.

When describing Pieriga region (which stands out among NUTS 3 regions due to amount of CO_2 emissions) and Latvia all together, the research indicated that the total CO_2 emissions from TT in Latvia in the period 2012–2017 have reduced by 426 tCO_2/year, i.e., by 1.7 times, which is a positive trend. The reasons behind this trend in CO_2 emission reduction are related to the renewal of the vehicles stock, reduction in the use of TT due to demographical and socio-economic reasons. The CO_2 emissions by TT (Table 6) indicates a trend in the auto industry – to reduce CO_2 emissions, which most significantly manifests in the Pieriga region, where the difference between annual emissions in 2012 and 2017 is 345 t/year. Combustion vehicles are becoming more environmentally friendly with smaller engines and reduced CO_2 emissions. In addition, inhabitants of the Pieriga region, according to the data by the RTSD, have purchased newer and more efficient vehicles. This is in line with the EU goal to reduce CO_2 emissions. The EURO standard sets the limits for the emissions of newly purchased passenger cars and buses according to the EC regulation No.715/2007 [19] Council of the European Union.

We can agree with other authors [12]–[15], that the transportation sector, similarly to tourism transportation in Latvia, is one of the sectors which causes a large quantity of CO_2 emissions. Therefore, it is necessary to have higher standards for both car, bus, and rail transportation emissions control as well as for the type fuel.

The research indicates that overall public transport, more specifically, diesel engine bus and rail, causes less CO_2 emissions. Should this type of public transport become more convenient to use, more tourists in Latvia would choose this type of transport instead of others, as well it would be a step towards mitigating negative impacts on climate change by the vehicles.

There is no precise method for calculating CO_2 emissions in tourism, due to both the relation of tourism with others fields of economics, as well as due to difficulties to collect data [55]. However, despite these challenges, the authors' contribution to the Latvia's TT CO_2 emissions research is innovative. Thus, in order to reduce the outflow of pollutant CO_2 gases, which are directly related to climate change, combined approach is needed. It also requires gathering more precise data for use in more general researches, as well as regular evaluation of CO_2 emissions in TT with broader variety of methods.

3.2. Relation between the Total GDP of Tourism and Total CO_2 Emissions from TT in Latvia

Once a regression model has been constructed, it may be important to confirm the appropriateness of the model and to define the statistical significance of the estimated parameters. The chosen correlation visualisation method includes a scatter diagram, which allows to visually determine a strong negative linear connection type between signs. Regression line equation is as follows:

$$y_i = b_0 + b_1 x_i = -0.0066 x_i + 2334.4\,, \tag{6}$$

where

y_i Dependent variable, CO_2 emissions, t/year;
b_0 Dependent variable intercept;
b_1 Slope;
x_i Independent (explanatory) variable, GDP, MEUR.

If the GDP total of TT in Latvia is 183 839.149 MEUR in 2012 [47], then the estimated level of CO_2 emissions is 340 462.468 t/year. Correlation coefficient $r = -0.898$ (Fig. 7) indicates a strong negative correlation. Determination coefficient $R^2 = 0.898$. Thus 89.9 % of the changes to the GDP total of TT can be explained with linear regression model.

Since the F-test p-value of 0.004, then we can conclude that the model is statistically significant with the probability value of 99.9 % as a result the alternative hypothesis should be accepted that between the total GDP of tourism (GDP total of TT) and CO_2 emissions from TT in Latvia (total CO_2), a linear connection exists.

TABLE 7. ANOVA MODEL SUMMARY EVALUATION OF LINEAR REGRESSION OF TOTAL GDP OF TOURIST TRANSPORTATION AND TOTAL DIOXIDE CARBON EMISSIONS FROM TOURIST TRANSPORTATION IN LATVIA (2013–2017)

ANOVA*					
Model	Sum of squares	Df	Mean square	*F*	Sig.
Regression	2 949 964 907.070	1	2 949 964 907.070	35.169	0.004**
Residual	335 516 830.035	4	83 879 207.509		
Total	3 285 481 737.105	5			

*Dependent variable: GDP total of TT, at current prices, million Euros;
**Predictors: (constant), total CO_2, tCO_2/year.

The direction coefficient 99.9 % probability interval is $-201.167 < \beta_1 < -72.870$. Since the hypothetical test value $\beta_1 = 0$ is not related to the interval then with probability 95 % the null hypothesis can be rejected and it can be assumed that the total CO_2 factor is relevant (Table 8).

TABLE 8. COEFFICIENTS TABLE OF TOTAL GDP OF TOURISM AND TOTAL CARBON DIOXIDE EMISSIONS FROM TT IN LATVIA (2013–2017)

Coefficients*									
Model	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.	95.0 % Confidence Interval for B		Collinearity Statistics	
	B	Std. error	β			Lower Bound	Upper Bound	Tolerance	VIF
Constant	341 910.206	21 566.910		15.853	0.000	282 030.865	401 789.548		
Total CO_2	–137.019	23.105	–0.948	–5.930	0.004	–201.167	–72.870	1.000	1.000

*Dependent variable: GDP total of TT, at current prices, million euros.

The Durbin-Watson coefficients d_{nov} is 2.654 of Auxiliary regression of Model Summary (b) (Table 8), if $d_{nov} > dU_{\alpha}$, 0.713 > 0.658 and 2.654 > 1.604. Values higher than 2 indicate a negative autocorrelation. Therefore, there is statistical evidence that the terms causing error are not positively auto-correlated. In this research 2.654 shows a negative auto-correlation, indicating that the tested variables of significance can be used as indicators for predicting the process-behaviour of interest.

If the value of the Variance Inflation Factor (VIF) is lower than 0.2 or greater than 4.0 then there is a problem with multicolinearity [53]. In this research, the VIF is 1.0, which is a rather low value, since the VIF < 3, and can indicate a low correlation among variables under ideal conditions.

The research proved that there is a relation between the GDP total of TT and the CO_2 total emissions caused by the TT in Latvia. Meanwhile there is a clear relation: the larger the amount of total CO_2 emissions from the TT, the smaller is GDP from TT and *vice versa*.

It is most common that the development of the tourism sector increases CO_2 emissions. Causality shows that there is a reversible relation or causal neutrality between the indicators of GDP as a factor of growth and CO_2 emissions, [53]–[55]. In certain cases, even no causality can be found between them [54]. In other cases, economic growth shows an important positive impact on CO_2 emissions; however, tourism (TT) causes significant negative impact on CO_2 emissions. These causalities are impacted by the level of the country's development, its economic size, economic and social environment, tourism infrastructure development and the timeline within which these causalities are assessed [56].

As it was noticed in the research calculation (see sub-chapter 3.1.1), certain TT types cause different CO_2 emissions. In fact, new vehicles, which consume fuel more efficiently, cause fewer emissions. Thus, although an increase in total number of TT trips increase total CO_2 emissions, there are further opportunities to reduce the amount of emissions on the level of a single TT unit, without negatively affecting the GDP as it was noted in this research.

Taking into account the CO_2 emissions' reducing impact factors in terms of the TT within the scope of Latvia and Latvian NUTS 3 regions, authors believe that there could be economic expenses associated with these reductions, which could possibly negatively impact the GDP, and should be analysed in further research. In addition, it was acknowledged that the overall situation in the country is an important factor and that the results of the research were impacted by the set limitations of the research – see TT generated CO_2 emission only from cars (car); buses (bus) and railway transportation (rail), as well as only from overnight trips – all of these factors left an impact on the research results.

Due to multiple research limitations and the chosen analyses methodology, authors assumed that in other settings would reach different results, while this research indicated of the development tendencies and new research areas for the future.

Apart from these impact reducing factors affecting CO_2 emissions from TT in this research, the intensity of TT per one vehicle on behalf of the tourists-passengers and the increase of the number of tourists in trip with rail diesel transport as one of the most efficient of traditional types of public transport, which should be analysed in the future.

4. Conclusions

In the period 2012–2017, CO_2 emissions in Latvia resulting from tourism transportation by car (car), bus (bus) and rail (rail) have decreased altogether from 1202 t/year until 728 t/year, despite an increase in the number of tourist overnight trips. The highest reduction of CO_2 emissions is evident in the Pieriga region – 345 tCO_2/year. The reason for this is socio-economic; demographic; increase in the quantity of new transport vehicles; increase in the quantity of cars and buses with diesel engines; use of more economical types of fuel factors, but it does not exclude the possibility of some other impacting factors. The calculations indicated that the reduction of CO_2 emissions caused by TT left a negative impact on the GDP. This calls for Latvia to look into finding the most economical approach for reduction of CO_2 emissions from TT.

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