ANALYSIS OF PUBLIC TRANSPORT AND DEMOGRAPHIC CHANGE IN EUROPE SINCE 2000

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Abstract: The population's structure may modify transport modelling. The main question is how to model transport demand changes due to an ageing population and a change in the working-age population. The correlation between transport and the total population is high and positive in the Scandinavian, Baltic and Western European countries and the former socialist countries. In Central European countries, the correlation is stable but only moderate. In former socialist countries, the correlation between transport and the total and dependent populations is different.

Keywords: demography, social reproduction rate, public transport, correlation, EEA countries.

1. Introduction

The most critical factors for mathematical modelling traffic are the motorization index, GDP and total population. However, there is a tendency to change the structure of the population, which should result in a modification of the factors in the modelling. The present work aims to examine the problem of whether transport demand is stagnating or declining, due to the ageing population and the declining working-age population, at least in Hungary. Is it a question of whether this only happens in Hungary or other countries? For the first time five years ago, in the "Development of National Origin-Destination Traffic Survey and Matrices (OCF-2016), TEN-T Analyzes" (2018) (KTI, 2018), the ageing of the population in Hungary was considered. However, in our work so far, we have not come across any material in the literature

that has applied this aspect of the study. For example, the "Methodological Guide to Cost-Benefit Analysis of Certain Transport Projects" (Trenecon, 2018) for the ever-increasing transport demand, at least in Hungary, does not take the population into account at all.

Similarly, in "Transport in the European Union Current Trends and Issues" (DG MOVE, 2019) it does not even use the population anywhere to predict it, let alone the ageing population. The situation is slightly better than these in the "Traffic Forecasting Accuracy Assessment Research" (NCHRP, 2020) but this also does not consider the ageing population, only the total population. Even more, the adult population (over 20 years of age) uses the "Manual on Air Traffic Forecasting" (ICAO, 2006) in modelling to forecast the demand for aviation but does not consider the ageing

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population. In "Demography, geography, and airport traffic" (Lucas, 2019), it was pointed out that the ageing of the population has an impact on the development of air traffic. However, the authors have not encountered the number and proportion of young people in any traffic modelling work. While this impacts to traffic, either individually or in combination, and different modes of travel, wonders how demand is evolving. Young people, or children (0-14 years old), travel by public transport or, within individual modes, by bicycle or scooter, travelling by car and motorbike only as passengers and with others. However, it is a direct consequence of the decrease in the number of young people that the traffic demand for children decreases. Although young people aged 15-24 travel alone and much more than children, they use public transport rather than cars. However, their headcount in Europe is declining, so is their demand for turnover.

Concerning the elderly, however, we encounter a different phenomenon. As someone retires, their need to go to work every day will cease! Of course, one will have more free time, but it does not follow that he/she spends his/her free time regularly. Older people also have / can have leisure activities, but not much more than they were in working age. In addition, as one ages, he/she will have less need to travel because one's age or medical condition. However, as life expectancy increases, so does the elderly population. Thus, due to the decreasing specific travel demand (travel/person) and the increasing number of the older population (person), the traffic demand in this population sequence decreases overall (Andrejszki *et al.,* 2015). The survival rate has grown nicely over the past few decades

until 2008, but due to declining overall birth rate and increasing life expectancy, the trend in the long-term survival rate is changing due to increasing ageing and not sustainable any more. Consequently, there has been a significant decrease in intercity public transport in Hungary, passenger numbers, and the passenger dimension. However, these phenomena are not developing in the same way in Europe. Some are similar to the Hungarian process; others are precisely the opposite. Moreover, there are countries where the interplay between demographic trends and transport is not visible. Our hypothesis that different European regions has different public transport performance due their different societies. The structured as follows, after introduction authors describe used statistical tools in methodology section, than results are communicated. At 4th chapter the evolution of public transport performance is analysed. At chapter 5th the links between demography and public transport has been discussed, finally the conclusion was drawn.

2. Methodology

Authors searched for answers using Eurostat data. Downloaded the following data from the central statistical database of the European Economic Area:

- Population on 1 January by age and sex [demo_pjan]);
- Population structure indicators at national level [demo_pjanind]);
- Volume of passenger transport relative to GDP [tran_hv_pstra]);
- GDP and main components (output, expenditure, and income) [nama_ten_gdp]);

- Modal split of passenger transport [tran_hv_psmod]).

If necessary, the population had to be recalculated with the data in the first two files. Data from European countries could then be grouped in different ways. The two GDP files and the travel data had to be converted using the following method. The ratio of passenger turnover to GDP is the 2010-based quotient as a percentage index, 1995-2020. With the GDP / capita data, the volume index can be calculated based on the 2010 base, also between 1995 and 2020. Finally, the two indices can be multiplied to give an index of passenger traffic, and the proportions of travel modes can be used to calculate data on public transport (trains, motor coaches, buses, and trolleys) and passenger cars (passenger cars).

$$\frac{\frac{ut_i}{GDP_i}}{\frac{ut_{2010}}{GDP_{2010}}} = \frac{ut_i}{GDP_i} \cdot \frac{GDP_{2010}}{ut_{2010}} = \frac{ut_i}{ut_{2010}} \cdot \frac{GDP_{2010}}{GDP_i} \tag{1}$$

$$\frac{\frac{ut_i}{GDP_i}}{\frac{ut_{2010}}{GDP_{2010}}} \cdot \frac{GDP_i}{GDP_{2010}} = \frac{\frac{ut_i}{ut_{2010}}}{\frac{GDP_i}{GDP_{2010}}} \cdot \frac{GDP_i}{GDP_{2010}} = \frac{ut_i}{ut_{2010}} \tag{2}$$

$$\frac{\frac{ut_i}{GDP_i}}{\frac{ut_{2010}}{GDP_{2010}}} \cdot \frac{GDP_i}{GDP_{2010}} \cdot \frac{split_i}{split_{2010}} = \frac{ut_i}{ut_{2010}} \cdot \frac{split_i}{split_{2010}} \tag{3}$$

No coherent, transparent database was found on passenger traffic data for European Union with long time series.

3. Results – How Demographic Change in Europe has evolved since 1995

In the following, the authors present the development of the population as a whole, then the absolute numbers and growth rates of the young and the elderly, and based on these, the authors show the development of the sustainability rate. The authors examined these factors in different European countries. Finally, authors note the grouping criteria: geographical, economic, policy, EEA countries can be classified. The thirty-one countries surveyed had a total population of 528.5 million in 2020. The number of children (0-14 years old) was 81.9 million and that of young people (0-24 years old) 138.6 million. At the same time, the camp for the elderly (65 years and older) was 107.0 million. The working-age population (15-64 years) thus increased to 339.7 million compared to 1995. The lowest survival rate was 48.8% in 2004, after which it steadily increased to 55.6% by 2020. In 2020, 10 (small countries) of the thirty-one countries surveyed with a population of less than five million. 19.5 million people live in the EEA, or 3.7% of the total population. The number of countries with a medium population (5-20 million people) is the highest: 15. 146.7 million people live in this group of countries, 27.8% of the region's total population. The six large countries, with a population of 362.4 million, accounting for 68.5% of the total population (see Table 1).

Table 1
EEA Member States by Size between 1995/2020, capita

Group/Year	1995	2000	2005	2010	2015	2020
Small Countries	19,532,093	19,349,999	19,274,459	19,547,884	19,366,802	19,542,018
Middle Sized Countries	141,706,979	142,680,319	142,838,210	143,913,428	145,126,788	146,696,478
Large Countries	333,861,945	337,150,752	344,800,695	352,670,941	357,759,874	362,444,709
Sum	495,101,017	499,181,070	506,913,364	516,132,253	522,253,464	528,683,205

Source: Eurostat, own editing

In the course of the visible grouping, we considered the development of partly geographical and partly political aspects. Member countries can be grouped according to their income (economic), geographical location, and historical past. Based on their lowest incomes and historical characteristics, most former socialist countries were grouped. The three small Baltic countries were removed and transferred to the Scandinavian group. The reason for this can be found in historical-economic relations. Similarly, due to the similarity of the historical past, lifestyle, and customs (adherence to a strict rule) and the common language (German), they were transferred to another group of so-called Central European countries (see Figure 1). Germany, Austria, and Switzerland. In the group of southern and western European countries, other countries are classified based on their natural geographical location.
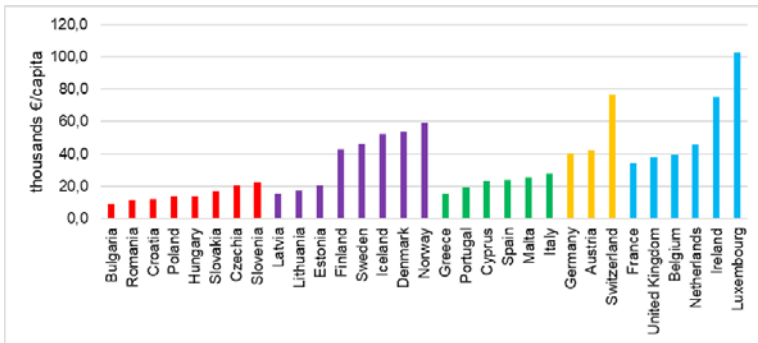

Fig. 1.
GDP per Capita by EEA Member Countries in 2020 at Current Prices (thousand € / capita)
Source: Eurostat, own editing

Eight of the thirty-one countries had a declining population between 1995 and 2020. These are all former socialist countries: the three Baltic and Polish countries, Balkan countries, and Hungary. Together, they have lost 8.2 million people in the last 25 years, a decline of about 9%. The population of five other countries grew by just a tiny 0.6 million people, for 3.4%. This group includes former socialist countries (Slovakia and Slovenia), small countries (Iceland and Malta) and Greece. The population of the other twenty countries increased by 41.2 million people, a total of 10.7% during the period under review. United Kingdom, France, and Spain are the leading countries, with 24.8 million people, or 15.8%. After that, we need to examine how the natural increase or decrease of the population has developed. As the natural fertility rate of women in each country is much lower than 2.1 in the 20 years studied, the population is declining due to natural reproduction. Within these, the situation was similar in the twenty years studied in the countries of southern, central, and western Europe. The value of the index first rose around 2008-2010 and then showed a downward trend again. Western European countries have the highest fertility rates at almost 1.95 (France and Ireland). It is followed by the Scandinavian countries with a value of 0.1, followed by Southern European countries, where the "peak" value (1.50) was measured in Greece in 2009.
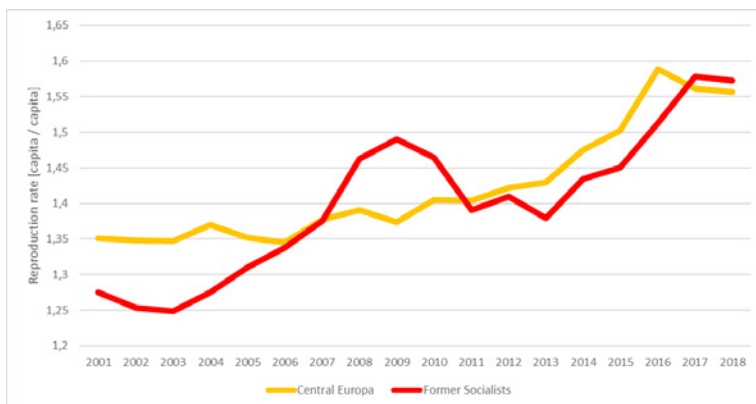
Fig. 2.
Fertility in EEA Central European and Former Socialist Countries 2001-2018, per Capita
Source: Eurostat, own editing

In contrast, the productivity rate in Central Europe and the former socialist countries developed differently (see Figure 2). The group showed an increasing trend between 2001 and 2016 (almost 1.6). From 2016 onwards, it will stagnate. In addition, there was a slight decline in the former socialist countries during the period of significant emigration. Romania (1.78) and the Czech Republic (1.71) peaked in 2016-2017. At the same time, at the end of the period (1.55), Hungary did not even reach the fertility calculated in 1995 (1.57). In Central European countries, however, fertility has been steadily increasing. Germany showed the peak in this group (1.60) in 2016. So, the growing population could only come from an external source through border crossing (Szabó and Sipos, 2022; Sipos *et al.,* 2021). The growing population of the EEA is due to immigration. Therefore (due to the lack of data in France), only data cumulated from 2006 onwards could be compared with population change. United Kingdom has the largest share of the growing population of English-speaking culture, France, and Spain. In addition, even as a result of intra-EEA migration, there is a significant population decline (Romania, Bulgaria, Lithuania) and population growth (Germany, the Netherlands, Sweden).

Migration was negative in the former socialist countries (Baltic countries, Bulgaria, Croatia, Poland, Romania) and the poor countries of southern Europe (Greece and Portugal) (1.9 million people). Particular attention should be paid to the four former socialist countries in the middle (Czech Republic and Hungary, Slovakia and Slovenia), where the total immigration balance from 2008 to 2019 was positive (0.5 million people). In the other EEA Member States (19), an additional population increase of sixteen million was due to immigrants.

The number of children has decreased (9.1 million), with the highest proportion (73%) occurring in the former socialist countries between 1995 and 2020. In addition, it increased by about 13% in Western European countries (Benelux, British Isles and France) (except for the Netherlands, where it decreased slightly).

It decreased slightly in the other countries studied, to less than 0.5% on average per year. Germany, Italy and Portugal recorded the most significant decreases in the latter group. In the age group of young people (15–24 years), the process was similar to that in the child population, where the decline was 12.5 million between 1995 and 2020. There was only one big difference. In Spain, the age group of young people did not increase that of children but decreased very much. In addition, the number of young people in France has fallen sharply, as has that of children. Mention should also be made of the Netherlands, where the number of children in this age group has increased slightly more than that of children. The other countries moved up or down 1-2 positions. Overall, the number of young people has fallen in the former socialist country (by 6.5 million people) and the southern European country (by 5.1 million people). Only the United Kingdom saw an increase in the number of young people (0.4 million), a slight increase in the other eleven countries (less than 0.1 million), but a decrease in nineteen of the thirty-one countries surveyed.

As a result of the above, the young people aged 0-24 decreased by 21.6 million. Only United Kingdom had a significant increase (1.1 million people), with nine countries (Cyprus being the smallest and Sweden the largest) adding another 0.8 million more young people. The other twenty-one countries have seen declines over the past 25 years. Most were absent among young people in Poland (5.2 million), followed by more than one million young people in 2020 than in 1995. The group of working-age people aged 15-64 increased by 8.2 million.

In all former socialist countries (except Slovakia) and Greece, Germany, Italy and Portugal, with 10.2 million people. In the other countries, however, the population of this age group increased by a total of 18.3 million. The largest numbers of working-age people were traditional non-European immigrants in their countries of destination: United Kingdom, France and Spain (12.1 million in the three countries alone) and significant intra-European migration from poorer EEA countries to richer countries, from groups of young students and people of working age. Finally, it should be noted that the significant decline in the number of young people is now strengthening the working-age group. Poland, for example, excels in this. The EEA as a whole is on an ageing trend. The absolute number of people aged 65 and over (34.5 million) and the proportion (+ 5%) of the total population increased. France, Italy and Spain are at the top of the list. These countries also have a high proportion of the elderly population in the total population (20-23%).

The development of the three major age groups in the EEA countries were examined over the past 25 years. As a final result of this study, we can determine how many people an active resident can support in each Member State.

As long as it declines, the sustainability rate is also said by demographic economies to "win the demographic dividend". The proportion of the productive population within the population is growing, and there are fewer and fewer people to support. However, the trend in Europe has been the opposite since 2004, and the total number of dependents per capita is increasing.

4. Analysis – How Changes in European Transport have evolved since 2000

The authors dealt only with passenger traffic, not freight transport. Furthermore, all the characteristics of the countries from which the separate groups could be formed are essential:

Table 2

Increase Passenger Traffic in the Member States of the EEA Continental Regions between 2000 and 2019 (country pcs.)

Increase Interval	Scandinavian and Baltic Countries	Western Europe	Central Europe	South Europe	Former Socialist country	Sum
-10%	1	0	0	1	1	3
11-20%	0	2	1	0	2	5
21-30%	2	1	0	2	1	6
31-40%	1	1	2	0	3	7
41-60%	2	0	0	1	0	3
61-195%	1	0	0	1	1	3
195- %	1	2	0	1	0	4

Note: intervals are not equidistant
Source: Eurostat, own edition

Of course, the effects of the economic crisis that began in 2008 were also visible. The increase in traffic varies widely between countries. Compared to total passenger traffic in 2000, it grew by up to 10% (Lithuania, Italy and Slovakia) and more than 100% (Cyprus, Ireland, Iceland and Luxembourg) by 2019. In addition, twenty-one of the thirty-one countries is evenly spaced between the two lanes, between 110% and 160%, incrementing by 10% points (see Table 2). Of course, the economic crisis that began in 2008 in traffic numbers was also analysed. In different countries and groups of countries, the peculiarities appear in the depths of the crisis and during the period of recovery. However, by the end of the period under review, the values had returned to the longer-term trend in passenger turnover.

The smallest increase in turnover occurred where there is a high density of settlements and populations, a high level of income and consequently GDP) and a high level of motorization. These include the largest countries in Western, Central and Southern Europe, in the continent's centre. At the same time, progress has been significant in peripheral countries over the past 25 years, with the economy and the demand for travel expanding significantly. Income shows a significant increase in the former socialist countries: the average annual growth was 3.6% between 1995 and 2019. This is followed by a group of Scandinavian and Baltic countries with an average annual GDP per capita of 1.9%. The EEA as a whole shows an increase of 1.5%. At the same time, it should be noted that the absolute backwardness was the same in the former socialist countries as the euro per capita (around € 12.8 thousand / per capita) and the second-lowest in the southern European countries (25.0 thousand € / person) between GDP / person. (Primarily because southern European countries have managed

to recover from the economic crisis for a more extended period of time.) The other key factor is motorization. This was led by the growth of the former socialist countries. While the expansion was smaller in the other countries, a large share of the population's income was spent on purchasing cars in Hungary - and the other members of the country group. In that group, the number of cars per thousand inhabitants increased 2.73 times between 1995 and 2018. The increase was highest in Romania: 3.7 times. At the other end of the list is France: a 1.1 increase in cars per thousand inhabitants. Of course, the base is also substantial: in 1995, there were 488 cars per thousand in the group of Central European countries, while there were 279 cars per thousand in our group. The EEA average is 532 cars / thousand people. The lowest in Romania is 357 car / thousand (in the former socialist countries, the average is 510 car / thousand, Poland - 642 car / thousand - is highest), the highest in Luxembourg is 681 car / thousand. In southern Europe and the Scandinavian and Baltic countries, the most prominent groups recorded more than one and a half times as vehicle-kilometre performance by car at the end of the study period as at the beginning.

In contrast, it showed an increase of only about 18% in Central European countries. In Western European and former socialist countries, the increase in vehicle mileage was about 1.4 times between 2000 and 2019. The mileage in Western European countries was about 11% longer than at the beginning of the period. In contrast, in the former socialist countries, the growth of the car fleet was much higher (about + 32%) than the use. Finally, in Central European countries, traffic performance was slightly lower (by 4% points) (112%) than car fleet growth (117%).

The authors have analysed the differences between countries for each mode of transport. Of course, the development of public transport differed from the passenger cars'. In Western and Central European countries, public transport has expanded significantly in regions where the rail network has improved in terms of significant quantity and quality (TGV and other high-speed rail). This includes the fact that car transport can no longer grow due to, for example, too much congestion (central European regions). In most countries, the share of land public transport has been lower in recent years. Furter more the population is significantly ageing (peripheral European regions). In the former socialist countries, the population has fallen sharply, and they are still concentrating on buying cars, which is what a significant part of the population "wants" to buy. However, these call for an even more profound examination of the relationship between the population and public transport.

5. Discussion – How the Links between Demography and Public Transport in Europe have evolved

Analysis of the relationship between young people and public transport has shown that the correlation between transport and age groups is strong. The correlation is positive with young people (94%) and negative (-87%) with older people in Hungary. However, shelf-life ages, i.e., ages 0-14 and 65+, did not correlate (-17%) as they were "quenched" as a result of the two vectors (see Figure 3).
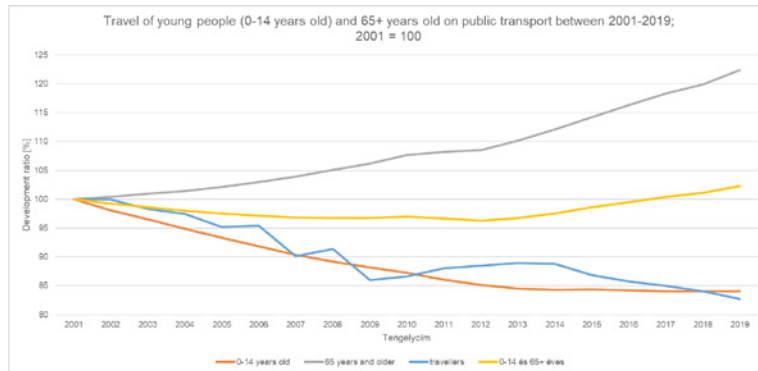
Fig. 3.
Public Transport Number of Trips of the Young (0-14 Years Old) and Older (65+ Years Old)
Population in Hungary between 2001-2019, 2001 = 100%
Source: Eurostat, own editing

The correlation between public transport and the total population and the dependent age group is high and one-way in the Scandinavian and Baltic, Central and Western European countries throughout the period. The strongest coefficients have reached their maximum since 2009. At the same time, the value of the population in southern European countries will continue to decline until 2009. Of course, more fluctuations can be felt in the long time series, but the correlation coefficient is significant. The correlation belonging to the sustainable population age group for the southern European and former socialist countries joined the other European country groups. The trend of the correlation coefficient between the total population and public transport changes. In the former socialist countries, the correlation coefficient for all populations is constantly and rapidly changing, its predictor is changing from positive to negative, and the correlation is becoming stronger.

In addition, the share of public transport in total traffic in the former socialist countries decreasing rapidly: in 1995, it was still 38.0%, while in 2019, it was only 21.2%. Public transport performance was 11.2% (Western Europe) and 19.7% (Southern Europe) in 1995 dropped to 15.1% -16.8%. One hand, this ratio is converging to 0% in other countries. Thus, while we can see a significant change in the proportion of public transport and demography in the former socialist countries, the population does not change such a change in habits in transport. Beyond what we see, southern European countries must join the rest of the world with a high correlation coefficient between the sustainability rate and public transport between 2007 and 2020. Further research may be based on the correlation between the time population and the age groups of sustainable transport and public transport has been stable in other countries (Matijošius *et al.,* 2022; Munkácsy *et al.,* 2022; Miskolczi *et al.,* 2021).

6. Conclusion

In the last decade, neither the population nor the transport has developed in the same way in the different EEA member states and countries. Due to the low natural population growth rate in the studied European region, the increase in the population can only be expected from external sources. The population is growing by millions of people, especially in the English, French and Spanish-speaking countries with historical ties. Nevertheless, the changing trend of Italy and Germany's otherwise very ageing population can also be considered. Smaller countries with high economic levels (Belgium, Ireland, the Netherlands, Norway, Austria, Switzerland and Sweden) are also experiencing significant population growth. The population of the former socialist countries is declining significantly, losing population due to a negative balance. The situation is even worst considering emigration.

However, the population has expanded in the EEA, but the survival rate has risen for more than a decade. Therefore, the travel habits of the population will be different. The change in the number of passengers per capita has increased slightly from 2000 to 2008 but has been constant since then. Public transport has developed similarly. However, the population and the traffic with different means of transport have not developed in the same way in the different EEA member states and countries in the last decade.

There has been a high correlation between population and traffic in different EEA countries and groups of countries with different modes of transport in the last decade. In general, the total population, the population aged 0-14 and 65+, and the population 65+ show a better correlation than the other population groups studied (see Table 3).

Table 3

Correlation Coefficients [%] between Different Modes of Transport and Different Age Groups of the Population during the Period 2009-2020

Name	Public Transport			Passenger Car		
	Sum	0-14 & 65+	65+	sum	0-14 & 65+	65+
Scandinavian and Baltic Country	98%	96%	95%	95%	91%	89%
South European	-57%	-63%	-62%	-26%	23%	36%
Central European	72%	80%	89%	59%	54%	68%
Western European	83%	83%	82%	26%	25%	27%
Former Socialist Country	-87%	94%	93%	-94%	98%	97%

Source: Eurostat, own edition

In most cases, a correlation coefficient of more than 90% can be detected between the population of the sustainability age group and public transport. This is only slightly lower for the Southern and Western European country groups and the 0-14 and 65+ age groups. However, the correlation between population and different modes of transport in southern European countries between 2012 and 2020 is weak. We can usually see a stronger correlation between car travel and different age groups. However, this is due to several factors that could be examined in further research.

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