The Impact of Seasonality on Sensitivity of Frequent and Occasional Motorway Users

Valentino Jakšić

A thesis submitted in partial fulfilment of the requirements of

Sheffield Hallam University

for the degree of Doctor of Business Administration

October 2024

Candidate Declaration

I hereby declare that:

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilist undertaking my research degree.
2. None of the material contained in the thesis has been used in any other submission for an academic award.
3. I certify that this thesis is my own work. The use of all published or other sources of material consulted have been properly and fully acknowledged.
4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy, and ethics approval has been granted for all research studies in the thesis.
5. The word count is 63.050

Name	Valentino Jakšić
Award	Doctor of Business Administration
Date	October 2024
Research Institute	College of Business, Technology and Engineering – Sheffield Business School
Director(s) of Studies	Jia Liu (SHU)
Supervisors	Hanh Song Thi Pham (University of Leeds) Goran Oblaković (ZSEM)

ABSTRACT

This study investigates the impact of seasonality on motorway travel demand and how motorway users' behaviour responds to changes in travel demand in the previous year, toll prices, fuel prices, the Croatian GDP per capita, the European Union GDP per capita, and tourist arrivals in Croatia between summer and non-summer periods. In addition, with a focus on car transactions, this study also distinguishes how different types of motorway users (frequent and occasional motorway users) change their travel demand patterns concerning changes in the explanatory variables throughout the year.

The study employs unique historical traffic and toll price data collected from one of the Croatian motorway concessionaires between 2014 and the end of 2019, with a total sample of 2,520 observations. Using the Weighted Least Squares (WLS) method, this study employs separate models to estimate the elasticities for each type of motorway user and season. Even Chow tests suggest structural differences between models, the results show a significant and positive impact of travel demand in the previous year on travel demand in the current year in all the models. This aligns with the historical records of Croatian motorway traffic and tourist arrivals. The remaining explanatory variables show that frequent motorway users negatively respond to increased fuel prices with higher sensitivity in the non-summer period than in the summer period. Occasional motorway users also exhibit a negative response to the increase in fuel prices on travel demand in the summer, with an insignificant impact during non-summer, indicating other factors may affect travel demand. Unlike extant research's findings, this study's results show that an increase in toll prices positively affects occasional motorway travel demand during the non-summer period. However, the small coefficient magnitude and traffic growth despite toll increases suggest motorway travel demand is weakly responsive to toll prices. The positive relationship may reflect occasional users as more tolerant of higher costs during the season of lower congestion, indicating that tolls have not reached their maximum levels. For robustness checks, the OLS findings are consistent with the WLS results despite heteroscedasticity issues. The remaining tests of GMM, FE, and RE models suggest GMM DIFF method as the most reliable for assessing three models, but with concerns about instrument validity in Model 3.

Besides providing the first evidence of travel demand on the Croatian motorways, the main contribution of this study to the literature and practice is showing that consideration of seasonality is an essential parameter in transportation knowledge since the same type of motorway user has different sensitivities towards travel demand in the previous year, toll and fuel prices during the year. Also, the thesis provides new insight into the importance of separate observation of motorway users by frequency of usage due to their different sensitivity levels concerning changes in explanatory variables.

Keywords: motorway; seasonality; travel demand; elasticity; frequency of usage.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

1.1. Background and motivation

Historically and across cultures, monetary and time budgets have bound people's travel distances and choices (Schafer, 2000). Their choices in the travel and transportation demand revolution impacted various technological innovations such as the introduction of cars and trucks, gasoline and diesel fuels, motorways, and automated vehicles, but also affected different policy measures that modify the activity of travel behaviour (Fouquet, 2012; Hardman et al., 2022; Lehtonen et al., 2022; Xie & Olszewski, 2011). In recent years, there has been increasing interest and studies in transportation demand management that attempt to identify various factors that may influence travel demand, as understanding such factors is crucial in practice for policymakers to affect toll revenues. Although the individual decision for travel may be pretty hard to predict, numerous studies have identified various factors that affect travel behaviour and travel demand and measured those effects using the concept of elasticity (Batarce et al., 2023; Dahl, 2012; Fontes et al., 2015; Goodwin et al., 2004; Litman, 2019; Matas & Raymond, 2003).

According to Fouquet (2012), who studied changes in travel demand between 1850 and 2010, travel behaviour has radically changed, primarily caused by changes in income and transportation prices. These factors have influenced the demand for various modes of travel, including rail, road, and air transport. Over time, with income increases and price reductions, people became less sensitive to the rise in the number of trips they took because of generally higher traffic levels on roads compared to the nineteenth century. Besides income and toll prices, a constant change in fuel prices influences road transport and travel behaviour. Estimates of the toll elasticities may vary across studies because of the specific set of covariates included in the model (Miller & Alberini, 2016). In tourist areas, it is expected that traffic is less sensitive to toll prices than in other areas and sections (Matas & Raymond, 2003). One of the reasons for such a remark is that foreign motorway users, due to a lack of information, have more inelastic demands than frequent motorway users. When travelling, travellers do not consider only tolls. Instead, they also consider the generalised cost (Odeck & Bråthen, 2008). De Borger and Proost (2021) indicate different tools available to local and federal governments to control travel demand on local roads, such as speed bumps, speed limits, and traffic lights, while tolls can affect motorway travel demand. The most commonly used factors widely considered through time in the collected literature are toll price, fuel price, GDP, GDP per capita, the value of time, and alternative toll-free roads (Batarce et al., 2023; Dahl, 2012; Fouquet, 2012; Goodwin et al., 2004; Litman, 2019; Wardman et al., 2016; Wohlgemuth, 1997). In addition, Hintermann et al. (2023) also remarked the negative effect of the COVID-19 pandemic and associated government measures on travelled distances, with gradual recovery during the subsequent re-opening of the economy. However, existing studies are inconclusive about the significance of the influence of each factor on driving demand and the appropriate statistical approach.

The studies discussed above suggest that many factors cause changes in travel behaviour and demand, which vary between countries and observed periods. Understanding travel behaviour and factors influencing traffic and journey length on a motorway is crucial for policy development for tolled motorways and roads in a specific country. Therefore, new findings about the impact of seasonality on motorway travel demand for different user types would enable policymakers and motorway operators to adapt to new conditions and market trends when defining and adjusting toll levels more effectively. In the case of Croatia, which is a country transitioning from a planned economy into a market economy, in recent years, tourist activity during the summer period had a significant impact on Croatian GDP with a share of 19.5% in 2022 (Ministarstvo turizma Republike Hrvatske, 2023), followed by the increase in average motorway traffic levels by +5.42% yearly between 2014 and 2019 (HUKA, 2016; HUKA, 2018; HUKA 2020). For the Croatian economy, where GDP is significantly dependent on tourist activity, understanding what affects motorway travel demand in Croatia is essential, as there is limited knowledge about factors influencing motorway traffic demand in Croatia. Except that studying the case of Croatia contributes new knowledge to the Croatian transporation literature and policymakers, studying Croatia also contributes valuable knowledge to a broader understanding of the explanatory variables in economies undergoing similar transitions, particularly economies with GDP highly dependent on tourism and seasonality. By comprehensively examining the factors influencing motorway travel demand in Croatia, the results and approach also serve as a template for countries navigating similar economic transformations and structural dependencies.

Therefore, this research aims to contribute new knowledge on how motorway travel demand in the previous year, toll prices, fuel prices, GDP, and tourist activity influence motorway travel demand in both summer and non-summer[1] periods, taking the Istrian

[1] Summer period is the observed period from 1 June until 30 September, while non-summer period is the observed period from 1 January until 31 May, and from 1 October until 31 December.

motorway from Croatia as a case study due to the unique historical traffic data collected. As this thesis attempts to confirm seasonality as an essential factor in motorway transportation, the main focus is testing the impact of seasonality on travel demand due to the absence of literature on how seasonality affects frequent and occasional motorway users' behaviour throughout the year.

In addition to providing general evidence on the impact of seasonality and type of traveller on motorway travel demand, it is also essential to contribute new knowledge in the case of the Croatian context due to the absence of literature on Croatian motorway travel demand and seasonality. In the Croatian context, the findings expect to be useful for policymakers to adjust their tolling policy during the higher and lower traffic periods by considering other factors different from tolls. The results also provide a potential for transferable insights and methodological frameworks to economies similar to Croatia with additional checks and data collection.

1.2. Problem identification and research questions

The existing literature that investigates the impact of various explanatory variables on travel demand is not exclusive to factors having the most significant impact on motorway travel demand. Instead, used explanatory variables differ among studies with ranges of coefficients and significance levels, depending on the specified model, type of data, and observed country or region (Acutt & Dodgson, 1995; Batarce et al., 2023; de Grange et al., 2015; Espey, 1997; Gibson & Carnovale, 2015; Gonzalez & Marrero, 2012; Jiwattanakulpaisarn et al., 2009). The common characteristic of the studies from the existing literature is that the elasticity values of each explanatory variable are usually determined in the short-run (one year) and long-run (more than one year) periods, where long-run elasticities are often higher than the short-run, primarily by factors of 2 to 3 times (Hanly et al., 2002; Odeck & Bråthen, 2008). However, the existing literature is missing distinction of elasticity values separately for the different periods of the year, thus omitting the impact of seasonality and changes in motorway traffic throughout the year.

Therefore, this research aims to understand if and how travel demand in the previous year, toll prices, fuel prices, the Croatian GDP per capita, the European Union GDP per capita, and tourist arrivals impact motorway travel demand on the Istrian motorway separately for frequent and occasional motorway users during summer and non-summer periods, testing the impact of seasonality. Even though the usage of explanatory variables differs among the studies, testing the impact of toll prices for frequent and occasional users aims to provide knowledge if tolls on the Istrian motorway have reached maximum levels by the end of 2019, after which level the traffic and revenues begin to fall. Due to availability of data, the thesis observes the fuel price as an explanatory variable, which is often investigated in the literature (Goodwin et al., 2004; Musso et al., 2013; Odeck & Johansen, 2016; Wang & Chen, 2014).

Besides observing the toll and fuel prices as monetary costs for using the motorway, the GDP variable tests the impact of economic activity on motorway travel demand. Even though consideration of national GDP concerning the region of observed motorway network is in accordance with literature (Álvarez et al., 2007; Börjesson et al., 2012; Matajič et al., 2015; Matas & Raymond, 2003), this thesis also observes the European Union GDP as, in period 2014-2019, 88.90% of total tourist arrivals in Croatia were foreign tourists, mainly from the European Union (Croatian Bureau of Statistics, n.d.a). Due to the significant dependence of the Croatian GDP on tourism (Ministarstvo turizma Republike Hrvatske, 2023), variable tourist arrivals is used to measure and understand the impact of tourist arrivals on motorway travel demand. Therefore, the use of GDP and tourist arrivals aims to provide new evidence on how domestic and foreign economic activity affect motorway travel demand.

To fulfill the research aim, the research questions are the following:

- **Research question 1:** Which factors significantly influence the Istrian motorway travel demand of frequent and occasional motorway users during the summer and non-summer periods?
- **Research question 2:** Which factor has the highest impact on the Istrian motorway travel demand of frequent and occasional motorway users during the summer and non-summer periods?
- **Research question 3:** How do seasonality and changes in traffic structure affect motorway travel demand of frequent and occasional motorway users?
- **Research question 4:** What are the recommendations for Croatian policymakers and countries with similar economies to Croatia to manage travel demand on tolled motorways?

1.3. Data description and key findings

This study uses quantitative data from 2014 to 2019 to examine the impact of seasonality on travel demand of frequent and occasional motorway users. The dependent variable is motorway traffic, denoted as VKT (Vehicle Kilometre Travelled), which is based on unique historical transaction data of the Istrian motorway. The Istrian motorway is selected because it provides specific information differentiated by motorway section, user type and season, indicating the presence of significant traffic movements throughout the year.

For the remaining data, the thesis employs lagged motorway traffic, toll prices, fuel prices, Croatian GDP per capita, European Union GDP per capita and tourist arrivals as explanatory variables. For the toll data, the Istrian motorway concessionaire provided historical toll prices for each motorway section, which were further adjusted and expressed in euros per kilometre. In addition, toll prices were separated by vehicle category and payment method, allowing for an in-depth investigation of traffic patterns between frequent and occasional motorway user, as well as variations in toll prices over time.

Historical fuel price data for gasoline and diesel prices in Croatia and the world were collected from GlobalPetrolPrices.com (GlobalPetrolPrices.com, personal communication, June 27, 2021), with distintion to monthly values, further adjusted and expressed in euros per litre. As mentioned in Chapter 2, between 2014 and 2019, most tourist arrivals in Croatia were international visitors, mainly from the European Union. Therefore, in addition to Croatian GDP per capita, European Union GDP per capita data were used, both expressed in euros and extracted quarterly from the official databases of Eurostat and the World Bank. Finally, this thesis uses tourist arrivals as an explanatory variable in this paper, as it is assumed that tourist arrivals can better explain road use than overnight stays by tourists, which do not provide information on travel behaviour during their stay in the accommodation. The Croatian Bureau of Statistics database provided data on the number of foreign and domestic tourist arrivals for each month of each year from 2014 to 2019.

Based on specific models from Chapter 6 that covered different types of motorway users and periods of the year while using the same explanatory variables, the results showed that seasonality has an impact on motorway travel. However, the effects are different for occasional and frequent users. The estimated elasticity values showed a positive impact of travel demand in the previous year on travel demand in the current year in all models, which is consistent with the historical records of Croatian motorway traffic and tourist arrivals. In addition, the study shows that frequent motorway users react negatively to higher fuel prices, with higher sensitivity in the non-summer period than in the summer period. Occasional motorway users also react negatively to fuel price increases in the summer, while having no significant impact in the non-summer, indicating that other factors influence travel demand. Even with a modest elasticity value, the results of this study suggest that an increase in toll prices has a positive effect on demand for occasional motorway travel in the non-summer period, which unusual finding in the literature is further discussed through this thesis.

1.4. Contributions

1.4.1. Focus of existing literature

Based on the previous sub-chapters, this thesis adds to the literature and practice by filling gaps in the existing research on motorway travel demand. This study, in particular, builds on previous research by investigating the impact of various explanatory variables on motorway travel demand while considering the moderating impact of seasonality and user segmentation by frequency of motorway usage.

The existing international studies have investigated the determinants of motorway travel demand by estimating elasticity values for various explanatory variables. The literature has focused on estimating short-run and long-run elasticities (e.g., Gonzalez & Marrero, 2012; Odeck & Johansen, 2016), with distinctions based on vehicle types such as light and heavy vehicles (e.g., Gomez & Vassallo, 2015; Gomez et al., 2016; Matajič et al., 2015) and number of axles (e.g., Batarce et al., 2023; Burris & Huang, 2011).

Regarding overview on the country level, in Spain, studies indicated that travel demand is more responsive to GDP changes than to variations in gasoline prices and tolls (Matas & Raymond, 2003). Other studies identified sector-specific GDP and employment levels as important determinants of travel demand for heavy and light vehicles (Gomez & Vassallo, 2015; Gomez et al., 2016), while Gonzalez and Marrero (2012) emphasised the importance of using appropriate estimation methods for induced demand analysis. Similarly, Bakhat et al. (2015) evaluated fuel price response during economic crisis, while Alvarez et al. (2007) used stated preference methods to assess the value of time savings.

In Norway, Odeck and Bråthen (2008) estimated elasticity values for 19 Norwegian road projects, considering generalised transport costs, household income, and toll rates, noting significant variability in user responses. Odeck and Johansen (2016) further explored fuel and travel demand elasticities, emphasizing the importance of rebound effects in policy considerations. Chilean research has focused on price elasticities in Santiago, demonstrating that highways with more alternative routes exhibit higher elasticity to tolls (de Grange et al., 2015), although economic growth is the primary variable explaining the increase in traffic flows (Batarce et al., 2023).

In the United States, Burris and Huang (2011) studied the effect of gasoline prices on travel demand for 12 tolled roads and discovered generally inelastic and negative responses. Cervero (2012) examined the effects of variable pricing on the San Francisco-Oakland Bay Bridge, highlighting shifts to alternative transport modes in response to toll increases. In California, Gillingham (2014) researched consumer responses to gasoline price changes, demonstrating that income levels influence vehicle usage patterns. Although fewer number of studies, several studies have also examined the sensitivity of travel demand, including Australia, France, Germany (Bastian et al., 2016), Italy (Gallo, 2011; Gibson & Canovale, 2015), Slovenia (Matajič et al., 2015), and the United Kingdom (Dargay, 2007; Dunkerley et al., 2020).

Regarding Croatia, the literature on travel demand is scarce. Instead, previous research has focused primarily on tourist demand rather than motorway use, even though a significant proportion of tourists travel to Croatia by car (Croatian Bureau of Statistics, n.d.b). Previous studies have examined factors influencing tourism, highlighting the importance of income levels in tourists' home countries, exchange rates and geopolitical instability, particularly the impact of war-related disruptions (Mervar & Payne, 2007; Payne & Mervar, 2002). In forecasting models for overnight stays in Croatia, macroeconomic indicators in Poland, the Czech Republic and Slovakia were identified as important predictors of tourism demand (Tica & Kožić, 2015). Studies on the elasticity of tourism have also shown that long-run income changes in certain European Union countries have a significant influence on Croatian tourism flows (Belullo & Křižman, 2000). However, Škrinjarić (2011) found that tourism demand is inelastic in terms of income and reacts more strongly to changes in relative prices. The issue of seasonality was also highlighted, with Croatia having a high seasonal concentration compared to other Mediterranean destinations due to the limited year-round utilisation of hotel capacity (Kožić, 2013). Čorluka (2018) suggested off-season tourism activities, the promotion of business tourism and targeted marketing strategies to address the problem of seasonality.

1.4.2. The importance of seasonality in motorway travel demand analysis

While prior research has examined the sensitivity of travel demand across different countries, they have not conclusively identified the unique factors influencing motorway travel demand. The explanatory variables used in these studies vary, with research in Croatia focusing primarily on tourism demand rather than motorway travel demand. While some studies distinguish between vehicle types (e.g., Burris & Huang, 2011; Matajič et al., 2015), the moderating effect of seasonality on travel demand of frequent and occasional motorway users has been disregarded. As a result, this thesis fills a gap by explicitly assessing the impact of seasonality on motorway travel demand using a consistent set of explanatory variables and analysing their effect over summer and non-summer periods. The findings highlight seasonality as important component in determining toll strategies and understanding motorway travel demand. This study differs from previous studies which only provide general short-run and long-run elasticity values (e.g., Gomez et al., 2016; Gonzalez & Marrero, 2012; Goodwin et al., 2004; Litman, 2019; Matas & Raymond, 2003; Odeck & Bråthen, 2008), offering a more precise approach for assessing demand fluctuations based on seasonal variations.

1.4.3. Distinguishing between frequent and occasional motorway users

In addition to measuring the impact of seasonality, this study is also unique as it separates users based on their frequency of motorway usage (users who pay for tolls manually with a tolling ticket and users who pay electronically with an on-board unit), which evidence is lacking in the existing literature. As a result, this thesis indicates that distinguishing between the movements of frequent and occasional motorway users is an important contribution due to their varying travel patterns throughout the year. Based on data acquired directly from the Bina-Istra Jsc company for the period of 2014 to 2019, on average, 58.75% of total occasional user traffic was associated with the summer period due to motorway traffic seasonality and the potential link to tourist activity in Croatia. The precise differences in travel patterns in Croatia and the Istrian motorway are discussed in Chapter 2.

1.4.4. Implications for research and policymakers

The findings of this thesis provide valuable insights for both literature and policymakers in different countries and scenarios with traffic seasonality similar to Croatian. The study provides a significant contribution by incorporating seasonality and user distinction into motorway travel demand analysis, providing new theoretical and practical insights into the need of using a tailored approach in travel demand research. This thesis informs policymakers in Croatia and other similar economic countries about the potential need for seasonally adjusted tolling strategies based on the season, frequency of motorway usage, and changes in explanatory factors. Also, considering the absence of elasticity estimates for motorway travel demand in Croatia, this thesis provides new evidence on how motorway travel demand in the previous year, toll prices, fuel prices, Croatian and European Union GDP, and tourist arrivals affect travel demand on the Istrian motorway.

1.5. Thesis structure

As this thesis observes the Istrian motorway as a case study to provide contributions to the literature and practice, Chapter 2 represents a review of the main characteristics of the Croatian motorway companies and historical changes in Croatia. The aim is to briefly show historical changes in motorway traffic patterns, structure, and payment means while highlighting the Istrian motorway trends. Chapter 2 also shows movements of the Croatian GDP compared to the European Union's GDP, together with historical patterns of fuel prices and trends in tourist activity in Croatia and Istrian County.

Chapter 3 discusses the methods used to collect the literature for this study. The chapter reviews the collected literature and findings, including elasticity values concerning explanatory variables observed in this study. This chapter shows historical literature findings on how changes in toll prices, fuel prices, GDP, income, and tourist activity influenced travel demand in different countries and what are the obtained elasticity values. Based on that, this chapter provides literature gaps and serves as a base for investigating the impact of seasonality for frequent and occasional motorway users, as well as how each explanatory variable impacts motorway travel demand on the Istrian motorway, Croatia.

Drawing on the literature review, Chapter 4 develops the conceptual framework to investigate how used explanatory variables impact frequent and occasional motorway travel demand caused by seasonality throughout the year. To test the impacts, this chapter formulates various hypotheses based on the literature's empirical findings and observations of collected data, whose usage is further examined through a discussion of the empirical model in Chapter 5.

In addition, Chapter 5 also reviews different research philosophies and argues usage of a particular research philosophy in this thesis to establish research questions, define an approach to collecting the data, and conduct the research. This chapter also represents a summary of applied research method, approach of data collection, and analysis to test the importance of seasonality and how different types of motorway users react to changes in determined explanatory variables.

Chapter 6 represents data analysis and results. The chapter also indicates the research problems, summarises the findings of the thesis, and discusses the results' implications.

In conclusion, Chapter 7 provides an overview of the research and answers the research questions. Based on the obtained results, this chapter briefly summarises the main contributions to the literature and practice, and highlights limitations as suggestions for further research.

CHAPTER 2. RESEARCH CONTEXT OF CROATIA

2.1. Introduction

Before testing the impact of seasonality on motorway travel demand and valuing how frequent and occasional motorway users react to changes in determined explanatory variables between summer and non-summer periods, this chapter introduces characteristics and historical pieces of information about the Croatian motorway companies and networks. The sub-chapter 2.2., Why Croatia?, briefly summarises the key academic and practical reasons why conducting a study in Croatia is important. The sub-chapter 2.3., Croatian Motorway Network, examines the characteristic details related to the historical evolution and construction of the Croatian motorways, including tolling systems and means of payment applied to the Croatian motorways. It describes the classification and characteristics of vehicle categories in Croatia, as the thesis tests the sensitivity of motorway travel demand on only one vehicle category: cars. To perform the tests, unique historical motorway transaction data was collected from the Istrian motorway concessionaire for the period between 2014 and 2019, representing one of the three Croatian motorway companies further described in the next sub-chapter.

Besides introducing crucial characteristics of the Croatian motorway network, Chapter 2 shows fluctuations in traffic levels between summer and non-summer. Such traffic fluctuations and inconsistency during the year indicate the presence of motorway traffic seasonality. Therefore, the thesis tests if the impact of each explanatory variable differs between summer and non-summer periods, separately for frequent and occasional motorway users. Furthermore, this chapter also summarises the critical statistical data on tourist activity, GDP, and fuel prices in comparison to international data where available. Providing an overview with identified differences and similarities in historical trends between Croatia and the world is valuable, as this thesis aims to provide new knowledge to the literature and practice not only for Croatia but also on an international level.

Based on the previous, the aims of this chapter are to:

- Show why conducting a study on the case of Croatia is important;
- Present an overview of the Croatian motorway network and companies, means of payment, traffic structure, and tolling policy with a focus on the Istrian motorway due to the application of historical transaction and toll price data in this thesis;

- Highlight historical traffic movements on the Croatian motorways with an additional presentation of traffic movements on the Istrian motorway through the year to indicate the presence of traffic seasonality between different vehicle categories;
- Show that motorway traffic levels vary through the year and that travel patterns between frequent and occasional motorway users differ;
- Represent historical movements of fuel prices and GDP values to show that their historical movements in Croatia were not radically different from international levels;
- Show the habits of domestic and foreign tourist arrivals in Croatia through time, as tourist activity represented a 19.5% share of the Croatian GDP in 2022 (Ministarstvo turizma Republike Hrvatske, 2023) with, on average, 73.98% of total tourist arrivals occurred during the summer period between 2014 and 2019 (Croatian Bureau of Statistics, n.d.a.).

2.2. Why Croatia?

With its extensive motorway network, continual increase in traffic levels, and reliance on tourism, Croatia represents a unique and compelling case for studying the impact of seasonality on motorway usage. For the Croatian economy, where tourism accounts for almost a 20% share in GDP (Ministarstvo turizma Republike Hrvatske, 2023), understanding what affects motorway travel demand is essential for both practical and academic reasons.

Based on historical data presented in Chapter 2, Croatian motorway traffic shows significant seasonal fluctuations, especially between the summer and non-summer periods. In the summer months, records show a significant increase in traffic volumes, tourist arrivals and cross-border transits. This trend indicates that Croatia is a major tourist destination. In addition, economic indicators such as Croatian GDP per capita and fuel prices tend to increase during the summer months, which may have an impact on motorway travel demand. In the case of the Istrian motorway, historical figures from 2014 to 2019 show that occasional users were more active during the summer, accounting for 58.75% of total annual traffic. This increase occurred despite the introduction of temporary toll increases of +10% during the summer months. In contrast, frequent motorway users maintained their monthly travel behaviour throughout the year, indicating that their travel behaviour is less influenced by the season.

From an academic perspective, the literature on travel demand specific to Croatia is limited. Croatian literature has primarily focused on understanding factors influencing tourism demand, rather than motorway usage, despite Croatia being a primarily autodestination country (Croatian Bureau of Statistics, n.d.b). Prior studies that investigated factors that influence tourism highlighted the importance of income levels in tourists' home countries as a key predictor of tourism demand, followed by exchange rates and geopolitical instability (Mervar & Payne, 2007; Payne & Mervar, 2002; Tica & Kožić, 2015). The research on tourism elasticity also indicated that long-run income changes in particular European Union countries significantly influence Croatian tourism flows (Belullo & Križman, 2000). Škrinjarić (2011) found that tourism demand is inelastic with respect to income and responds more intensely to changes in relative prices. The issue of seasonality in tourism has been highlighted with higher seasonal concentration in Croatia during the summer compared to the other Mediterranean destinations due to limited year-round utilisation of hotel capacity (Kožić, 2013). To address seasonality concerns, Čorluka (2018) proposed off-season tourist activities, business tourism promotion, and targeted marketing strategies.

Therefore, examining the moderating impacts of seasonality and traveller type on motorway use is critical for several reasons. Seasonal variations in motorway use, cross-border road traffic, tourist arrivals, and GDP can significantly affect traffic volumes, toll revenues, road safety, and environmental implications due to increased emissions from road transportation. By examining these seasonal trends, policymakers can determine specific tolling strategies to optimise traffic flow and influence toll revenues, road safety and environmental issues in different seasons. Due to differences in travel habits, assessing the sensitivity of frequent and occasional users to changes in toll prices, fuel prices, GDP and tourist arrivals also allows for a more nuanced analysis of motorway use. By observing the effects of different explanatory variables on travel demand on the Istrian motorway, this thesis aims to fill an academic and practical gap by providing the first comprehensive evidence on the role of seasonality. Studying Croatia also contributes valuable knowledge to a broader understanding of the explanatory variables in economies undergoing similar transitions, particularly economies with GDP highly dependent on tourism and seasonality. Furthermore, by examining its importance in accounting for different types of travellers by providing elasticity values for occassional and frequent users, it contributes not only to the Croatian but also to the international literature by highlighting seasonality and the type of motorway users as important factors in travel demand.

2.3. Croatian motorway network

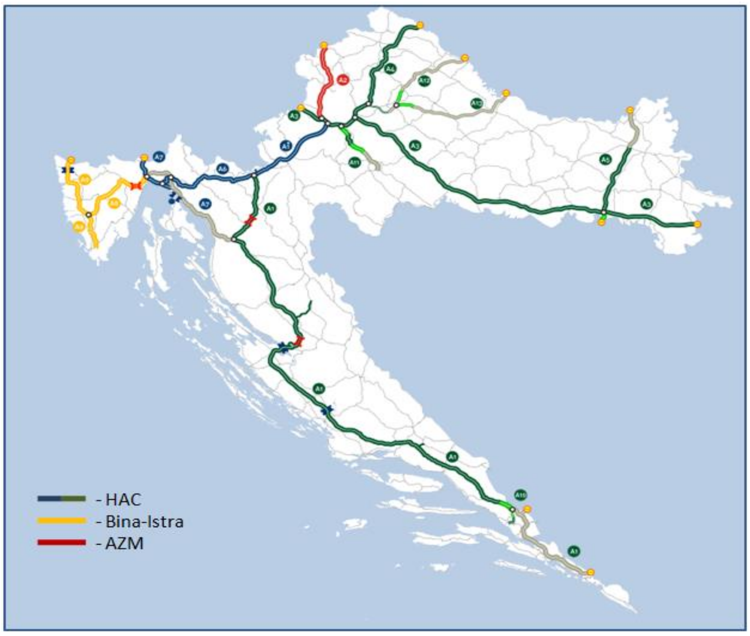
Construction of the existing Croatian motorway network, with a total length of 1,306.53 km in 2019 (HUKA, 2020), was performed in several phases to attract more tourists to Croatia. The state built the first part of the motorway network, Zagreb-Karlovac and Rijeka-Grobnik, with a length of 48 km, at the beginning of the 1970s. Accelerated motorway construction began with the Croatian Public Road Construction and Maintenance Programmes from 2001 to 2004 (402.1 km) and 2005 to 2008 (258.4 km). In the last two Public Road Construction and Maintenance Programmes between 2009–2012 and 2013–2016, a slowdown in the expansion of the Croatian motorway network has been present (ASECAP, n.d.). However, in the Istrian region, where a public-private agreement is in force between the State and Bina-Istra Jsc for the Istrian motorway with a total length of 141.00 km, extensive works on 17 km of the motorway were conducted in the period from November 2018 to mid-2021. The remaining sections became part of the complete motorway profile with tolls on September 25, 2021. The works aimed to improve traffic flow, safety, and minimise traffic congestion, especially during the four months of the summer period. According to data collected from Bina-Istra, on average, 51.01% of total yearly motorway traffic was realised in the summer period between 2014 and 2019.

Since 1991, Croatian Governments have applied various ownership models to build a modern motorway network, among which is a concession model with a public-private partnership (ASECAP, n.d.). Therefore, a particular share of the Croatian motorway network falls under the public-private partnership model defined by Concession Agreements. According to the latest data collected from HUKA (2023), three motorway companies manage the total network length in Croatia as follows:

- Autocesta Zagreb-Macelj Ltd. (AZM) = 60.00 km;
- Bina-Istra Jsc (Bina-Istra) = 141.00 km;
- Hrvatske autoceste Ltd. (HAC) = 1,105.53 km.

Figure 2.1.

The Croatian motorway network



Note: Adapted from HUKA (2023).

Autocesta Zagreb-Macelj Ltd. (AZM) is part of the motorway network in Croatia. Located in the European traffic corridor Xa and Pyhrn motorways, it connects Croatian motorways with the European motorway network (Autocesta Zagreb-Macelj, n.d.). The company was established on March 27, 2003, by the Government's decision to finance, build, operate, and maintain the motorway network between Zagreb and Macelj, with a total length of 60.00 km. Under the model of a public-private partnership, the Republic of Croatia has a company share of 49% and Pyhrn Concession Holding GmbH has 51%. According to data from the official website of Autocesta Zagreb-Macelj Ltd, the company is under a concession agreement signed on July 11, 2003, between the Republic of Croatia and the company Autocesta Zagreb-Macelj Ltd, which has acquired exclusively the right to develop, design, finance, build, operate, and maintain the motorway and all facilities for 28 years, until 2032.

Hrvatske autoceste Ltd. (HAC) is a state-owned company established on April 11, 2001, to operate, build, and maintain the Croatian motorway network, except for those managed by the concession companies Autocesta Zagreb-Macelj Ltd. and Bina-Istra Jsc (Hrvatske autoceste, n.d.). HAC merged with Autocesta Rijeka-Zagreb Jsc on January 1, 2020, due to a decision of the Government of the Republic of Croatia to reform the road sector and restructure road companies to achieve cost optimization (Ministarstvo mora, prometa i infrastrukture, 2020).

Bina-Istra Jsc (Bina-Istra), whose historical traffic and toll price data have been collected and used for this study, has been the concessionaire of the Istrian Motorway since 1995 based on the Concession Agreement with the Republic of Croatia and represents the first kind of public-private partnership in Croatia (Bina-Istra, n.d.a). The company's main activities are the design, financing, construction, operation, and maintenance of the motorway network, with a total length of 141.00 km. The Istrian motorway connects the city of Pula with the town of Umag and the city of Rijeka, where the central part of the motorway expands through the County of Istria and the Primorsko-Goranska County. According to collected data from the Bina-Istra tolling system, in the record year of 2019, the Istrian motorway registered 10.6 million transactions, with summer peaks of over 60,000 vehicles per day.

2.4. Payment means on the Croatian motorways

The existing Croatian toll network applies two tolling systems: open and closed tolling systems. The open tolling system represents the system where the toll plaza serves as both entry and exit, charging toll transactions to each class of user passing the toll station. In the case of Croatia, just two shorter motorway sections apply an open tolling system: toll stations Rupa and Bregana, which are in charge of HAC (HUKA, 2023). Unlike the open tolling system, the closed tolling system on the Croatian motorways represents the most usual way to pay the tolls. In a closed system, at the entrance to the motorway, the user takes the entry ticket, or the system records the entry of the ENC (on-board) device, and the payment is made at the exit toll station based on the length travelled. The tolls paid at the exit plaza are calculated per vehicle category and travelled distance of the motorway between the entry and exit toll plaza, where all vehicle classes are subject to tolling.

Under provisions of the European Parliament and of the Council on charging of heavy goods vehicles for the use of certain infrastructures (Directive 1999/62/EC) and its amendments (Directive 2006/38/EU; Directive 2011/76/EU), the Croatian ordinance of toll regulations (Pravilnik o cestarini NN 130/2013) and its amendments (Pravilnik o cestarini NN 122/2014; Pravilnik o cestarini NN 96/2017; Pravilnik o cestarini NN 151/2022) prescribe a methodology for toll price determination, construction costs, financing costs, infrastructure charges, and vehicle categories for toll collections.

By that, there are five vehicle categories.

Table 2.1.

Vehicle category categorization

Vehicle category	Description
IA	Motorcycles, motorised tricycles and quads
I	Motor vehicles with two axles of a height of up to 1.90 m
II	a) Motor vehicles with two axles, of a height of more than 1.90 m, whose maximum weight does not exceed 3,500 kg b) motor vehicles with two axles, of a height less than 1.90 m, regardless of the number of axles and height of the trailer
III	a) motor vehicles with two or three axles, whose maximum allowable mass exceeds 3,500 kg, towing a trailer with one axle b) motor vehicles with two axles, whose maximum allowable mass exceeds 3,500 kg, towing a trailer with one axle c) motor vehicles belonging to vehicle category II a) towing a trailer, regardless of the number of axles of the trailer
IV	2.1st motor vehicles with four or more axles whose maximum allowable mass exceeds 3,500 kg 2.2nd motor vehicles with two axles, whose maximum allowable mass exceeds 3,500 kg, towing a trailer with two or more axles 2.3rd motor vehicles with three axles, maximum allowable mass exceeds 3,500 kg, towing a trailer, regardless of the number of axles of the trailer

Note: Adapted from Pravilnik o cestarini NN 130/2013.

According to Pravilnik o cestarini NN 130/2013, the tolls vary between each vehicle category and depend on the distance between two tolling sections and the unit price per kilometre. The unit price per kilometre can differ among each motorway section, and the toll discount is based on the tariff policy of each Croatian motorway company. Toll discounts differ among motorway companies. At Bina-Istra and HAC, toll discounts are applied with ETC subscription models, while on AZM, toll discounts are applied with Smart cards as the tolling system of AZM does not support ETC as payment means (Autocesta Zagreb-Macelj, n.d.; Bina-Istra, n.d.b; Hrvatske autoceste, n.d.).

An electronic toll collection system (ETC or ENC) is a programmable remote automatic vehicle identification system that uses microwave technology to identify the presence of a vehicle in the toll lane. It is used to automatically charge the ENC account for travelling on the motorway road section, usually by using traditional technology classified as a Dedicated Short Range Communication (DSRC) system, as the tag installed in the vehicle in this system communicates only with the roadside unit (RSU) (Hensher, 1991; Lee et al., 2008). The charging procedure in the ENC system considers using the on-board unit encoded into the ENC account with a dedicated toll price list placed on the vehicle's front windscreen. The benefits of applying the ENC system are increasing the capacity of toll plazas by reducing the time of toll payment, increasing the safety of travellers, and minimizing air pollution and fuel consumption (Lee et al., 2008). It also impacts the reduction of operation and staff costs for motorway operators and generally aims to improve traffic flow and reduce congestion. In their study, Levinson and Chang (2003) found that the fixed cost of the tag is the most essential item for using the ENC system.

Generally, the ENC subscription represents two models: prepaid and postpaid. In the prepaid model, after the user opens the ENC account, it is necessary to top up the account with the particular funds. Each time the user conducts the transaction based on the toll price determined by the toll operator for each motorway section, travelled distance, and vehicle category, the funds are reduced from the ENC account. In the context of Croatian motorway companies, Bina-Istra and HAC provide ENC prepaid packages, which offer different toll discounts using ENC prepaid subscription models and tag prices. As Bina-Istra and HAC are separate companies, the interoperability of the ENC prepaid system does not exist. Instead, an on-board device purchased at Bina-Istra has to be encoded at the point of sale of HAC, open an ENC account, and top up the account before using the device at HAC motorway sections. This process is applied, and vice versa as well. Based on that, the choice between manual ENC payments depends on the out-of-pocket cost and the time associated with each alternative (Levinson & Chang, 2003). It includes the one-time fixed cost of purchasing an ENC on-board device, the frequency of motorway usage, the convenience associated with avoiding cash or tickets, and the toll agency or motorway company making the on-board device available.

Even if ENC interoperability did not exist in prepaid models between Bina-Istra and HAC until the date of issuing this study, postpaid interoperability has been available since August 2020. The ENC postpaid model at Bina-Istra and HAC enables motorway users to use the on-board device to travel the motorway with the usage of the ENC system, where for each ENC transaction, the bank card or petrol card is debited based on the toll price determined by the toll operator for each motorway section (travelled distance and vehicle category). Before usage of the ENC postpaid model, the user has to purchase the on-board device, open an ENC account, and link a valid bank or petrol card to the ENC account, debited for each transaction realised on Bina-Istra and HAC motorway sections. As the tolling system of AZM does not support the ENC system, the motorway company provides the prepaid model with a Smart card applicable only to the motorway network of AZM, with a deduction of funds paid in advance for each transaction with the application of the appropriate amount of toll discount. Even if using traditional manual toll payment with an entry ticket does not require any additional costs for the user, the usage of ENC causes lower air pollution, a reduction in travel times between toll plazas, and a reduction in operating costs due to increased traffic flow (Jou et al., 2012; Peters & Kramer, 2005).

Besides the previously mentioned electronic payment models, motorway users on the Croatian motorways also have the option to pay for tolls on all motorway sections in cash or by bank card. Conduction of toll payment by using an entry ticket at the full price is further named in this thesis as "Full price" or “occasional motorway users”. In this payment model, the user at the entry toll plaza manually collects the entry ticket encoded with information about the entry toll plaza, which ticket is given to the cashier or inserted into the automatic payment machine at the exit toll plaza. In that case, the toll operator charges the user for travelled distance and by vehicle category. Based on previously examined means of payment on the Croatian motorways (ENC and Full price), it is essential to remark that Bina-Istra provided unique historical motorway traffic and toll data of ENC and Full price users, further examined in sub-chapter 2.5., Traffic. This thesis uses obtained data to investigate the impact of seasonality on the relationship between determined explanatory variables and motorway travel demand, taking the Istrian motorway as a case study.

Due to traffic levels in the summer period and the requirement for additional employee engagement and increase of operating costs, starting on June 1, 2015, based on the approval of the Republic of Croatia, every year on the Istrian motorway network for all vehicle categories, a seasonal toll increase of +10% is applied exclusively to regular toll prices (Full prices). The toll increase has been applied each year in the period from June 1 until September 30, while for ENC users, such a measure is not applied. On the motorway network of HAC and Autocesta Rijeka-Zagreb Jsc[2], as a part of a project launched by the Ministry of Sea,

[2] Autocesta Rijeka-Zagreb merged with Hrvatske autoceste on 1 January 2020.

Traffic, and Infrastructure in cooperation with the World Bank for financial restructuring of companies in the transport sector (Hrvatske autoceste, n.d.), a 10% summer toll increase was introduced in the following periods:

- From July 1 until September 30, 2017, applied exclusively to the I and IA vehicle categories;
- From June 15 until September 14, 2018, applied exclusively to I, IA, and II vehicle categories;
- From June 15 until September 14, 2019, it was applied exclusively to the I, IA, and II vehicle categories.

Therefore, for the purpose of this thesis, the Full price transaction data is used to test the impact of explanatory variables on occasional motorway users on the Istrian motorway. In the period between 2014 and 2019, full price transactions represented 65.84% of total realised transactions on the Istrian motorway, suggesting as the main mean of toll payment.

Regarding ENC subscription packages, as the tolling system of the Istrian motorway company provided unique collected data for this study, there are four ENC subscription packages (Bina-Istra, n.d.b):

- **ENC Plus (prepaid model):** applicable to all vehicle categories, where Category I, IA, and II receive up to a 50% toll discount on tunnel Učka and a 30% toll discount on all other motorway sections, valid for 90 days. Category III and IV provide up to a 40% toll discount on transactions through Tunnel Učka and a 30% toll discount on all other motorway sections, valid for 120 days. According to Bina-Istra, this model is suitable for frequent motorway users;
- **ENC Easy (prepaid model):** applicable to all vehicle categories and offers a 10% toll discount on all motorway sections of the Istrian motorway without validity limitation. According to Bina-Istra, this model is suitable for occasional motorway users;
- **ENC No Limit (prepaid model):** applicable to Category I and II and offers unlimited usage for transactions on the tunnel Učka, but without toll discount on the rest of the motorway sections. This package is valid for one calendar month and, according to Bina-Istra, is suitable for users that frequently travel through the tunnel Učka;
- **ENC Next (postpaid model):** applicable to all vehicle categories and offers no toll discount with a charging bank card or petroleum card for each transaction. According to Bina-Istra, this model is suitable for occasional motorway users.

As the ENC Easy package was introduced on June 1, 2015, observing historical ENC traffic data in the period June 1, 2015–December 31, 2019 shows that ENC Plus traffic represented 97.30% of the total realised ENC traffic, followed by the ENC Easy package at 2.70%, while the combined traffic of ENC Next and No Limit was less than 1%. Therefore, this study uses historical data from ENC Plus to test the impact of explanatory factors on frequent motorway users. The thesis further refers to the ENC Plus transactions as "frequent users". The aim of using the ENC Plus historical data is to understand the sensitivity of frequent motorway users during the summer and non-summer periods to changes in travel demand in the previous year, toll prices, fuel prices, GDP values, and tourist activity. It is important to note that this thesis does not take into account the potential impact of the introduction of the ENC Easy, ENC Next, and ENC No Limit packages on motorway travel demand due to their low share of total transactions. In addition, the ENC No Limit package is applicable only on crossings through tunnel Učka. Also, policies regarding toll discounts and conditions for usage of all ENC packages have not changed in the period observed in this thesis.

2.5. Traffic

This sub-chapter represents an overview of historical traffic movements and vehicle structure on the Croatian and European motorways. The sub-chapter also focuses on a detailed presentation of the Istrian motorway historical traffic data to show differences and similarities in travelling patterns through the year among each vehicle category and by frequency of motorway usage.

According to collected data between 2010 and 2019 (HUKA, 2012; HUKA, 2014; HUKA, 2016; HUKA, 2018; HUKA, 2020), 78.86% of total motorway transactions in Croatia were realised at the HAC and ARZ networks, 11.82% at the Bina-Istra network (which data is used as a case study for this thesis), and the fewest transactions were realised at the AZM network (9.32%). These details are expected, as HAC has the most extensive motorway network of 1,105.53 km, while AZM manages a network of 60.00 km.

Table 2.2.

The historical traffic on the Croatian motorways 2010-2019

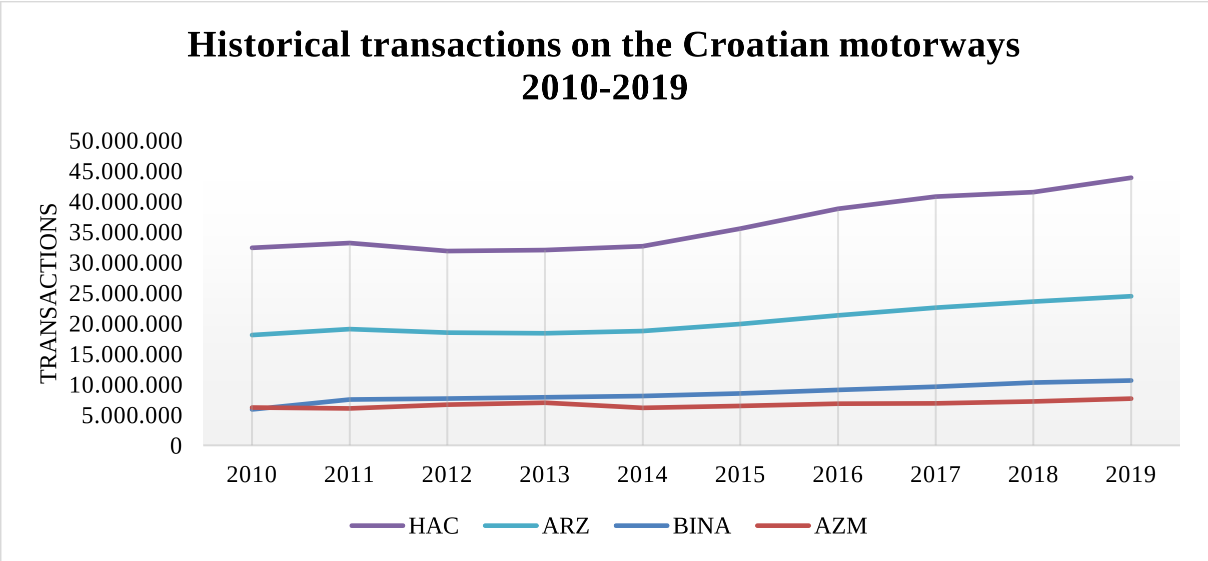
	Light + Heavy vehicles (in million transactions)									
Company	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
HAC	32.41	33.19	31.88	32.04	32.65	35.57	38.82	40.82	41.56	43.90
ARZ	18.10	19.04	18.49	18.39	18.74	19.90	21.34	22.59	23.58	24.46
Bina-Istra	5.89	7.51	7.65	7.86	8.10	8.49	9.07	9.60	10.29	10.63
AZM	6.18	6.05	6.69	6.99	6.17	6.44	6.81	6.89	7.18	7.66
TOTAL	**62.58**	**65.79**	**64.71**	**65.28**	**65.66**	**70.40**	**76.04**	**79.90**	**82.61**	**86.65**

Note: Adapted from HUKA (HUKA, 2012; HUKA, 2014; HUKA, 2016; HUKA, 2018; HUKA, 2020).

Even if motorway traffic volume differs among the companies due to geographical position and total length of their motorway network, the upward slope of the curves from Figure 2.2. shows a positive trend of yearly traffic growth for all Croatian motorway companies in period between 2010 and 2019.

Figure 2.2.

Historical transactions on the Croatian motorways 2010-2019



Note: Adapted from HUKA (HUKA, 2012; HUKA, 2014; HUKA, 2016; HUKA, 2018; HUKA, 2020).

With a focus on the period between 2014 and 2019, Table 2.3. shows that average annual traffic movements on the entire Croatian motorway network increased by +5.42%. HAC recorded the most significant traffic changes, with an average yearly growth of +6.14%, followed by Bina-Istra growth of +5.60%. These results are expected, as HAC has significantly the most extensive motorway network in Croatia. The historical records suggest that average yearly traffic movements among motorway companies did not deviate significantly from the average yearly growth, indicating similar patterns in traffic movements on the entire Croatian motorway network.

Table 2.3.

Changes in traffic levels 2014-2019

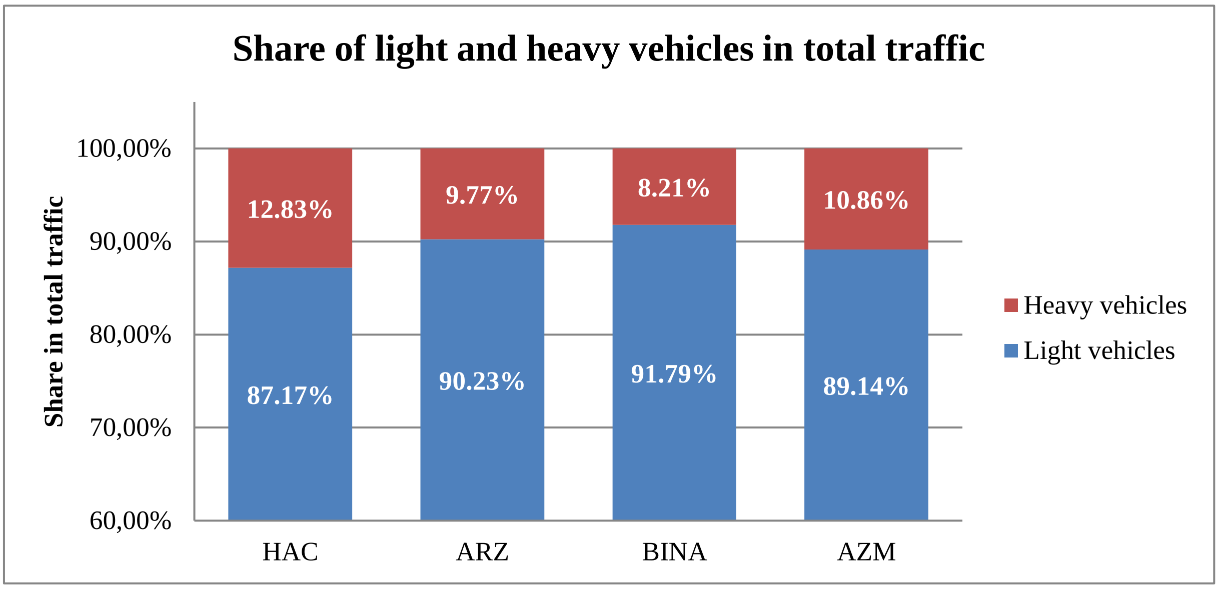
Motorway companies	Δ% 2015 vs. 2014	Δ% 2016 vs. 2015	Δ% 2017 vs. 2016	Δ% 2018 vs. 2017	Δ% 2019 vs. 2018	Average yearly
HAC	+8.94%	+9.15%	+5.16%	+1.80%	+5.65%	**+6.14%**
ARZ	+6.18%	+7.27%	+5.84%	+4.38%	+3.77%	**+5.49%**
Bina-Istra	+4.84%	+6.76%	+5.84%	+7.28%	+3.28%	**+5.60%**
AZM	+4.35%	+5.81%	+1.17%	+4.14%	+6.73%	**+4.44%**
Average	**+6.08%**	**+7.25%**	**+4.50%**	**+4.40%**	**+4.85%**	**+5.42%**

Note: Adapted from HUKA (HUKA, 2012; HUKA, 2014; HUKA 2016; HUKA 2018; HUKA, 2020).

Regarding the traffic structure, light vehicles represented the majority of total transactions with a share of 88.47%, while heavy vehicles represent the remaining 11.53% of total transactions. By classification, a light vehicle is a motor vehicle with a maximum weight of up to 3.5 tons (I, IA, and II vehicle categories), while a heavy vehicle is a motor vehicle with a maximum weight of over 3.5 tons (III and IV vehicle categories) (HUKA, 2020). The distinction between light and heavy vehicles made by each motorway company is graphically presented in Figure 2.3.

Figure 2.3.

Share of light and heavy vehicles on the Croatian motorways 2014-2019



Note: Adapted from HUKA (HUKA, 2012; HUKA, 2014; HUKA 2016; HUKA 2018; HUKA, 2020).

Even though light vehicles dominated at all motorway companies in Croatia, Bina-Istra had the highest share of light vehicle traffic, with 91.79% of total traffic. Despite the shorter period of available data for tourist arrivals (2016–2019), the historical records of tourist arrivals followed this trend. The records show that 23.45% of total tourist arrivals in Croatia were realised in Istrian County, classifying it as a region with the most tourist arrivals in Croatia (Croatian Bureau of Statistics, n.d.a). The sub-chapter 2.8., Tourist Activity, further examines the structure of tourist arrivals in Croatia and shows that travelling by car represented the main mean of cross-border transit in Croatia, indicating importance for observing this vehicle category.

Based on historical data, Table 2.4. shows a comparison of the historical average daily traffic growth in Croatia and other European motorways.

Table 2.4.

Average daily motorway traffic by country 2014-2019

Country	2014	2015	2016	2017	2018	2019	Average daily traffic growth
Austria	36,500	37,500	38,400	39,400	40,200	40,300	**+2.00%**
Croatia	13,902	14,809	14,845	15,660	16,465	17,191	**+4.36%**
France	27,144	27,749	28,531	29,049	28,755	29,799	**+1.90%**
Hungary	21,382	23,530	24,109	30,671	28,202	27,512	**+5.85%**
Italy	36,729	37,969	38,898	39,865	40,006	42,508	**+2.98%**
Portugal	14,092	15,022	15,869	16,861	15,812	16,393	**+3.19%**
Slovenia	28,054	28,550	29,821	31,419	32,414	34,106	**+3.99%**
Spain	16,828	17,854	18,833	19,850	23,410	24,775	**+8.15%**

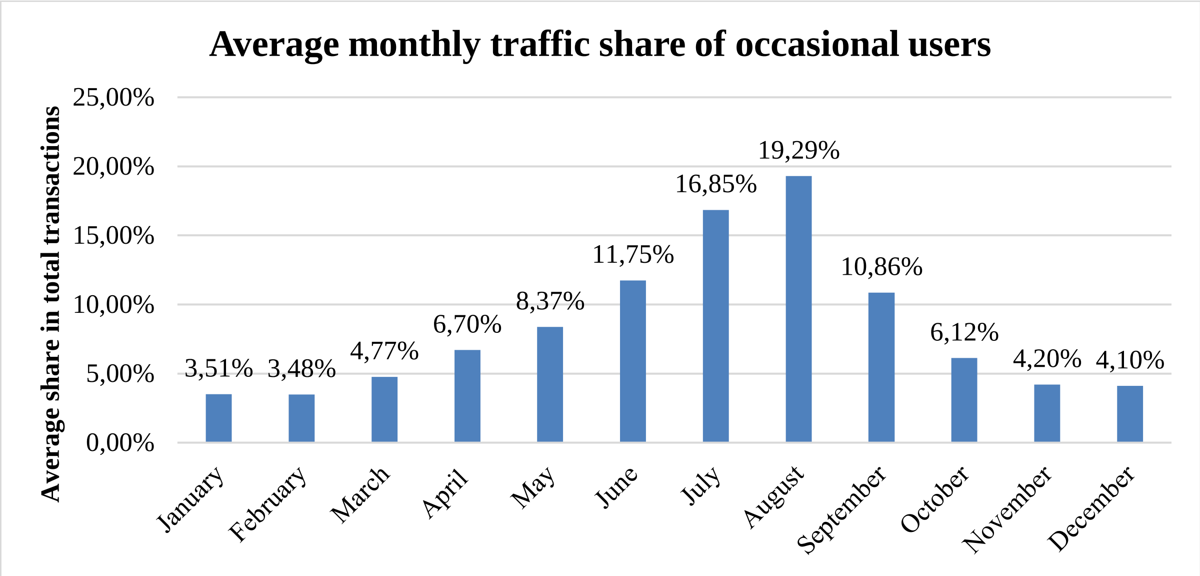
Note: Adapted from ASECAP (ASECAP, 2015; ASECAP, 2016; ASECAP, 2017; ASECAP 2018; ASECAP 2019; ASECAP, 2020).

Even if traffic levels differ among countries due to their geographical position and size, toll prices, GDP, tourist activity, and other factors (Abrantes & Wardman, 2011; Gallet & Doucouliagos, 2014; Goodwin et al., 2004; Litman, 2019; Mervar & Payne, 2007; Odeck & Bråthen, 2008; Odeck & Johansen, 2016), Table 2.4. shows a positive trend in growth of average daily motorway traffic levels in all countries between 2014 and 2019. In Croatia, the average daily traffic growth of +4.36% was the closest to the neighborhood cross-border country of Slovenia, with an average daily growth of +3.99%. When observing the average daily traffic of light vehicles, the difference in traffic growth between Croatia and Slovenia was even more negligible, with +3.88% for Croatia and +4.00% for Slovenia. The similar trends in traffic growth could be explained by the cross-border statistics for the period 2014–2019, when on average 49.12% of total light vehicle transits were realised on the Croatian–Slovenian border (Croatian Bureau of Statistics, n.d.b). Although these pieces of information may suggest a possible relationship between Croatian and Slovenian motorway traffic, it is beyond the scope of this thesis to perform such an investigation.

While Chapter 5 further describes the detailed traffic data of the Istrian motorway used for modeling in this thesis, Figures 2.4. and 2.5. show trends of average monthly traffic changes at the Istrian motorway between 2014 and 2019.

Figure 2.4.

Average monthly traffic of occasional users on the Istrian motorway 2014-2019



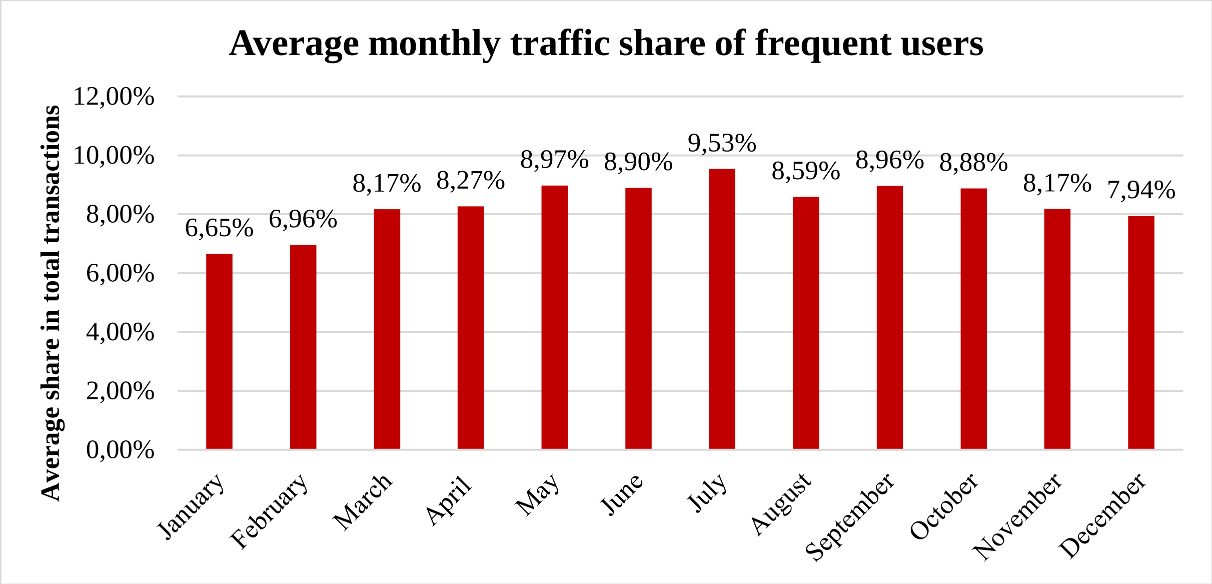
Note: Adapted from Bina-Istra (2020).

The graphical presentation of average monthly movements between 2014 and 2019 in Figure 2.4. indicates that August had the highest frequency of motorway transactions, with 19.29% of the total yearly transactions of occasional motorway users. On the contrary, February was the month with the fewest realised transactions by occasional motorway users. Since this thesis separately observes summer and non-summer periods, the statistical data shows that 58.75% of total occasional motorway user transactions were realised during the four months of the summer period, indicating the presence of traffic seasonality. By definition, seasonality represents changes that are predictable and recursive every calendar year (Kenton, 2020). The impact of seasonality is also further discussed in sub-chapter 2.8., Tourist Activity, which shows tourist movements during the year.

Regarding frequent motorway user traffic changes, Figure 2.5. graphically presents shares of their average monthly movements between 2014 and 2019. The graph indicates July as the month with the highest frequency, with 9.53% of total yearly transactions by frequent motorway users. For this user type, on average, 35.98% of total frequent user transactions were realised in the summer period.

Figure 2.5.

Average monthly traffic of frequent users on the Istrian motorway 2014-2019

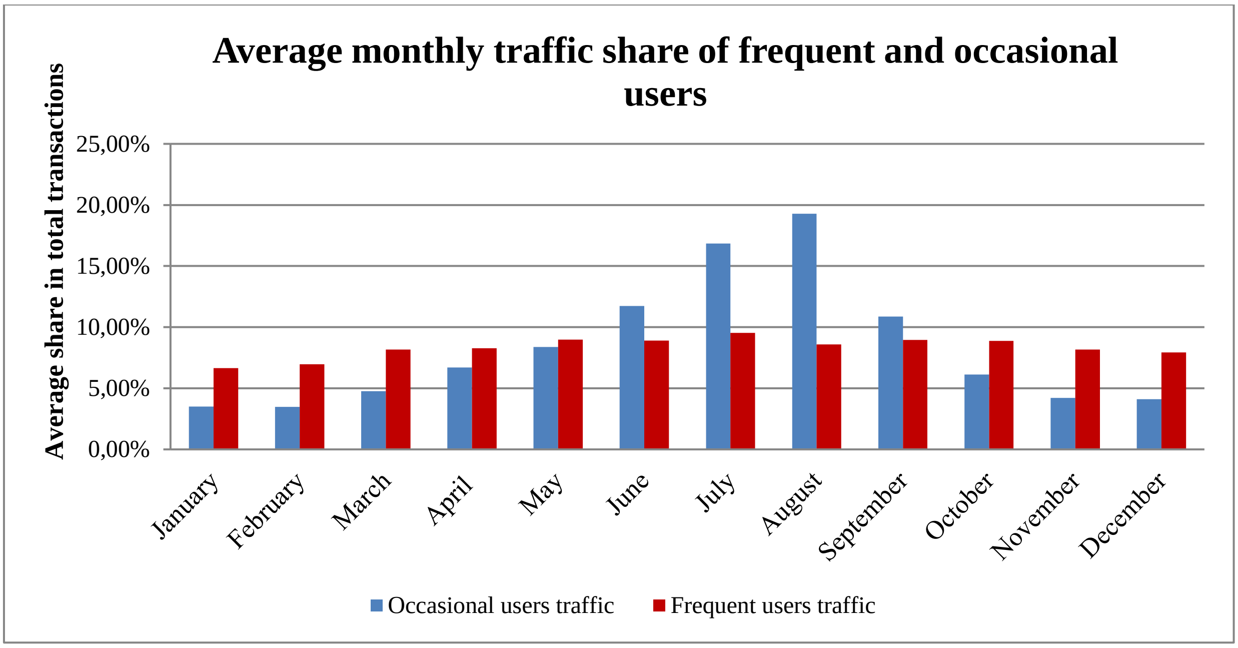


Note: Adapted from Bina-Istra (2020).

Even the previous paragraphs showed trends in average monthly movements on the Istrian motorway based on frequency of use, Figure 2.6. graphically integrates the data. The figure highlights the differences in motorway usage patterns between frequent and occasional users, as well as the seasonality effect, which affects their traffic shares differently.

Figure 2.6.

Average monthly traffic of frequent and occasional users on the Istrian motorway 2014-2019



Note: Adapted from Bina-Istra (2020).

Considering specifics between the types of motorway users, historical movements for frequent motorway users show consistent motorway usage with fewer monthly fluctuations, which is in line with the intended purpose of the ENC Plus package. According to Bina-Istra (n.d.b), the package is suitable for frequent travellers on the Istrian motorway due to the limited validity of toll discounts. The steady share of frequent users suggests that their motorway usage might be driven by year-round needs, mostly unaffected by seasonal fluctuations. Against that, Figure 2.6. shows a pronounced seasonal variation of occasional user traffic, with their traffic share increasing considerably in the summer months, indicating inconsistent motorway usage throughout the year. Seasonality and monthly fluctuations of occasional user traffic suggest a potential relationship between higher economic activity in Croatia during the summer period and tourist arrivals, as between 2014 and 2019, 73.98% of tourist arrivals were realised in the summer period (Croatian Bureau of Statistics, n.d.a). Following Figure 2.6., the seasonal disparity is most noticeable during the summer season, when occasional users' shares surpass those of frequent users by significant margins. In contrast, in winter and spring, frequent users consistently show a larger share of motorway usage. These records demonstrate how frequent users provide a consistent baseline of motorway activity, whereas occasional users contribute to significant spikes during specific seasons. Based on these indications, this thesis further tests if periods of the year have different impacts on frequent and occasional motorway user behaviour.

2.5.1. Occasional motorway user traffic

Before further observation of traffic movements, this paragraph summarises three critical features of occasional motorway users:

- First, the historical traffic data of occasional motorway users indicates the presence of traffic seasonality, as most transactions were realised during the summer period, accompanied by high road cross-border transits during the same period;
- Second, most of the occasional user's transactions were realised by the I vehicle category, suggesting the importance of observing the impact of seasonality on this vehicle category;
- Third, this sub-chapter indicates that light vehicles (I, IA, and II categories) had more traffic fluctuations through the year than heavy vehicles (III and IV categories), suggesting heavy vehicle traffic movements are less likely to be impacted by the period of the year. As stated in sub-chapter 7.5., Suggestions for future research, additional analysis and tests are necessary to confirm the suggestion.

As summarised in the previous paragraph and Figure 2.4., historical records indicate the presence of traffic seasonality for occasional motorway users in the observed period of 2014–2019. During the four months of summer between June and the end of September, 58.75% of total transactions by occasional motorway users were realised. It is important to note that transactions of occasional motorway users paid by using entry tickets represented 65.84% of total transactions on the entire Istrian motorway network and were the main means of payment.

Diversification of occasional motorway traffic by vehicle category between 2014 and 2019 shows the I vehicle category as dominant, with a share of 86.52%. In comparison, the IA category represented a minor share of 0.87% of the total occasional traffic; a tabular presentation of traffic shares is in Table 2.5.

Table 2.5.

Distribution of Full price traffic by vehicle category 2014-2019

Vehicle category	Share in total transactions of occasional motorway users
I cat	86.52%
IA cat	0.87%
II cat	9.39%
III cat	2.22%
IV cat	1.00%

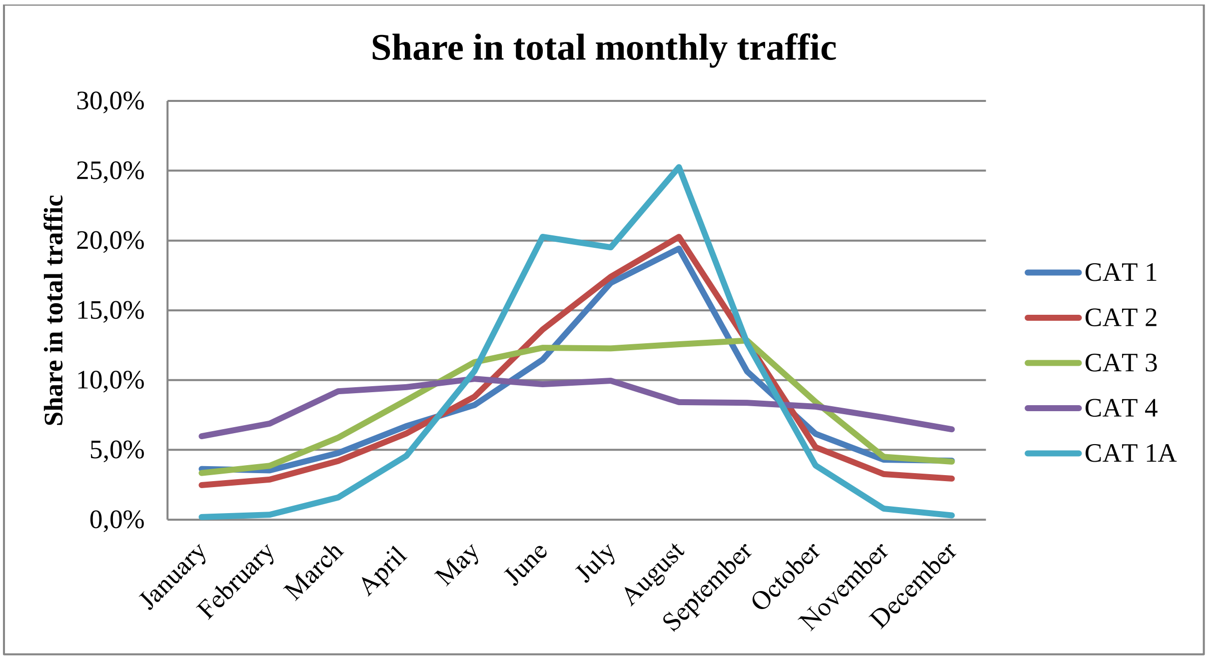
Note: Adapted from Bina-Istra (2020).

When considering the breakdown of occasional motorway user traffic on monthly levels and by vehicle category, Figure 2.7. indicates fluctuations in monthly traffic levels between 2014 and 2019. The entire summer period shows higher traffic levels than non-summer. During the summer period, monthly fluctuations were more significant for light vehicles than for heavy vehicles. More precisely, on average, 59.18% of total yearly light vehicle traffic was realised during the summer period, with a peak in August, when, on average, 19.55% of total annual light vehicle traffic was realised. Higher motorway traffic activity during the summer period followed the evidence of road cross-border transits in Croatia, with 46.67% of total car cross-boardings occurring during the summer period. Even if the IA vehicle category recorded the highest traffic fluctuation with 77.68% of total yearly traffic in summer, this thesis considers it with caution due to the low quantity of IA vehicles in total transactions (a share of 0.87% in total traffic of occasional motorway users), where minor changes in traffic level cause a significant impact on monthly shares.

The distribution of heavy vehicle traffic represented fewer fluctuations through the year; on average, 45.80% of total yearly heavy vehicle traffic was realised during the summer period, when 35.56% of total heavy vehicle cross-boardings were realised. For the III vehicle category, the peak was in September with an average realised 12.84% of total yearly traffic, while for the IV vehicle category, the peak was in May with 10.09% of total yearly traffic.

Figure 2.7.

Monthly traffic share of occasional motorway users by vehicle category on the Istrian motorway 2014-2019



Note: Adapted from Bina-Istra (2020).

2.5.2. Frequent motorway user traffic

Before further observation of frequent motorway user traffic movements, this paragraph summarises three key features of this type of traveller:

- First, the historical records suggest that frequent motorway user traffic had more consistent monthly traffic levels throughout the year than occasional motorway users;
- Second, the I vehicle category realised the most frequent motorway user transactions. As the same evidence is present for occasional users, this confirms the I vehicle category as the most used vehicle category on the Istrian motorway and the relevance of focusing the study on this vehicle category. This statement follows the fact that between 2014 and 2019, most registered vehicles in Croatia were passenger cars;
- Third, under Figure 2.8., this sub-chapter shows similar monthly traffic movements between each vehicle category except for the IA category, whose records represent an unsignificant share of total traffic.

As summarised in the previous points, frequent motorway users had more consistent monthly traffic than occasional users. This is in line with the statement in an earlier sub-chapter 2.4., Payment Means on the Croatian Motorways, the ENC Plus package is convenient for frequent motorway users who use electronic toll devices regularly and pay for tolls with an applied discount. The ENC Plus transactions represented 33.42% of total realised transactions on the Istrian motorway between 2014 and 2019 and were the second most used means of payment. Diversification of ENC Plus traffic by vehicle category shows the I vehicle category as dominant with a share of 72.70% in total ENC Plus traffic, with the least at the IA vehicle category with a share of 0.14%.

Table 2.6.

Distribution of ENC Plus traffic by vehicle category 2014-2019

Vehicle category	Share in total transactions of frequent (ENC Plus) motorway users
I cat	72.70%
IA cat	0.14%
II cat	9.22%
III cat	9.23%
IV cat	8.71%

Note: Adapted from Bina-Istra (2020).

Considering that the I vehicle category represented the majority of realised transactions on the Istrian motorway, both for occasional and frequent motorway users, these results follow the records of the Croatian Bureau of Statistics for 2014–2019 (Croatian Bureau of Statistics, n.d.b), where passenger cars represented 72.96% of total registered road motor vehicles and trailers in Croatia.

Table 2.7.

Registered road motor vehicles and trailers by type of vehicles 2014-2019

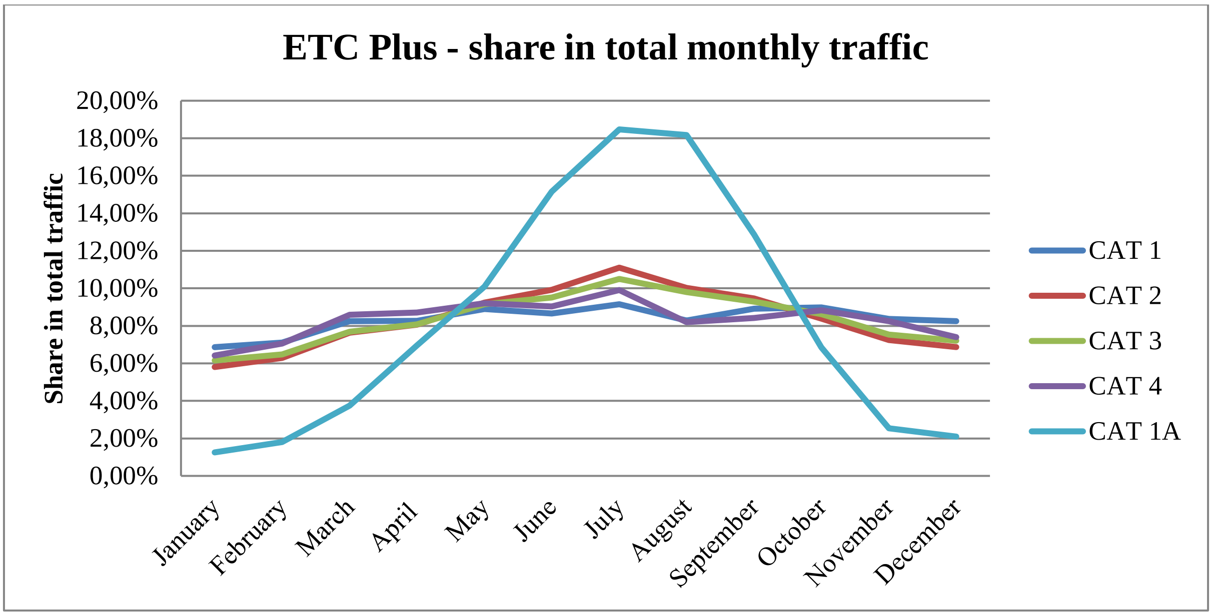
Vehicle	2014	2015	2016	2017	2018	2019
Mopeds	93,410	90,069	87,507	85,121	83,362	80,738
Motorcycles	61,688	61,208	65,366	69,148	73,997	78,650
Passenger cars	1,474,495	1,499.802	1,552,904	1,596,087	1,666,413	1,724,900
Buses and coaches	5,040	5,276	5,513	5,698	5,877	6,041
Lorries	132,045	136,854	146,230	156,724	169,175	180,674
Road tractors	8,662	9,329	10,443	11,334	12,229	12,976
Special purpose vehicles	11,257	11,439	12,083	12,824	13,548	14,514
Agricultural tractors	112,941	113,588	116,010	119,191	123,461	128,482
Trailers	25,015	26,115	27,367	29,105	30,992	33,423
Semi-trailers	10,258	10,842	11,927	12,927	13,803	14,629

Note: Adapted from the Croatian Bureau of Statistics (n.d.b).

When considering ENC Plus traffic breakdown on monthly levels, Figure 2.8. shows that traffic movements and share in monthly traffic in both light and heavy vehicles followed a similar pattern, except for the IA vehicle category with fluctuations in motorway usage between summer and non-summer periods. Even if the IA vehicle category recorded the highest traffic fluctuations with, on average, 64.66% of their yearly traffic during the summer period, this thesis takes it with caution due to the low quantity of IA vehicle transactions (a share of 0.14% in total ENC Plus traffic), where minor changes in traffic level cause significant impact on changes in monthly shares.

Figure 2.8.

Share of monthly ENC Plus traffic by vehicle category on the Istrian motorway 2014-2019



Note: Adapted from Bina-Istra (2020).

Considering the transaction averages of all light vehicle categories realised together, 35.68% occurred during the summer period, with a peak in July and realised 9.38% of total yearly light vehicle traffic. The average monthly traffic share during the summer period was 8.92% and 8.04% for the non-summer period, which indicates that peak traffic value in July for light vehicles did not significantly deviate from the average monthly shares. Except for the IA vehicle category, these traffic movements show the appropriateness of using the ENC Plus package by regular users of the Istrian motorway during the whole year.

Regarding monthly traffic movements for heavy vehicles, 37.37% occurred during the summer period (similar to light vehicles), with a peak in July and realised 10.21% of total yearly heavy vehicle traffic. The average monthly traffic share during the summer period was 9.34% and 7.83% for the non-summer period. These pieces of information suggest that travelling patterns of light and heavy vehicle frequent users did not significantly deviate from the average monthly shares and were not significantly affected by road cross-border traffic, as it was the case with occasional motorway user traffic.

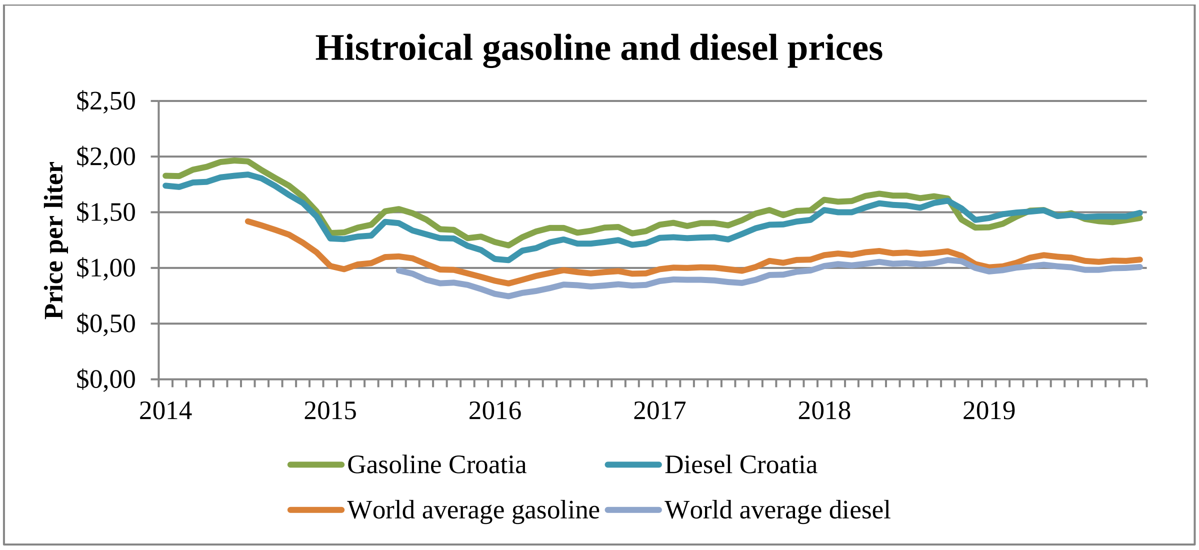
2.6. Fuel prices

Even by comparison, diesel and gasoline prices in Croatia were higher than the world average, Figures 2.9. and 2.10. show a similar pattern in yearly and monthly fuel price movements between 2014 and 2019. Althrough higher fuel prices during the summer period, both in Croatia and around the world, similar price trends are valuable for this thesis when considering the implications of the results on other practices. However, applying the obtained results of fuel prices to other motorway practices would require the conduct of additional tests with data related to that specific motorway to check the impact of seasonality on frequent and occasional motorway user traffic. The historical fuel prices from this sub-chapter also indicate a possible relationship between fuel prices and increased travel movements during the summer period, whose impact this thesis further tests.

Following the previous paragraph, gasoline and diesel fuel prices differ among counties, primarily but not exclusively because of different fuel tax rates (Small & Van Dender, 2018). In most cases, diesel prices are lower than gasoline prices because of differences in taxation (Dahl, 2012). This statement aligns with historical gasoline and diesel price data for 2014–2019 received from GlobalPetrolPrices.com (GlobalPetrolPrices.com, personal communication, June 27, 2021). Figure 2.9. graphically shows the gasoline and diesel price movements in Croatia and the world average.

Figure 2.9.

Historical gasoline and diesel prices in Croatia and the world 2014-2019



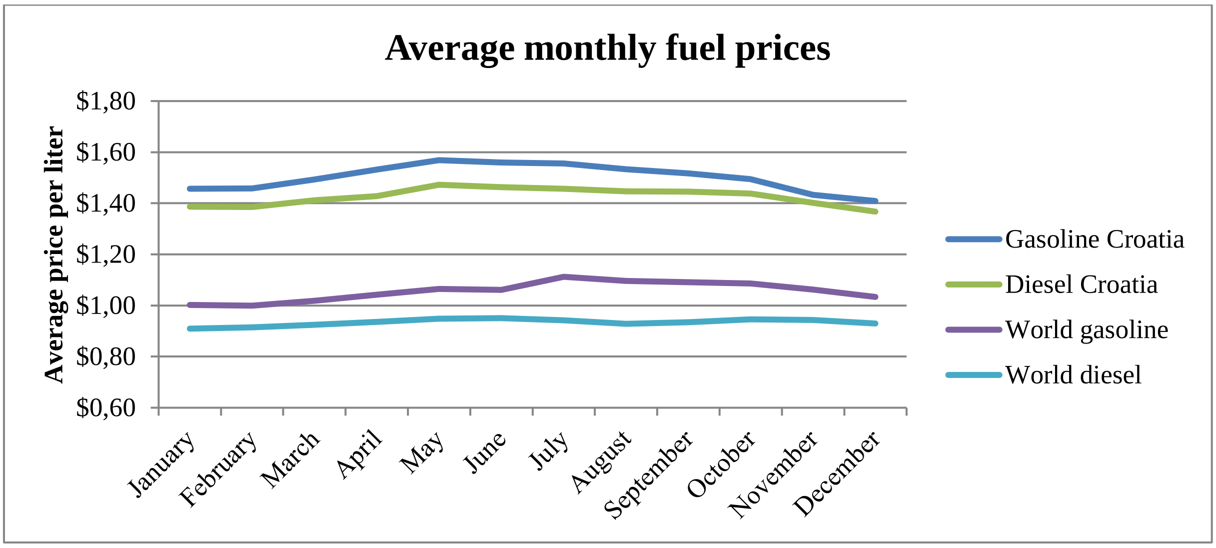
Note: Adapted from GlobalPetrolPrices.com (personal communication, June 27, 2021).

From 2014 to 2019, the average monthly gasoline price in Croatia was 1.50 $/litre. In summer, the average monthly price was 1.54$/litre while 1.48$/litre in the non-summer period. The highest average gasoline price was achieved in May, with a price of 1.57$/litre. Even if diesel prices were lower than gasoline prices, the changes in their prices follow almost the same pattern: higher prices during the summer with an average monthly price of 1.45$/litre and lower prices in the non-summer (1.41$/litre).

When comparing Croatian fuel prices with the world average, the price movements followed almost the same pattern. The average monthly gasoline price in the world was 1.09$/litre in the summer, with 1,04$/litre during the non-summer. The average monthly world diesel price was 0.94$/litre in the summer, which is slightly higher than the non-summer average price of 0.93$/litre.

Figure 2.10.

Average monthly fuel prices 2014-2019



Note: Adapted from GlobalPetrolPrices.com (personal communication, June 27, 2021).

The comparison of fuel prices in Croatia and around the world shows that in Croatia, gasoline and diesel prices during the summer period were on average higher by +3.39% than in the rest of the year. In the case of the world, summer prices were on average higher than the rest of the year by +2.97%. Even if Figures 2.9. and 2.10. show similar patterns in fuel price movements in the period 2014–2019, it is worth remarking that fuel prices in Croatia were higher than the world average (gasoline prices by +0.44 $/litre and diesel prices by +0.50$/litre). Higher fuel prices in terms of transportation costs may impact both personal and commercial vehicle journeys, potentially leading to reduced traffic levels. However, to value the impact of fuel prices on motorway travel demand, it is necessary to further estimate elasticity values.

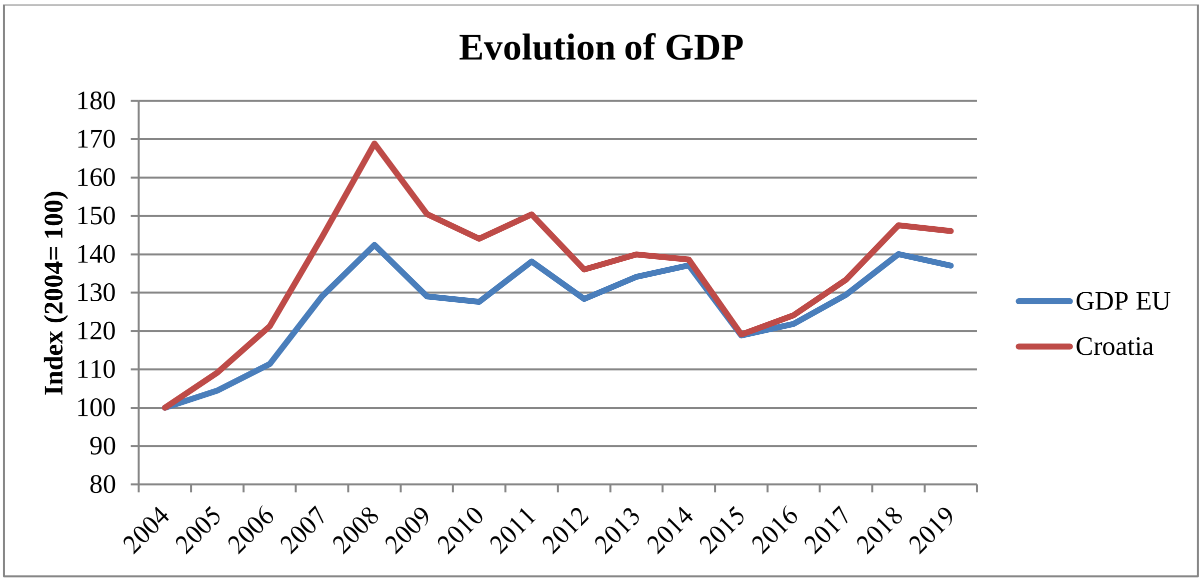
2.7. GDP and the unemployment rate

Following Eurostat's data, between 2014 and 2019, the Croatian economy showed significant fluctuations in GDP movements compared to the European Union, indicating higher sensitivity to economic changes (Eurostat, n.d.). In that period, the Croatian GDP values recorded continuous yearly economic growth with a reduced unemployment rate. Despite positive economic movements in terms of increasing national GDP and reducing the unemployment rate, Croatia recorded a population decrease. However, this thesis does not cover the discussion of reasons for the population decrease. Therefore, to better capture the impact of GDP movements on motorway travel demand, this sub-chapter argues for the use of GDP per capita instead of GDP to obtain more consistent estimates.

Regarding GDP as an economic variable that impacts travel demand and general country activities (Abrantes & Wardman, 2011; Havranek & Kokes, 2015; Litman, 2019), the European economy grew steadily until the 2008 economic crisis. For the period 2004–2008 before the economic crisis, the compound average growth rate (CAGR) of the European Union GDP was +7.33% and +11.05% in Croatia (World Bank, n.d.). However, 2008 was the turning point in the world economy. As graphically shown in Figure 2.11., GDP values became unstable until 2015, in which period the European Union's CAGR declined with a value of -2.24%, while the Croatian CAGR was -4.27%, showing higher sensitivity of the Croatian than the European Union economy.

Figure 2.11.

Evolution of the European Union and Croatian GDP 2004-2019



Note: Adapted from the World Bank (n.d.).

Since 2015, the GDP movements have become positive and gradually recovered. Until the end of 2019, the European Union CAGR increased by +2.90%, while the Croatian CAGR increased by +4.17%. The historical evidence shows higher sensitivity to economic changes in Croatia than it is for the European Union globally, whose economy was generally more stable with fewer fluctuations.

Table 2.8.

The average compound growth rates of the Croatian GDP 2004-2019

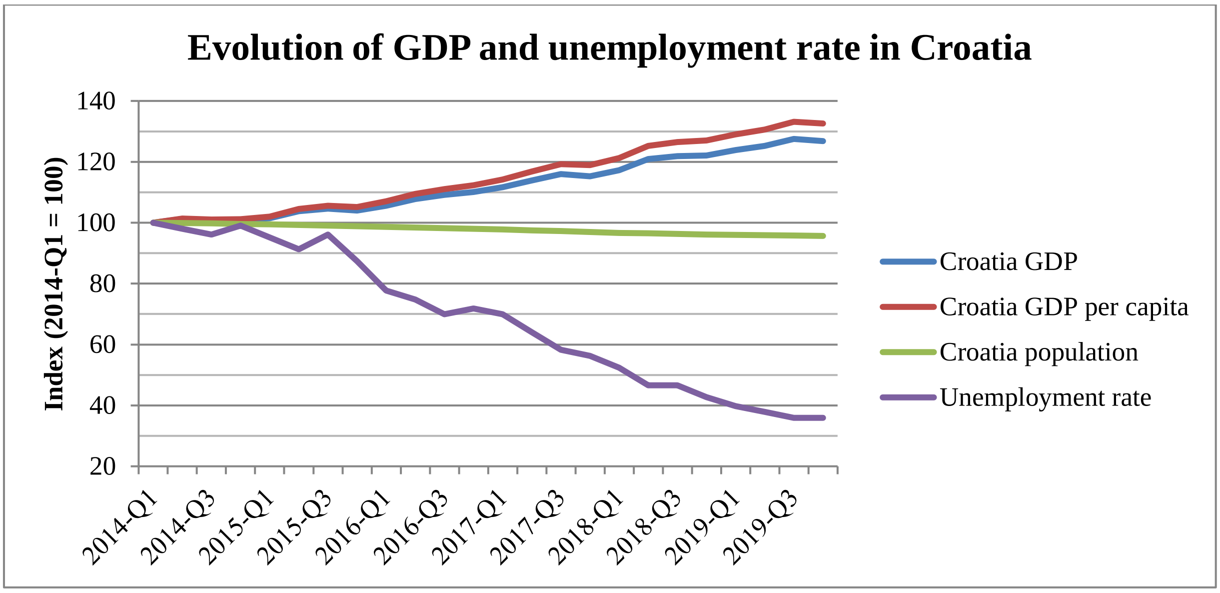
Period	CAGR EU	CAGR Croatia
2004 - 2008	+7.33%	+11.05%
2008 - 2015	-2.24%	-4.27%
2015 - 2019	+2.90%	+4.17%

Note: Adapted from the World Bank (n.d.).

As this thesis investigates the impact of GDP on motorway travel demand in different periods of the year, Figure 2.12. represents an evolution of the Croatian GDP, GDP per capita, population, and unemployment rate quarterly for 2014–2019. These data collected from the Eurostat database (Eurostat, n.d.) aim to show historical movements among different factors to further argue for using GDP per capita as an explanatory variable. Even though the literature does not provide consensus on which indicator of economic development is most suitable to observe the impact on travel demand (Barla et al., 2009; Bastian et al., 2016; Hanly et al., 2002), consideration of the GDP per capita in the Croatian case is important due to the population decrease between 2014 and 2019 by 4.34%. Therefore, as the GDP per capita curve rose slightly more than the national GDP until the end of 2019, this adjustment highlights that the average economic output per person has improved, making GDP per capita a more reliable measure of economic health and living standards than the national GDP.

Figure 2.12.

Changes in GDP, GDP per capita, and population values in Croatia 2014-2019



Note: Adapted from Eurostat (n.d.).

Even if GDP measures the monetary value of all the final goods and services produced and sold in a specific period and country (Callen, 2008), the usage of per capita terms is also in line with previous studies (Bastian et al., 2016; Gonzalez & Marrero, 2012). In the study of light vehicle demand evolution in interurban toll roads in Spain, Gomez et al. (2016) showed that observation of GDP per capita constitutes a better proxy of personal income than GDP as it provides more consistent estimates and improves the performance of GDP (while employment as a variable only considers the part of the population that is employed).

2.8. Tourist activity

Tourist activity in Croatia significantly impacted national GDP, with a share of 19.5% in the last available data for 2022. Most tourists were international, mainly from the European Union, as highlighted: Germany 14.87%, Slovenia 7.79%, Austria 7.56%, Poland 4.93%, and Italy 6.79%. (Croatian Bureau of Statistics, n.d.a; Ministarstvo turizma Republike Hrvatske, 2023). The data further confirms Croatia as a motor destination, making it appropriate to observe the impact of tourist arrivals on motorway travel demand. The historical records of tourist arrivals in Croatia suggest the presence of seasonality, as between 2014 and 2019, 74.42% of tourist arrivals were realised in the summer, while 25.58% were realised during the remaining period of the year. Despite the recent growth in non-summer arrivals, this confirms the importance of observing seasonality as an essential factor in transportation.

Table 2.9.

Share in tourist arrivals in Croatia 2014-2019

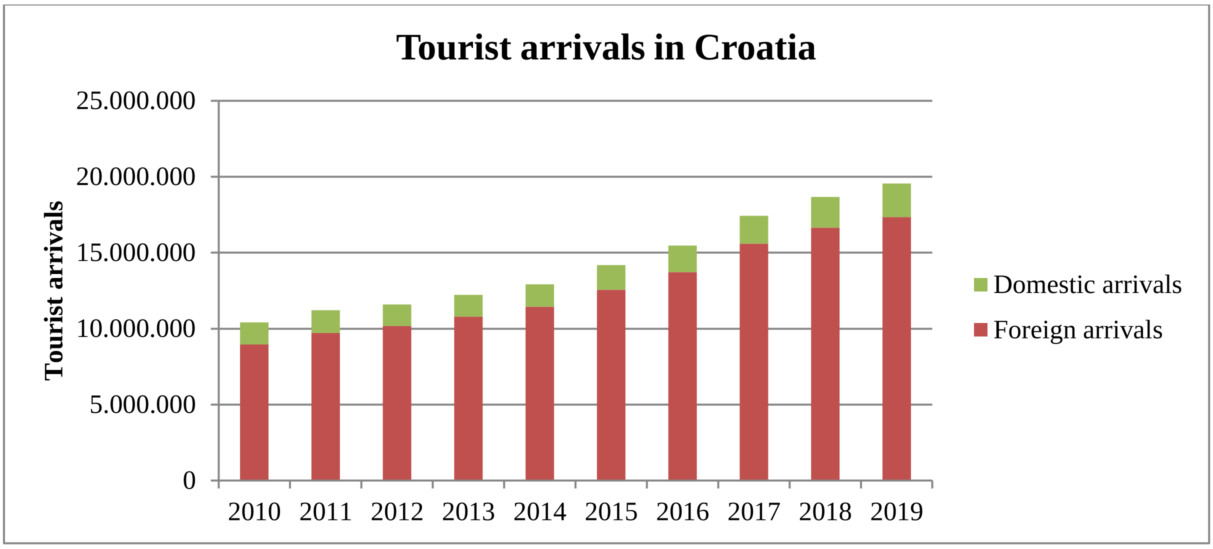
Year	Share in tourist arrivals	
	Summer	Non-summer
2014	75.73%	24.27%
2015	75.56%	24.44%
2016	75.39%	24.61%
2017	75.30%	24.70%
2018	72.93%	27.07%
2019	72.61%	27.39%

Note: Adapted from the Croatian Bureau of Statistics (n.d.a).

Between 2010 and 2019, most tourist arrivals in Croatia were international; 88.90% were foreign tourists (mainly from the European Union), while the remaining 11.10% were domestic tourists (Croatian Bureau of Statistics, n.d.a). The CAGR for foreign tourist arrivals was +7.17%, with +7.16% for domestic tourist arrivals, which growth suggests importance of investigating the impact of tourist activity on motorway traffic levels. This thesis applies tourist arrivals data as the most common measure (Li et al., 2005) rather than the number of tourist overnights because the number of tourist overnights does not represent tourist movements or travel. Figure 2.13. shows tourism levels in Croatia as measured by the number of arrivals, both for foreign and domestic tourists.

Figure 2.13.

Tourist arrivals in Croatia 2010-2019



Note: Adapted from the Croatian Bureau of Statistics (n.d.a).

The data on Croatian cross-border passenger traffic from 2014 to 2019 suggests that Croatia is predominantly a motor vehicle destination. Specifically, 92.93% of passengers used road traffic, highlighting the preference for road travel, possibly due to the convenience and flexibility of car travel for tourists. As air traffic accounted for only 4.91% of total cross-border traffic, the results reflect a possibly limited number of airports compared to the extensive road and motorway networks.

Table 2.10.

Cross-border traffic of passengers by type of transport 2014-2019

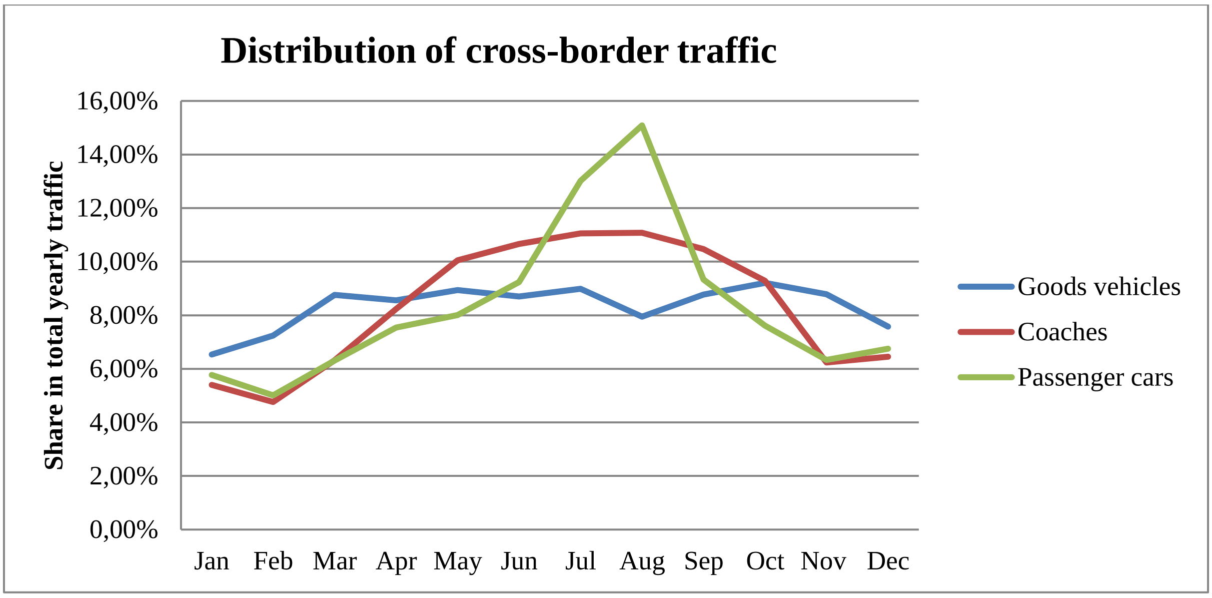
Traffic (in thousands)	2014	2015	2016	2017	2018	2019	TOTAL	Share
Road traffic	136,312	148,713	152,351	155,000	145,096	151,270	888,742	**92.93%**
Air traffic	5,733	6,190	7,052	8,415	9,360	10,225	46,975	**4.91%**
Maritime traffic	2,686	2,724	2,854	2,477	2,771	3,039	16,551	**1.73%**
Railway traffic	761	654	734	544	491	479	3,663	**0.38%**
Inland waterway traffic	67	63	62	66	79	119	456	**0.05%**

Note: Adapted from the Croatian Bureau of Statistics (n.d.b), data provided by the Ministry of Interior.

Regarding the distribution of road cross-border traffic for the period 2014–2019, car transactions were dominant, accounting for realised 90.89% of total road cross-border transactions, followed by goods vehicles (7.92%) and coaches (1.19%). As graphically expressed in Figure 2.14., the peak in the cross-border road traffic of passenger cars and coaches was achieved in the summer, when 46.67% of passenger car transactions and 43.26% of coach transactions were realised. Althrough goods vehicles show the slightest fluctuations in the distribution of traffic during the year, this category realised 34.41% of their yearly transactions in the summer period. The movement of historical data indicates that the traffic of goods vehicles is potentially not as affected by the period of the year as is the case with coaches and passenger cars.

Figure 2.14.

Distribution of average cross-border road traffic 2014-2019



Note: Adapted from the Croatian Bureau of Statistics (n.d.a), data provided by the Ministry of Interior.

When observing the most active road cross-borders between 2014 and 2019, Table 2.11. shows that 49.12% of total road cross-border traffic was realised on the Croatian-Slovenian border. As unique historical motorway traffic data relates to the Istrian motorway, it is valuable to note that the Croatian-Slovenian border is the only land border for the Istrian County.

Table 2.11.

Road cross-border traffic of passenger motor vehicles 2014-2019

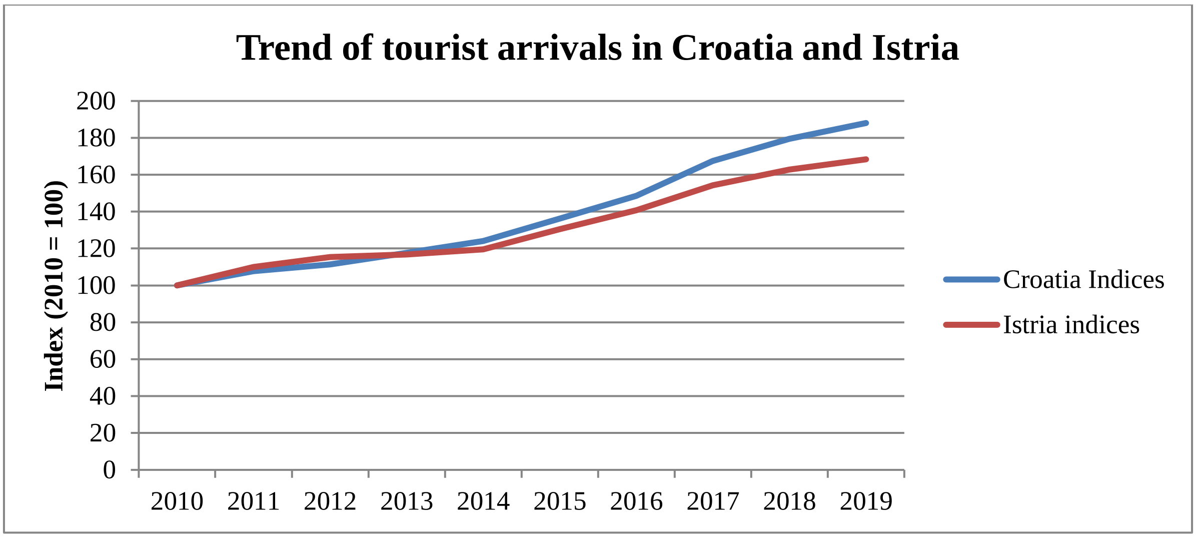
	Traffic, thousands							
Border	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**TOTAL**	**Share**
Croatian-Slovenian	21,639	23,233	24,540	24,747	24,582	25,817	144,558	**49.12%**
Croatian - BIH[3]	16,025	16,523	17,311	18,590	19,100	19,928	107,477	**36.52%**
Croatian-Serbian	4,048	4,175	4,509	4,706	4,757	4,946	27,141	**9.22%**
Croatian-Hungarian	1,431	1,604	1,756	1,916	2,071	2,159	10,937	**3.72%**
Croatian-Montenegrin	575	629	663	712	787	798	4,164	**1.41%**

Note: Adapted from the Croatian Bureau of Statistics (n.d.b).

Due to the geographical position of the Istrian motorway in the Istrian county, Figure 2.15. represents trends in tourist arrivals in Croatia and Istrian County between 2014 and 2019. The Croatian CAGR of tourist arrivals was +7.17%, followed by the Istrian County CAGR with the same trend as the national but a slightly lower value of +5.88%. In the observed period, Istrian County recorded 24.42% of total tourist arrivals in Croatia, representing the county with the most tourist arrivals.

Figure 2.15.

The trend of tourist arrivals in Croatia and Istria 2014-2019



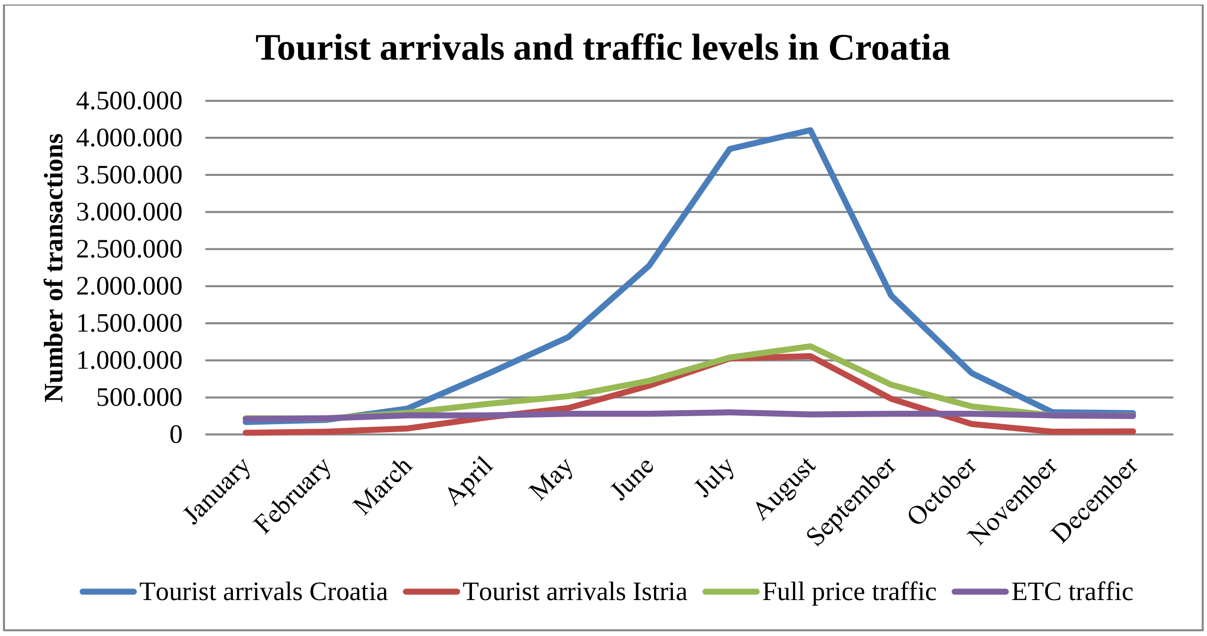
Note: Adapted from the Croatian Bureau of Statistics (n.d.a).

[3]Bosnian and Herzegovinian border.

To graphically capture the traffic movement of frequent and occasional motorway users and tourist arrivals in Croatia and Istrian County between 2014 and 2019, Figure 2.16. shows average trendline movements through the year. The curves graphically illustrate the presence of seasonality and significant tourist activity during the summer period, with realised 73.98% of total tourist arrivals and a peak value in August. The curve for tourist arrivals in Istrian County follows the same pattern, with realised 77.34% of tourist arrivals in summer, also with the peak in August. The obtained data shows that tourist activity and seasonality in the micro area (Istrian County) follow the same pattern of tourist activity in the wider area (Croatia).

Figure 2.16.

Tourist arrivals and traffic levels in Croatia 2014-2019



Note: Adapted from the Croatian Bureau of Statistics (n.d.a) and Bina-Istra (2020).

As shown in sub-chapter 2.5, Traffic, occasional motorway traffic realised 58.75% of total yearly traffic during the summer, reaching its peak in August. These pieces of information confirm summer period and August as periods of the highest tourist activity and motorway traffic levels in Croatia and the Istrian motorway. However, frequent motorway users generally did not show significant fluctuations throughout the year. It can be explained by the commercial promotion of the ENC Plus package, which is adequate for users that frequently use motorways, where the validity of the toll discount is limited to 90 days counting from the day of the last account top-up for light vehicles and 120 days for heavy vehicles (Bina-Istra, n.d.b).

2.9. Conclusion

This chapter showed the general characteristics of the Croatian motorway network and the historical movements of each explanatory variable used in this thesis, with focus between 2014 and 2019. The chapter showed a positive trend in motorway traffic growth across all motorway companies in Croatia. This is essential, particularly as a sample of historical motorway traffic data is related to the Istrian motorway (Bina-Istra), taken as a case study. In terms of passenger transportation, an analysis of collected data confirmed Croatia as a primary road destination, with 92.93% of cross-border traffic realised on the roads. In addition, the historical records confirmed the high dependence of Croatian tourism on foreign tourist arrivals, with a share of 88.90% of total tourist arrivals.

Regarding motorway traffic movements, the chapter showed monthly fluctuations in occasional motorway traffic, with 58.75% of the traffic realised during the four months of summer, despite the seasonal toll increase of 10% and higher fuel prices. The records indicate that occasional users are not significantly sensitive to the increase in toll prices during the summer period, suggesting that until the end of 2019, the Istrian motorway had not reached optimum toll prices, after which point traffic levels began to fall. Althrough higher traffic activity during the summer period, in contrast, monthly traffic fluctuations for frequent motorway users are considered insignificant, which is in line with the purpose of the ENC package mainly used by drivers who regularly use the motorway network.

Concerning vehicle structure on the Croatian motorways, this chapter showed the dominance of light vehicles. The I vehicle category represented 86.52% of total occasional motorway user transactions and 72.70% of frequent motorway user transactions. A similar pattern was present in road cross-border traffic, with 90.89% of transactions realised by passenger cars, which is essential to highlight due to the usage of the I vehicle category to test the impact of seasonality on motorway travel demand. Chapter 7 further discusses suggestions for observing other vehicle categories through future research.

Although GDP movements between Croatia and the European Union showed positive trends, the Croatian GDP has been notably more volatile than in the European Union, following the 2008 global economic crisis and a reduction in the national population. Building on extant literature, this chapter supports using GDP per capita as variable as it serves as a better proxy for personal income and offers more consistent estimates due to consideration of population levels.

The evidence presented in this chapter illustrates higher values of each observed explanatory variable during the summer period, with significant fluctuations in occasional motorway traffic and tourist activity, confirming the presence of seasonality in Croatia. Therefore, the higher values observed in the summer period for both independent and dependent variables underscore the necessity of examining their impact on motorway travel demand. This is important, as traffic patterns reveal significant differences between frequent and occasional motorway users. Understanding these dynamics can inform better infrastructure planning and traffic management strategies to accommodate varying travel behaviours.

CHAPTER 3. LITERATURE REVIEW

3.1. Introduction

This chapter summarises the collected literature that investigates the impacts of various explanatory variables on travel demand. Conducting the literature review is essential for understanding the topic, the findings, and the key issues (Hart, 1998). Therefore, the remaining content starts with an explanation of the research process for the literature, followed by a definition of the elasticity concept, which in the context of this thesis is an essential item used to evaluate the impact of each explanatory variable on motorway travel demand. Chapter 3 also examines and discusses the collected studies, focusing on the impact of toll prices, fuel prices, income, and tourist activity on travel demand. These studies are reviewed in various contexts, including the direct, indirect, and combined impacts of each observed variable on travel demand. The chapter concludes with identification and addressing the gaps in current Croatian and international literature, with the aim of contributing new insights and knowledge to both academic research and practical applications.

3.2. Methodology for literature review

A literature review represents a way of synthesizing existing knowledge to show evidence on a meta-level and to uncover areas where more research is needed, which is a critical component of building conceptual models (Easterby-Smith et al., 2015; Snyder, 2019). This thesis employs the Theoretical literature review approach to summarise existing knowledge and theories and identify research gaps relevant to motorway demand. By examining established theories, the literature review lays the groundwork for developing and testing new hypotheses (Dudovskiy, 2018).

While there are different types of literature review, this thesis excludes Agumentative, Integrative, and Systematic reviews due to their limits in aligning with the aims of the thesis. Instead, a targeted approach was applied, guided by the author’s extensive experience in motorway transportation and the known literature (Goodwin et al., 2004; Litman, 2019; Matas & Raymond, 2003; Odeck & Bråthen, 2008), as well as additional criteria for relevance, recency, and the availability of elasticity estimates (Dunkerley et al., 2020). This approach follows the note of Easterby-Smith et al. (2015), who state that a good literature review is not only concerned with sources such as books and articles, but can also include knowledge from experts on the topic.

The literature research used databases of Google, Google Scholar, Elsevier, Taylor and Francis Online, Research Gate, Sage Pub, Science Direct, and the Sheffield Hallam University Online Library, with keywords including travel demand, seasonality, elasticities, toll prices, fuel prices, GDP, and tourist activity. This yielded 190 studies, narrowing focus on critical variables while addressing literature gaps. Consideration of the broad span of the literature enabled understanding the main concepts and each explanatory variable's elasticity variations through time. It is worth emphasizing that during this thesis's literature research and collection, the literature on the impact of toll prices, fuel prices, GDP, and tourist arrivals on motorway travel demand in Croatia was absent. However, there is limited evidence of literature investigating the impact of seasonality and tourist activity in Croatia (Corluka, 2018; Kožić, 2013; Mervar & Payne, 2007), but not on motorway travel demand.

3.3. The concept of elasticity

Numerous studies investigated transport elasticities and influencing factors using different methods (Abrantes & Wardman, 2011; Goodwin et al., 2004; Litman, 2019; Odeck & Bråthen, 2008; Odeck & Johansen, 2016). In their work, Odeck and Bråthen (2008) explained elasticity as a concept frequently used to measure the responsiveness of demand to changes in factors determining the level of demand. The elasticity measures the degree of response to particular changes (Litman, 2013). Knowing elasticities is necessary to evaluate potential adverse effects, such as the misallocation of traffic between tolled and alternative local untolled roads (Matas & Raymond, 2003).

Elasticity values are classified by magnitude, where elasticities of less than 1.0 absolute value are called inelastic (meaning that changes in an independent variable cause less than a proportional change in the dependent variable). In contrast, elasticities greater than 1.0 in absolute value are called elastic (meaning that changes in an independent variable cause more than a proportional change in the dependent variable) (Litman, 2019). Another vital issue to consider when calculating elasticities is the notion of short-run and long-run elasticities, where short-run elasticities represent an effect of an independent variable on travel demand within one year. Odeck and Bråthen (2008) noted that the immediate response to toll change will be included in the short-run elasticity only if the effect persists a year after the toll change. In contrast, the long-run elasticities measure the response to change over time, from three to ten years, when consumers adjust their behaviour (Goodwin et al., 2004). Generally, elasticities tend to increase over time as consumers incorporate changes in long-run decisions

(Litman, 2013). The literature also notes that the long-run elasticity is approximately two to three times higher than the short-run (De Jong & Gunn, 2001; Goodwin et al., 2004; Litman, 2019; van Dender & Clever, 2013). Even though applied regression models vary among studies due to data type and set aims, this thesis follows common practice and uses the econometric package to calculate the elasticity values (Llorca et al., 2018; Matas & Raymond, 2003; Park, 2011; Pham & Tran, 2020; Wooldridge, 2012). As examined in the thesis, the econometric package R software enabled the calculation of the elasticity values. This approach expresses the elasticity as an estimated coefficient with different significance levels for each explanatory variable used in the models.

The following sub-chapters represent a literature review separately for tolls, fuel prices, GDP values, and tourism in relation to travel demand. However, grouping the literature in each sub-chapter by traditional magnitude categories (elastic and inelastic) is inappropriate, as elasticity values from the collected literature are generally inelastic. Therefore, this thesis follows the approach of Matas and Raymond (2003), which categorised toll elasticities into four categories and organised the literature estimates in absolute values to:

- High short-run elasticity: coefficients larger than 0.6;
- Middle-high short-run elasticity: coefficients between 0.4 and 0.6;
- Middle-low short-run elasticity: coefficients between 0.3 and 0.4;
- Low short-run elasticity: coefficients between 0 and 0.3.

Sice the thesis investigates the impact of seasonality on motorway travel demand by estimating short-run elasticity values, where available, the long-run literature elasticity estimates are also reported in this chapter.

3.4. The impact of tolls on travel demand

Tolls are a common way to fund motorway and bridge improvements and are often in conjunction with road privatization. However, they are structured to maximise revenues and success (Litman, 2019). There are different types of road pricing, such as cordon tolls, distance pricing, time pricing, and congestion pricing (May & Milne, 2000). The authors of the study concluded that time-based pricing provides the most significant overall benefits, followed by distance-based pricing (used in Croatia), congestion pricing, and cordon pricing. In support of the distance-based pricing method, Santos (2004) indicated that a vehicle user charge based on distance-based pricing is highly suitable for addressing transport-related environmental problems.

Numerous studies examine the elasticity of toll prices concerning road travel behaviour, and it is beyond this thesis's scope to review them all. Estimates of the toll elasticities may also vary across studies because of the specific set of covariates included in the model (Miller & Alberini, 2016). The price elasticity of travel demand shows travellers' responsiveness to changes in travel costs, which in the case of motorway travel demand include the toll paid for using the facility (Burris & Huang, 2011). Even though estimations vary between the studies due to the set of explanatory variables, type of vehicle, and data for specific countries and regions, the results summarised in Table 3.1. suggest the negative impact of toll price growth on travel demand. Therefore, this sub-chapter summarises relevant literature that estimates the impact of tolls on travel demand.

The following groups (Groups 1–4) represent a summary of the literature that studied the impact of tolls sorted by elasticity range.

- *Group 1: Literature with high short-run elasticity values (coefficients larger than 0.6 in absolute values)*

Regarding the literature with estimated elasticity values above 0.6 in absolute terms, in the study on investigating travellers' response to changes in the cost of travel in the United States of America, Burris and Huang (2011) estimated the toll elasticity of demand for 2-axle vehicles in range from -0.02 to -0.79, while for 5-axle vehicles ranged from -0.09 to -0.85. Even if the results of existing studies are based on different samples and by country, the differences in elasticities for various tolled roads are also affected by the availability and quality of alternative toll-free roads, the length of the tolling section, and the location of the road in a tourist destination (Matas & Raymond, 2003). In addition, by using panel data, Matas and Raymond (2003) covered the period of 18 years to evaluate potential adverse effects on Spanish-tolled motorways. They argued that travel demand is slightly more elastic on longer motorway sections, which explains why travel demand is more sensitive to tolls when the total amount increases. The authors used a dynamic model to identify short-run and long-run responses to changes in determined vital variables, including toll price as an explanatory variable. The results suggested that travel demand is relatively sensitive to variable changes, with short-run elasticities ranging from -0.21 in the most inelastic section to -0.83 in the most elastic section. In contrast, the authors ranged the long-run elasticities from -0.33 to -1.31.

In the case of Chile, Batarce et al. (2023) observed the behaviour of different vehicle categories on urban highways in Santiago and found that light vehicles have more exposed sensitivity concerning toll prices (short-run -0.82, and long-run -1.29) than buses and trucks (short-run -0.68, and long-run -0.96) as well as trucks over two axles (short-run -0.66, and long-run -1.15)[4]. These results showed higher sensitivity than the study of de Grange et al., (2015) for urban highways in Santiago, who found toll elasticities below -0.05 for two freeways, -0.16 for the third, and -0.47 for the fourth, which had more alternative routes. A comparison of two studies related to the City of Santiago with different estimates suggests variability of results depending on the dataset, methods, and focus of the study used.

- *Group 2: Literature with middle-high short-run elasticity values (coefficients between 0.4 and 0.6 in absolute values)*

In the literature with middle-high short-run elasticity values, Odeck and Bråthen (2008) investigated elasticities and user attitudes towards 19 Norwegian road projects. They supplemented their survey data with data from traffic counts and other sources and found a consensus that transportation demand concerning tolls is inelastic. The calculated average toll elasticity was -0.54 in the short run and -0.82 in the long run. The authors found that public attitudes concerning tolls tend to become favorable when people understand how to use generated revenues. Matas et al. (2012) obtained similar results in their study of traffic movement forecasting under the uncertainty of long-term predictions on the tolled motorways in Spain. More precisely, they investigated the impact of GDP, gasoline price, toll per kilometre, and a set of dummy variables representing the significant changes in the road network from 1980 to 2008. Even if the following sub-chapters present GDP and gasoline price elasticity values, they ranged obtained toll elasticities in the short run from -0.155 to -0.488. The long-run elasticities were from -0.256 to -0.805.

In the case of Spain, other studies showed similar results with estimated toll elasticity values concerning travel demand with the inclusion of GDP, GDP per capita, employment, and fuel cost in a range of -0.19 to -0.43 for heavy vehicles and -0.19 to -0.40 for light vehicles (Gomez & Vassallo, 2015; Gomez et al., 2016). The authors suggested a stable trend of toll elasticities, potentially caused by inflation adjusting the real toll rates in Spain and, therefore, remaining stable.

[4] The authors remark that the estimated short-run effect is related to one month, while the long-run effect corresponds to one year or more.

- *Group 3: Literature with middle-low short-run elasticity values (coefficients between 0.3 and 0.4 in absolute values)*

Regarding the study on the case of the city of Milan, where the effect of road pricing on driver behaviour and air pollution was evaluated by observing the role of fees charged to enter congested downtown areas, Gibson and Carnovale (2015) determined that a one percent price increase decreases entries by charged vehicles by -0.3. As the area observed in the study was a relatively small part of total trip cost, including time, fuel, and depreciation, the authors concluded that demand response to price is significant.

Besides observing the impact of tolling different types of roads, Cervero (2012) investigated the impact of variable pricing on the San Francisco-Oakland Bay Bridge. The study estimated a negative short-term elasticity of -0.30 for high-occupancy vehicle (HOV) lanes, which suggests a significant share of vehicles during peak periods forewent travel, switched routes, shifted to public transit, or opted to drive alone. Regarding regular traffic elasticities in response to variable pricing, it showed a negative value of -0.23, indicating inelastic behaviour in pricing during the peak period.

- *Group 4: Literature with low short-run elasticity values (coefficients between 0 and 0.3 in absolute values)*

Per their study and findings of the difference in user sensitivity on motorway sections, Matajič et al. (2015) found that the toll price elasticity of transportation demand on Slovenian motorways is not unique across a motorway. However, they had estimated in regression models that a 1% increase in tolls per kilometre of toll road would cause a decrease in travel demand on toll motorways in Slovenia by -0,09% for passenger cars and -0,083% for trucks. Besides investigating the impact of tolls, the authors considered the effect of other variables, such as GDP per capita and fuel prices. The following sub-chapters present the results.

- *Conclusion*

Findings in the collected literature indicate that drivers are sensitive to toll changes, where setting a toll on a road can result in a misallocation of traffic to the alternative toll-free road or trip reduction. The findings confirm that tolls can significantly impact motorway traffic where the level of impact varies across the countries, road sections, type of data, observed period, method, and determined explanatory variables used in the model. This statement also aligns with Giuliano and Narayan (2003) finding of trip rates in the United States of America and

Great Britain, which showed that the effect of a particular explanatory variable is different in the two countries. In their case, the finding was related to the household income effect.

Even in the in the collected literature and Table 3.1. which summarises toll price elasticity values for the short and long run, there is no evidence that authors split and differentiate elasticity values during one year for frequent and occasional motorway users with consideration of seasonality. In that case, the traffic volume can change due to tourist arrivals, frequency of motorway usage, vehicle category, or other factors that could cause fluctuations in traffic volumes. As mentioned in Chapter 1, one of the critical focuses of this thesis is to investigate the impact of changes in motorway travel demand sensitivity separately on frequent and occasional motorway users concerning changes in toll prices between the summer and non-summer periods, taking the Istrian motorway as a case study. Chapter 4 examines and establishes various hypotheses for testing throughout this thesis, especially as, despite regular toll prices increase during the summer period by 10%, traffic levels did not decrease.

Table 3.1.

Review of toll price elasticity values from the collected literature

Elasticity group	Source	Year Coverage (Country)	Elasticities
High short-run elasticity	Burris and Huang (2011)	2000 – 2010 (USA)	-0.79 to -0.02 (for 2-axle), -0.85 to -0.09 (for 5-axle)
	Matas and Raymond (2003)	1981 – 1998 (Spain)	-0.83 to -0.21 in short-run; -0.33 to -1.31 in long-run
	Batarce et al. (2023)[5]	2013 – 2018 (Chile)	light vehicles: -0.82 short-run, -1.29 long-run buses and trucks: -0.68 short-run, -0.96 long-run trucks over two axles: -0.66 short-run, -1.15 long-run
Middle-high short-run elasticity	Odeck and Bråthen (2008)	1987 – 2002 (Norway)	-0.54 in short-run; -0.82 in long run
	Matas et al. (2012)	1980 – 2008 (Spain)	-0.488 to -0.155 in short-run; -0.805 to -0.256 in long-run
	de Grange et al. (2015)	2009 – 2011 (Chile)	-0.47 to -0.05
	Gomez and Vassallo (2015)	1990 – 2011 (Spain)	-0.43 to -0.19 for heavy vehicles

[5]Even if authors observed different vehicle categories, sorted by elasticity value of the light vehicle category as this thesis applies tests on the I vehicle category (light vehicle).

Elasticity group	Source	Year Coverage (Country)	Elasticities
Middle-high short-run elasticity	Gomez et al. (2016)	1990 – 2011 (Spain)	-0.40 to -0.19 for light vehicles
Middle-low short-run elasticity	Gibson and Carnovale (2015)	2008 – 2012 (Italy)	-0.30
	Cervero (2012)	2009 – 2011 (USA)	-0.30 and -0.23
Low short-run elasticity	Matajič et al. (2015)	2001 – 2006 (Slovenia)	-0.09 for passenger cars and -0.083 for trucks

Note: Developed and summarised by the author from other studies.

3.5. The impact of fuel prices on travel demand

The literature observes varying estimates of the impact of fuel prices on travel demand. Even though differences in estimated elasticity values vary due to observed data, method, vehicle category, country/region, and period, the literature suggests a negative impact of fuel price growth on travel demand and fuel consumption (e.g., Dahl, 2012; Odeck & Johansen, 2016; Wang & Chen, 2014; Yang & Timmermans, 2012). This negative impact suggests fuel prices are an essential factor in transportation, which causes changes in travelled distances and travel behaviour.

Changes in fuel prices affect the share of fuel costs in the total cost of driving (Small & Van Dender, 2018). The authors found that rising incomes reduce the significance of fuel costs in decisions to travel, meaning that the fuel cost elasticity of travelled distance increases with higher income levels. However, price influence on freight vehicles can differ among individuals, mainly because commercial vehicle operators are part of a broader production and distribution process (Goodwin et al., 2004). Based on these considerations, the authors indicated that direct fuel costs are likely a smaller proportion of freight vehicles' total costs than passenger transport, suggesting that goods traffic (heavy vehicle traffic) is less sensitive to price than private cars (light vehicles). Even if there are many ways to reduce travelled distance, one way is to treat fuel prices as a policy tool where higher fuel prices should lead to lower travelled distance and a change in travel behaviour (Wang & Chen, 2014). The remaining text groups the literature into four categories, ranged by estimated elasticity values.

- *Group 1: Literature with high short-run elasticity values (coefficients larger than 0.6 in absolute values)*

Although the collected literature indicates low values of estimated fuel elasticity values across different periods and contexts, particular studies have demonstrated cases where short-run elasticities have absolute values above 0.6. As an example of a high short-run elasticity value, Matajič et al. (2015) showed different user sensitivity of passenger and freight transport to changes in fuel price on the Slovenian motorways. The authors estimated that a 1% increase in fuel prices in euros resulted in a decrease in the volume of freight transport demand by 0.67% and 0.12% in passenger demand.

- *Group 2: Literature with middle-high short-run elasticity values (coefficients between 0.4 and 0.6 in absolute values)*

Similar to Group 1, the literature with estimated middle-high short-run elasticity values is limited. In the case of urban freeway use in Santiago, Chile, de Grange et al. (2015) found fuel price elasticities with values of approximately -0.45 for two freeways and -0.21 for the third, whereas for the fourth (which had the fewest alternatives), it was -0.07. They found that toll price elasticity was always lower than the fuel price elasticities for every freeway, indicating higher driver sensitivity to fuel prices. This suggests that the quality of alternative routes may affect user sensitivity regarding changes in fuel prices. Considering other studies that fit into Group 2, the study on heavy vehicles conducted by Gomez and Vassallo (2015) in the case of Spain ranged fuel cost elasticity estimated from -0.56 to -0.01.

- *Group 3: Literature with middle-low short-run elasticity values (coefficients between 0.3 and 0.4 in absolute values)*

A wide variety of results with middle-low elasticity values are present in the collected literature. In their simplistic model of investigating if traditional variables GDP and fuel prices are sufficient to explain the trends in a decrease in VKT (Vehicle Kilometres Travelled) per capita, the results indicated that GDP per capita and fuel price could explain most of the trends in VKT per capita (Bastian et al., 2016). The obtained gasoline price elasticities varied among the countries: for the United States, -0.14, Germany, -0.18, Sweden, -0.23, France, -0.31, Australia, -0.36, and the UK, -0.37, suggesting that elasticities may vary across countries due to a specific set of covariates (Miller & Alberini, 2016). The following sub-chapter represents the results for GDP per capita values.

In terms of the influence of price and income on fuel price consumption and, ultimately, on transport demand and travel behaviour in different countries, Dahl (2012) investigated if elasticities are constant across countries with different incomes and prices. The study showed some effects for gasoline, with lower-priced countries having a less elastic price response than higher-priced countries, while lower-income countries have a less elastic price response than higher-income countries. The author ranged gasoline price elasticities between -0.11 and -0.33, diesel between -0.13 and -0.38, and income elasticities between 1.26 and 0.66. In the case of Croatia, the author reported gasoline price elasticities of -0.32 and -0.13 for diesel, while for income, the elasticity was 1.35.

Regarding Spain, Gomez and Vassallo (2015) conducted a study on travel demand to explain the evolution of light vehicle demand on tolled roads in Spain between 1990 and 2011. The study applied dynamic panel data methodology and used socioeconomic variables to describe the changes in light vehicle travel demand over time. Concerning the impact of fuel prices on vehicle kilometres travelled, the results for the short run were between -0.37 and -0.01. However, the results showed that GDP per capita and employment lead to more stable and consistent results in demand evolution on toll roads than GDP, with short-run elasticity ranging from 0.94 to 1.18. With the application of different econometric methods in a dynamic approach, Matas et al. (2012) obtained similar results in the case of Spain and estimated gasoline price short-run elasticity values of -0.380 and -0.628 for the long-run. These estimates indicate that elasticity values may depend on the method used, as numerous studies use different econometric approaches to gain insights into the impact of explanatory variables (Bakhat et al., 2017; Matajič et al., 2015; Odeck & Johansen, 2016).

- *Group 4: Literature with low short-run elasticity values (coefficients between 0 and 0.3 in absolute values)*

In the case of the thesis, the collected literature with low-short fuel price elasticity values contains the most broad sources and estimated values. In a review of price elasticities for road traffic demand, Hanly et al. (2002) concluded that if the real fuel price increases by 10%, the traffic level volume will reduce by around 1% within a year and by 3% in the long-run. In another review of scientific articles that determine the response to changes in fuel prices, through a compressive survey of elasticities for automobile fuel demand, Graham and Glaister (2002) concluded fuel price elasticity in the short-run is between -0.2 and -0.3 and from -0.6 to -0.8 in the long-run. The authors concluded that raising fuel prices is more effective in reducing the quantity of fuel consumption than reducing traffic volume. These indications about lower fuel price elasticity values are followed by Dunkerley et al. (2020) in their report on existing literature on road traffic demand elasticities to population growth, income growth, and fuel cost changes, suggesting that the range of estimated fuel price elasticities is relatively tiny between -0.10 and -0.50, although using a variety of data types and methodologies. Furthermore, De Jong and Gunn (2001) reviewed the available evidence concerning the elasticities of private car travel demand concerning time and cost changes. The study focused on associate member states of the European Union and studies conducted in 1985 and later. The authors reported that short-run fuel price elasticity was -0.16 for both car trips and cars per kilometre. In the long-run, the elasticity of car per kilometre to fuel prices increased to -0.26, but only marginally for car trips with a value of -0.19.

When estimating the elasticities of fuel and travel demand to fuel prices and income with different approaches, in the case of Norway, Odeck and Johansen (2016) applied two different econometric approaches: the error correction model (ECM) and the dynamic model (OLS). The dynamic model exhibited greater explanatory power and a better fit for the obtained data, so it was considered a more appropriate approach. The short-run elasticities of fuel and travel demand concerning fuel prices were -0.26 and -0.11, while the long-run elasticity values were higher: -0.36 and -0.24, respectively. In addition to the previous, Gonzalez and Marrero (2012) investigated the impact of GDP, fuel price, and vehicle fleet on road traffic in the case of Spain by applying a dynamic panel data model. Considering OLS, Fixed Effects, GMM DIFF (Generalized Method of Moments Difference), and GMM SYS (Generalized Method of Moments System) models, the most appropriate and chosen method for their study was GMM SYS. The estimated short-run elasticity for fuel prices was -0.282 and -0.607 for the long-run. These results suggest the possibility of applying different methods for estimating elasticity values depending on the data and aims of the study.

Regarding another Spanish case study, Álvarez et al. (2007) determined the time value in a traffic context characterised by a road parallel network. They found statistically significant elasticity for fuel prices with a value of -0.09. Bakhat et al. (2017) examined different short-run and long-run price elasticities of transport fuels in Spain separately for diesel and gasoline between 1999 and 2015. During the crisis period (2008–2013), the short-run elasticities for diesel and gasoline were -0.019 and -0.067. The long-run elasticities also increased to -0.035 for diesel and -0.193 for gasoline. In the non-crisis period, short-run diesel elasticities were -0.015 and gasoline elasticities were -0.064, while long-run elasticities were -0.026 and -0.185, respectively.

On the Slovenian motorways, a neighboring country to Croatia, Matajič et al. (2015) conducted estimates for passenger and freight transportation on tolled roads in Slovenia. They showed that a 1% increase in fuel prices in euros would result in a 0.12% decrease in the volume of passenger transport demand (as well as a reduction of 0.67% for freight traffic). This finding for passenger transport is valuable for this thesis, as 49.12% of the total cross-border roads between Slovenia and the Republic of Croatia were realised in 2014–2019 (Croatian Bureau of Statistics, n.d.b).

According to the study of fuel surcharge policy for reducing road traffic greenhouse gas emissions in the case of Italy, Gallo (2011) investigated car users who prefer to shift towards more efficient fuel vehicles than to use public transportation, with the explanation that an increase in fuel prices of 22% corresponds only to a 2.6% decrease in car usage. Concerning that, a fuel price increase of 10% would result in a 1% reduction in fuel consumption (Hughes & Knittel, 2006; Small & Van Dender, 2018), which could harm traffic behaviour and demand, especially on tolled road sections with good alternative toll-free routes. Barla et al. (2009) obtained similar results in Canada by using panel data from 1990 to 2004 to estimate the rebound effect and other elasticities for light-duty vehicles. They found that in the long-run, a fuel price increase of 10% reduces driving by 2% and by 1% concerning the average fuel consumption rate. In addition to the North American context studies, Hymel et al. (2010) found the elasticity for the use of the vehicle in the US concerning per kilometre fuel cost was -0.026 in the short-run and -0.131 in the long-run (evaluated at 2004 levels), while when evaluated at 1996–2004 mean levels were -0.047 in the short-run and -0.241 in the long-run. These elasticity values tend to decline in magnitude with income and increase as fuel prices rise. The authors concluded that long-run travel elasticities are between 3.4 and 9.4 times higher than short-run elasticities. Gillingham (2014) examined how consumers and buyers of new vehicles respond to gasoline price changes in California. The empirical results of the medium-run elasticity of vehicle miles travelled for gasoline prices for new vehicles were -0.22 during the first six years of their vehicle's lifespan. The study indicated that vehicle travel responsiveness increases with income, perhaps due to household switching of vehicles with an increase in income. Dargay (2007) showed that car travel is more affected by car purchase costs (short-run -0.35 and long-run -0.46) than by fuel prices, which implies the usage of cars despite rising variable costs reflected through the fuel price. The study analysed the factors determining household car travel and the effect of prices and income in the United Kingdom. Regarding fuel price elasticities, the estimate was -0.10 in the short-run and -0.14 in the long-run.

- *Conclusion*

The summary of the results from Table 3.2. suggests that the elasticity values are unstable over time, influenced by economic aspects and geographical frameworks (Odeck & Bråthen, 2008). Fuel prices vary by country, which is primarily but not exclusively because of different tax fuel rates (Romero-Jordán et al., 2010; Small & Van Dender, 2018), while user sensitivity may also differ across other countries if transportation patterns are different (Bastian et al., 2016; Gallo, 2011). The literature states that there is no specific procedure to apply the transferability procedure to each country (Musso et al., 2013) or to have common elasticities across countries (Dahl, 2012; Espey, 1997). The previously reviewed studies indicate various magnitudes of fuel price impacts on travel demand within the observed geographical area and applied econometric method.

Table 3.2.

Review of fuel price elasticity values from the collected literature

Elasticity group	Source	Year Coverage (Country)	Elasticities
High short-run elasticity	Matajič et al. (2015)	2001 – 2006 (Slovenia)	-0.12 for passenger transport; -0.67 for freight transport
Middle-high short-run elasticity	Gomez et al. (2016)	1990 – 2011 (Spain)	-0.56 to -0.01 in the short run (heavy vehicles)
	Dunkerley et al. (2020)	Not specified (UK and international)	-0.50 to -0.10
	de Grange et al. (2015)	2009 – 2011 (Chile)	-0.45 to -0.07
Middle-low short-run elasticity	Matas et al. (2012)	1980 – 2008 (Spain)	-0.380 in short-run; -0.628 in long-run
	Gomez and Vassallo (2015)	1990 – 2011 (Spain)	-0.37 to -0.01 in the short-run (light vehicles)
	Bastian et al. (2016)	1980 – 2014 (United Kingdom) 1980 – 2013 (Australia) 1980 – 2014 (France) 1980 – 2014 (Sweden) 1991 – 2012 (Germany) 1980 – 2015 (USA)	United Kingdom: -0.37 Australia: -0.36 France: -0.31 Sweden: -0.23 Germany: -0.18 USA: -0.14

Elasticity group	Source	Year Coverage (Country)	Elasticities
Middle-low short-run elasticity	Dahl (2012)	Not specified (124 countries)	-0.33 to -0.11 for gasoline price: -0.13 to 0.38 for diesel price Croatia: -0.32 for gasoline; -0.13 for diesel
Low short-run elasticity	Odeck and Johansen (2016)	1980 – 2011 (Norway)	-0.26 and -0.11 in short-run; -0.36 and -0.24 in long-run
	Gonzalez and Marrero (2012)	1998 – 2006 (Spain)	-0.282 in short-run; -0.607 in long-run
	Gillingham (2014)	2001 – 2003 and 2005 – 2009 (USA)	-0.22 in medium-run
	Barla et al. (2009)	1990 – 2004 (Canada)	-0.20 to -0.10 in long-run
	De Jong and Gunn (2001)	1985 and later (European countries)	-0.16 in short-run; -0.26 in long-run
	Graham and Glaister (2002)	Not specified (International)	-0.15 in short-run; -0.30 in long-run
	Gallo (2011)	1997 – 2008 (Italy)	-0.12
	Dargay (2007)	1976 – 1995 (UK)	-0.10 in short-run; -0.14 in long-run
	Hughes et al. (2006)	1975 – 1980 and 2001 – 2006 (USA)	-0.10
	Álvarez et al. (2007)	1989 – 2000 (Spain)	-0.06 for light vehicles; -0.09 for heavy vehicles
Low short-run elasticity	Bakhat et al. (2017)	1999 – 2015 (Spain)	In the crisis period: -0.067 to -0.019 in the short-run; -0.035 and -0.193 in the long-run In the non-crisis period: -0.015 and -0.064 in short-run; -0.026 and -0.185 in long-run
Low short-run elasticity	Hymel et al. (2010)	1966 – 2004 (USA)	-0.047 and -0.026 in short-run; -0.241 and -0.131 in long-run

Note: Developed and summarised by the author from other studies.

3.6. The impact of GDP and income on travel demand

The extant literature observes the impact of GDP and income on travel demand. Besides income and GDP, various factors that change over time, including new technologies and cheaper travel, allow individuals to spend more on travel and change their lifestyles (Bannister, 2011; Schafer, 2000), except during recession periods. This is particularly true for the recession period between 2008 and 2011, which caused an increase in the unemployment rate and other social impacts in Europe (Kelly & McGuinness, 2015). Regarding that, Musso et al. (2013), who investigated motorway traffic changes in Greece by considering GDP trends, concluded that road traffic sensitivity refers primarily to price and income. In general, the collected literature suggests that increasing GDP, GDP per capita, and income positively affect travel demand and travelled distances, enabling people to spend more money on travel. Since literature findings show a range of estimated elasticity values, this sub-chapter provides an overview of the collected literature regarding the impact of GDP and income on travel demand by grouping the literature from higher to lower elasticity values.

- *Group 1: Literature with high short-run elasticity values (coefficients larger than 0.6 in absolute values)*

When studying historical trends in income and price elasticities of transportation demand between 1850 and 2010, the income elasticity for passenger transportation demand in the United Kingdom was 3.1 in the mid-nineteenth century and declined to 0.8 in 2010 (Fouquet, 2012). That trend indicates the potential for gradual elasticity decline as the country's economy develops.

Concerning the relation between congestion, travel, and income, Dargay (2007) found that the income elasticity of cars is asymmetric, where an increase in income has a more significant impact on car travel (0.83 in the short-run, 1.09 in the long-run) than in the case of income reduction (0.65 in the short-run and 0.86 in the long-run). Income also impacts public transportation demand, meaning that an increase in income generally reduces public transportation usage and shifts people to other modes of transportation. Holmgren (2007) obtained a value of -0.62, meaning that an increase in income leads to a decrease in public transportation usage. However, the author remarked on paying more attention to income elasticity towards public transport demand.

Besides income, GDP per capita is also used as a proxy for income (Baranzini & Weber, 2013; CrÔtte et al., 2010). Income elasticities based on household incomes are generally smaller than GDP as they include a broader range of factors than average household income (Dunkerley et al., 2020). When comparing countries with similar GDP per capita, energy consumption can vary considerably due to GDP structure, where in the case of freight transport, dematerialization and shifting towards lighter materials reduce the number of additional tonne-kilometres to be covered (Wohlgemuth, 1997). The author indicated short-run and long-run income for distance travelled with values of 0.78 and 0.88 for the United States of America, 0.23 and 1.04 for Europe, 0.33 and 1.12 for Japan.

In the case of Spain, Matas and Raymond (2003) used real GDP as a variable instead of disposable income to better capture Spain's economic activity level. Their study of the elasticity of demand for various Spanish-tolled motorways found that travel demand is less sensitive to gas and toll prices than GDP. The authors indicated demand elasticity concerning GDP, with a value of 0.890 in the short-run and 1.405 in the long-run. Besides examining the impact of gasoline and fuel prices per kilometre on travel demand presented in the previous sub-chapter, Matas et al. (2012) found short-run elasticity values of 0.754 and 1.244 for the long-run real GDP value.

Regarding the impact of the GDP variable on motorway traffic by type of vehicle, Gomez and Vassallo (2015) analysed explanatory variables that impact heavy vehicle volume on toll roads in Spain over time. The results show that GDP may not constitute a suitable explanatory variable for heavy vehicle traffic demand but rather consider only the GDP of sectors with a high impact on transport demand. Therefore, the authors ranged the GDP elasticities of highly transport-intensive sectors from 0.55 to 0.99 on the national level and from 0.74 to 1.28 on the provincial level. When observing light vehicles, Gomez et al. (2016) showed that GDP is not the most appropriate explanatory variable, as employment or GDP per capita show stable and consistent results. Concerning GDP per capita, the authors ranged elasticity values from 0.94 to 1.18 on the national level and from 0.77 to 0.98 on the provincial level.

During the study of investigating if GDP and fuel prices are sufficient to explain the trends in vehicle kilometres travelled, Bastian et al. (2016) obtained GDP per capita elasticity values of 0.41 for Australia, 0.63 for Sweden, 0.71 for the United States of America, 0.94 for Germany, 1.07 for the United Kingdom, and 1.08 for France. These findings show that elasticity values and user sensitivity vary among countries and are not unique. However, there are also cases where the impact of GDP is insignificant (Gonzalez & Marrero, 2012), which suggests that an increase in GDP per capita has no significant effect on an increase in vehicle kilometres travelled through the set model. Such finding could reflect that greater distances are often covered in rural areas with lower income levels (Fulton et al., 2000).

- *Group 2: Literature with middle-high short-run elasticity values (coefficients between 0.4 and 0.6 in absolute values)*

The results in the case of Great Britain showed that long-distance travel is significantly and strongly related to income, where air transportation is the most income-elastic, followed by rail, car, and coach (Dargay & Clark, 2012). The authors also showed that long-distance car journeys are more income elastic than short journeys, with elasticity values between 0.47 and 0.70 for long-distance journeys (above 150 miles) and between 0.31 and 0.53 for short-distance journeys (less than 150 miles). Even if results indicate an overall income elasticity value of 0.46 for car journeys, the most significant impact is observed for air travel, with a value of 1.44, suggesting it to be a luxury mode. In the case of Slovenian motorways, Matajič et al. (2015) researched that an increase in GDP per capita by 1% in Slovenia would lead to an increase in transportation demand by 0.56% for light vehicles and 1.016% for heavy vehicles.

- *Group 3: Literature with middle-low short-run elasticity values (coefficients between 0.3 and 0.4 in absolute values)*

Concerning the literature review of empirical studies on the effects of price and income on fuel consumption and traffic levels, Goodwin et al. (2004) argued that an increase in real income of 10% impacts the volume of traffic by 2% in the short-run and 5% in the long-run. Even with limited evidence, Wohlgemuth (1997) observed the distance travelled by passenger cars and light trucks in the United States of America, Europe, and Japan, and estimates vary between the regions. In that sense, only a middle-low short-run elasticity value for distances travelled concerning income was estimated for Japan with a value of 0.33, positioned between Europe (0.23) and the United States of America (0.78).

- *Group 4: Literature with low short-run elasticity values (coefficients between 0 and 0.3 in absolute values)*

Even if Schafer (2000) argued that higher income affects longer travel distances since people can purchase faster transportation (which ensures covering longer distances within a given time), Paulley et al. (2006) provided similar conclusions. They calculated that trip lengths increase with income ranging from 0.09 to 0.21, with more substantial growth for car commuting, business trips by rail, and business trips by bus.

When exploring the relationship between GDP and passenger kilometres travelled, van Dender and Clever (2013) investigated ten countries from 1980 to 2007 and found GDP per capita in the range of 0.120 to 0.217 for the short-run. The elasticity values in the long-run ranged from 0.376 to 1.425, depending on the equation model. The results also show that the short-run elasticity rises over time while the long-run elasticity decreases (short-run elasticity of 0.168 until 2000 and 0.217 after 2000; long-run elasticity of 1.313 until 2000 and 0.376

after 2000). They explain the decline in long-run elasticity as a reduced lagged effect as the short-run elasticity has increased.

Besides the impact of the equation model on estimates, Odeck and Johansen (2016) estimated the elasticities of fuel and travel demand concerning fuel prices and income, using Norway as a case study from 1980 to 2011. Even if the authors conducted static and dynamic methodological approaches, the dynamic model exhibited more significant explanatory power for the collected data, so the authors consider it preferable. The results showed 0.061 short-run income elasticity concerning vehicle kilometres travelled and 0.130 in the long-run.

In the context of North America, Hymel et al. (2010) investigated road traffic demand elasticities using collected data at the level of the United States of America from 1966 to 2004 and determined the ordinary income elasticity of vehicle travel with a value of 0.10 in the short-run and 0.50 in the long-run. Their results showed that congestion negatively affects travel demand more significantly when incomes increase. In the case of Canada, Barla et al. (2009) found that GDP has a positive and significant impact on travelled distance per adult. They found higher elasticity values where an increase in the GDP per capita of 10% caused an increase in driving distance by 2-3% as well as up to 4% in vehicle stock per adult.

- *Conclusion*

The presented literature showed that changes in the income of an individual can affect vehicle kilometres driven by changes in the number of trip journeys and distance travelled (Dunkerley et al., 2020), as higher income allows individuals to spend more money on travel (Fouquet, 2012; Mcmullen & Eckstein, 2012; Metz, 2010). In their evidence of papers related to the United Kingdom, Dunkerley et al. (2020) reported long-run income elasticity values ranging from 0.5 to 1.4. However, this relationship is inconsistent across countries (Wohlgemuth, 1997). Concerning historical and more recent drivers' sensitivity to travel concerning GDP (Abrantes & Wardman, 2011; Dahl, 2012; Havranek & Kokes, 2015; Litman, 2019), it can be concluded that with time, higher economic activity and increases in income and GDP reduce price elasticities and user sensitivity to travel. This thesis separately observes the impact of the Croatian GDP per capita and the European Union on motorway traffic volume due to the seasonality of tourist activity and road cross-borders. The proposed research for this thesis investigates if and how summer and non-summer motorway traffic volume on the Istiran motorway is affected by the European Union and Croatian GDP per capita, considering that between 2010 and 2019, 88.90% of total tourist arrivals in Croatia were international (Croatian Bureau of Statistics, n.d.a).

Table 3.3. summarises some of the previous studies of the elasticity of travel demand concerning GDP and income.

Table 3.3.

Review of GDP elasticity values from the collected literature

Elasticity group	Source	Year Coverage (Country)	Elasticities
High short-run elasticity	Matas and Raymond (2003)	1981 – 1998 (Spain)	0.890 in short-run; 1.405 in long-run
	Dargay (2007)	1976 – 1995 (UK)	0.83 in short-run; 1.09 in long-run
	Gomez et al. (2016)	1990 – 2011 (Spain)	0.77 to 1.18
	Matas et al. (2012)	1980 – 2008 (Spain)	0.754 in short-run; 1.244 in long-run
	Bastian et al. (2016)	1980 – 2014 (United Kingdom) 1980 – 2013 (Australia) 1980 – 2014 (France) 1980 – 2014 (Sweden) 1991 – 2012 (Germany) 1980 – 2015 (USA)	Australia: 0.41 Sweden: 0.63 USA: 0.71 Germany: 0.94 France: 1.08 United Kingdom: 1.07
	Holmgren (2007)	Not specified (International)	-0.62 (concerning public transportation)
Middle-high short-run elasticity	Matajič et al. (2015)	2001 – 2006 (Slovenia)	0.56 (light vehicles); 1.016 (heavy vehicles)
	Gomez and Vassallo (2015)	1990 – 2011 (Spain)	0.55 to 1.28
	Dunkerley et al. (2020)	Not specified (UK and international)	0.50 to 1.40 in long-run
	Dargay and Clark (2012)	1995 – 2006 (Great Britain)	0.47 to 0.70 (long-distance journey); 0.31 to 0.53 (short-distance journey)
Middle-low short-run elasticity	Wohlgemuth (1997)	Not specified (Global)	Japan: 0.33 in short-run; 1.12 in long-run
Low short-run elasticity	Wohlgemuth (1997)	Not specified (Global)	Europe: 0.23 in short-run; 1.04 in long-run United States of America: 0.78 in short-run; 0.88 in long-run

Elasticity group	Source	Year Coverage (Country)	Elasticities
Low short-run elasticity	Barla et al. (2009)	1990 – 2004 (Canada)	0.20 to 0.30
	Hanly et al. (2002)	1929 – 1991 (UK and international)	0.20 in short-run; 0.50 in long-run
	Goodwin et al. (2004)	1929 – 1998 (UK and international)	0.20 in short-run; 0.50 in long-run
	van Dender and Clever (2013)	1980 – 2007 (Ten countries)	0.120 to 0.217 in short-run; 0.376 to 1.425 in long-run
	Hymel et al. (2010)	1966 – 2004 (USA)	0.10 in short-run; 0.50 in long-run
	Paulley et al. (2006)	1980 – early 2000s (Great Britain and international)	0.09 to 0.21
	Odeck and Johansen (2016)	1980 – 2011 (Norway)	0.061 in short-run; 0.130 in long-run

Note: Developed and summarised by the author from other studies.

3.7. The impact of tourist activity on travel demand

Tourism research has expanded in the past two decades due to the growing global demand for tourism. Even studies observe different factors that may impact tourism, including income and price factors, this sub-chapter indicates literature limitations in estimating the direct impact of tourism on road travel demand. However, this sub-chapter provides an overview of the literature that suggests the positive impact of various factors on tourism demand. At the same time, the rise in transportation costs and living costs at the destination may hurt tourism in the long-run as people have enough time to adjust their spending. Due to omissions in estimated direct elasticity values between motorway travel demand and tourism, grouping the literature by elasticity range is not applicable in this sub-chapter.

Tourism is an essential economic activity in Croatia, considering the period from 2010 to 2019, with a total of 143.66 million tourist arrivals, of which 88.90% were international (Croatian Bureau of Statistics, n.d.a). Tourism also impacted the Croatian GDP, with a share of 19.5% in 2022 (Ministarstvo turizma Republike Hrvatske, 2023). Hence, tourist activity in the case of Croatia plays a vital role in transportation management and economics, as 73.98% of total tourist arrivals were generated during the summer season (Croatian Bureau of Statistics, n.d.a), indicating the presence of seasonality.

Academic literature considers seasonality in tourism as an essential topic where tourism's characteristics contain temporal and spatial demand variations throughout the year (Cannas, 2012). In their paper on measuring seasonality across Europe, Ferrante et al. (2018) concluded that despite relevant changes in the European population and economic and social changes, the seasonality pattern remained almost unchanged in the observed 10-year time. They indicated that the level of tourist demand may depend on different factors, such as environmental, institutional (related to school and work timetables), social, and cultural factors. In the review of tourism seasonality, Corluka (2018) indicated a lack of theoretical knowledge and methods, as knowledge of tourism seasonality is instead based on practical evidence.

In the last five decades, worldwide tourist demand has rapidly increased (Peng et al., 2015). Most tourist demand and elasticities studies focus on one-dimensional variability (Li et al., 2005; Song & Li, 2008). These studies estimated different price and income effects for the source markets and destinations analysed, but under constant parameters (Gunter & Smeral, 2016; Mervar & Payne, 2007; Peng et al., 2015). Tourism generally includes two price elements: the cost of travel to the destination and the costs of living and spending budget on goods in the destination (Mervar & Payne, 2007; Seetaram et al., 2016). Following that, Peng et al. (2015), who conducted a meta-analysis of international tourism demand elasticities, emphasised that transportation costs have attracted much less attention in empirical studies than costs of living and money spending due to a lack of precise measures for effective transportation costs. In countries where most foreign tourists arrive by car, the proxy is usually oil or gasoline prices (Mervar & Payne, 2007). The international tourism demand model is typically estimated as a function of the income of the origin country, relative prices, exchange rates, transportation costs from origin to destination, dummy factors, and deterministic trends (Mervar & Payne, 2007).

Most empirical studies demonstrate that, following economic theory, income positively affects tourism demand (Peng et al., 2015), suggesting that tourists are more sensitive to income and price changes over the long-run (Li et al., 2005). In the short-run, existing travel arrangements may constrain their response to income and price changes. However, in the long-run, tourists have enough time to adjust their behaviour fully and are likely to display more income and price-elastic behaviour (Peng et al., 2015).

Concerning the analysis of tourists' travel by car or air in the case of New Zealand, the results of Becken and Schiff (2011) indicated that tourist characteristic variables such as the purpose of a visit, length of stay, or age are more important factors than the price of transport. This conclusion is valuable for transport policy because it shows that price-based measures may not have the desired effects on traffic. The authors revealed that economic conditions strongly influence travel demand by international visitors who come to New Zealand in their home country, where income elasticities are statistically significant and relatively high, indicating that travelling to New Zealand is a luxury good.

According to Matas and Raymond (2003), in the case of Spain, a tourist area with a significant percentage of tourist traffic is less sensitive to price due to the lack of information given and the fact that they are not frequent users. One of the reasons for such a remark is that foreign motorway users, due to a lack of information, have more inelastic demands than frequent motorway users and are unaware of their options. In their study, Nicolau and Más (2006) propose that travelling distance and prices are moderated and affected by tourist motivations when choosing a destination. The authors indicated that destinations with suitable climates and cultural aspects attract individuals prepared to travel longer distances. The study has especially detected that tourists searching for cultural aspects are generally more willing to pay higher prices. In contrast, those tourists searching for climate tend to pay less. However, in the long-run, tourists usually plan their international journeys, so in the short-run, the arrangements may constrain their response to price and income changes, while in the long-run, they have time to adjust their arrangements and behaviour according to price and income changes (Peng et al., 2015).

Generally, the tourism markets in Europe have different degrees of seasonality, the level of which varies among countries (Ferrante et al., 2018). Gomez et al. (2016) indicate that the economy in coastal Spanish regions is highly dependent on tourism activities, which have a meaningful impact on light vehicle traffic volume, while the traffic on interior roads tends to be in line with global economic variables and more sensitive to toll rates. Due to the experienced traffic decrease on Spanish toll roads and the recession, the authors remarked that the results are inconclusive.

Regarding the Croatian literature concerning the impact of tourist activity on travel demand, no studies estimate the direct effects of tourism on travel demand, including motorway journeys. Instead, Payne and Mervar (2002) suggest that the income of the origin countries substantially affects tourist demand. Although income and price are the most commonly used factors in terms of the main factors that influence the demand for tourism (Mervar & Payne, 2007; Peng et al., 2015), as mentioned before, there is no evidence of a correlation between tourist activities and traffic volume on the motorways.

3.8. Empirical research in Croatia

Although the literature on travel demand in Croatia is limited, this sub-chapter discusses findings from existing evidence to understand what has been done in Croatia to address seasonality and travel demand. The sub-chapter highlights the thesis contributions, which include valuable insights into the role of seasonality on travel demand combined with independent observations based on the frequency of motorway usage. Despite the fact that tourism contributes significantly to Croatian GDP, with the majority of foreign tourists arriving by car (Croatian Bureau of Statistics, n.d.b), limited research has been performed into the factors that influence travel demand. Specifically, no empirical analysis has been conducted to investigate factors that influence driver behaviour as a result of changes in various factors. Instead, the extant literature related to Croatia focuses on tourism travel demand.

In an economy as Croatian, Mervar and Payne (2007) underlined the importance for policymakers to understand the sensitivity of international tourism demand in relation to its primary determinants. The authors estimated the long-run elasticity of Croatian tourist demand between 1994 and 2004 to examine the factors that influence international tourism demand for Croatian destinations. The study found that international demand is influenced by income levels in their home countries, while real exchange rates and transportation costs (proxied by oil prices) had no statistically significant impact on foreign tourism demand. The occurrence of war-related political instability in Croatia in the 1990s influenced demand for Croatian destinations, while the seasonal effect in the third quarter of each year generated the highest effect in the model. Similarly, Payne and Mervar (2002) underlined the role of the European Union's GDP and currency exchange rates as important precursors of the Croatian tourist revenues from 1993 to 1999. Their findings revealed that an increase in the European Union GDP leads to higher tourism revenues with an elasticity value of 3.60, whereas fluctuations in the real effective exchange rate have a lower impact with an elasticity value of 0.84. Geopolitical considerations were also identified as crucial, with the 1995 military action in Croatia having a negative impact on tourism revenues. The authors remarked that policymakers should be aware of the potential effect that changes in economic activity in EU countries may have upon the tourism sector and, as a result, overall economic activity in Croatia.

Belullo and Križman (2000) examined the income elasticity of Croatian tourism demand based on income changes in Slovenia, Italy, Germany, and Austria between 1994 and 1998.

The authors noted that foreign tourists generate the majority of the tourist traffic in Croatia, which is significant because their spending has a multiplicative effect on the national economy. Except for a significant decrease in overnight stays and tourist arrivals in Croatia as a result of military actions in 1995, the findings show that tourists make their travel decisions based on long-run income changes rather than short-term changes. This implies that stable economic growth in these countries is critical for maintaining consistent tourism flows to Croatia. Additionally, Škrinjarić (2011) explored various demand factors on the tourism demand by using a dataset of 19 countries in the period 1994-2009. The findings show that tourism demand is inelastic with respect to income and responds more intensely to changes in relative prices. Capital investments also have positive effects on the model, but one of the most important factors is the contentment of tourists. Beyond observing the impact of military actions in Croatia, Tica and Kožić (2015) developed a forecasting model for overnight stays in Croatia. The authors identified real GDP and imports in Poland, as well as gross wages in the Czech Republic and Slovakia, as leading indicators of tourism demand in Croatia. Their study suggests that tourists from these countries are representative foreign visitors to Croatia, and it is very likely that tourists from Western and Eastern European countries have a similar standard of living and travelling habits.

Despite the significant correlation between income levels and tourism demand, Kožić (2013) measured tourism seasonality by comparing Croatia with other Mediterranean destinations. The study found that Croatia has the highest degree of seasonality, followed by Montenegro and Greece, while Malta, Spain, and Portugal exhibit lower seasonal concentration. The study showed that the source of a high degree of seasonality is hotel capacity, which is not employed throughout the year and is concentrated near the coast, with a focus on summer tourism. Čorluka (2018) reviewed 64 studies on tourism seasonality and emphasised that Croatia's tourism model remains underdeveloped in terms of spreading demand across different seasons, which is essential for long-run sustainability. To address seasonality, strategies such as off-season holiday packages, festival development, business tourism promotion, and targeted marketing campaigns have been proposed. From a demand-side perspective, the study of Jelušić (2017) reinforced the idea that analysing and forecasting expenditures is essential for tourism-orientated economies, as it allows for improving strategic planning.

Based on reviewed literature, this sub-chapter identified limitations in the existing evidence about factors that directly affect travel demand in Croatia. Instead, the extant literature focuses on factors influencing tourism demand (e.g., Belullo & Križman, 2000;

Mervar & Payne, 2007; Payne & Mervar, 2002), as well as an overview of tourism seasonality (Čorluka, 2018; Kožić, 2013). Considering the literature gaps and historical records examined in Chapter 2, which revealed Croatia as a primarily auto-destination country, this study demonstrates the importance of directly investigating what factors influence motorway travel demand and what the role of seasonality is. The findings on how motorway traffic volumes in the previous year, toll prices, fuel prices, Croatian and European Union GDP per capita, and tourist arrivals influence motorway travel demand contributes new evidence to the existing literature on user sensitivity in Croatia.

As existing literature focuses on developing short-run and long-run elasticity values, this evidence confirms the uniqueness of this thesis to directly evaluate the impact of seasonality on motorway travel demand. Models are developed separately based on the period of the year to determine elasticity values of the same explanatory variables in summer and non-summer. The purpose of separate estimations is to determine whether and how user sensitivity changes through the year, which findings should contribute new evidence to the literature while also being valuable for policymakers and practice.

Despite evaluating the impact of seasonality between summer and non-summer periods, another uniqueness of this study is additional user segmentations based on frequency of motorway usage, which is lacking in previous research. As stated in Chapter 2, the purpose of distinguishing between frequent and occasional motorway users rather than vehicle category is based on historical records which showed seasonal fluctuations for occasional users and more stable for frequent users. As a result, additional distinctions and results by frequency of motorway usage contribute new evidence to the literature about the importance of monitoring travel demand by frequency on motorway usage in practices and motorways with seasonal patterns similar to Croatia.

3.9. Conclusion

Through the presentation of collected literature and findings from recent studies regarding the impact of toll and fuel prices, GDP, income, and tourism activity on travel demand, this chapter showed various literature findings and conclusions. Regarding Croatia, the literature on travel demand is scarce. Instead, existing research has primarily focused on tourism demand rather than motorway usage, despite the significant proportion of tourists who travel to Croatia by car. The chapter confirmed that there are no unified and unambiguous elasticity values among studies and no unique method. Instead, the impact of each explanatory variable varies across the countries, period, used variables, methods, and collected data. Except for the diversification of traffic by light/heavy vehicles and 2-axle and 5-axle vehicles (e.g., Burris & Huang, 2011; Matajič et al., 2015), the extant literature does not distinguish the impact of seasonality on motorway travel demand by frequency of motorway usage, which this study aims to eliminate. To eliminate the gap, this thesis develops four models to separately observe and measure the impact of each explanatory variable on occasional and frequent motorway users during the summer and non-summer periods.

CHAPTER 4. CONCEPTUAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

4.1. Introduction

This chapter outlines a conceptual framework designed to investigate the impact of seasonality on motorway travel demand. Based on defined framework, this thesis tests how various factors, including travel demand in the previous year, toll prices, fuel prices, GDP, and tourist arrivals, influence travel demand throughout the year. Furthermore, sub-chapter 4.2., Conceptual Framework, provides justifications for evaluating the impact of defined explanatory variables and seasonality in the context of the Istrian motorway, which is crucial to the research and has substantial policy implications. As a result, this thesis tests several hypotheses established in sub-chapter 4.3, Hypotheses, using current literature findings and collected data, while sub-chapter 4.4., Conclusion, summarises this chapter.

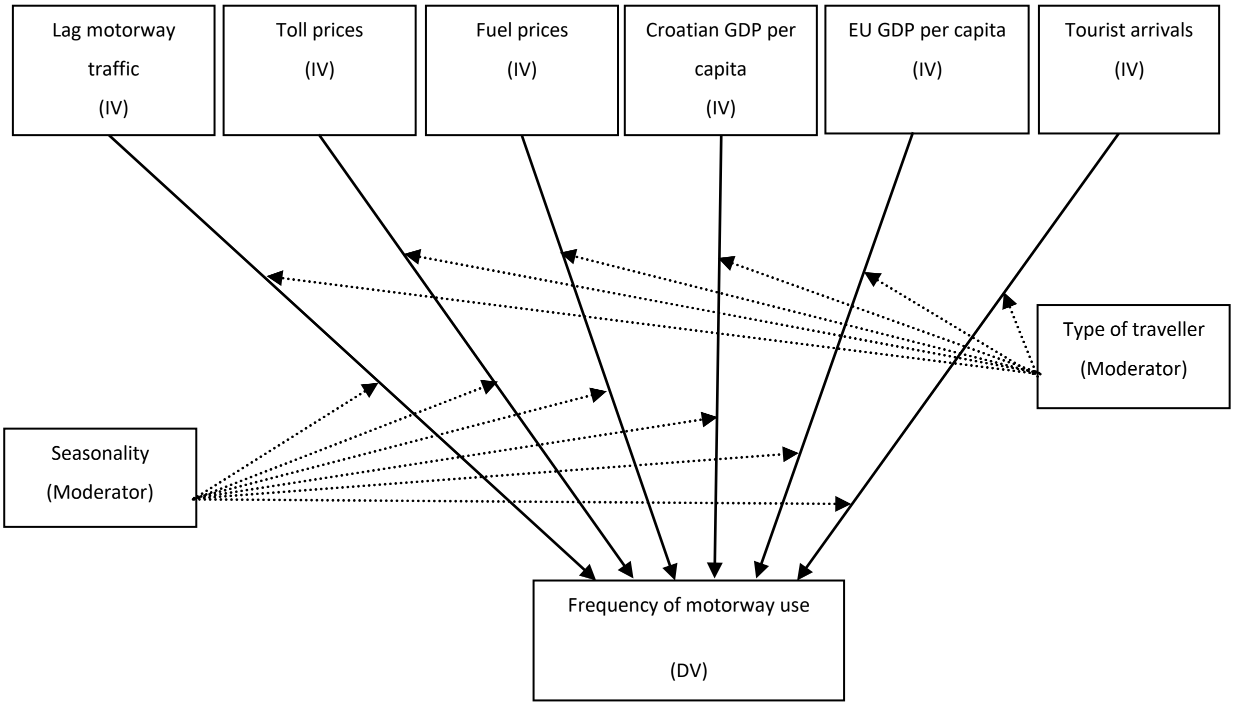
4.2. Conceptual framework

By considering the phenomenon of seasonality, which represents a period of significantly higher or lower volume compared to the remaining period of the year (Cannas, 2012), this thesis investigates if and how seasonality affects motorway travel demand. As a reminder, sub-chapter 2.4, Traffic, showed the presence of traffic fluctuations on the Istrian motorway throughout the year, especially for occasional motorway users. The crucial aspect for evaluating the impact of seasonality on motorway travel demand is that there is no evidence of how the elasticity values of each explanatory variable fluctuate depending on the period of the year and the frequency of motorway use.

To test and identify the role of seasonality, this thesis observes the impact of motorway traffic in the previous year, toll prices, fuel prices, Croatian GDP per capita, the European Union GDP per capita, and tourist arrivals on motorway travel demand, taking the Istrian motorway as a case study due to the availability of unique traffic data.

Figure 4.1.

Conceptual framework design



Note: Developed by the author.

Based on the literature review and research questions, the conceptual framework illustrates expected relationships between independent variables and the dependent variable. As graphically shown in Figure 4.1., this thesis expects that changes in each independent variable impact the frequency of motorway usage, measured by the concept of elasticity. Even arguments for coefficient signs of each independent variable are developed in sub-chapter 4.3., Hypotheses, this thesis expects to find:

- Positive impact of lagged motorway traffic, Croatian GDP per capita, European Union GDP per capita, and tourist arrivals on frequency of motorway usage;
- Negative impact of toll and fuel prices on frequency of motorway usage.

Even obtaining the expected coefficient signs would be consistent with the literature, the aim is to provide the first evidence in the case of Croatia regarding the factors influencing motorway travel demand. This study extends the research by including two relationship moderators: seasonality and type of traveller. The purpose of introducing moderators is to identify their influence on the relationship between independent and dependent variables, thereby adding to the existing literature and pracitce. As a result, this thesis expects that seasonality has an important role in motorway travel demand, causing different impacts of each independent variable on the frequency of motorway usage between summer and non-summer periods. Except for finding the moderating effect of seasonality on the frequency of motorway usage, the conceptual framework also demonstrates the expected influence of type of traveller as a moderator on the relationship between independent and dependent variables. In that regard, this thesis expects that frequent and occasional motorway users do not have the same sensitivity to changes in independent variables due to their differing travel patterns.

This framework not only elaborates the complex interactions among observed variables, but also serves as a foundation for empirical analysis aimed at understanding motorway usage patterns in varying economic and seasonal contexts. In that sense, investigation of how seasonality effects the impact of each explanatory variable on motorway traffic demand is essential to the study to provide new knowledge for the literature and motorway practices similar to Croatian patterns because of the following:

- According to the author's best knowledge, there is an absence of how seasonality influences motorway travel demand by frequency of motorway usage in different periods of the year. The existing literature determines the elasticity values concerning travel demand on short-run and long-run values by vehicle category, number of axles, light/heavy vehicles (Batarce et al., 2023; Burris & Huang, 2011; Dunkerley et al., 2020; Goodwin et al., 2004; Matajič et al., 2015). Therefore, determining if seasonality and period of the year cause changes in motorway travel behaviour by frequency of motorway usage would contribute to the literature to expand the determination of elasticity values not only on a yearly basis but also to distinguish through the year and frequency of motorway usage;
- Despite using unique historical motorway traffic data from the Istrian motorway to test the impact of seasonality, the results are beneficial for different practices with seasonality and similar patterns to expand understanding of what affects motorway travel demand. By separating the study into frequent and occasional motorway users, the findings on how different user types react to changes in explanatory variables between summer and non-summer periods provide valuable insights for policymakers to adapt their tolling levels.

Besides providing valuable contributions applicable to the literature and worldwide practices, the Croatian context is also beneficial to study due to the following reasons:

- The existing literature is missing evidence on factors impacting Croatian motorway travel demand. Instead, it focuses on foreign demand for Croatian destinations, price and income elasticities, and transport demand management in urban areas (Brčić et al., 2016; Dahl, 2012; Ferrante et al., 2018; Mervar & Payne, 2007). While the literature provides an overview of tourism seasonality research findings (Corluka, 2018) and explores tourism seasonality in Croatia (Kožić, 2013), it does not address the role of seasonality in motorway travel demand. Therefore, this thesis offers the first insights into the impact of previous year's motorway travel demand, toll prices, fuel prices, Croatian GDP per capita, EU GDP per capita, and tourist arrivals on motorway travel demand in Croatia;

- Unique historical data from 2014 until the end of 2019 was collected from the Istrian motorway concessionaire. During that period, total traffic volume consistently increased despite changes in toll prices, including both seasonal[6] and regular annual toll increases. These results contradict existing literature, which shows a negative impact of increase in toll prices on travel demand (Gomez & Vassallo, 2015; Gomez et al., 2016; Matas & Raymond, 2003; Matas et al., 2012; Odeck & Bråthen, 2008). The findings of this thesis provide new insights into the significance of toll increase on motorway travel demand, revealing that an increase in the direct cost of using the motorway did not negatively impact traffic volume on the Istrian motorway.

To contribute new knowledge, this thesis utilises an example of the Istrian motorway as follows:

- It collects 56 million unique motorway traffic data of all vehicle categories (46 million related to the I vehicle category) from manual and automatic lanes of the Istrian motorway for 2014–2019, further used for statistical modeling;
- The collected traffic data represents exact values recorded by the tolling system for passages on each combination of entry and exit toll plazas, vehicle category, means of payment, and period of the year. These data provide precise travel patterns in the observed period, not influenced by the formulation of the survey questions, which can impact responses (Grisé et al., 2019). This approach is considered more effective than surveys and questionnaires, which might be less useful if respondents lack experience or find it difficult to understand and imagine the purpose (Odeck & Bråthen, 2008).

[6] Seasonal toll increase – a toll increase on all sections of the Istrian motorway by 10% in the period 1 June until 30 September with rounding toll prices (if the toll increase is equal or higher than 0.5, applied rounding of toll price on the higher value. If toll increase is below 0.5, applied rounding of toll price on lower value). The application of Seasonal toll increase on the Istrian motorway relates to the period from 1 June 2015 onwards.

Therefore, using recorded data for frequent and occasional users aims to provide valuable insights into the impact of seasonality on motorway travel demand;

- According to collected traffic transaction data for 2014–2019, 51.08% of total traffic volume was generated during the 4 months of the summer period, which initially implies the presence of motorway traffic seasonality, as detailed in Chapter 2;
- Tourist activities represented 19.50% of the Croatian GDP in 2022 (Ministarstvo turizma Republike Hrvatske, 2023). During the observed period from 2014 to 2019, on average, 88.90% of total tourists were from outside of Croatia. This suggests that foreign tourists could significantly impact the Istrian motorway traffic structure and elasticities between the summer and non-summer periods.

Therefore, identifying how seasonality and explanatory variables impact motorway travel demand throughout the year will undoubtedly provide valuable insights for adopting an effective tolling policy. It is still unclear how seasonality affects the level of impact of each explanatory variable throughout the year. While it is not feasible to include and test all the variables that may impact travel demand, the thesis considers them fixed and does not examine their influence on travel demand. The new findings are expected to help policymakers adapt and optimise their tolling policies during periods of varying traffic volumes and to consider traffic by frequency of motorway usage separately.

4.3. Hypotheses

4.3.1. The impact of motorway traffic in the previous year on motorway travel demand

Concerning testing the impact of traffic in the previous year on the existing travel demand, it is common in the literature to include the lag traffic variable in the model expressed in the form of AADT (Annual Average Daily Traffic) or VKT (Vehicle Kilometre Travelled)[7]. Although studies vary in the estimated coefficients for the impact of of previous year's travel demand on current travel demand, their coefficients are positive. For example, Gonzalez and Marrero (2012), who observed the impact of induced demand on traffic, estimated that the lagged traffic variable has a positive impact with respect to travel demand with a coefficient of 0.5346. Other studies also suggested a positive impact of lagged traffic variables on current travel demand, with values varying from 0.3659 to 0.410 (Gomez & Vassallo, 2015; Gomez

[7] More details on AADT and VKT properties in sub-chapter 5.7, Data Analysis Method.

et al., 2016; Matas & Raymond, 2003). Even though the introduction of a lag traffic variable in the literature shows a positive impact on travel demand, it is also used to develop a dynamic nature of the model where the lag term accounts for long-run elasticity values (Gomez & Vassallo, 2015; Gonzalez & Marrero, 2012).

Considering the seasonality observed on the Istrian motorway and the continuous traffic growth despite toll increases from 2014 to 2019[8], this thesis measures the impact of travel demand in the previous year on current year. Finding a positive impact of travel demand in the previous year on the current year would confirm that Istrian motorway traffic is influenced by the traffic levels in the previous year, suggesting that past motorway traffic may help in forecasting future travel demand accurately. Therefore,

- **H_{1a}:** Increase in motorway travel demand in the previous year positively affects travel demand of frequent users in the summer and non-summer periods;
- **H_{1b}:** Increase in motorway travel demand in the previous year positively affects travel demand of occasional users in the summer and non-summer periods.

4.3.2. The impact of toll prices on motorway travel demand

Implementation of tolls on roads can affect different aspects of travel patterns in terms of vehicle travel reductions, vehicle ownership, changes in the origin or destination of the trip, and shifting to alternative modes (Litman, 2019). Nevertheless, toll elasticities can show a wide range of values that depend on trip purpose, trip distance, overall trip costs, and the quality of alternative roads (Lake & Ferreira, 2002). Even if tolls are often in conjunction with road privatization, they are structured to maximise revenues and company success (Litman, 2019). There are different types of road pricing, such as cordon tolls, distance pricing, time pricing, and congestion pricing (May & Milne, 2000). As remarked in Chapter 3 for the case of Croatia, the applied distance-based pricing approach is also effective in addressing transport-related environmental problems (Santos, 2004).

Estimates of the impact of tolls on traffic levels vary across studies because of the specific set of covariates included in the model (Miller & Alberini, 2016). In an attempt to investigate differences in toll prices across the motorway, several studies suggested that the impact of tolls differs among sections, with a negative impact on travel demand. According to Cervero (2012), tolling bridges also negatively impact travel behaviour. Based on a study of potential

[8] During the summer period, an additional 10% toll increase was applied to regular toll prices for occasional users.

adverse effects on the motorways in the context of Spain, Matas and Raymond (2003) showed that travel demand is slightly more elastic on longer sections than on shorter sections, except for tourist areas, as foreign visitors have more inelastic demands than frequent motorway users due to a lack of information given to the occasional users. They suggested that travel demand is more sensitive to higher tolls, with an indicated negative relationship ranging from -0.21 in the most inelastic section to -0.83 in the most elastic section. In the same vein, Matajič et al. (2015) found that transportation demand's toll price elasticity was not unique across motorway sections for the Slovenian motorways. They estimated that a 1% increase in tolls per kilometre of toll road causes a decrease in travel demand by -0.09 for light vehicles and -0.083 for heavy vehicles. Except for observing how motorway toll impact differs among the sections, Boarnet et al. (2014) found that depending on conditions, roads with fewer essential trips and more viable alternatives/lower congestion levels tend to have higher elasticities, with typical elasticity ranges between -0.10 and -0.45. Other scholars also reported a negative relationship between toll prices and travel demand in different country contexts (Batarce et al., 2023; Boarnet et al., 2014; Burris & Huang, 2011; de Grange et al., 2015; Gibson & Carnovale, 2015; Matas et al., 2012).

Historical evidence of traffic movements from sub-chapter 2.4., Traffic, showed motorway traffic growth despite increases in toll prices. This observation challenges the literature expectation that increases in toll prices, which constitute part of the overall travel cost, lead to a reduction in vehicle travel (Litman, 2019). In light of this evidence, this thesis follows the literature and tests if an increase in tolls has a negative impact on Istrian motorway travel demand. Considering traffic growth despite toll increase, finding an insignificant impact of the toll increase on traffic levels would confirm that the toll increase is insufficient to reduce traffic levels on the Istrian motorway in the short-run. As the thesis observes the impact of seasonality on motorway travel demand, the impact of tolls is observed separately by season and type of traveller. Therefore, this thesis develops the following hypotheses:

- **H_{2a}:** Increase in toll prices negatively affects travel demand of frequent users in the summer and non-summer periods;
- **H_{2b}**: Increase in toll prices negatively affects travel demand of occasional users in the summer and non-summer periods.

The thesis tests the impacts of tolls on motorway travel demand during summer and non-summer periods to identify differences in motorway user sensitivities throughout the year. In the literature, there is no evidence about distinguishing data and testing the impact of seasonality on explanatory variables and motorway traffic levels. As described in Chapter 2, historical traffic and toll data indicated that during the summer period, traffic levels do not decrease despite a temporal full price increase every year by 10%. In favor of that, Figures 2.4. and 2.5. graphically showed the traffic movements of frequent and occasional users throughout the year, where traffic fluctuations were particularly significant for occasional users in the summer.

Besides the distinction between the impact of tolls on summer and non-summer traffic, testing H_{2a} and H_{2b} also distinguishes the impact on occasional and frequent users. The tests conducted aim to show if, besides the period of the year, the influence of toll prices on motorway traffic levels differs between occasional and frequent users. The finding would be in line with the study of Matas and Raymond (2003), which found that foreign visitors have more inelastic demands than frequent motorway users due to a lack of information. As a note, occasional motorway users manually collect a toll ticket at the entry toll plaza to determine the toll amount payable at the exit toll plaza. Since this means of payment does not require pre-registration and account top-up, as described in 2.3., Payment Means on the Croatian Motorways, it is the most widely used option to pay for tolls on the Istrian motorway. According to collected traffic data for the Istrian motorway, on average, 64.44% of total traffic was related to toll tickets, while on average, 58.75% of their transactions were realised in the summer period of June–September, when tourist arrivals were the most significant (Bina-Istra, n.d.; Croatian Bureau of Statistics, n.d.a).

4.3.3. The impact of fuel prices on motorway travel demand

This study uses the collected historical gasoline and diesel price data in Croatia to construct the fuel variable and test the impact on motorway travel demand. Small and Van Dender (2018) highlighted that changes in fuel prices affect the share of fuel costs in the total cost of driving, where income increase reduces the significance of fuel costs in the decision to travel. Even if fuel prices vary by country, which is primarily but not exclusively due to different tax rates (Romero-Jordán et al., 2010; Small & Van Dender, 2018), the existing literature suggests a negative relationship between fuel price and travel demand both for light vehicles and heavy vehicles (Bastian et al., 2016; Gallo, 2011; Gomez & Vassallo, 2015; Goodwin et al., 2004). In analysing price and income elasticities for motorway transportation fuel demand by using historical studies, Dahl (2012) showed that lower-priced countries have a less elastic price response than higher-priced countries. On average, the author ranged gasoline price elasticities regarding fuel demand between -0.11 and -0.33, and diesel prices between -0.13 and -0.38. In the case of Croatia, the gasoline price elasticity estimate was -0.32 and -0.13 for the diesel price. Although negative impact on demand for transport fuels, Bastian et al. (2016) showed that fuel price elasticities vary among countries: for the United States, -0.14, Germany, -0.18, Sweden, -0.23, France, -0.31, UK, -0.37, and Australia, -0.36. In addition, other studies also confirmed that an increase in fuel prices corresponds to a reduction in fuel consumption, which can harm traffic behaviour, especially on tolled roads with good alternative toll-free sections (de Grange et al., 2015; De Jong & Gunn, 2001; Hymel et al., 2010; Matas et al., 2012). Considering literature findings as well as historical data from sub-chapter 2.5., Fuel prices, which suggests similar patterns in fuel price movements between Croatian and the world average through the year, this thesis expects that:

- **H_{3a}**: Increase in fuel prices negatively affects travel demand of frequent users in the summer and non-summer periods;
- **H_{3b}**: Increase in fuel prices negatively affects travel demand of occasional users in the summer and non-summer periods.

H_{3a} and H_{3b} test if the impact of fuel prices on travel demand has a negative effect on the Istrian motorway traffic during the whole year (which would be in line with the collected literature) or if it has a different impact between summer and non-summer. Besides checking the impact of fuel prices on travel demand by period of the year, the tests also provide valuable insight if occasional users have more inelastic demand than frequent motorway users due to a lack of information given on their trip (Matas & Raymond, 2003).

4.3.4. The impact of GDP on motorway travel demand

Even changes in the income of an individual can affect the distance travelled and the number of trips conducted, this relation is inconsistent across countries (Dunkerley et al., 2020; Fouquet, 2012; Mcmullen & Eckstein, 2012; Metz, 2010; Wohlgemuth, 1997). Hymel et al. (2010) indicated that congestion negatively affects travel demand when income increases. Despite the different levels of impact of income on travel demand, the existing literature shows a positive impact of income and GDP on travel demand. Dargay (2007) found that an increase in income significantly impacts travel demand more than income reduction. In the case of the rise in income, the elasticity was 0.83 in the short-run and 1.09 in the long-run. In in the case of income falling, the estimate was 0.65 in the short-run and 0.86 in the long-run. In their study, Dargay and Clark (2012) stated that long-distance car journeys are more income elastic than short journeys, with elasticity values between 0.47 and 0.70 for long-distance and between 0.31 and 0.53 for short-distance journeys. When separately observed by vehicle type, Matajič et al. (2015) found that an increase in GDP per capita by 1% in the case of Slovenia would lead to an increase in transportation demand by 0.56% for light vehicles and 1.016% for heavy vehicles. Considering literature suggestions that increase in income and GDP have a positive impact on travel demand (sub-chapter 3.6., The impact of GDP and income on travel demand), as well as economic growth in Croatia and in the European Union between 2014 and 2019 (sub-chapter 2.6., GDP and the unemployment rate), when motorway companies in Croatia also recorded traffic growth, this thesis expects:

- **H_{4a}**: Increase in the Croatian GDP per capita positively affects travel demand of frequent users in the summer and non-summer periods;
- **H_{4b}**: Increase in the Croatian GDP per capita positively affects travel demand of occasional users in the summer and non-summer periods;
- **H_{5a}**: Increase in the European Union GDP per capita positively affects travel demand of frequent users in the summer and non-summer periods;
- **H_{5b}**: Increase in the European Union GDP per capita positively affects travel demand of occasional users in the summer and non-summer periods.

Due to seasonality in the context of Croatia and variations in motorway traffic levels between the summer and non-summer periods, the impact of the Croatian GDP per capita and the European Union GDP per capita on traffic is observed separately for occasional and frequent motorway users. Testing H_4 and H_5 identifies the impact of each GDP per capita variable on occasional and frequent motorway users, as on average 88.90% of total tourist arrivals in Croatia between 2014 and 2019 were foreign tourists (Croatian Bureau of Statistics, n.d.a).

4.3.5. The impact of tourist arrivals on motorway travel demand

With the expansion of world tourist demand in the last five decades (Peng et al., 2015), according to data from the Croatian Bureau of Statistics a similar trend affected Croatia. Between 2013 and 2019, 92.93% of total tourist arrivals in Croatia were realised by road usage (Croatian Bureau of Statistics, n.d.b). The sub-chapters 2.7., Tourist activity, and 3.7., The impact of tourist activity on travel demand, suggested a positive impact on traffic levels. Areas with exposed tourist traffic tend to be less sensitive to prices due to their lack of information and the fact that people are generally not well-informed and aware of their travel options (Matas & Raymond, 2003; Sammer, 2016). However, tourist activity tends to be more sensitive to income and price changes over the long-run than in the short-run, as they have enough time to adjust their behaviour (Li et al., 2005). Even though the European tourism markets have different degrees of seasonality (Ferrante et al., 2018), income positively affects tourism demand (Peng et al., 2015). In their analysis of foreign tourism demand for Croatian destinations, Mervar and Payne (2007) stated that international tourism demand is a function of various factors: the income of the origin country, relative prices, exchange rates, transportation costs, dummy factors, and deterministic factors. In addition, Becken and Schiff (2011) indicated that the purpose of visit, length of stay, or age are more significant factors than the price of transport.

Therefore, considering literature suggestion that income growth positively impacts tourist activity while the direct impact of tourism on motorway travel demand is not available, accompanied by the historical data from Chapter 2, which shows the constant yearly growth of the European Union GDP, Croatian GDP, and tourist arrivals in Croatia for the period 2014–2019, this thesis expects that:

- **H_{6a}**: Increase in tourist arrivals positively affects travel demand of frequent users in the summer and non-summer periods;
- **H_{6b}**: Increase in tourist arrivals positively affects travel demand of occasional users in the summer and non-summer periods.

4.3.6. The impact of the season of the year and type of traveller on motorway travel demand

With an extension to the determined hypotheses H_1 – H_6 and their expected effects on motorway travel demand, this sub-chapter determines hypotheses for testing if the period of the year and type of traveller have an impact on motorway travel demand. Even this thesis addresses literature gaps, it is important to emphasise the lack of existing evidence as a foundation for developing hypotheses about the role of seasonality and type of traveller on motorway travel demand. However, historical evidence from 2014 to 2019 shows that 73.98% of tourist arrivals in Croatia occurred during the summer period (Croatian Bureau of Statistics, n.d.a), followed by higher levels of Croatian GDP per capita (Eurostat, n.d.) and fuel prices (GlobalPetrolPrices.com, personal communication, June 27, 2021), indicating seasonal patterns. As remarked in Chapter 2, the Istrian motorway also has exhibited seasonality, with 58.75% of total occasional user transactions occurring in summer. In contrast, despite increased motorway usage during the summer, frequent motorway users showed lower traffic fluctuations throughout the year, with 35.98% of transactions realised during the summer period. Therefore, this thesis tests if the season of the year has an impact on motorway travel demand and defines the following hypothesis:

- **H_7**: Observed period of the year has an impact on travel demand, but differently for frequent and occasional motorway users.

Accepting the H_7 would confirm the important role of seasonality in motorway travel demand and contribute to the literature about the need to distinguish the estimation of the impact of explanatory variables on motorway travel demand by different periods of the year. Such distinctions would provide more precise elasticity estimates with varying impact on motorway travel demand depending on the period of the year. As earlier remarked, the existing literature has focused on estimating short-run and long-run elasticities (e.g., Gonzalez & Marrero, 2012; Odeck & Johansen, 2016), distinctions based on vehicle types (e.g., Gomez & Vassallo, 2015; Gomez et al., 2016; Matajič et al., 2015) and number of axles (e.g., Batarce et al., 2023; Burris & Huang, 2011). Even summarised literature from Chapter 3 showed varying elasticity values between studies, thus confirming that elasticity values can not be transferable within countries (Espey, 1997; Musso et al., 2013), the existing literature does not differ elasticity values between summer and non-summer periods. In the case of Croatia, the historical data exhibited in Chapter 2 represent evidence on varying movements of motorway traffic levels and remaining explanatory variables through the year. Therefore, since there is no evidence about distinguishing elasticity values by period of the year, there are no clear expectations about difference in elasticity values between summer and non-summer periods due to different motorway traffic structures. However, it is worth noting that these relationships are expected to be complex and need to be further tested through the development of various models.

As described in sub-chapter 2.4., Traffic, travelling patterns of frequent and occasional motorway users differ through the year. The historical records indicated significant monthly fluctuations for occasional motorway user traffic, with traffic share significantly rising in summer months. These results suggest inconsistent motorway usage through the year and the possibility of being affected by various seasonal factors. Considering the specifics of the ENC Plus package, suitable for frequent travellers with limited validity of toll discounts (Bina-Istra, n.d.b), frequent motorway users demonstrated consistent usage with fewer monthly fluctuations and peak traffic levels during the summer months. Due to historical evidence on the Istrian motorway traffic and differences in travelling habits, this thesis investigates if the impact of explanatory variables used in this thesis differs by type of traveller with testing the following hypothesis:

- **H_8**: Type of motorway user has an impact on the level of how explanatory variables affect travel demand.

Even differences in travelling patterns through the year between vehicle categories are also present on the Istrian motorway, this thesis further tackles the historical evidence which shows significant variations in shares of monthly traffic levels through the year. Therefore, accepting the H_8 would confirm that separate observation of travel demand by frequency of motorway usage is crucial due to their different travelling patterns. The exploration of hypotheses H_7 and H_8 is crucial for understanding how seasonality impacts various factors influencing motorway travel demand. The obtained results intend to provide new knowledge to theory and policymakers if the observed period of the year and type of motorway users are essential factors that must be considered when defining and adjusting their tolling policy. In addition, by analysing the differential effects on frequent and occasional users, this thesis aims to provide insights that can inform policymakers in developing adaptive tolling strategies, emphasizing the need for targeted approaches to manage traffic effectively through the year.

Although previous sub-chapters presented expected coefficient intercepts for each explanatory variable, this sub-chapter also addresses the expected direction of seasonality on each explanatory variable.

- *Lag motorway traffic*

As mentioned in Chapter 2, despite an annual and temporary summer toll increase of 10%, as well as changes in fuel, GDP per capita, and tourist arrivals, travel patterns remained stable with continuous traffic growth from 2014 to 2019. These indications of stable travel patterns are consistent with the findings of Ferrante et al. (2018), who reported that seasonality in Europe remained almost unchanged over a 10-year period despite population, economic, and social changes. As a result, this thesis expects to find a similar impact of lagged motorway traffic on motorway travel demand during summer and non-summer periods and across different types of motorway users.

- *Toll and fuel price*

Even users when travelling do not consider only tolls but also the generalised cost (Odeck & Bråthen, 2008), Matas and Raymond (2003) remarked that due to a lack of information, foreign visitors are expected to have more inelastic demand than frequent users and tend to be less price sensitive. In the short-run, the tourist response to income and price changes may be constrained by existing travel arrangements, while in the long-run they have enough time to fully adjust and display more income and price-elastic behaviour (Peng et al., 2015). In Croatia, historical data reveals that between 2014 and 2019, 74.72% of tourist arrivals and 58.75% of total occasional user transactions occurred over the summer, despite the application of a temporary toll increase. Considering higher activity during the summer period, this thesis expects to find that toll and fuel price increases have a higher impact on occasional user travel demand during the non-summer period when tourist activity is significantly lower than in summer.

Despite frequent users showing stable motorway usage through the year, with a peak in the summer, the thesis expects that toll and fuel price increases have a higher impact on frequent user travel demand during the non-summer period. It could also be explained by a lower number of active users of the ENC Plus package in the non-summer period than in the summer by 9.20% in 2019, indicating an increased demand for travel during the summer season and lower sensitivity to travel costs.

- *GDP per capita and tourist arrivals*

As mentioned in Chapter 2, Croatia is a country economically dependent on tourism with exhibited seasonal trends in traffic movements and Croatian GDP per capita values (Eurostat, n.d; Ministarstvo turizma Republike Hrvatske, 2023). Even records for the Istrian motorway show that the majority of occasional motorway user traffic occurred in the summer, the evidence also confirms summer as the peak of frequent user traffic (Bina-Istra, 2020). This thesis expects to find that the Croatian GDP per capita increase has a higher influence on both occasional and frequent user travel demand during the summer than in the rest of the year, when economic activity and tourist arrivals are lower. Even frequent users showed stable trends in motorway usage throughout the year, this thesis expects to find a higher impact of the Croatian GDP per capita on frequent users in summer than in non-summer, when the percentage of active users is lower.

Regarding tourist arrivals between 2014 and 2019, 74.42% occurred during the summer periods, with 88.90% realised by foreign users, mainly from the European Union countries whose GDP per capita is significantly higher than Croatian (Croatian Bureau of Statistics, n.d.a). Following recent works which suggested that the income of the origin countries substantially affects tourist demand (Mervar & Payne, 2007; Payne & Mervar, 2002; Tica & Kožić, 2015) this thesis expects to find a higher impact of the European Union GDP per capita and tourist arrivals on both occasional and frequent user travel demand in summer than in non-summer.

4.4. Conclusion

The determination of the conceptual framework represents the starting point of the thesis for organizing ideas to value the impact of seasonality on motorway travel demand. The conceptual framework dinsticted observed explanatory variables motorway (travel demand in the previous year, tolls, fuel prices, Croatian and European Union GDP per capita, and tourist activity), further built into the model to estimate their impact on motorway traffic demand through the year. This chapter also argued why using the Istrian motorway as a case study is essential and how it will bring new knowledge to theory and practice, especially valuable for policymakers. In that sense, the usage of 46 million transactions of I vehicle category realised on the Istrian motorway in Croatia represents unique data summarised by motorway sections, vehicle categories, frequency of motorway usage, and period of the year. The collected motorway traffic data are precious as they show real traffic data and precise historical motorway user travel habits. Such a dataset is considered to be more reliable than surveys and questions, as they might show limited usefulness since respondents may have no experience or it is hard for them to understand and imagine their purpose (Odeck & Bråthen, 2008). Besides testing the relation between seasonality and motorway travel demand, this thesis showed that the context of the Istrian motorway and Croatia is essential to investigate due to the significant share of tourist activity in GDP and fluctuations in explanatory variables between summer and non-summer periods.

Besides that, considering the extant literature findings and casualties in the collected data, this chapter represented a set of hypotheses further tested and discussed in the following chapters. As this thesis investigates the impact of seasonality on motorway travel demand, the chapter also showed the distinction of hypotheses by frequency of motorway usage and period of the year. However, application of the obtained results to other motorway practices requires the conduct of additional tests by including specific data related to that motorway.

CHAPTER 5. RESEARCH METHODOLOGY

5.1. Introduction

This chapter represents a summary of the research methodlogy used to test the impact of explanatory variables on motorway travel demand through the different periods of the year. As explained below, the application of various data collection methods combined with research philosophy aims to answer research questions from Chapter 1 and contribute new knowledge concerning the impact of seasonality on motorway travel demand.

The following sub-chapter 5.2., Ontological, Epistemological, and Axiological positions, introduces their importance in the research process as well as the assumptions of this thesis. The sub-chapter 5.3., Philosophical positions and research philosophy, describes and argues for using positivist philosophy in this thesis to conduct the research and provide new knowledge to practice and literature. The sub-chapter 5.4., Theory development approaches, discusses considered approaches and argues for using a deductive approach. Furthermore, sub-chapter 5.5., Research method, distinguishes research methods and argues for appropriateness in applying quantitative research methods for this thesis due to the nature and form of the collected data. The sub-chapter 5.6., Data collection and data sample, describes the data collection method for each variable (motorway traffic, toll price, fuel price, the Croatian GDP per capita, the European Union GDP per capita, and tourist arrivals in Croatia) and characteristics of the final data sample. The sub-chapter 5.7., Empirical model, provides a description of the empirical model applied to test hypotheses and explain the effects of explanatory variables on motorway traffic levels over time. Prior to the conclusion of Chapter 5, the sub-chapter 5.8., Baseline model estimation, shows how the variables are built into the model, which is further tested and discussed in Chapter 6. Finally, sub-chapter 5.9., Conclusion, provides an overview and generalised comment on Chapter 5.

5.2. Ontological, Epistemological, and Axiological positions

Before discussing each research philosophy and its characteristics, it is necessary to distinguish their properties by considering the differences in the research assumptions. It is worth remembering that business and management researchers do not agree on the best philosophy (Knudsen & Tsoukas, 2003). Therefore, prior to starting a research project, every researcher has to know how to distinguish different research philosophies, which include but are not limited to assumptions about the realities encountered in the research (ontological assumptions), human knowledge (epistemological assumptions), and the extent and ways in which researchers own values influence the research process (axiological assumptions) (Saunders et al., 2019). Together, ontological and epistemological assumptions construct a paradigm (Mack, 2010), a term first introduced by Thomas Kuhn in his book "The Structure of Scientific Revolutions" from 1962 referred to an overall theoretical research framework, with a second edition in 1970 (Kuhn, 1970). Central to Kuhn's thesis is the concept of "paradigm," derivated from the Greek word “paradeigma," which stands for a pattern, model, or plan. In his work, Kuhn refers to a set of beliefs, values, and assumptions centered on examples of successful practical application.

5.2.1. Ontological position

Ontology represents the starting point, likely leading to researchers' theoretical framework (Mack, 2010). It refers to assumptions about reality, shaping how the researcher sees and studies research objects such as organizations, management, individuals’ working lives, and organizational events (Saunders et al., 2019). Regarding ontological positions, objectivism (or positivism) implies that social phenomena and their meanings have an existence that is independent of social actors (Bryman & Bell, 2011). On the contrary, subjectivism (or constructionism or interpretivism) perceives that social phenomena are created from perceptions by social actors (Dudovskiy, 2018). In summary, the main difference between objectivism and subjectivism is their beliefs about the nature of reality. Objectivists believe in the existence of a single reality, while subjectivists believe that reality is subjective and dependent on the observer. Considering this thesis examines the impact of external factors on motorway traffic demand to check the role of seasonality in motorway travel demand, the thesis assumes there is an objective reality that exists independently of individual perception or interpretation. The study undertakes to identify the objective impact of particular variables (traffic in the previous year, tolls, fuel prices, GDP, and tourist arrivals) on travel demand and seeks objective truth about the impact of seasonality on motorway travel demand. It is important to note that the study may involve some level of subjective judgement in the discussion from Chapter 6. However, its overall focus on finding objective relationships between variables suggests an objectivist ontological position.

5.2.2. Epistemological position

Since ontology studies what researchers mean when they say something exists, epistemology studies what we mean when we say we know something (Mack, 2010). It concerns assumptions about knowledge—what is acceptable, valid, and legitimate knowledge, and how to communicate knowledge to others (Bryman & Bell, 2011; Burrell & Morgan, 1979). Easterby-Smith et al. (2015) remarked that as ontology is related to the nature of reality and existence, epistemology is related to the theory of knowledge and assists researchers in understanding the best way of enquiring into the nature of the world. It refers to assumptions about the best way to study the world using an objective or subjective approach (Bhattacherjee, 2012). According to McAuley et al. (2014), epistemology raises the issue of whether or not a researcher can objectively or neutrally know what is in the world and thereby collect the necessary evidence. The authors identified two entirely different epistemological positions: epistemological objectivist (who assume it is possible to neutrally observe social work and the behaviour of organizations through the act of observation or perception) and subjectivity (who believe that what researchers perceive is an outcome of researchers' conceptual understanding of the world, where the researcher needs to be trained in the methods of the approach). As different business and management researchers may adopt different epistemologies in their research, Saunders et al. (2019) emphasised the importance of understanding the implications of different epistemological assumptions on the chosen method. The authors also note the importance of considering the strengths and limitations of subsequent research findings by applying a particular research philosophy. Considering the nature of the data and the aims of the thesis, the epistemological position of this study relates to objectivism and positivism, as it assumes that there is an objective reality in motorway travel demand that exists independently of human perception and researcher's experience. Also, it seeks to find the objective impact of observed variables on traffic levels. In terms of positivism, this study employs empirical analysis using quantitative data to systematically test hypotheses and analyse the results to discover objective truths about the world.

5.2.3. Axiological position

Axiology represents a branch of philosophy that studies judgments about value and ethics (Saunders et al., 2019). Due to its focus on what the researcher values in the research, Dudovskiy (2018) remarked on the on the importance of axiology, as the researcher's values affect how to conduct the research and what is vital in the research findings. In their study, Biddle and Schafft (2015) remarked that axiology is essential in selecting and formulating research questions, driving their interest in particular issues over others. From an axiological point of view, this study is undertaken in a value-free way, as the researcher is independent of the collected numerical and quantitative data related to large samples of motorway traffic data throughout the year, accompanied by other quantitative data (toll and fuel prices, GDP values, and the number of tourist arrivals in Croatia).

5.3. Philosophical positions and research philosophy

This sub-chapter describes the research philosophy used in this thesis, as it is an integral part of any kind of research, and is central to research design (Bahari, 2010). In general, research philosophy refers to a system of beliefs and assumptions about the development of new knowledge in a particular field, which knowledge may not be related to dramatic development but even answering a specific problem in the particular case (Dudovskiy, 2018; Saunders et al., 2019). Based on different ontological and epistemological positions, there are different research philosophies used in business and management research, whose discussion is beyond this thesis's scope. Following the work of Saunders et al. (2019), this thesis highlights the differences between the following research philosophies:

1. Positivism
2. Pragmatism
3. Critical Realism
4. Interpretivism
5. Postmodernism

Positivism, the scientific paradigm, aims to prove or disprove a set hypothesis (Mack, 2010). This perspective combines objective epistemology and objective ontology. It assumes there are social facts with an objective reality apart from individuals' beliefs (Bahari, 2010). Positivism claims the existence of one absolute reality independent of human action, which reality needs to be discovered by researchers whose role is to observe and measure reality objectively and unbiasedly (Oltmann & Boughey, 2012). The positivist approach argues that different researchers who observe the same issue by using statistical tests and a similar research process will generate similar results (Creswell, 2009).

Pragmatism and critical realism perspectives combine objective ontology and subjective epistemology. Pragmatist supporters start with a research question to determine their research framework. The pragmatists believe objectivist and subjectivist perspectives are not mutually exclusive (Wahyuni, 2012). In their work, Kelemen and Rumens (2008) defined pragmatism as a theory of meaning that asserts that concepts are only relevant as much as they are suitable for action. It strives to reconcile both objectivism and subjectivism, facts and values, accurate and rigorous knowledge (Saunders et al., 2019). The authors remark that if the researcher undertakes pragmatist research, the most critical determinant for the research design and strategy is the research issue and addressed question. Critical realism explains what can be seen and experienced regarding the underlying structures of reality that shape observable events (Saunders et al., 2019). The origin of critical realism dates from the late 20th century, mainly from the work of Roy Bhaskar. For critical realists who see reality as external and independent, reality is the most essential philosophical consideration, with a structured and layered ontology being crucial (Fleetwood, 2005).

Like critical realism, interpretivism was developed as a critique of positivism from a subjectivist perspective. Interpretivism studies meanings that humans are different from physical phenomena as they create meaning (Saunders et al., 2019). As stated by Bahari (2010), interpretivists view facts and values as not different, where the researcher's perspectives and values influence findings. In this perspective, the research is valuable because the researcher is part of the research objective and cannot be separated (Dudovskiy, 2018). Contrary to interpretivism, postmodernists go further in their critique of positivism, attributing even more importance to the role of language (Easterby-Smith et al., 2015; Saunders et al., 2019). In the postmodernist perspective, the researchers are interested in the constructed nature of individuals and organizations, the relationship between knowledge and power, and how people differ between positions and discourses (McAuley et al., 2014).

The summary of characteristics and differences of each research philosophy in ontological, epistemological, and axiological positions, as well as by methods used in the research process and data analysis, is specified in Table 5.1.

Table 5.1.

Research philosophies in business and management research

Ontology (nature of reality or being)	**Epistemology** (what constitutes acceptable knowledge)	**Axiology** (role of values)	**Typical methods**
		Positivism	
Real, external, independent One true reality (universalism) Granular (things) Ordered	Scientific method Observable and measurable facts Law-like generalizations Numbers Casual explanation and prediction as a contribution	Value-free research Researcher is detached, neutral, and independent of what is researched Researcher maintains objective stance	Typically deductive, highly structured, large samples, measurement, typically quantitative methods of analysis, but a range of data can be analyzed.
		Critical realism	
Stratified/layered (the empirical, the actual, and the real) External, independent Intransient Objective structures Casual mechanisms	Epistemological relativism Knowledge historically situated and transient Facts are social constructions Historical causal explanation as a contribution	Value-laden research Researcher acknowledges bias by world views, cultural experience, and upbringing Researcher tries to minimise bias and errors Researcher is as objective as possible	Retroductive, in-depth historically situated analysis of pre-existing structures and emerging agency. Range of methods and data types to fit subject matter

Ontology (nature of reality or being)	**Epistemology** (what constitutes acceptable knowledge)	**Axiology** (role of values)	**Typical methods**
		Interpretivism	
Complex, rich Socially constructed through culture and language Multiple meanings, interpretations, and realities Flux of processes, experiences, practices	Theories and concepts too simplistic Focus on narratives, stories, perceptions, and interpretations New understandings and worldviews as a contribution	Value-bound research Researchers are part of what is researched, subjective Researcher interpretations key to contribution Researcher reflexive	Typically inductive Small samples, in-depth investigations, and qualitative methods of analysis, but a range of data can be interpreted
		Postmodernism	
Nominal Complex, rich Socially constructed through power relations Some meanings, interpretations, and realities are dominated and silenced by others Flux of processes, experiences, practices	What counts as "truth" and "knowledge" is decided by dominant ideologies Focus on absences, silences, and oppressed/repressed meanings, interpretations, and voices Exposure of power relations and challenge of dominant views as a contribution	Value-constructed research Researcher and research embedded in power relations Some research narratives are repressed and silenced at the expense of others Researcher radically reflexive	Typically deconstructive – reading texts and realities against themselves In-depth investigations of anomalies, silences, and absences Range of data types, typically qualitative methods of analysis

Ontology (nature of reality or being)	**Epistemology** (what constitutes acceptable knowledge)	**Axiology** (role of values)	**Typical methods**
	Pragmatism		
Complex, rich, external "Reality" is the practical consequences of ideas Flux of processes, experiences, and practices	Practical meaning of knowledge in specific contexts "True" theories and knowledge are those that enable successful action Focus on problems, practices, and relevance Problem-solving and informed future practice as a contribution	Value-driven research Research initiated and sustained by the researcher's doubts and beliefs Researcher reflexive	Following research problem and research question Range of methods: mixed, multiple, qualitative, quantitative, action research Emphasis on practical solutions and outcomes

Note: Adapted from Saunders et al. (2019).

- *Application in the thesis*

By considering determined objective ontological and epistemological positions, this thesis adopts positivism as a research philosophy to investigate the impact of seasonality and explanatory variables on motorway travel demand. In positivism, the researcher's role is limited to data collection and interpretation in an objective way with minimal interaction with participants. In this type of study, the researcher emphasisesfindings that are typically observable and measurable (Dudovskiy, 2018; Easterby-Smith et al., 2015). The positivist approach is helpful for this thesis due to the large sample of explanatory variables collected in numerical form. Unique historical traffic and toll data collected directly from the Bina-Istra tolling system eliminated the need for direct interaction with motorway users. An alternative approach would result in a smaller sample of participants and questionable efficiency. Therefore, even if the data collection approach applied in this thesis provides precise and detailed motorway travel habits on a large sample, it is also in line with the characteristics of the positivist approach, where findings are observable and quantifiable. The quantitative view is described as realist or positivist, while the worldview underlying qualitative research is considered subjectivist (Sukamolson, 2007). This means that positivists use objective research methods to uncover an existing reality, being detached from the research as much as possible by using the methods to minimise their involvement in the research process.

5.4. Theory development approaches

Regarding theory development, there are three approaches:

1. Deductive approach
2. Inductive approach
3. Abductive approach

Based on knowledge about a particular domain and theoretical considerations, in the deductive approach, the researcher creates a set of hypotheses subject to empirical study (Bryman & Bell, 2011). This approach aims to test and evaluate the hypotheses related to an existing theory using new empirical data (Bhattacherjee, 2012). The deductive approach is not just to test a theory but also provides a possibility to improve and extend it. The main advantages of using the deductive approach are explaining causal relationships between concepts and variables, measuring concepts quantitatively, and generalizing research findings to a certain extent (Dudovskiy, 2018).

The logical ordering of induction is the opposite of deduction, where the theory is the outcome of research, which involves drawing generalizable inferences out of observations (Bryman & Bell, 2011; Gill & Johnson, 2002). It begins with research questions, aims, and objectives to achieve during the research process (Dudovskiy, 2018). Researchers who apply an inductive approach often use a grounded theory approach in the data analysis to generate a new theory. According to the author’s knowledge, Glaser and Strauss (1967) first outlined the grounded theory approach, which helps generate new theories based on collected data.

The third approach, abduction, begins with observing "a surprising fact," which brings a theory of how particular event has occurred. A surprising fact may emerge when a researcher encounters empirical phenomena that are not possibly explained by the existing theories, but by choosing the best explanation among alternatives to explain the "surprising fact" identified at the beginning of the research process (Dudovskiy, 2018; Saunders et al., 2019). Table 5.2. provides a detailed summary and classification of the three approaches.

Table 5.2.

Differences between research approaches

	Deduction	Induction	Abduction
Logic	The conclusion must be proper in a deductive inference when the premises are true.	In inductive inference, known premises are used to generate untested conclusions.	In an abductive inference, known premises are used to generate testable conclusions
Generalizability	Generalizing from the general to the specific	Generalizing from the specific to the general	Generalizing from the interactions between the specific and the general
Use of data	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns, and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework, and test this through subsequent data collection and so forth
Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification: incorporating existing theory where appropriate to build new theory or modify existing theory

Note: Adapted from Dudovskiy (2018).

Considering the epistemological and ontological positions of this research as well as the relation of positivism to the quantitative research strategy (Bahari, 2010; Saunders et al., 2019), the thesis applies a deductive research approach. Generally, deductive conclusions also tend to be stronger than inductive ones (Bhattacherjee, 2012). Application of the deductive approach enables testing if the results align with the hypotheses from sub-chapter 4.3., Hypotheses, based on the existing literature findings and observation of historical data. The new findings are of particular interest as this thesis distinguishes the impact of each explanatory variable on summer and non-summer periods to find the impact of seasonality on frequent and occasional motorway users, which is not examined in extant literature.

On the contrary, the inductive research approach does not consider the formulation of hypotheses as it starts with research questions and objectives that need to be achieved during the research process (Dudovskiy, 2018), which approach is unsuitable for this thesis. Also, while the deductive approach is characteristic of quantitative research, the inductive approach relates to qualitative research (Sukamolson, 2007), which is not helpful and applicable in the thesis due to the fact that the data is obtained in numerical form. Table 5.3. represents a summary of significant differences between quantitative and qualitative research approaches.

Table 5.3.

Differences between quantitative and qualitative research approaches

Paradigm/Worldwiev (assumption about the world)	**Quantitative Approach**	**Qualitative Approach**
Research Purpose (rationale)	Positivism/Realism	Interpretivism/Idealism
Ontology (nature of reality)		
Epistemology (theory of knowledge)	Dualist/Objectivist	Subjectivist
Methodology (aims of scientific investigation)	Experimental/Manipulative	Hermeneutical/Dialectical
Research Methods (techniques and tools)	Empirical examination Measurement Hypothesis testing Randomization Blinding Structured protocols	Ethnographies Case studies Narrative research Interviews Focus group discussion Observations

Paradigm/Worldwiev (assumption about the world)	**Quantitative Approach**	**Qualitative Approach**
	Questionnaires	Field notes Recordings & Filmings
Scientific Method (role of theory)	Deductive approach, testing of theory	Inductive approach, generation of theory
Nature of Data Instruments	Variables Structured and Validated-data collection instruments	Words, images, categories In-depth interviews, participant observation, field notes, and open-ended questions
Data Analysis	Identify statistical relationships among variables	Use descriptive data, search for patterns, themes, and holistic features and appreciate variations
Results	Generalizable findings	Particularistic findings; provision of insider viewpoint
Final Report	Formal statistical report with: - Correlations - Comparisons of means - Reporting of statisticsl significance of findings	Informal narrative report

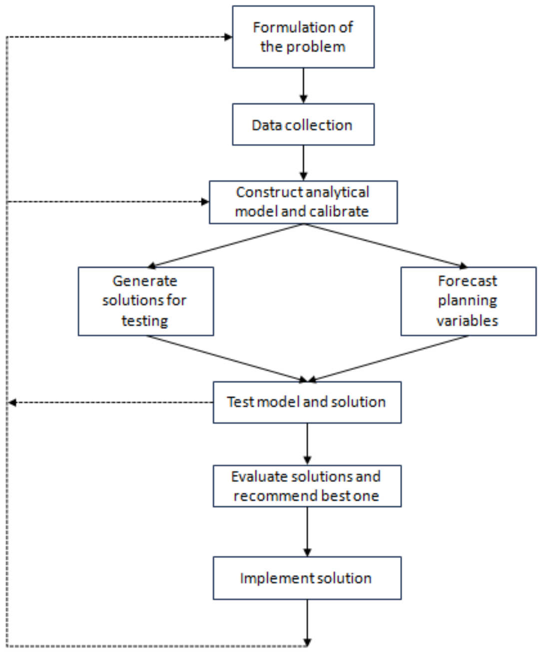
Note: Adapted from Antwi & Kasim (2015).

To additionally argue the application of the deductive approach, the unique historical data obtained from the Bina-Istra tolling system is used as a sample to understand the impact of seasonality on motorway travel demand. Testing the impact of seasonality relates to changes that concern the toll price of each Istrian motorway section, changes in fuel prices, the Croatian and European Union GDP per capita, and the number of tourist arrivals in Croatia during the observed period from 2014 until the end of 2019, but separately by frequency of motorway usage. It is important to note that Bina-Istra agreed to share their historical toll transactions recorded by the tolling system to write this thesis and contribute new knowledge to the literature and practice, without having any commercial interest or impact on the thesis including interaction with the author regarding the content of the thesis.

Concerning the approach this thesis used to confirm deductive approach, Figure 5.1. shows the conceptual framework for rational decision-making. For the purpose of this thesis, formulation of the problem is based on the existing literature limitation regarding the impact of seasonality on motorway travel demand and limited evidence in the Croatian context.

Figure 5.1.

Conceptual framework for rational decision-making with models



Note: Adapted from Ortúzar & Willumsen (2011).

Regarding the following steps, the sub-chapters, 5.5., Research method, 5.6., Data collection method, and 5.7., Data analysis method, examine approaches of data collection and analysis applied to test the model. Building and testing the model aim to bring new knowledge to literature and practice by showing the impact of seasonality on motorway travel separately by frequency of motorway usage. Also, it aims to fill the geographical gap as there is no data about the impact of motorway travel demand in the previous year, tolls, fuel prices, the Croatian and European Union GDP per capita, and tourist arrivals on motorway travel demand in Croatia. Based on the obtained results discussed in Chapter 6, Chapter 7 summarises newly generated knowledge of theory and practice, with limitations, while their implementation depends on the motorway operators and policymakers.

5.5. Research method

Generally, there are two different research methods: qualitative and quantitative. Qualitative research emphasises using words rather than quantification in the collection and analysis of data (Antwi & Kasim, 2015; Bryman & Bell, 2011; Dudovskiy, 2018). The qualitative research method seeks to understand the research question from the perspective of the local population it involves. The main strength of qualitative research is the ability to textually describe people's experiences on a given research issue (Mack et al., 2005). In the qualitative research approach, the data is usually collected through observations, interviews, case studies, and document analysis, with a summary of the findings through narrative or verbal means (Lodico et al., 2008). However, it has weaknesses, such as lacking generalizability and subjectivity, where social constructions influence how people see and understand their worlds (Antwi & Kasim, 2015).

While the qualitative research method bases its research on words, sounds, and videos, the quantitative research method focuses on numerical data that describes and measures occurrences based on numbers and mathematical calculations (Dudovskiy, 2018). The method considers stating hypotheses and then testing them with collected empirical data. The aim is to confirm the support of set hypotheses with the application of the deductive approach, characteristic of quantitative methods where researchers deduce from their hypotheses the observable consequences that should occur with new empirical data if the hypotheses they set are true or to conclude that their theory is false (Antwi & Kasim, 2015).

Qualitative and quantitative research methods differ in their analytical objectives, the types of questions they pose, data collection instruments, forms of data they produce, and degree of flexibility built into the study design (Mack et al., 2005). As the qualitative method relies on using words, videos, and sounds instead of numerical data, it is more flexible than the quantitative method as it enables a researcher to have a broader set of answers from the study participants by using their own words instead of forcing them to choose answers from fixed responses. Therefore, the entire interaction between the researcher and research participants is recorded, as a lack of standardization for creating qualitative data restricts the number of individuals the researcher can work with and limits the usage of statistical comparisons (Easterby-Smith et al., 2015). Also, in qualitative research, setting a hypothesis is not needed to start the research. Instead, it allows for a design to evolve rather than having a complete design at the beginning of the study due to the impossibility of predicting the outcome of interactions due to the diverse perspectives of the researcher and study participants (Antwi & Kasim, 2015).

On the contrary, using quantitative approaches, such as surveys and questionnaires, the researcher asks all the study participants identical questions by providing them with closed-ended, prescribed, inflexible answers. Even if the quantitative method has inflexibility with responses, it is valuable for a researcher as it allows comparison of responses across study participants. Quantitative research findings ensure less pressure for researchers than qualitative methods to justify and explain their choice of methods and present obtained results in a more summarised way (Pratt, 2008). According to Bahari (2010), the differences between qualitative and quantitative research methods are not just the question of the chosen methodology, the difference between statistical analysis, in-depth interviews, or surveys—but also a selection of strategy that involves some views that underlie the situation of the studied object. In addition, qualitative methods are more effective in identifying intangible factors such as social norms, socioeconomic status, and gender roles (Mack et al., 2005), which are not suitable in the context of this study. Therefore, determining an appropriate research method was necessary to provide new knowledge for practice and literature on motorway travel demand. As unique historical motorway traffic data were available for the period 2014-2019 and collected from the tolling system of the Istrian motorway concessionaire in numerical form, the qualitative method was not suitable due to its' properties and focus on words, sounds, and videos with application of the inductive approach.

Bearing in mind the application of positivism, this thesis selects a quantitative research methodology to adequately analyse and represent results regarding the impact of seasonality on motorway travel demand by frequency of motorway usage. The reason is an expression of historical traffic data between each motorway section numerically, further separated by vehicle category and frequency of motorway usage. Besides that, the toll price, fuel price, GDP values, and tourist arrivals data were collected numerically as well. Application of the quantitative method aims to answer research questions defined in Chapter 1 and test the hypotheses defined in sub-chapter 4.3., Hypotheses. According to Easterby-Smith et al. (2015), researchers can obtain necessary data by collecting data on their own, which gives them control over both the structure of the sample and the data obtained from each study respondent, providing significant confidence that the data will match the study objectives. For this study, the researcher exclusively and directly collected the unique motorway traffic data for each motorway section from the Bina-Istra tolling system database with classification to summer and non-summer periods for each observed year in 2014–2019, accompanied by toll prices data. As remarked in sub-chapter 4.4., Empirical model, using secondary sources by sending direct e-mail requests to GlobalPetrolPrices.com, obtained historical gasoline and diesel prices in Croatia and for world averages (GlobalPetrolPrices.com, personal communication, June 27, 2021). The official Eurostat database as a secondary source also provided historical GDP per capita data for Croatia and the European Union, while the official database of the Croatian Bureau of Statistics ensured historical data on the number of tourist arrivals in Croatia.

5.6. Data collection and data sample

Chapters 2 and 3 showed a review of the collected data for this thesis. To choose the appropriate approach based on literature findings related to the investigation of various factors that impact travel demand, based on data availability, this thesis chose the most commonly used explanatory variables to test changes in their impact through the year with observation of seasonality. It is important to note that the variables used in this thesis do not represent all the possible variables that affect travel demand, as it is impossible to consider all of them and construct an experiment in ideal conditions (Hughes et al., 2006). However, prior to confirmation of using motorway travel demand in the previous year, toll prices, fuel prices, the Croatian and European Union GDP per capita, and tourist arrivals in Croatia as explanatory variables, it was essential to check their data availability for monthly and quarterly levels specifically for each year from 2014 until the end of 2019.

Even if quantitative methodology considers using a different set of methods to collect and analyse numerical data (Dudovskiy, 2018; Ortúzar & Willumsen, 2011; Waters, 2011), Odeck and Bråthen (2008) showed that surveys and questions might show limited usefulness since respondents may have no experience, or it is hard for them to understand and imagine their purpose. For these reasons, economists consider stated preference survey methods with skepticism, preferring choices observed in the marketplace (Wardman, 1988). In the case of this thesis, surveys and questionnaires were not used. Instead, using the unique historical motorway traffic data collected directly from the Istrian motorway concessionaire is similar to other studies with a collection of traffic data from national databases (Gonzalez & Marrero, 2012; Matas & Raymond, 2003). In addition, Odeck and Bråthen (2008) applied a similar approach with traffic data collected from the tolling system, adding questionnaire surveys for travellers before and after the toll was implemented or removed. The collected data for this thesis expressed numerically represent the real and all traffic data between each motorway section, separately distinguished by vehicle category, frequency of motorway usage, and summer/non-summer periods. The advantage of the applied approach is that information about user behaviour in each section is precisely identified for the complete period 2014–2019. Compared to the surveys and questionnaire approach, this thesis covers a more significant number of observations that would be collected by conducting surveys and questionnaires of motorway users. That fact shows the relevance of the obtained results from Chapter 6, where the impact of seasonality and explanatory variables on motorway travel demand are presented and discussed separately by season and frequency of motorway usage. As Ortúzar and Willumsen (2011) pointed out in their book, there are no precise answers to calculate sample size in every situation. Therefore, modeling the collected historical data is crucial to understanding real changes in motorway traffic levels and distinguishing between summer and non-summer periods. The aim is to identify how seasonality impacts motorway travel demand by measuring the impact of each explanatory variable through the year separately by frequency of motorway usage, as existing literature does not consider it.

Regarding the remaining data, the Istrian motorway concessionaire provided historical toll prices for each motorway section as well. Information about toll prices for each year in the period 2014–2019 were separated by five vehicle categories (I, IA, II, III, and IV categories) and by means of payment (regular toll prices and discounted toll prices with ETC devices). The data obtained as an Excel spreadsheet document allowed to distinguish traffic movements of frequent and occasional motorway users to changes in toll prices over time. Having Excel data enabled the conversion of toll prices from the currency Kuna to the Euro, adjusted by inflation, and additionally modified and expressed as Euro (€) per kilometre as the length between toll plazas varies across the motorway. This approach of presenting the toll price as Euro per kilometre follows other studies (Jou et al., 2012; Matajič et al., 2015; Matas & Raymond, 2003; Gomez et al., 2016; Gomez & Vassallo, 2016), which allowed having a unit toll price per kilometre for each section. Although expressed in the Croatian national currency (Kuna), their conversion to Euro currency was necessary to have unified currency values, as collected data for the Croatian GDP per capita, the European Union GDP per capita, and fuel prices were all in Euro currency.

Furthermore, to develop the model and test the impact of GDP on motorway travel demand, which factor along with fuel prices represent traditional explanatory factors used to explain the observed trends in traffic (Bastian et al., 2016), it was necessary to obtain the

Croatian GDP data. As indicated in Chapter 2, 88.90% of total tourist arrivals in Croatia between 2014 and 2019 were foreign tourists, mainly from the European Union. Therefore, the data collection for the European Union GDP was necessary. The official Eurostat and the World Bank databases presented the source for collecting historical GDP data for both Croatia and the European Union, expressed in Euro currency, also as an Excel spreadsheet. The extant literature uses many different measures, such as GDP, GDP per capita, and income (Hanly et al., 2002). Due to historical evidence regarding Croatian population decrease through the years and following the work of Gomez et al. (2016), which argued that observation of GDP per capita constitutes a better proxy of personal income than GDP, this thesis applies the measure of GDP per capita expressed in Euro currency (Abrantes & Wardman, 2011; CrÔtte et al., 2010; Fouquet, 2014). An Excel spreadsheet from Eurostat provided the population data to determine GDP per capita values for Croatia and the European Union.

Based on a direct e-mail request sent to GlobalPetrolPrices.com, the researcher obtained historical fuel price data (GlobalPetrolPrices.com, personal communication, June 27, 2021). The collected information contains monthly fuel prices in Kuna separately for gasoline and diesel prices per litre in Croatia for the period 2014–2019. In addition, the data contain the U.S. dollar and Euro exchange rates together with the world average gasoline and diesel prices in U.S. dollars. Again, the currency exchange rates are crucial to express fuel price values as Euro per litre to have the same base among all explanatory variables with currency values.

The selection of the data on total tourist arrivals was necessary to test the impact of tourist activity on motorway travel demand. Therefore, this thesis observes tourist arrivals as an explanatory variable due to the assumption that tourist arrivals could better explain the usage of roads instead of tourist overnights, whose data does not show travel patterns during their stay in accommodation. The Croatian Bureau of Statistics database provided the data regarding the number of foreign and domestic tourist arrivals for every month of each year between 2014 and 2019 as an Excel spreadsheet.

Table 5.4. provides a summary of variable definitions, measurements, and data sources.

Table 5.4.

Description of variables used in the thesis

Variable	Definition	Measurement	Data source
Motorway traffic	Vehicle transactions between each motorway section	Count of travelled kilometres	Bina-Istra (2020)
Lag motorway traffic	Vehcile transactions between each motorway section in previous period (year)	Count of travelled kilometres	Bina-Istra (2020)
Toll price	Price charged per kilometre travelled on motorway section	Euro per kilometre	Bina-Istra (2020)
Fuel price	Price of fuel per litre	Euro per litre	GlobalPetrolPrices.com, personal communication, June 27, 2021)
GDP Croatian per capita	Croatian Gross Domestic Product per capita	Euro	Eurostat (n.d.)
GDP EU per capita	European Union Gross Domestic Product per capita	Euro	Eurostat (n.d.)
Tourist arrivals	Number of tourist arrivals in Croatia	Count of arrivals	Croatian Bureau of Statistics (n.d.a)

Note: Adapted by the autor.

Considering this thesis tests the impact of seasonality on the I vehicle category (cars) separately by frequency of motorway usage and period of the year, the initial dataset comprised summer and non-summer observations separately for frequent and occasional motorway users covering 136 motorway sections over the six-year period from 2014 to 2019. Each observation contains information on motorway traffic, toll price, fuel price, Croatian GDP per capita, European Union GDP per capita, and tourist arrivals. This resulted in an initial sample size of 3,264 observations (six years x 136 motorway sections x two periods of the year x two types of motorway users). However, during data validation, missing values were identified in the historical toll price of ten motorway sections that were not in the complete motorway profile and under tolls. In order not to affect the results, these motorway sections were omitted from the database. Although data is available for six years, the 2014 data was used solely for the lag motorway traffic variable and was excluded from analysis for other explanatory variables. With the usage of the lagged motorway traffic variable, the actual analysis considers the period between 2015 and 2019, while 2014 serves as a reference year for lag calculations.

After processing missing values and excluding data from 2014 for data integrity reasons, the final dataset used for the analysis comprises 2,520 observations (five years x 126 motorway sections x two periods of the year x two types of travellers). This dataset provides a solid basis for assessing the impact of seasonality on motorway travel demand using different models. By introducing historical data in a structured way, this thesis ensures the reliability of the results presented in Chapter 6, which provide valuable insights into motorway traffic trends across different seasonal periods and for different types of travellers.

5.7. Empirical model

Based on the reference works that use the panel data approach (e.g., Barla et al., 2009; Gonzalez & Marrero, 2012; Matajič et al., 2015; Matas & Raymond, 2003), this section provides an overview of the explanatory variables summarised in Table 5.5. The section also describes the expected correlation between explanatory variables and motorway travel demand using the panel data approach, taking the Istrian motorway as a case study.

Table 5.5.

Observed explanatory variables that impact travel demand

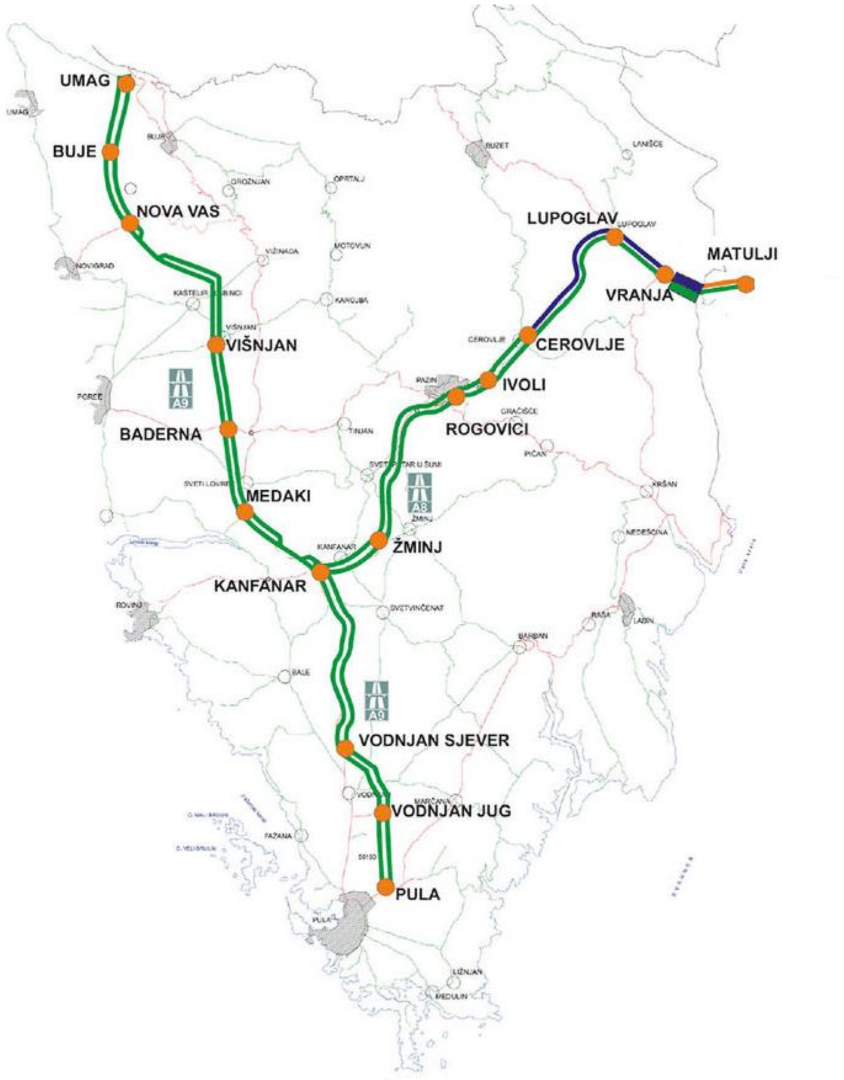
Independent variable	Dependent variable
Lag motorway traffic	
Toll price	
Fuel price	Motorway traffic
GDP Croatian per capita	
GDP EU per capita	
Tourist arrivals	

Note: Developed by the author.

In their 2015 meta-analysis, Havranek and Kokes (2015) explored the income elasticity of gasoline demand and its impact on travel over the past four decades, finding that a wide range of approaches have been used to estimate demand elasticities. However, there is no consensus in the existing literature on the best approach, as different authors prefer different methods. Therefore, using a panel data approach to observe the impact of explanatory variables on motorway travel demand is appropriate for this study as it allows multiple observations on the same cross-sectional units over a given period (Wooldridge, 2012) where adjustment of travel demand results from changes in transportation policies and socioeconomic variables over time (Matas & Raymond, 2003). In this case, observed cross-sectional units represent seventeen toll plazas of the Istrian motorway, with unique historical traffic data obtained between each combination of toll plazas.

Figure 5.2.

Toll plazas on the Istrian motorway



Note: Reprinted from the Bina-Istra internal document.

To test the impact of seasonality and explanatory variables on motorway travel demand, this thesis assumes that the general model of traffic volume on a motorway section is a function of lag motorway traffic ($TRAFFIC_{it-1}$), monetary costs, level of economic activity, and tourist activity. Therefore, the empirical model is expressed as follows:

$$TRAFFIC_{it} = \beta_0 + \beta_1 TRAFFIC_{it-1} + \beta_2 toll_{it} + \beta_3 gdp\_cro_t + \beta_4 gdp\_eu_t$$
$$+ \beta_5 fuel_t + \beta_6 tourist_t + \beta_7 season_t + \beta_7\, ENC\_PlusNo_t + \mu_t \quad (1)$$

where monetary costs represent toll prices ($toll_{it}$) and fuel prices ($fuel_t$). The level of economic activity is measured as the gross domestic product per capita, whose impact on motorway traffic levels is separated into Croatian (gdp_cro_t) and European Union (gdp_eu_t) values. The thesis also considers tourist arrivals in Croatia ($tourist_t$) to test the impact on motorway traffic levels. Since it is impossible to capture all the possible variables that impact travel demand and construct a perfect controlled experiment (Hughes et al., 2006), the thesis assumes other costs as constant over time on motorway sections while μ_t expressing other non-observed variables. Even further remarks in limitations in Chapter 6 and Chapter 7, for the purpose of testing the moderating impact of seasonality and type of motorway user on motorway travel demand, this thesis uses a limited number of explanatory variables which are consistent in each model. Even this approach minimises the risk of multicollinearity issues, it also ensures obtaining comparable results of different datasets through usage of the same baseline model and set of explanatory variables.

Due to literature limitations regarding investigating what impacts motorway travel demand (Gomez & Vassallo, 2015; Gomez et al., 2016), the range of control variables applicable in this thesis is limited. In their study, de Grange et al. (2015) used vehicle flows along four important toll-free arterial roads as a measure of the level of activity in the city of Santiago, Chile. Hymel et al. (2010) used non-local lane miles per adult, Vehicle Miles Travelled (VTM) per capita lagged, VMT per adult lagged, per capita income, per adult income, cost of fuel, population per adult, and degree of urbanization as control variables. Furthermore, Gonzalez and Marrero (2012) considered the real regional GDP, the real full price, and the vehicle fleet as control variables in their study of induced road traffic in Spain. As this thesis uses the GDP and fuel prices as explanatory variables, their usage as control variables was inappropriate. Due to limitation in the availability of statistic data and the primary aim of this study to value the impact of seasonality on motoroway travel demand, this study uses variables $season_t$ and ENC_PlusNo_t as control variables to indicate the impact of season and type of traveller on motorway travel demand. The constant β_0 represents the mean value of the dependent variable when all the explanatory variables in the model are equal to zero. The error term μ_t in the equation accounts for omitted variables and any other factors influencing dependent variable that are not explained by the independent variables such as local policies, geographic and social characteristics, with the assumption of normal distribution of error term and constant variance.

Considering that unique traffic data for the Istrian motorway contains detailed transaction data separated by month, origin-destination for each toll plaza, type of vehicle category, and frequency of motorway usage for the period 2014–2019, travel demand is modeled and tested by:

- **I vehicle category**: testing motorway travel demand solely for the I vehicle category, as in the collected traffic data, 86.52% of total Full price transactions and 72.70% of ENC Plus transactions were realised by the I vehicle category. In addition, total road cross-border traffic of passenger cars represented 90.89% of total traffic between 2014 and 2019 (Croatian Bureau of Statistics, n.d.b), thus indicating the importance of focusing on the I vehicle category;
- **Frequency of motorway usage**: testing motorway travel demand by frequency of motorway usage, with consideration of (i) occasional motorway users as users that pay tolls manually by using toll tickets at the full price, and (ii) frequent motorway users as users of the ENC Plus package that pay tolls with limited validity of toll discounts. Understanding the impact of explanatory variables on motorway travel demand for both types of users is essential due to the different patterns of motorway usage throughout the year. As shown in sub-chapter 2.4., Traffic, occasional user traffic significantly fluctuated between summer and non-summer months, compared to frequent user traffic, whose monthly traffic levels were more stable;
- **Period of the year**: distinguishing data between summer and non-summer periods is vital to identifying variations and the significance of the impact of each explanatory variable throughout the year and finding the effect of seasonality.

A separation of occasional and frequent motorway traffic to summer and non-summer periods enables testing hypotheses H_{1a}, H_{1b}, H_{2a}, and H_{2b} – what is the impact of motorway travel demand in the previous year and toll prices on travel demand in the current year in different periods of the year? Testing the impact of toll prices on travel demand separately for occasional and frequent users also enables identifying how each type of traveller reacts to changes in toll prices, considering their travel preferences. The negative and significant impact of the increase in toll prices on travel demand would be in line with literature findings (Boarnet et al., 2014; Odeck & Bråthen, 2008; Gomez et al., 2016; Gomez & Vassallo, 2015). However, the tests in the context of this thesis are relevant, as on average, 58.75% of total yearly occasional motorway user traffic was realised during the summer period, despite the application of a temporary summer toll increase of 10%, while frequent motorway users did not show significant monthly fluctuations.

Per other hypotheses that distinguish the impact of explanatory variables by season and frequency of motorway usage, the set hypotheses H_{3a} and H_{3b} follow the same pattern for testing the fuel price on travel demand. A negative impact would be in line with the literature (Dahl, 2012; Fontes et al., 2015; Gallo, 2011; Hymel et al., 2010). Besides testing if the impact of fuel prices is in line with the literature, the tests also attempt to identify if and how different types of motorway users react to changes in fuel prices through the year. The founding is expected to be valuable to policymakers in determining and adjusting tolling policy.

As tourism impacts Croatian GDP (Ministarstvo turizma Republike Hrvatske, 2023), besides observation of the Croatian GDP per capita, this thesis also considers an impact of the European Union GDP per capita as most of the foreign tourists arrived in Croatia by cars from the European Union (Mervar & Payne, 2007; Croatian Bureau of Statistics, n.d.b). Besides testing whether the impact of the Croatian GDP per capita and the European Union is in line with the extant literature (Abrantes & Wardman, 2011; Dahl, 2012; Fouquet, 2012; Gomez & Vassallo, 2015; Gomez et al., 2016; Matas & Raymond, 2003), usage of GDP per capita enables extension of testing how increase in the Croatian and the European Union GDP per capita impact travel demand separately by frequency of motorway usage and period of the year (H_{4a}, H_{4b}, H_{5a} and H_{5b}).

Regarding tourist activity as an explanatory variable to test the impact on motorway travel demand, as stated in sub-chapter 2.8., Tourist activity, tourism significantly impacted the Croatian economy, with a share of 19.6% in the total Croatian GDP (Ministarstvo turizma Republike Hrvatske, 2023). Such information is in line with historical occasional motorway user traffic levels, with a realization of 58.75% yearly transactions during the four months of the summer period. To check the impact of tourist activity on travel demand for occasional users in the summer and non-summer periods, this thesis also tests the impact on frequent users to identify how they react during higher and lower tourist activity periods (H_{6a} and H_{6b}). Based on collected data about tourist arrivals and motorway traffic levels on the Istrian motorway during the year, testing the hypotheses about the impact of tourist activity for both user types (H_7 and H_8) aim to bring new knowledge to practice and literature about sensitivities to changes in tourist activity. The results intend to provide new knowledge on whether the observed period of the year and type of motorway users are essential factors that impact motorway travel demand, which must be considered when defining their tolling policy.

5.8. Baseline model estimation

This sub-chapter provides the data analysis method used in this thesis and describes the process of defining the baseline model estimation method. Also, the sub-chapter evaluates and justifies methodological choices used for data modeling and contribution to practice and knowledge. The panel data set (or longitudinal data) widely used in transportation studies (Gomez & Vassallo, 2015; Gunter & Smeral, 2016; Havranek & Kokes, 2015; Hymel & Small, 2015; Matajič et al., 2015; Matas & Raymond, 2003; Miller & Alberini, 2016; Seetaram et al., 2016) enables observation of the same cross-sectional units over a given period. Having multiple observations on the same units allow researchers to control for certain unobserved characteristics of individuals, including observation of lags, which information can be significant as economic policies can expect to have an impact with the passage of time (Wooldridge, 2012). The temporal dimension of panel data also allows modeling the dynamic adjustment of demand resulting from changes in transportation policy and other variables used over time (Matas & Raymond, 2003).

By using the panel data approach, this thesis observes six years of data (2014–2019) for each of seventeen toll plazas on the Istrian motorway[9]. The collected traffic and toll price per kilometre data differ across each motorway section, while GDP per capita, fuel price, and tourist arrivals are considered to be the same on each motorway section for the corresponding period. As particular motorway sections were not in the complete motorway profile and under tolls (toll prices on these sections were zero during the whole observed period 2014–2019), this thesis omitted these observations to not impact the results. The omitted motorway sections are listed in Table 5.6. and marked with "X".

[9] Locations of toll plazas in Figure 5.2., sub-chapter 5.7., Empirical model.

Table 5.6.

Omitted motorway sections in semi-profile without toll between 2014-2019

	Vranja	Lupoglav	Cerovlje	Ivoli	Rogovići
Vranja		X	X	X	X
Lupoglav	X		X	X	X
Cerovlje	X	X		X	X
Ivoli	X	X	X		X
Rogovići	X	X	X	X	

Note: The author collected traffic data from the tolling system of Bina-Istra.

As remarked in sub-chapter 2.4., Payment means on the Croatian motorways, this thesis does not observe the potential impact of the introduction of the ENC Easy, ENC Next, and ENC No Limit packages on motorway travel demand due to their low share in total transactions. Also, policies regarding toll discounts and conditions for usage of all ENC packages have not changed during the observed period in this thesis.

To standardise the values of explanatory variables, all the variables were transferred in the natural logarithmic form to obtain a constant elasticity model and express the effect of each explanatory independent variable as a percentage (Wooldridge, 2012). This approach is also in line with the extant literature related to the investigation of travel demand (e.g., Álvarez et al., 2007; Batarce et al., 2023; CrÔtte et al., 2010; de Grange et al., 2015; Gomez & Vassallo, 2015; Odeck & Johansen, 2016; Zamparini & Reggiani, 2007). Therefore, the following equation presents all the variables expressed in logarithms:

$$ln(vkt_{it}) = \beta_0 + \phi ln(vkt_{it-1}) + \beta_1 ln(toll_{it}) + \beta_2 ln(fuel_t) + \beta_3 ln(gdp\_cro_t) + \beta_4 ln(gdp\_eu_t) + \beta_5 ln(tourist_t) + \beta_6 season_t + \beta_7 ENC\_PlusNo_t + \mu_{it} \quad (2)$$

vkt_{it} = traffic volume on motorway section i in period t,

$toll_{it}$ = toll price on motorway section i in period t adjusted by deflator to 2015 values, expressed in euro per km,

gdp_cro_t = the Croatian GDP per capita in period t adjusted by deflator to 2015 values, expressed in euro,

gdp_eu_t = the European Union GDP per capita in period t adjusted by deflator to 2015 values, expressed in euro,

$fuel_t$ = average gasoline and diesel price in Croatia in period t adjusted by deflator to 2015 values, expressed as euro per litre,

$tourist_t$ = total domestic and foreign tourist arrivals in Croatia in period t,
season = dummy variable that indicates the year (summer or non-summer period),
ENC_PlusNo_t = dummy variable that indicates the type of traveller (Full price or ENC Plus user).

In Eq. 2, toll prices ($toll_{it}$) and fuel prices ($fuel_t$) represent monetary costs in Croatia adjusted to 2015 values by using the Croatian deflator published by the Croatian Bureau of Statistics (n.d.c). Adjustment to 2015 values ensures reflection of their real values over time (Hughes et al., 2006; Hymel et al., 2010). In addition, this thesis converted historical toll rates from kuna to euro currency, expressed in per kilometre terms (euro/km) (Matas & Raymond, 2003; Matajič et al., 2015; Gomez et al., 2016; Gomez & Vassallo, 2016). The reason to express toll prices in euro/km is to ensure a better estimation of the model, as each combination of motorway sections differs by section length and amount of toll price. Further, this thesis measures the level of economic activity as the gross domestic product (GDP) rather than disposable income to better capture the level of economic activity (Matas & Raymond, 2003; Millard-Ball & Schipper, 2011). The Croatian GDP values (gdp_cro_t) were adjusted to the year 2015 by using the Croatian deflator, while the European Union GDP values (gdp_eu_t) were adjusted by using the European Union deflator obtained from the FRED graph (Federal Reserve Bank, n.d.). To estimate the effect of tourist activity in Croatia on motorway travel demand, the thesis considers the total number of tourist arrivals ($tourist_t$), which variable is used in the literature to measure tourist activity (Mervar & Payne, 2007; Fuleky et al., 2014; Peng et al., 2015; Seetaram et al., 2016).

As historical data for 2014-2019 showed higher tourist arrivals and motorway traffic levels during the summer period than in the remaining period of the year (Croatian Bureau of Statistics, n.d.a), to investigate the impact of seasonality on motorway travel demand, the I vehicle category traffic data were separated into two periods:

- January 1–May 31 and October 1–December 31 (non-summer period);
- June 1–September 30 (summer period).

The reason to separate the collected data on each explanatory variable into two periods is that since 2015, the Istrian motorway concessionaire has applied a temporary toll increase of an additional 10% during the summer period with rounding regular toll prices (ENC users are not affected by this measure). Therefore, the transactions were collected for three periods:

(i) From January 1 until May 31;
(ii) From June 1 until September 30;
(iii) From October 1 until December 31.

For the purpose of this thesis, the data for (i) and (iii) of each observed year were merged to reflect the non-summer period due to the realization of transits with the same toll prices.

Regarding traffic data, the thesis observes the daily traffic as vehicle kilometres travelled (VKT or vkt) which represents the distance travelled by vehicles on roads. Application of VKT is one of the most frequently used methods in practice and literature to indicate mobility patterns, travel trends, and traffic demand (Bastian et al., 2016; Boarnet et al., 2014; de Grange et al., 2015; Fontes et al., 2015; Gomez & Vassallo, 2015; Leduc, 2008). Except for VKT, another variable frequently used in practice and literature is AADT (Average Annual Daily Traffic), which represents total transactions in a particular section divided by the number of days (Gomez et al., 2016; Gonzalez & Marrero, 2012; Leduc, 2008). This study prefers the use of the VKT instead of the AADT, as the VKT considers the length of each motorway section, which is an important feature due to differences in length between each motorway section. Since particular motorway sections during the period 2014–2019 were toll-free as the road was not in a complete profile, this thesis eliminates the toll-free motorway sections from the model. The historical toll prices on the Istrian motorway were divided by the section length to obtain the toll price per kilometre with additional conversion to euro currency, adjusted by using a deflator to the year 2015 value to have real values. Following the literature, obtained toll prices for each motorway section allowed comparison between each toll plaza (Hughes et al., 2006; Hymel et al., 2010; Gomez et al., 2016; Gomez & Vassallo, 2016).

The fuel price expression per litre follows the literature (Goodwin et al., 2004). To take into account the impact of fuel prices on travel demand on the Istrian motorway and to test the set hypotheses, the monthly data were merged into summer and non-summer periods to construct an average value separately for diesel and gasoline prices. The obtained gasoline and diesel values were additionally merged into the average values, thus constructing *fuel* variable to avoid potential collinearity between the movements of gasoline and diesel prices. The obtained fuel prices per litre were adjusted by the Croatian deflator to 2015 values as well.

Regarding GDP variables, this thesis uses quarterly historical GDP per capita values (Q1, Q2, Q3, and Q4) for both Croatia and the European Union, collected from the Eurostat database, and expressed in euros. The Croatian deflator adjusted the Croatian GDP per capita data to the 2015 values, while the European Union deflator adjusted the European Union GDP per capita to the same year. Since the summer period in this thesis considers the period June–

September while the non-summer period includes the remaining months of the year, the GDP per capita data were adjusted to monthly average to fit the model:

- The formula used to determine the average monthly GDP per capita for the summer period:

$$GDP\ per\ capita\ summer = \frac{GDP\ per\ capita\ Q2 \times \frac{1}{3} + GDP\ per\ capita\ Q3}{4} \quad (3)$$

- The formula used to determine the average monthly GDP per capita for the non-summer period:

$$GDP\ per\ capita\ nonsummer = \frac{GDP\ per\ capita\ Q1 + GDP\ per\ capita\ Q2 \times \frac{2}{3} + GDP\ per\ capita\ Q4}{8} \quad (4)$$

The summer period spans four months, while the non-summer period encompasses the remaining eight months. To calculate the average monthly GDP per capita for each period, the GDP per capita for the summer period was divided by four, and the GDP per capita in the non-summer period was divided by eight. Due to differences in duration between the summer and non-summer periods, adjustments were necessary to have comparable GDP per capita values. Otherwise, ratios would favor higher non-summer values, thus impacting the results. A similar adjustment principle was not found in the existing literature, since there is no evidence of testing the impact of seasonality on motorway travel demand by observing specific periods. The sub-chapter 7.4., Limitations, further remarks on this issue.

The data on tourist arrivals for 2014–2019 was collected from the Croatian Bureau of Statistics (n.d.a) in million of arrivals, separately by each month. To obtain average monthly tourist arrivals in the summer and non-summer periods, the total number of tourist arrivals in the summer period was divided by four (four months of the observed period), while the total number of tourist arrivals in the non-summer period was divided by eight (eight months of the observed period). Due to differences in period length between the summer and non-summer periods, the adjustment was necessary to have comparable tourist arrival values between the two periods. Otherwise, ratios would favor non-summer values and impact the model results.

In Eq. 2., the coefficients of the independent variables β represent short-run elasticities, referring to the effect on demand within one year of a change in the independent variable (Goodwin et al., 2004). The formula to calculate the long-run elasticities is $\beta/1\text{-}\phi$, where $1\text{-}\phi$ represents the adjustment factor that measures the speed of adjustment: the larger the value of ϕ means the slower the speed of adjustment and the more significant the difference between short-run and long-run elasticity values (Dargay, 2007; Goodwin et al., 2004; Matas &

Raymond, 2003; Odeck & Bråthen, 2008). The presence of the lagged variable vkt_{t-1} suggests that individuals adjust their travel behaviour with delay, which is essential to estimating long-run elasticities. However, as this thesis aims to test and provide new knowledge on impact of seasonality on motorway travel demand by using short-run estimates, this thesis does not calculate long-run elasticities.

As testing the relationship between the dependent and independent variables can be expressed through different model architectures, the thesis observed various techniques from the literature that test the impact of different factors on travel demand. However, certain conditions and tests must be fulfilled to choose a particular model. Despite using the Generalized Method of Moment Differential (GMM-DIFF) and Generalized Method of Moment System (GMM-SYS) to test the impact of travel demand (Gomez & Vassallo, 2015; Gomez et al., 2016; Gonzalez & Marrero, 2012), the application of GMM-DIFF and GMM-SYS violated assumptions in particular datasets to accept these methods. Following the literature on panel data (Batarce et al., 2023; Hsiao, 2022; Wooldridge, 2012), this thesis also considered Fixed Effects (FE) and Random Effects (RE) methods with an estimated Hausman test that rejected the usage of the RE method in all four models and favoured FE.

By considering data type and literature that investigated the impact on travel demand, this thesis also observed Ordinary Least Squares (OLS) and Weighted Least Squares (WLS) methods (Bastian et al., 2016; Matas & Raymond, 2003; Matas et al., 2012; Wei, Wu, & Zhou, 2020). Firstly, the OLS method is a linear regression method extensively documented and widely applied due to its simplicity and interpretability (Montgomery et al., 2012). It is used in statistics to establish a correlation between an attribute and a label in the presence of other potentially correlated features. It represents a technique that uses linear regression to deduce a correlation between a variable and an outcome, representing the likelihood of each real value to be a true correlation (Sheffet, 2019). This method assumes a linear relationship between the mean response of the dependent variable and the explanatory independent variables. In cases where the variability or spread of errors (residuals) in a regression model is not constant across all levels of independent variables, it implies the presence of heteroscedasticity. In their study on the impact of GDP, gasoline prices, and toll levels on travel demand, Matas and Raymond (2003) applied the WLS method instead of OLS due to the presence of heteroscedasticity. Comparing OLS with WLS, the authors stated that the latter produced results with similar estimates while the standard error decreased.

This study employs the WLS method as a baseline model to analyse the impact of determined explanatory variables on travel demand. In panel data analysis, WLS represents a robust estimation method, particularly in the presence of heteroscedasticity (Matas & Raymond, 2003; Matas et al., 2012). As traffic levels vary significantly between sections, where particular sections generate consistently higher volumes, these indications suggests potential heteroscedasticity and violating the homoscedasticity assumption of OLS. As a result, application of OLS method may generate inefficient and biased estimates due to the unequal variance of errors. To address the issue, application of the WLS model assigns weights to observations based on their variance, ensuring that sections with more reliable traffic data contribute proportionally more to the estimation process. Usage of the WLS mitigates the impact of measurement errors, potentially more pronounced in sections with lower traffic volumes due to higher relative variability. From an economic perspective and policy implications, ensuring efficiency in estimation is crucial for obtaining accurate elasticity estimates regarding the impact of tolls, fuel prices, and GDP per capita on travel demand.

As the validity of the WLS method depends on validity of particular assumptions, the assumptions were addressed through this thesis as summarised:

- *No perfect multicollinearity* – as explained in sub-chapter 6.3., Multicollinearity test, the presence of multicollinearity can lead to unstable estimated coefficients, where even small changes can result in significant changes in estimated coefficients. To check for multicollinearity issues, this thesis applied the Variance Inflation Factor (VIF), which assesses how much the variance of the estimated regression coefficient increases with correlated predictors (Akinwande et al., 2015; Mansfield & Helms, 1982; Montgomery et al., 2012). Since the variables gdp_eu and tourists showed VIF values higher than 10, these variables were omitted not to impact the results.
- *Correct specification of weights* – considering that the graph of the standard residuals for the data used in OLS suggested heteroscedasticity, where the variability of the residuals decreases with an increase in prediction values (Figure 6.14), as detailed in sub-chapter 6.4., Regression results, application of specific weights through the WLS model accounted for heteroscedasticity issues.
- *Independence of errors* – according to the assumption that the error terms should be uncorrelated, meaning that the residuals should not exhibit autocorrelation, the Durbin-Watson test was used to assess first-order autocorrelation. As detailed in sub-chapter 6.4., Regression results, the autocorrelation was not detected in the models.

In addition to the application of dummy season and ENC_PlusNo variables, year-fixed effects were initially considered in the panel data estimation to account for unobserved, time-specific factors potentially influencing motorway travel demand. However, the year dummies for 2018 and 2019 were consistently omitted due to multicollinearity in all model specifications, suggesting redundancy in their inclusion (Wooldridge, 2010). This result indicates that much of the year-to-year variation is already explained by other model variables. In particular, the lagged vehicle kilometre travelled variable consistently emerged as a significant predictor. Its inclusion captures dynamic patterns over time, absorbing a large portion of temporal variation and reducing the added value of year dummies (Arellano & Bond, 1991; Baltagi, 2021). This is consistent with transport modelling literature, where past volumes are frequently found to be strong predictors of current demand. Additionally, macroeconomic indicators such as GDP per capita and fuel prices are included to account for systemic temporal influences. These variables have been shown to be major determinants of road traffic demand, often substituting for time-fixed effects by capturing broader economic trends (Goodwin et al., 2004).

As discussed in sub-chapter 5.7. on the empirical model, this study prioritises consistency and comparability across models by maintaining a uniform specification. Introducing year-fixed effects could have necessitated model re-specification or selective variable inclusion, potentially increasing the risk of omitted variable bias or interpretive inconsistencies. From a modelling perspective, a parsimonious specification not only improves generalisability but also reduces the risk of overfitting, particularly in panel datasets with limited time periods (Babyak, 2004; Burnham & Anderson, 2002).

Finally, the use of WLS as the baseline estimation method addresses concerns of heteroscedasticity, autocorrelation, and multicollinearity, ensuring that estimates reflect population-level relationships rather than being skewed by smaller, lower-traffic segments.

In summary, year-fixed effects were evaluated but ultimately excluded due to collinearity, redundancy, and the sufficiency of other controls. This decision is theoretically grounded, methodologically justified, and consistent with best practices in panel data modelling.

5.9. Conclusion

This chapter demonstrated the ontological, epistemological, and axiological positions of this thesis, as well as the empirical model and research approach applied to collect and analyse data in an appropriate form. The application of particular methods aims to test set hypotheses and answer established research questions to identify the impact of seasonality and type of motorway user on motorway travel demand. The chapter showed the suitability of positivist research philosophy due to collecting extensive historical data in numerical form without interaction with motorway users, thus providing significantly higher precision than direct interaction with users through interviews or questionnaires on considerably lower samples. Therefore, using the quantitative method for this study has an advantage over the qualitative method to model large samples of collected numerical data. In addition, this chapter argues for the application of the quantitative method as the unique historical traffic data were also collected in numerical form separately for each section of the Istrian motorway, time of the year, by means of payment, and vehicle category.

CHAPTER 6. RESEARCH FINDINGS AND DISCUSSION

6.1. Introduction

This chapter is the central part of the thesis on the contribution of new knowledge to the literature and practice, which is precious for motorway policymakers. The study addresses specific objectives, research questions, and hypotheses to test the impact of explanatory variables on motorway travel demand for the I vehicle category. This thesis also seeks to contribute new understanding about the impact of seasonality on motorway travel demand by separating estimated coefficients of independent variables on motorway travel demand during the year and by type of traveller, using the Istrian motorway as a case study.

The following sub-chapter 6.2., Descriptive statistics, summarises the description and properties of the variables employed, as well as their relevant data evaluated prior to their application in the econometric model. The sub-chapter 6.3., Multicolinearity tests, provides an overview of tests performed to ensure the validity and suitability of the variables utilised. The sub-chapter 6.4., Regression results, presents estimations separately by type of traveller and by period of the year. These distinctions demonstrate whether and in what proportions seasonality influences motorway travel demand by estimating coefficient of explanatory variables based on the time of the year. The sub-chapter 6.5., Robustness check, shows the outcomes of various methods used to confirm robustness of the results obtained with the WLS method chosen for results interpretation. Although the existing literature does not show whether the impact of various explanatory variables on motorway travel demand varies between summer and non-summer periods, sub-chapter 6.6., Discussion of obtained results, provides an overview of obtained results as well as discussion on validating hypotheses.

6.2. Descriptive statistics

This sub-chapter describes the data used in this thesis, which involves panel data from 2520 observations between 2014 and 2019. As mentioned earlier, the variables observed in this thesis are vkt_{t-1}, *toll*, *fuel*, *gdp_cro*, *gdp_eu*, *tourist*, and two dummy variables: *season* and *ENC_PlusNo*. In that sense, the dependent variable is vkt_t, while the remaining variables represent independent explanatory variables whose impacts on the dependent variable are further tested. All other variables that potentially impact traffic levels, such as weather conditions, the quality of the alternative toll-free roads, and traffic on the alternative toll-free roads, are unobserved and considered unchanged during the whole period (2014–2019). The control variables used as dummies are *season* (summer and non-summer) and *ENC_PlusNo* (type of traveller), as examined in sub-chapter 5.7., Empirical Model. It is important to note that this thesis focuses only on observing the I vehicle category (cars), as that category represented the share of 86.52% of total occasional motorway user transactions and 72.70% of frequent motorway user transactions. A similar pattern was also present in road cross-border traffic, with 90.89% realised by cars.

Table 6.1.

Descriptive statistics and correlation matrix

No.	Variable	Mean	SD	Min	Max	vkt_{t-1}	*toll*	*fuel*	*gdp_cro*	*gdp_eu*	*tourist*
1	vtk_{t-1}	6.036	2.314	0.000	12.102	1					
2	*toll*	-2.826	0.415	-4.423	-1.321	0.444 ***	1				
3	*fuel*	0.211	0.051	0.130	0.305	0.061 **	0.136 ***	1			
4	*gdp_cro*	2.509	0.104	2.327	2.685	0.125 ***	0.170 ***	0.598 ***	1		
5	*gdp_eu*	3.391	0.018	3.370	3.424	0.022	0.144 ***	0.660 ***	0.558 ***	1	
6	*tourist*	0.273	0.879	-0.814	1.262	0.138 ***	0.096 ***	0.302 ***	0.777 ***	-0.044 *	1

*p-values in parentheses; *** p < 0.001; ** p < 0.01;*
** p < 0.05; . P <0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

Following the process in other studies (Batarce et al., 2023; de Grange et al., 2015; Gomez et al., 2016; Graham et al., 2009; Odeck & Johansen, 2016), all variables observed in this thesis are in logarithmic value to have standardised values as well as to ensure a higher degree of normality than the original variables. Therefore, for simplicity, the remaining text uses the term "variable" instead of "the logarithm of the variable".

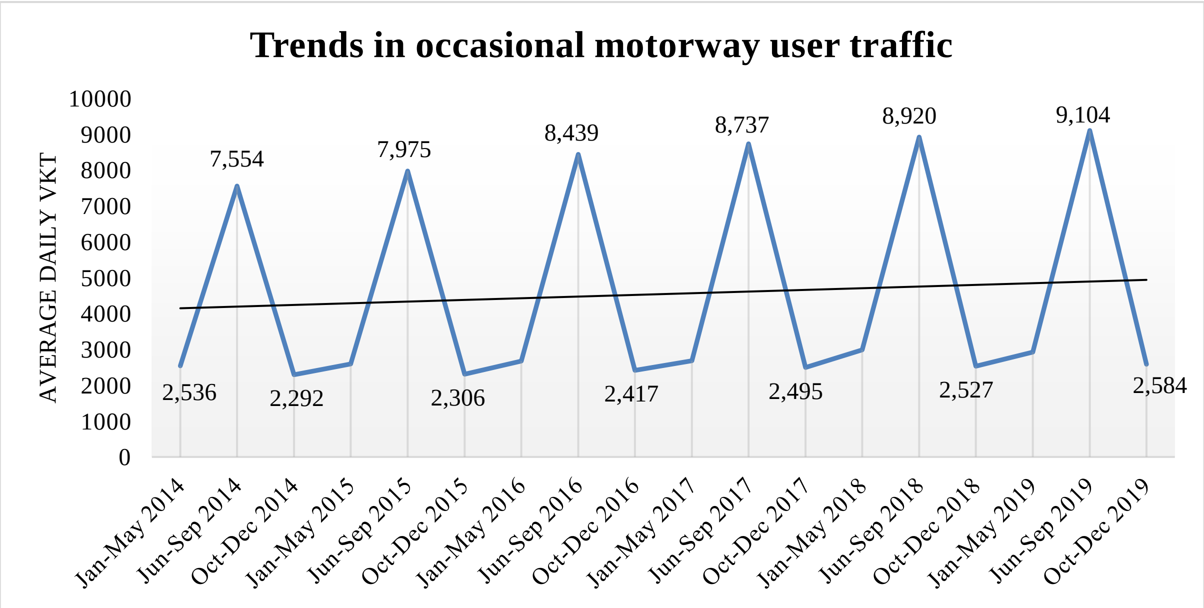
- *Vehicle kilometre travelled variable (vkt_t)*

The lag vkt_t variable (vkt_{t-1}) represents the average daily vehicle kilometres travelled for the I vehicle category on section *i* in period *t-1*, separately distinguished by frequent and occasional transactions and by period of the year (summer and non-summer periods). The vkt_t variable used in transportation literature reflects vehicle kilometres travelled on each motorway section as motorway sections are not the same length (Bastian et al., 2016; Boarnet et al., 2014; de Grange et al., 2015; Fontes et al., 2015; Gomez & Vassallo, 2015; Leduc, 2008). According to the collected data from Bina-Istra, the average length of motorway sections on the Istrian motorway was 43.84 km. Collected numerical transaction data constructed the *vkt* series, which refer to the distance vehicles travelled on roads. As particular Istrian motorway sections were not in the complete motorway profile and under tolls (the toll prices on these sections were zero during the whole observed period 2014–2019), this thesis omitted these observations from the data not to impact the results, as listed in Table 5.4. of sub-chapter 5.8., Baseline model estimation. In addition, Table 6.1 ranged the vkt_{t-1} logarithmic values from 0.000 to 12.102. The overall mean value was equal to 6.036, while the standard deviation of the observations was 2.314.

The graph in Figure 6.1. shows patterns of daily vehicle kilometres travelled and fluctuations between summer (June–September) and non-summer (January–May and October–December) periods, with a positive trendline in the yearly increase of traffic levels.

Figure 6.1.

Trends of occasional motorway user traffic movements 2014-2019



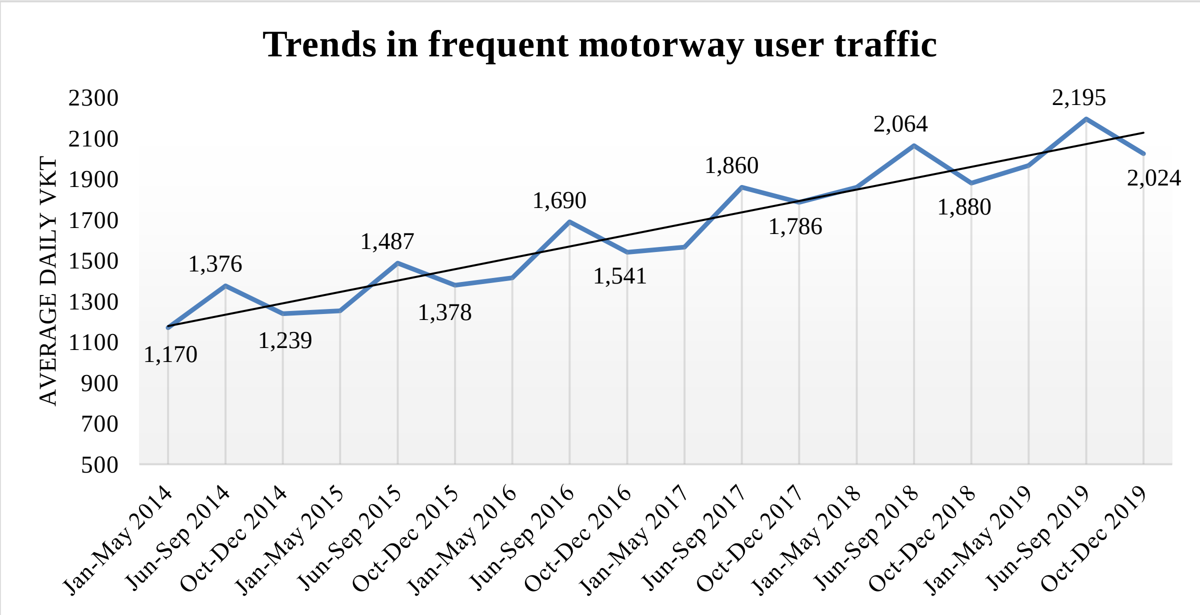
Note: Adapted from Bina-Istra (2020). The data do not include the traffic from the omitted toll-free motorway sections specified in sub-chapter 5.8., Baseline model estimation.

Considering all periods of the year, the lowest daily vehicle kilometres travelled for occasional users occurred in the period October–December, with an average value of 2,437 daily vehicle kilometres travelled. The highest daily vehicle kilometres travelled were recorded between June and September, with an average daily value of 8,455.

Regarding trends in frequent motorway traffic, Figure 6.2. reports positive traffic movements through the years. Although the graph represents a pattern of traffic fluctuations between summer and non-summer periods, the period January–May showed the lowest records with an average value of 1,538 daily vehicle kilometres travelled. The highest values occurred in the period June–September, with an average daily value of 1,779.

Figure 6.2.

Trends of frequent motorway user traffic movements 2014-2019



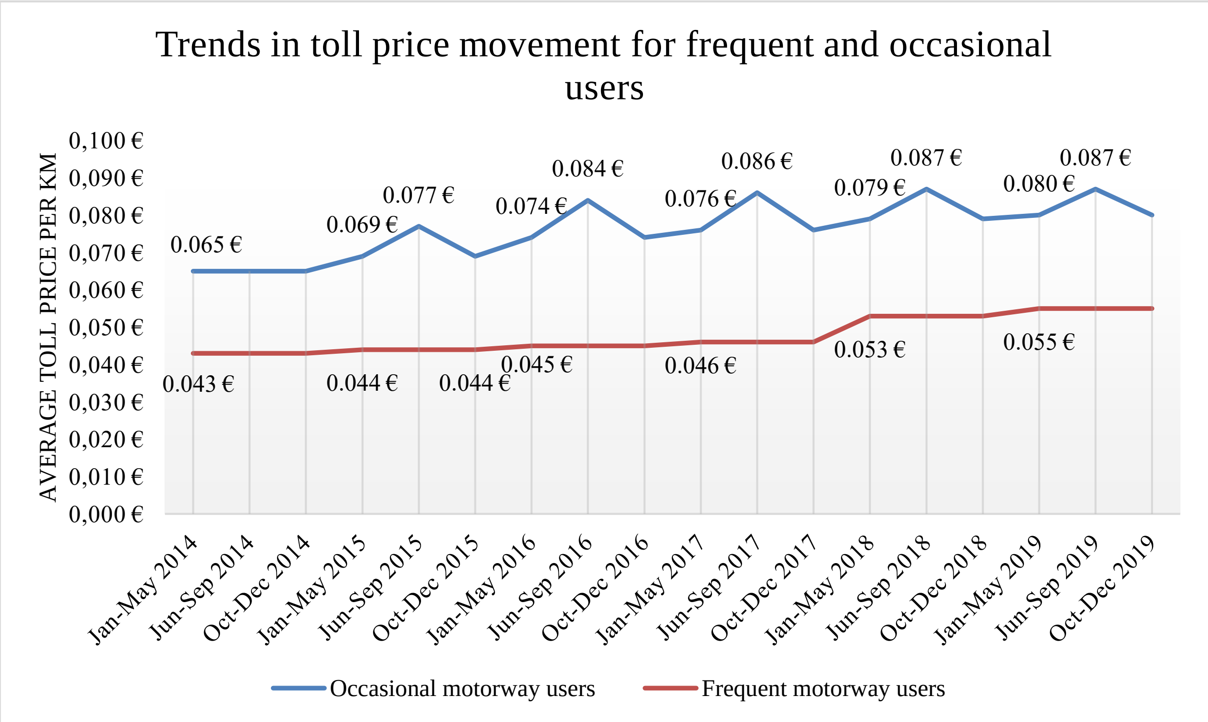
Note: Adapted from Bina-Istra (2020). The data do not include the traffic from the omitted toll-free motorway sections specified in sub-chapter 5.8., Baseline model estimation.

- *Toll price variable (toll)*

The variable toll represents an average price per kilometre adjusted by inflation on each motorway section i in period t expressed in euro currency (€). The graph in Figure 6.3. shows toll price movements between 2014 and 2019, with a trendline of toll increase during the years. It is worth noting that summarising the data over three time periods per year (January-May, June-September, and October-December) is appropriate, as temporary toll increases have only been applied during the June-September periods[10], while yearly changes in tolling policies took effects on January 1. Therefore, the lines in Figure 6.3. indicate seasonal fluctuations in toll prices for occasional motorway users caused by the application of a temporary toll increase during the summer period. Even if the tendency to increase tolls through the years was present for both user types, the specific tolling policy measure during the summer period did not negatively affect frequent motorway users.

Figure 6.3.

Trends of frequent and occasional motorway user price changes 2014-2019



Note: Adapted from Bina-Istra (2020).

Given the implementation of a temporary summer toll increase beginning in summer 2015, the average toll price for the I vehicle category in summer 2015 was 0.077 €/km. In 2019, the average summer toll price for occasional users increased by 12.99%, reaching 0.087 €/km. During the non-summer period, the average toll price was 0.069 €/km in 2015 and 0.080 €/km in 2019, representing a 15.94% increase over the years. Because the temporary summer toll rise did not apply to the ENC Plus package, their toll rates remained constant

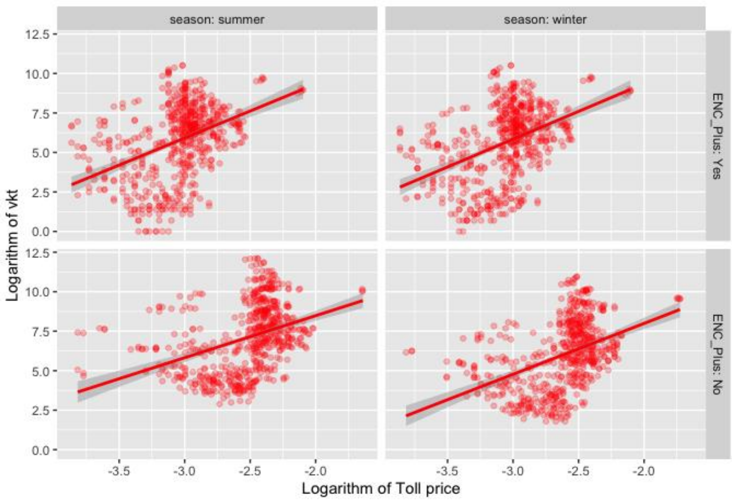
[10] Rounding rules specified in sub-chapter 4.4., Empirical model.

during the summer and non-summer periods. Therefore, the average toll price was 0.043 €/km in 2015 and 0.055 €/km in 2019, showing a 27.91% rise throughout that time.

Regarding the graphical correlation between variables *toll* and vkt_t, Figure 6.4. graphically shows the relationship based on the indication of using the ENC Plus package (if used: “Yes”, if no used “No”) and the period of the year (summer and winter (non-summer) period).

Figure 6.4.

Graphical correlation between toll (x-axis) and vkt_t *(y-axis)*



Note: Graphical correlation between *ln(vkt)* and *ln(toll)* during the summer and non-summer (winter) period, separated by additional criteria if using the ENC Plus package for travelling or not.

An analysis of the correlation between *toll* and vkt_t variables indicated a positive correlation in all cases. However, it is worth remarking that the positive correlation between *toll* and vkt_t is a cause-and-effect relationship, as there are other factors that might impact the correlation between *toll* and vkt_t variables. Therefore, it is necessary to conduct further investigation and analysis in order to precisely understand the relationship and identify other relevant factors that could impact motorway traffic.

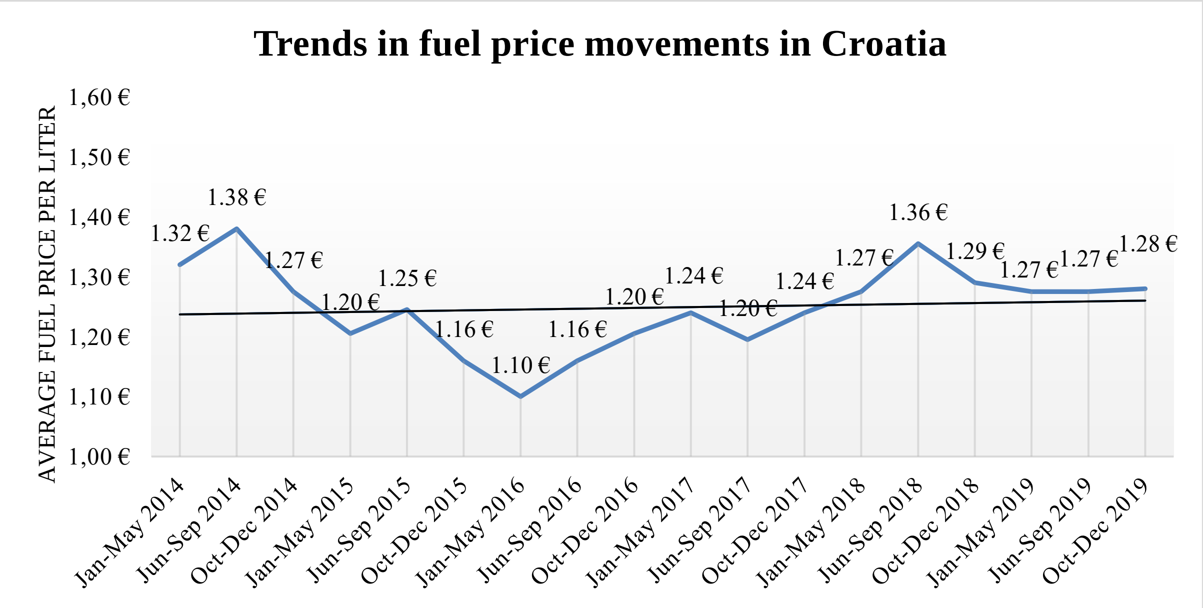
- *Fuel price variable (fuel)*

The variable *fuel* represents an average fuel price (between gasoline and diesel prices) per litre in period *t* in Croatia expressed in euro currency (€), adjusted to 2015 values by using the Croatian deflator. Following the graphical presentations for variables vkt_t and *toll*, Figure 6.5.

shows trends in average monthly fuel price movements in Croatia. Even the data indicates fluctuations in average fuel prices throughout the year, the average fuel price during the summer period of 2015 was 1.25 €/l and 1.18 €/l in non-summer, showing a difference of 5.93%. The average fuel price increased over time, reaching 1.27 €/l in 2019.

Figure 6.5.

Trends of fuel price movements in Croatia

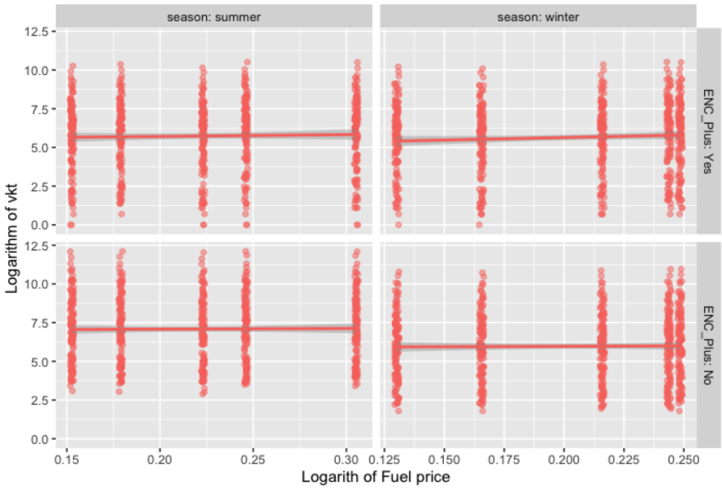


Note: The author obtained and adopted the data from GlobalPetrolPrices.com (personal communication, June 27, 2021).

Following the same principle applied in observing variables *toll* and vkt_t, Figure 6.6. graphically indicates the correlation between variables *fuel* and vkt_t depending on whether the ENC Plus package is used and the period of the year. As the price per litre is the same for all motorway sections, the variable *fuel* has only six possible values. The graph excludes the value for the year 2014 due to using vkt_{t-1}, as the *fuel* value for 2013 was not available. For graphical presentation, this thesis introduces a slight amount of data noise by adding pseudorandom error, normally distributed with low variance (noise is not included in the further analysis).

Figure 6.6.

Graphical correlation between variable fuel (x-axis) and vkt_t (y-axis)



Note: Graphical correlation between *ln(vkt)* and *ln(fuel)* during the summer and non-summer (winter) period, separated by additional criteria if using the ENC Plus package for travelling or not.

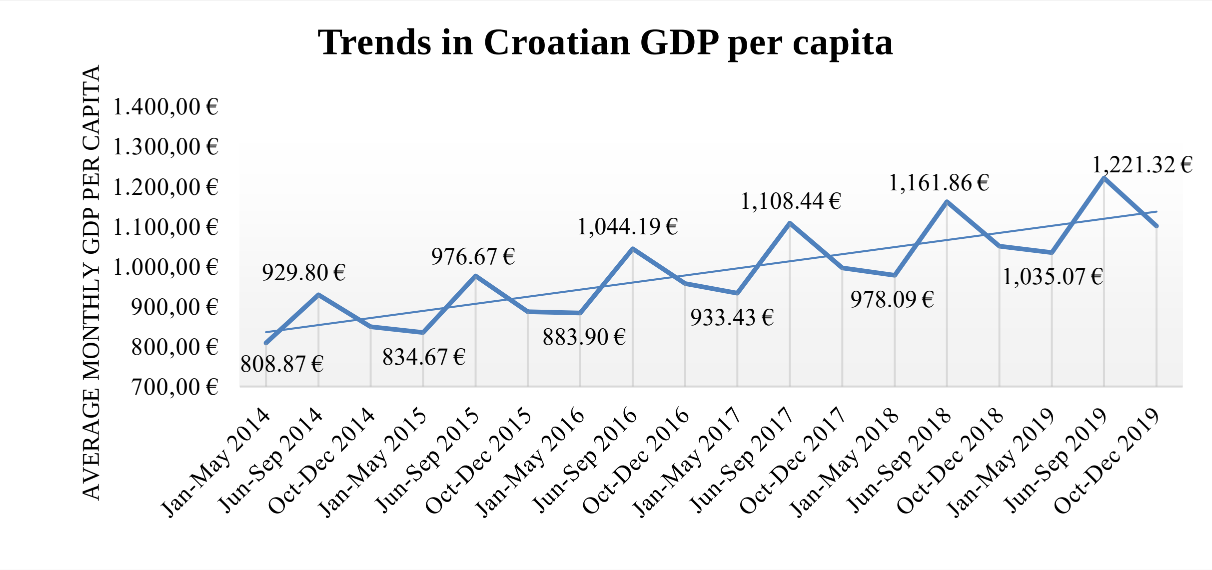
The graph of *fuel* and vkt_t suggests an unclear positive correlation between these two variables. However, it is worth mentioning that this relationship might be complex and subject to the influence of other factors, the same as earlier stated for the *toll* variable.

- *The Croatian GDP per capita variable (gdp_cro)*

The Croatian GDP per capita variable, which represents the average monthly GDP per capita in Croatia in the period *t* expressed in thousands of euros, was adjusted to the 2015 year to obtain real Croatian GDP per capita using the available Croatian deflator. Considering all periods of the year, June–September recorded the highest Croatian GDP per capita value with an average monthly value of 1,073.71 € between 2014 and 2019. In contrast, the period January–May generated the lowest monthly Croatian GDP per capita with a value of 912.34 €, thus indicating a difference of 17.69% between the highest and the lowest GDP per capita values.

Figure 6.7.

Trends in the Croatian GDP per capita movements 2014-2019

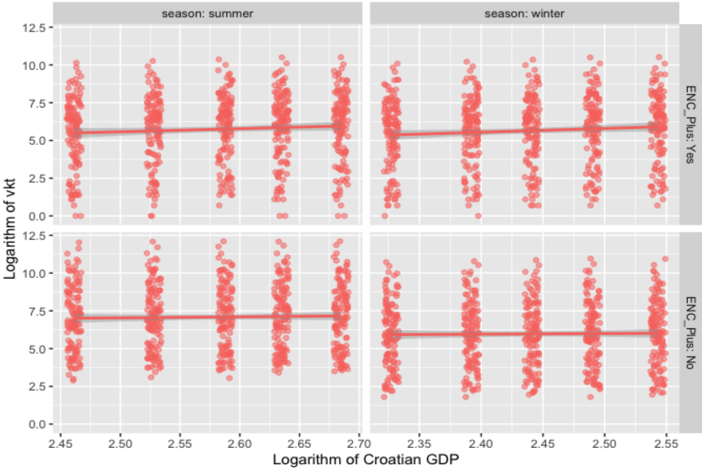


Note: Adapted from Eurostat (n.d.).

The graphical observation of the correlation between *gdp_cro* and vkt_t in Figure 6.8. shows an unclear positive correlation between the variables, suggesting that the relationship between *gdp_cro* and vkt_t could be complex and dependent on other variables.

Figure 6.8.

Graphical correlation between gdp_cro (x-axis) and vkt$_t$ (y-axis)



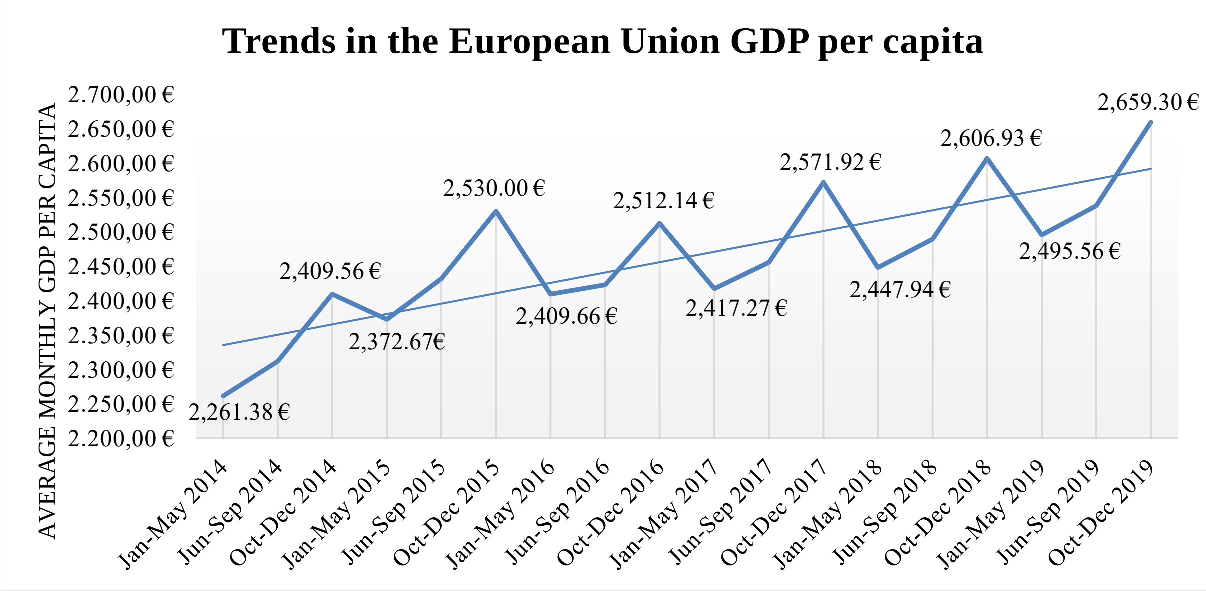
Note: Graphical correlation between log(vkt) and log(gdp_cro) during the summer and non-summer (winter) period, separated by additional criteria if using the ENC Plus package for travelling or not.

- *The European Union GDP per capita variable (gdp_eu)*

As with the Croatian GDP per capita, the exact process applies for the European Union GDP per capita in period *t* expressed in thousands of euros, with value adjustment to the 2015 year but by using the European Union deflator. Graphical comparisons for the Croatian and European Union GDP per capita values in Figures 6.7. and 6.9. indicate that both variables had a positive trend in terms of an increase in their values with fluctuations throughout the year. Based on data for the European Union GDP per capita between 2014 and 2019, the period from October to December showed the highest average monthly value of 2,548.31 €. The lowest average monthly value of 2,400.75 € was recorded in period from January to May, indicating difference of 6.15% between the highest and lowest values. However, comparing changes in the historical GDP per capita data between the European Union and Croatia should be approached with caution, as the Croatian GDP per capita values were affected by population reduction, as graphically shown in Figure 2.10., sub-chapter 2.7., GDP and unemployment.

Figure 6.9.

Trends in the European Union GDP per capita movements 2014-2019

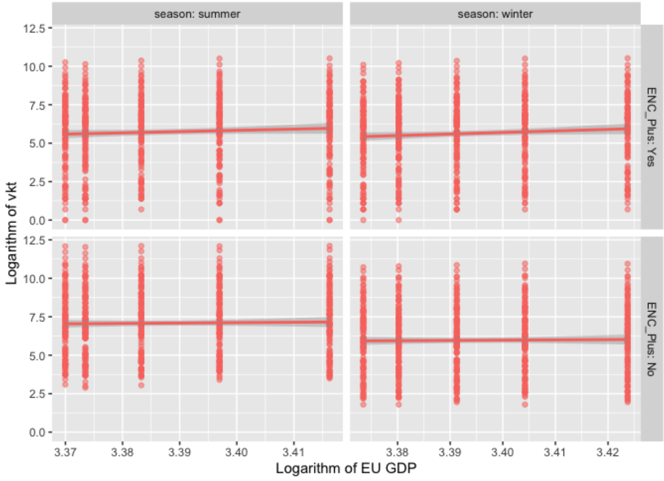


Note: Adapted from Eurostat (n.d.).

Figure 6.10. shows a graphical correlation between *gdp_eu* and vkt_t. Observation of the relationship between two variables separately using the ENC Plus package and by period of the year indicates a possible positive correlation, suggesting that higher motorway traffic might correlate with higher GDP per capita in the European Union. However, following the same principle as before, it is essential to note that the relationship between GDP per capita and traffic might be complex and subject to the impact of other factors.

Figure 6.10.

Graphical correlation between gdp_eu (x-axis) and vkt_t (y-axis)



Note: Graphical correlation between *ln(vkt)* and *ln(gdp_eu)* during the summer and non-summer (winter) period, separated by additional criteria if using the ENC Plus package for travelling or not.

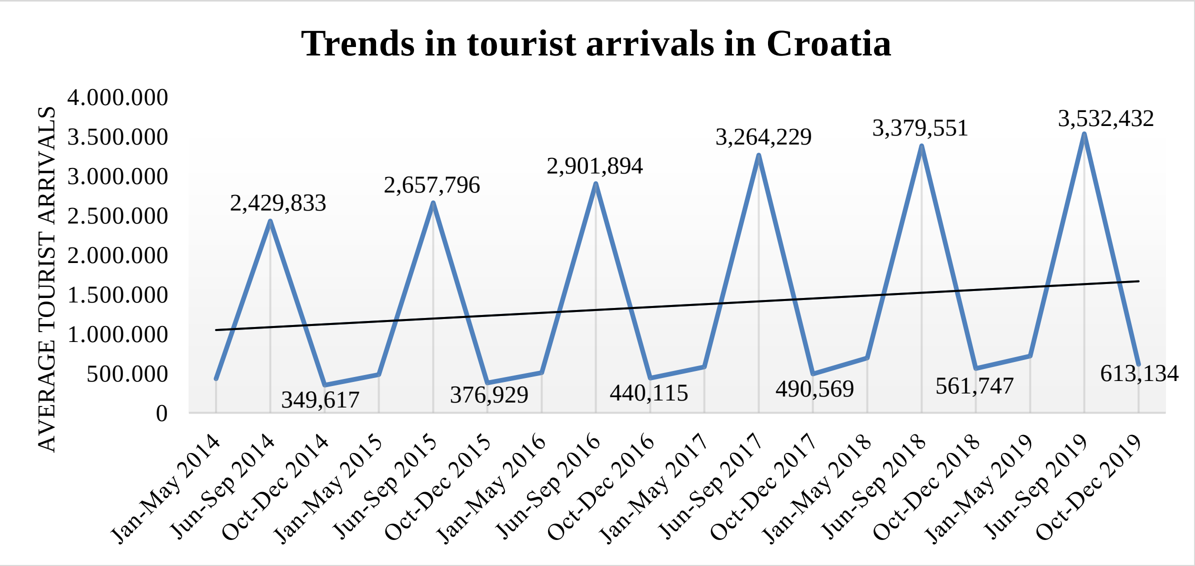
- *Tourist arrivals in Croatia variable (tourists)*

Variable *tourist* shows average monthly tourist arrivals in period *t* expressed in millions of total tourist arrivals in Croatia. The data shows that the average monthly tourist arrivals in 2015 in the non-summer period were 0.443 million and 2.658 million in the summer. With the passage of time, the average monthly tourist arrivals in the non-summer period in 2019 were 0.680 million and 3.532 million in the summer period, showing an increase of 53.50% in the non-summer and 32.88% in the summer period, respectively.

Regarding trends in tourist movements, the graph in Figure 6.11. illustrates a positive trendline in the number of tourist arrivals with significant fluctuations through the years. Considering all the periods of the year, the historical pattern shows the highest number of tourist arrivals during the summer period between June and September, with an average monthly value of 3,027,623 tourist arrivals. In average, the period October–December recorded the lowest number of tourist arrivals, with a monthly value of 472,019 transactions.

Figure 6.11.

Trends in tourist arrivals movements 2014-2019

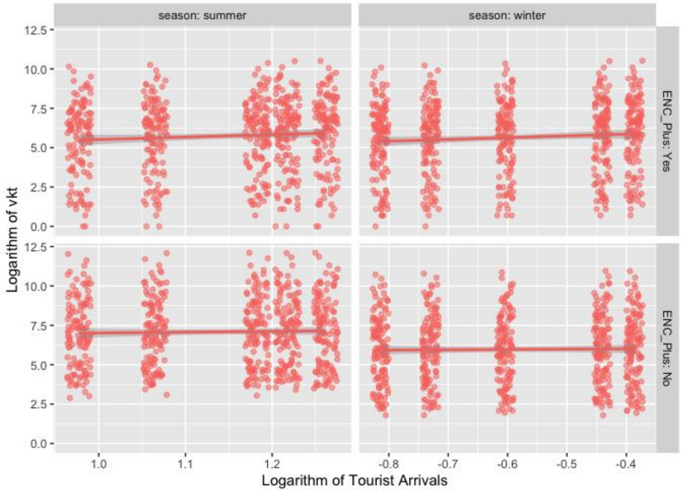


Note: Adapted from the Croatian Bureau of Statistics (n.d.a).

A graphic presentation of the relationship between variable *tourist* and vkt_t depending on usage of the ENC Plus package and period of the year, shows a slight positive correlation between tourist arrivals and motorway traffic for frequent (ENC Plus) users. This indication for frequent users was expected due to increase in active ENC Plus packages during the summer periods. The lack of indication for a positive correlation between tourist arrivals and vehicle kilometres travelled by occasional users was unexpected, considering higher tourism and motorway traffic activities during the summer. However, this relationship might be complex could be influenced by other variables, which are examined in further analysis.

Figure 6.12.

Graphical correlation between tourist (x-axis) and vkt_t (y-axis)



Note: Graphical correlation between *ln(vkt)* and *ln(tourist)* during the summer and non-summer (winter) period, separated by additional criteria if using the ENC Plus package for travelling or not.

- *Period of the year (season) and type of traveller (ENCPlus_No) variables*

Except for the above variables and their collected data, this thesis introduces the variable *season* in the model. The variable represents a dummy variable, which denotes the period of the year (1 if summer season and 0 if non-summer season). Also, the thesis includes another dummy variable, *ENC_PlusNo*, indicating a type of traveller. The variable is 1 if traffic is related to the Full price user and 0 if traffic is related to the ENC Plus user. Therefore, the use of these two variables in the models tests the impact of the period of the year on traffic and whether the type of traveller impacts the traffic levels. Even the descriptive statistics in this sub-chapter show the relation and movements of each explanatory variable with the dependent variable between summer and non-summer, the following paragraphs represent descriptive statistics of the variables *season* and *ENC_PlusNo*. The summary provides a comprehensive understanding of the characteristics of the variable season and type of traveller in the dataset, which is crucial for interpreting its impact on motorway travel demand.

Regarding season, the dataset in Table 6.2. shows lower values for all used explanatory variables during the non-summer period than in the summer. For frequent motorway users, the average daily vehicle kilometres travelled were 1,590 in the non-summer and 1,779 in the summer, showing a difference of 11.89%. The difference is more significant for occasional motorway users, as the average daily vehicle kilometres travelled in non-summer were 2,585 and 8,455 in the summer period, showing higher levels during the summer by 227.08%. The tourist arrivals records followed these results, with an average of 85.34% of total tourist arrivals realised during the summer period.

For the toll price variable, an average toll price of 0.049 €/km for frequent motorway users does not show differences between summer and non-summer periods due to the application of a temporary measure of summer toll increase only for occasional motorway users. The average toll price for occasional users in the non-summer period was 0.076 €/km, while in the summer period, it increased to 0.084 €/km.

Table 6.2.

Comparison of average values by variables

	Summer		**Non-summer**	
	Frequent	Occasional	Frequent	Occasional
vkt (average daily)	1,779	8,455	1,590	2,585
*toll**	0.049 €/km	0.084 €/km	0.049 €/km	0.076 €/km
fuel (average in period t)	1.27 €/l		1.24 €/l	
gdp_cro (average monthly)	1,073.72 €		935.38 €	
gdp_eu (average monthly)	2,441.62 €		2,456,08 €	
tourist (average monthly)	3,027,623		520,294	

*data for 2014 not included due to the application of summer toll increase from 2015

Note: Developed by author based on collected data.

Regarding variable fuel, the data shows that the average price during the non-summer period was 1.24 €/litre and 1.27 €/litre in the summer period. Lower values in the non-summer period were also recorded for the variable Croatian GDP per capita. The average monthly value in the non-summer period was 935.38 €, while in the summer period, it increased to 1,073.72 €. However, the European Union GDP per capita values suggest that higher economic activity during the non-summer period: 2,456.08 € in the non-summer period and 2,441.62 € in the summer period.

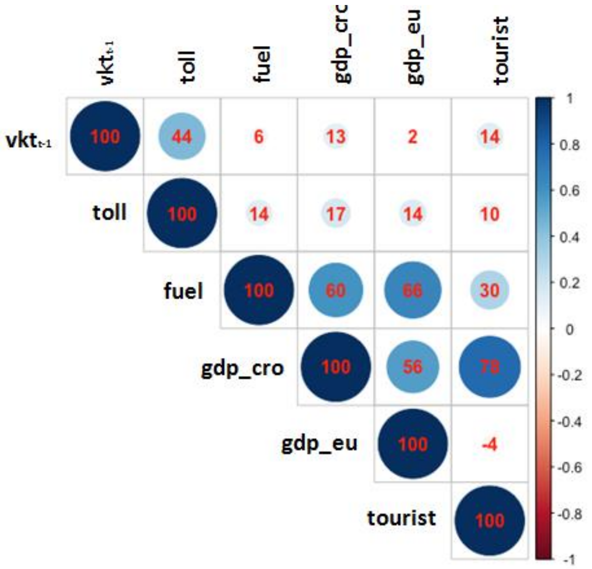
6.3. Multicollinearity tests

Prior to model building, this thesis follows the procedure of Pham and Tran (2020) and checks if a multicollinearity problem is present between observed variables. The concept of multicollinearity is a crucial issue, representing a high correlation between two or more independent variables (Wooldridge, 2012). An issue with multicollinearity can cause significant problems in analysis for several reasons. Firstly, it is difficult to determine each variable's impact as part of variability can be correlated with other variables. Secondly, multicollinearity issues can lead to unstable estimated coefficients. When variables are highly correlated, even small changes can result in significant changes in estimated coefficients, causing unreliable results and making it difficult to produce reliable conclusions. Third, multicollinearity can reduce model precision and increase standard errors of estimates (Montgomery et al., 2012). To detect multicollinearity issues, this thesis applies the correlation matrix and the Variance Inflation Factor (VIF), which assesses how much the variance of an estimated regression coefficient increases with correlated predictors (Akinwande et al., 2015; Mansfield & Helms, 1982; Montgomery et al., 2012). The correlation matrix ensures a visual presentation of the correlation of all variables. At the same time, VIF quantitatively measures the significance of multicollinearity between the variables: a higher VIF means a higher degree of multicollinearity and significant issues. Therefore, if VIF equals 1, variables are uncorrelated, and multicollinearity is not a problem. The regressors may be moderately correlated if the VIF is higher than 1 and less than 5. If the VIF value is between 5 and 10, it indicates a high correlation that may be problematic. Finally, if the VIF is above 10, it is assumed that the regressors are poorly estimated and that a multicollinearity problem exists.

The correlation matrix results in Figure 6.13. and Table 6.3. show high correlations for particular variables, which indicate the possibility of multicollinearity issues between them. More precisely, the results provide evidence of a high positive correlation between the variables *fuel* and *gdp_cro* (60) and *fuel* and *gdp_eu* (66). Also, the results show a high correlation between *gdp_cro* and *tourist* (78). This correlation suggests the possibility of a correlation between Croatia's GDP per capita and tourist arrivals. Althrough with lower significance, there are also particular correlations between other variables, such as vkt_{t-1} and *toll* (44), and *gdp_cro* and *toll* (17).

Figure 6.13.

The variables correlation matrix



Note: Developed by author based on collected data.

The results described in the previous paragraph indicate the first signs of multicollinearity between the observed variables. Therefore, this thesis uses VIF to check the multicollinearity problem further.

Table 6.3.

VIF values: all variables

Variable	VIF
vkt_{t-1}	1.26
toll	1.28
fuel	2.35
gdp_cro	23.75
gdp_eu	11.90
tourist	17.57

Note: Developed by author based on collected data.

Based on the results from Table 6.3., there are three variables whose VIF values are higher than 10: *gdp_cro* (23.75), *gdp_eu* (11.90), and *tourist* (17.57). These results indicate a multicollinearity issue and a high correlation of variables *gdp_cro*, *gdp_eu*, and *tourist* with other variables in the model.

Although Montgomery et al. (2012) proposed several techniques for dealing with multicollinearity problems, such as collecting additional data, model respecification, and others, this thesis does not apply them due to the limited data availability. Instead, this thesis applies the solution of removing highly correlated predictors from the model (Akinwande et al., 2015):

I. Considering the GDP and tourist arrivals data of 2019, the average monthly Croatian GDP per capita in the summer period was higher than in the non-summer period by 15.22%. This evidence could be explained by the fact that 73.98% of total tourist arrivals in Croatia arrived during the summer period. Also, the data suggests that higher spending during the summer period accompanied by realised 74.42% of total yearly tourist arrivals may positively reflect on GDP values in the summer period than in the remaining period of the year, making it appropriate to test the impact of seasonality;

II. The usage of national GDP as an explanatory variable is in line with other studies that investigate the impact of various explanatory variables on traffic levels in the observed country (Gomez et al., 2016; Gonzalez & Marrero, 2012; Matas & Raymond, 2003; Matas et al., 2012);

III. Using *gdp_cro* rather than *gdp_eu* avoids damaging and potentially unreliable results obtained by using *gdp_eu*, affected by changes in the GDP of other tourist countries (e.g., Italy, France, Spain, Germany) rather than the Croatian GDP.

Therefore, when excluding variables *gdp_eu* and *tourist*, the VIF values are significantly below 5, and multicollinearity is not a problem anymore. Table 6.4. shows the results with an average value of 1.417.

Table 6.4.

VIF values: reduced model

Variable	VIF
vkt_{t-1}	1.25
toll	1.27
fuel	1.56
gdp_cro	1.58

Note: Developed by author based on collected data.

These findings confirm that the variables indicated in Table 6.4. are independent, where each variable separately provides valuable information necessary to explain their impact on motorway traffic. Further analysis uses these variables and is reliable to interpret their impact on traffic levels. Therefore, the adjusted model equation is as follows:

$$ln(vkt_{it}) = \beta_0 + \phi ln(vkt_{it-1}) + \beta_1 ln(toll_{it}) + \beta_2 ln(fuel_t) + \beta_3 ln(gdp\_cro_t) + \beta_4 season_t + \beta_6 ENC\_PlusNo_t + \mu_{it} \quad (5)$$

Based on the previously specified model without multicollinearity issues, the following sub-chapter builds various econometric models and argues for using particular models instead of others. The sub-chapter also describes the robustness of the chosen model and finally provides the regression results.

6.4. Regression results

Based on data analysis and determined multicollinearity issues from the previous sub-chapter, this sub-chapter uses explanatory variables presented in Eg. 5 to build the complete model with all variables. Before proceeding to the regression results of the complete model, due to multicollinearity issues that led to omitting variables *gdp_eu* and *tourist*, testing the hypotheses regarding the impact of the European Union GDP per capita and tourist arrivals on motorway travel demand (H_5–H_6) is impossible and not examined through this thesis. The sub-chapter 7.4., Limitations, further highlights this limitation.

6.4.1. Regression results – complete model

As summary, to estimate the impact of explanatory variables on motorway travel demand, this thesis constructed the complete model by using all variables from Eq. 5. The complete model tested if the period of the year (variable *season*) and type of user (variable *ENC_PlusNo*) applied in the model significantly impact vehicle kilometres travelled. Table 6.5. presents the results of the complete model when using the OLS and WLS methods. Despite application of robust standard error option to account for potential heteroscedasticity, due to the presence of heteroscedasticity issues when using the OLS method (Figure 6.14.), this thesis employed the WLS method with appropriate weights for result interpretation instead.

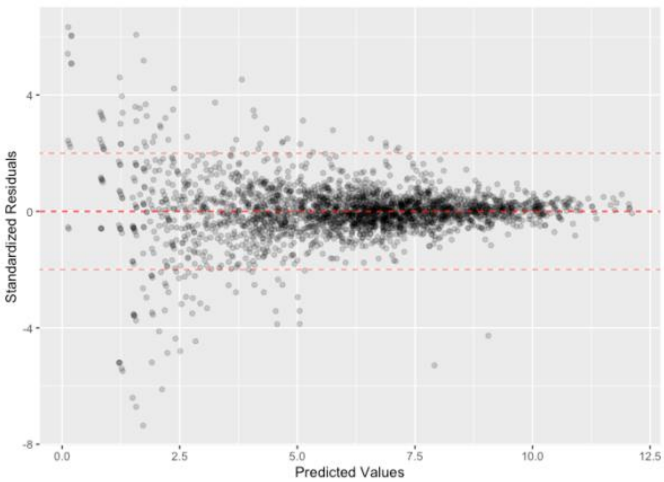
With the use of correctly specified weights, this thesis also accounted for autocorrelation in the data by deploying the Durbin-Watson test, arguing that autocorrelation is not an issue.

The additional argument for supporting the validation of the WLS results is the VIF test, which showed no multicollinearity issues among the used variables. Except for identifying the presence of heteroscedasticity issues when using the OLS method, sub-chapter 6.5., Robustness check, provides estimations by using other methods where particular violated the tests.

By definition, the OLS method minimises the sum of squared residuals (Wooldridge, 2012) and is used in statistics to establish a correlation between an attribute and a label in the presence of other potentially correlated features. It represents a technique that uses linear regression to deduce a correlation between a variable and an outcome, representing the likelihood of each real value to be the true correlation (Sheffet, 2019). Figure 6.14. which graphically shows standard residuals for the data used in the OLS, suggests heteroscedasticity issues as the variability of the residuals decreases with an increase in prediction values. Therefore, the model modification was necessary.

Figure 6.14.

Graph of standardised residuals complete model: OLS method



Following the work of Matas and Raymond (2003), who investigated the impact of toll price, gasoline price, GDP, and section length on traffic volume in the case of Spain with application of the WLS method instead of the OLS method due to the presence of heteroscedasticity, this thesis also applied the WLS method to address similar heteroscedasticity issues. When using the WLS method, the weights must be known. In this method, the deviation between the observed and expected values of y_i was multiplied by a weight w_i chosen inversely proportional to the variance of y_i (Montgomery et al., 2012).

However, in most cases, the choice of weights in WLS has a degree of arbitrariness (Wooldridge, 2012). Montgomery et al. (2012) indicated that in many practical cases, it is necessary to guess the weights, perform the analysis, and then reestimate the weights based on the results, where several iterations may be necessary. In the case of this thesis, when observing the graph of residuals, the variability of the residuals exponentially decreases. Therefore, if using the weights of some explanatory variables, the aim is to undo the influence of heteroscedasticity. In this case, the weights considered the following vector:

$$(vkt_{t-1} - 1)^2$$

The vector of weights was selected based on the empirical analysis of the residuals from the OLS model. It was observed that the variance of the residuals decreases with the square of the $vkt_{t-1} - 1$ value. Therefore, the thesis used weights that square the difference between vkt_{t-1} and the value of 1. Shifting by "-1" is an arbitrary choice, but it represents the value around which the residuals are the most dispersed. It allows more importance to be attached to the observations that are significantly different from that reference value. The graph of the standardised residuals of the WLS complete model expressed in Figure 6.15. is more uniform than the OLS complete model.

Figure 6.15.

Graph of standardised residuals complete model: WLS method

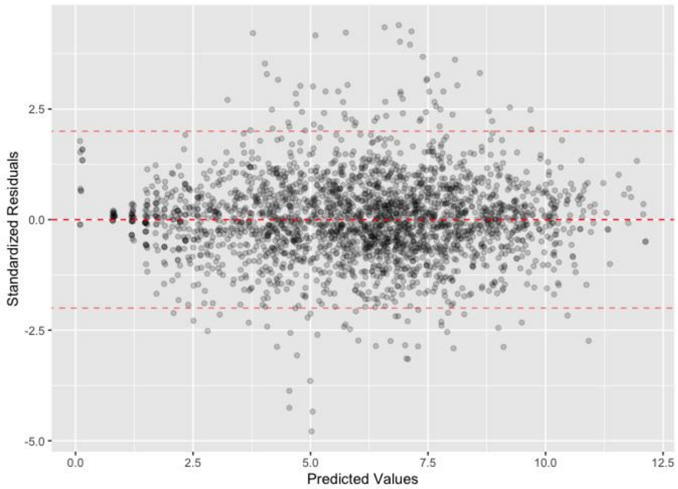


Table 6.5. combines the results of the complete model using the OLS and WLS methods. As remarked, due to the presence of heteroscedasticity when using the OLS method, the thesis further uses the WLS results for interpretation.

Table 6.5.

The result of the complete model: OLS and WLS methods.

Dependent variable: vkt_t

Variable	OLS	WLS
vkt_{t-1}	0.9927***	0.9980***
toll	0.0243*	0.0061
fuel	-0.5553***	-0.1975**
gdp_cro	0.1679*	0.0635
season	0.0143	-0.0010
ENC_PlusNo	-0.0976***	-0.0795***
Observations	2520	2520
Adjusted R^2	0.99	0.596
F-value	39890.47	929.91
Durbin-Watson	1.987	2.018

*p-values in parentheses; *** p < 0.001; ** p < 0.01;*
** p < 0.05; . P <0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

The complete model showed a highly significant and positive impact of the lag variable (vkt_{t-1}) on vkt_t with a value of 0.9980, confirming the solid and positive impact of motorway traffic from the previous year on the existing travel demand. The results also identified a negative and highly significant impact of variable *fuel* on vkt_t with a value of -0.1975, suggesting that an increase in fuel price negatively impacts the number of vehicle kilometres travelled. The results showed that other explanatory variables (*toll* and *gdp_cro*) have insignificant impact motorway travel demand in the complete WLS model. Considering the impact of the season of the year and if the type of traveller had an impact on traffic levels, the WLS method showed a highly significant and negative impact only for the *ENC_PlusNo* variable on vkt_t with a value of -0.0795, showing that the type of user has an impact on traffic levels.

When comparing the obtained results in complete models, both OLS and WLS methods showed similar significance of the coefficients. Some differences in p-values between the two methods may be the consequences of associated weights in the WLS method, which considers data heteroscedasticity. In the case of the OLS, the value of 0.99 for the adjusted coefficient of determination (adjusted R^2) indicates that most of the variance in the dependent variable is explained by the independent variables in the model. In the baseline WLS model, the adjusted R^2 value of 0.596 suggests a moderate fit, indicating that the model explains a significant portion of the variance. Even adjusted R^2 values suggest that the OLS model fits the data better than WLS, these differences could be due to the weighting scheme used in WLS to account for heteroscedasticity issues in OLS. Therefore, the results suggest that the chosen explanatory variables are appropriate to explain travel demand on the motorway. These findings, obtained by using two different methods with similar significance for the coefficients, confirm the validity of the results. Wooldridge (2012) noted that the OLS and WLS estimates will always differ due to sampling erros. However, the reason to be suspicious about obtained results and potential functional form misspecification is when statistically significant estimates in OLS and WLS differ in sign, which was not the case in this thesis. Even though the used variables showed no autocorrelation, multicollinearity, and heteroscedasticity issues when using the WLS method, sub-chapter 6.5., Robustness Check, additionally checks for the robustness of the results when using the WLS instead of other considered methods.

Although the results of the complete OLS and WLS models showed similar estimates, the limitation occurs in the impossibility of testing the impact of seasonality on motorway user behaviour. Also, the complete model was not useful to test hypotheses defined in sub-chapter 4.3., Hypotheses, except for H_8, whose result indicated a highly significant impact of the type of user (*ENC_PlusNo*) on vehicle kilometres travelled. In addition, the estimations do not provide distinction on how each motorway user type reacted to each explanatory variable separately during the summer and non-summer periods. Even if the variable *season* showed insignificant impact on vehicle kilometres travelled in the complete model, the separate models in the following sub-chapters additionally test hypothesis H_7 and how seasonality impacts travel demand for occasional and frequent motorway users.

6.4.2. Regression results – separate models

To test how frequent and occasional motorway user types react to explanatory variables during the summer and non-summer periods, this thesis introduces reduced models. The reduced models test hypotheses from sub-chapter 4.3., Hypotheses, and provide a deeper understanding of the specific effects of seasonality on frequent and occasional motorway traffic.

Prior to developing four models which observe the impact of determined explanatory variables on motorway travel demand separately by type of motorway user combined with period of the year, this thesis distinguishes the complete model database and develops the following models:

- **Model Summer:** Investigation of the impact of explanatory variables on complete motorway traffic during the summer period;
- **Model Non-summer:** Investigation of the impact of explanatory variables on complete motorway traffic during the non-summer period;
- **Model Frequent users:** Investigation of the impact of explanatory variables on frequent users during the whole year;
- **Model Occasional users:** Investigation of the impact of explanatory variables on occasional users during the whole year;

The purpose of developing previously defined models is to identify significant structural breaks between regression models, which evidence and approach enhance the analysis of the moderating effects of seasonality on any types of motorway users on motorway travel demand. Following the approach and variables applied in the complete model, the thesis checked for multicollinearity for each model separately, as the data used differs among the models.

Table 6.6.

VIF values: separated models (summer, non-summer, frequent, occasional)

Variable	Model Summer	Model Non-summer	Model Frequent users	Model Occasional users
vkt_{t-1}	1.30	1.18	1.18	1.25
toll	1.33	1.22	1.24	1.27
fuel	1.31	3.09	1.58	1.56
gdp_cro	1.33	3.12	1.57	1.64

Note: Developed by the author based on collected data.

Table 6.6. shows that VIF values of most variables were close to or slightly above 1, except for Model Non-summer where the VIF values of variable *fuel* and *gdp_cro* were 3.09 and 3.12 but still lower than 5. The results confirmed that multicollinearity was not a problem between the explanatory variables in the models, which enabled a reliable investigation of the influence of each explanatory variable on motorway traffic in each of the determined models.

As presented in Table 6.7. and Table 6.8., the application of the Durbin-Watson test showed no autocorrelation issues, additionally confirming the result validity. As a result, Table 6.7. represents the estimates of Model Summer and Model Non-summer. With consideration of the baseline WLS model, the results for both summer and non-summer periods show significant impacts of lag variable (vkt_{t-1}), *fuel*, and *gdp_cro* on motorway travel demand. Although an uncommon finding in the literature, Model Non-summer also indicated a positive and highly significant impact of tolls on motorway travel demand.

Table 6.7

The result of period of the year model: OLS and WLS methods.

	Model Summer		**Model Non-summer**	
Variable	OLS	WLS	OLS	WLS
vkt_{t-1}	0.9961***	0.9965***	0.9926***	0.8718***
toll	-0.0526**	0.0446	-0.0533**	0.5748***
fuel	-0.5553***	-3.817***	-0.6522**	3.3503***
gdp_cro	0.1196	2.6896***	0.4097**	-0.8476**
Observations	1260	1260	1260	1260
Adjusted R^2	0.989	0.589	0.990	0.709
F-value	27271.39	451.69	30280.07	769.44
Durbin-Watson	2.089	2.005	2.056	1.964

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . p < 0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

As the purpose of Model Summer and Model Non-summer is to identify structural differences between the two periods of the year, this thesis applies the Chow test (Chow, 1960). The Chow test indicates a significant structural break between two datasets, as although the F-statistic is moderate (1.765), the p-value < 0.05 confirms statistical significance at the 5% level.

Regarding estimates between types of motoroway users, Table 6.8. represents the estimates of Model Frequent users and Model Occasional users. With consideration of the baseline WLS model, the results for both types of motorway users show a significant impact of the lag variable (vkt_{t-1}) on motorway travel demand. In addition, the Model Frequent users also showed a significant and negative impact of *fuel* on motorway travel demand, while Model Occasional users indicated a marginally significant impact of *fuel* on motorway travel demand at the 10% level.

Table 6.8.

The results of type of motorway user model: OLS and WLS methods.

	Model Frequent users		**Model Occasional users**	
Variable	OLS	WLS	OLS	WLS
vkt_{t-1}	0.9899^{***}	0.9942^{***}	0.9854^{***}	0.9918^{***}
toll	0.0167	-0.0225	0.0236	-0.0083
fuel	-0.8717^{**}	-0.2232^{*}	-1.2923^{**}	-0.3797.
gdp_cro	0.1393	-0.0004	0.6380^{**}	0.1971
Observations	630	630	630	630
Adjusted R^2	0.981	0.425	0.989	0.570
F-value	8216.36	117.30	13532.87	209.39
Durbin-Watson	2.101	2.054	2.051	1.953

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . p < 0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

Following the same approach applied in Table 6.7. to identify structural differences between the two types of motorway users, the Chow test indicated a significant structural break between the two datasets. Although the F-statistic is moderate (1.828), the p-value < 0.05 confirms statistical significance at the 5% level. Therefore, even the results of both Table 6.7. and Table 6.8. showed different elasticity values of the same observed explanatory variables between season and frequency of motorway usage, the results of the Chow test confirmed structural differences between the models. These findings are in line with set hypotheses H_7 and H_8 that the observed period of the year and type of motorway user have different impacts on motorway travel demand. However, with the purpose of enhancing the analysis of the moderating impact of seasonality and type of motorway users on travel demand, this thesis develops the following models:

- **Model 1:** Investigation of the impact of explanatory variables on frequent motorway user traffic during the summer period (Frequent users, summer period);
- **Model 2:** Investigation of the impact of explanatory variables on frequent motorway user traffic during the non-summer period (Frequent users, non-summer period);
- **Model 3:** Investigation of the impact of explanatory variables on occasional motorway user traffic during the summer period (Occasional users, summer period);
- **Model 4:** Investigation of the impact of explanatory variables on occasional motorway user traffic during the non-summer period (Occasional users, non-summer period).

Since the models examine the impact of vkt_{t-1}, *toll*, *fuel*, and *gdp_cro* on vkt_t, the usage of dummy variables *season* and *ENC_PlusNo* was irrelevant in these models, as the collected data on vkt_{t-1}, *toll*, *fuel*, and *gdp_cro* were separated by season and frequency of motorway usage. Before conducting four separate models, the thesis checked for autocorrelation by using Durbin-Watson tests which rejected the hypothesis for presence of correlation between the residuals in all four separated models[11]. In addition, this thesis checked for multicollinearity and VIF values for each model separately as the data used differs among the models.

Table 6.9.

VIF values: separated models

Variable	Model 1	Model 2	Model 3	Model 4
vkt_{t-1}	1.17	1.20	1.18	1.22
toll	1.26	1.22	1.27	1.26
fuel	1.33	1.31	3.10	3.09
gdp_cro	1.36	1.34	3.15	3.13

Note: Developed by the author based on collected data.

Table 6.9. shows the summary of VIF values for each of the four separate models. Most variables were close to or slightly above 1, except for Model 3 and Model 4, where the VIF values of variable *fuel* and *gdp_cro* were between 3.09 and 3.15 but still lower than 5. The results confirmed that multicollinearity was not a problem between the explanatory variables in all separate models. These findings enabled a reliable investigation of the influence of each explanatory variable on motorway traffic in each of the determined models.

[11] The results of Durbin-Watson tests presented in Table 6.10. and Table 6.11.

To perform the analysis, the thesis followed the same procedure applied to the complete model by using the OLS and WLS methods. When using the OLS method, the residuals followed the same pattern as when using the complete model. Therefore, the application of the analog vector of weights in the WLS method removed the issue.

6.4.2.1. The impact of explanatory variables on frequent motorway users

ENC Plus motorway users represent drivers who frequently (on a daily or weekly basis) travel across the Istrian motorway, using the unique benefits of toll discounts of up to 50%. This package is specific due to its limited validity for toll discounts. As this thesis focuses on the I vehicle category, the validity of the ENC Plus toll discount for this category is 90 days (Bina-Istra, n.d.b). Testing the impact of each explanatory variable on vkt_t followed the same procedure as with the complete model when observing the OLS and WLS methods. Table 6.10. represents the results of both methods.

Table 6.10.

Separated models (Model 1 and Model 2): frequent motorway users

	Model 1 Frequent users, summer period		**Model 2 Frequent users, non-summer period**	
Variable	OLS	WLS	OLS	WLS
vkt_{t-1}	0.9899***	0.9942***	0.9854***	0.9918***
toll	0.0167	-0.0225	0.0236	-0.0083
fuel	-0.8717**	-0.2232*	-1.2923**	-0.3797.
gdp_cro	0.1393	-0.0004	0.6380**	0.1971
Observations	630	630	630	630
Adjusted R^2	0.981	0.425	0.989	0.570
F-value	8216.36	117.30	13532.87	209.39
Durbin-Watson	2.101	2.054	2.051	1.953

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . p < 0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

The obtained results for Model 1 and Model 2 were similar and had the same estimated intercepts when using the OLS and preferred WLS methods. The adjusted R^2 for Model 1 was found to be 0.425, while Model 2 exhibited a higher adjusted R^2 of 0.570. The difference in adjusted R^2 sugessts that the explanatory variables included in the models exhibit differential predictive power depending on the seasonal context. A higher adjusted R^2 in Model 2 indicates that a higher proportion of variance in the dependent variable is explained by the chosen predictors, relative to Model 1. This discrepancy could arise due to seasonal changes in the relationships between independent and dependent variables and the possibility that Model 1 may introduce additional external factors that are not captured by the used explanatory variables.

Regarding variables that impact frequent motorway user travel demand during the summer period, the estimates from Model 1 showed a highly substantial impact of vehicle kilometres travelled in the previous year on the current year with an elasticity value of 0.9942. Model 2 indicated a similar impact with a value of 0.9918 , showing how frequent motorway user traffic reacted to an increase in explanatory variables during the non-summer period. Although in Model 2, variable *fuel* with elasticity of -0.3797 was marginally significant at the 10% level, Model 2 suggested a significant impact of variable *fuel* on vehicle kilometres travelled. The estimated elasticity value of -0.2232 showed that an increase in fuel prices negatively affects the travel demand of frequent motorway users during the summer period.

Even if frequent motorway users were more consistent in their usage of the motorway during the year than occasional users (Figure 2.5., sub-chapter 2.5., Traffic), the results confirmed that the impact of explanatory variables varied between the summer and non-summer periods for this type of traveller.

6.4.2.2. The impact of explanatory variables on occasional motorway users

As described in Chapter 2, Full price traffic represents motorway transactions realised by users who pay the toll at the full price by using entry tickets. Contrary to the ENC Plus package, which is suitable for frequent users, a Full price payment method using an entry ticket is suitable for occasional motorway users. To test how this type of motorway user reacts to changes in each explanatory variable during the summer and non-summer periods, this sub-chapter followed the same procedure applied for the complete model.

Table 6.11.

Separated models (Model 3 and Model 4): occasional motorway users

	Model 3 Occasional users, summer period		**Model 4 Occasional users, non-summer period**	
Variable	OLS	WLS	OLS	WLS
vkt_{t-1}	1.0029^{***}	1.0025^{***}	0.9927^{***}	0.9952^{***}
toll	-0.0037	-0.0021	0.0572^{**}	0.0505^{*}
fuel	-0.2778^{*}	-0.2889^{**}	-0.0216	0.2131
gdp_cro	0.0164	0.0372	0.0336	0.0110
Observations	630	630	630	630
Adjusted R^2	0.995	0.988	0.992	0.976
F-value	33101.51	13132.67	19696.31	6511.74
Durbin-Watson	1.905	1.900	1.987	2.004

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . p < 0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

The results from Model 3 represent the impact of explanatory variables on occasional user traffic during the summer period. The estimates showed a high impact of vehicle kilometres travelled in the previous year on the current year, with a value of 1.0025. Even with a lower estimated lag variable, Model 4 generated a similar result for the non-summer period with a value of 0.9952 .

Concerning other variables, the results from Model 3 showed a significant but negative impact of fuel price on vehicle kilometres travelled with a value of -0.2889, suggesting that an increase in fuel prices negatively affects the travel demand of occasional users during the summer period. These estimates are similar to those of frequent motorway users, showing a negative relationship between variable fuel and vehicle kilometres travelled during the summer period. Although the estimated value was low, Model 4 showed a positive and significant sensitivity of occasional motorway users towards the increase in toll prices in the non-summer period, with a value of 0.0505.

6.5. Robustness check

Aside from monitoring OLS and WLS methods, this thesis performed additional robustness checks to assess the sensitivity of the results to different methods. As stated in sub-chapter 5.8., Baseline model estimation, in addition to OLS and WLS methods, this thesis investigated alternative methodologies as well. Considering application of lag motorway traffic variable as explanatory variable and the literature that investigated the impact of various explanatory variables on traffic by using dynamic model (Gomez & Vassallo, 2015; Gomez et al., 2016; Gonzalez & Marrero, 2012), the thesis considered General Methods of Moment Difference (GMM DIFF) and General Methods of Moment System (GMM SYS) methods. In addition, as each motorway section represents an individual observed over time, the thesis also considered Fixed Effects (FE) and Random Effects (RE) methods often used in panel data (Batarce et al., 2023; Hsiao, 2022; Park, 2011; Wooldridge, 2012).

In order to solve possible endogeneity issues, both GMM and FE methods were used in this thesis. Endogeneity in regression models refers to the condition that an explanatory variable in a multiple regression model is correlated with the error term due to an omitted variable, measurement error or simultaneity (Wooldridge, 2012). By using instrumental variables, such as lagged values of endogenous regressors, GMM ensures consistent estimation under minimal distributional assumptions. In this sense, Arellano and Bond (1991) proposed the GMM DIFF method, which improves efficiency by introducing instruments and transforming them, subtracting the past value of a variable from its present value to become uncorrelated with the fixed effects (Roodman, 2009). Therefore, lagged values of the dependent variable are used as instruments to control for endogenous relationships. However, the GMM DIFF can perform poorly on data with persistent series because the lagged variables often correlate only weakly with the first-difference equations (Blundell & Bond, 1998; Bond & Temple, 2001; Graham et al., 2009). To address the issue, this thesis also considered the GMM SYS method, which increases efficiency by including additional instruments and transforming them to be uncorrelated with the error terms. It establishes the system of equations in both first differences and level equations, with the instruments in the level equations following the first differences (Arellano & Bover, 1995; Blundell & Bond, 1998; Roodman, 2009).

To address endogeneity issues, the FE method can partially address the issue. Even though the FE method is useful for controlling unobserved heterogeneity by differencing time-invariant factors that could influence both the dependent and explanatory variables, the FE does not address time-varying endogeneity. However, this method is particularly beneficial when endogeneity arises from omitted variable bias due to unobserved individual characteristics that correlate with explanatory variables (Wooldridge, 2010). Therefore, to account for endogeneity concerns in panel data analysis, this sub-chapter presents the results obtained by applying GMM DIFF, GMM SYS, FE, and additionally RE methods and shows particular test violations, leading to choosing the WLS as a baseline method instead.

6.5.1. GMM DIFF and GMM SYS methods

To check the validity of the set hypotheses assumed in GMM models, the thesis checked the Sargan test, Wald test, autocorrelation AR(1) and AR(2) tests (Arellano & Bond, 1991; Gonzalez & Marrero, 2012). The Sargan test checks for the validity of the instruments used in the model and detects possible correlations between the instruments and the differenced residuals μ_{it} (Gomez et al., 2016). It is worth pointing out the limitations of the Sargain test and its low power in case too many instruments are used in the GMM model, so the results should be considered carefully (Graham et al., 2009). Roodman (2009) suggested adopting an alternative approach by using only the first lag instead of all available lags for instruments in the demand equation. According to Gonzalez and Marrero (2012), where the p-value of the Sargan test was equal to 1, the GMM-DIFF and GMM-SYS showed a symptom of the too many instruments problem and the low power of the test. However, the results of this thesis did not show such issues. The Wald test was used to assess the significance of the models parameters, to check if they are sufficiently unimportant and could be eliminated (Hayashi et al., 2007). The use of AR(1) and AR(2) tests were performed to check that serial correlation is not present in the estimated residuals μ_{it} (Gomez et al., 2016).

As the introduction of the lagged variable vkt_{it-1} also transfers the model from static to dynamic, in case that particular explanatory variable violates the endogeneity test, according to Graham et al. (2009), the main issue in the context of dynamic panel estimation is a correlation between the lagged endogenous terms (vkt_{t-1}) and the unobserved cross-section individual effects (a_i). In that case, where the explanatory variable violates the assumption of exogenous, to eliminate the individual effects (a_i), the Generalized Method of Moments is more appropriate than 2SLS, which estimator suffers from significant inefficiency problems (Arellano & Bond, 1991; Fulton et al., 2000; Wooldridge, 2012). Even if GMM removes the fixed effect with the differentiation process, the endogeneity problem remains as lagged vkt_{it-1} is still correlated with the transformed error $\Delta\mu_{it}$ due to the correlation between vkt_{it-1} and μ_{it-1}.

To solve the endogeneity problem, Arellano and Bond (1991) suggested using a difference GMM estimator (GMM-DIFF), which solves the endogeneity problem. The method introduces more instruments to improve efficiency and transforms the instruments to become uncorrelated with the fixed effects (a_i). In practice, the GMM-DIFF estimator shows poorly on data with persistent series, as sometimes the lagged variables tend to have weak correlations with the first-difference equations (Blundell & Bond, 1998; Bond & Temple, 2001; Graham et al., 2009). To solve the problem, the GMM-SYS method introduces more instruments to improve efficiency and transforms them to make them uncorrelated with the error terms. It establishes the system of equations in both first differences and levels, where the instruments in the level equations lag behind the first differences of the variables (Arellano & Bover, 1995; Blundell & Bond, 1998; Roodman, 2009).

To test for the validity of the instrument used, this thesis used the R econometric software for the GMM-DIFF and GMM-SYS methods, both for occasional and frequent motorway user data in summer and non-summer periods. The purpose was to identify, through various tests, which method gives better results. Therefore, following the same approach used when modeling the data by using the OLS and WLS methods with separation of collected data by season and frequency of motorway usage, the GMM methods observed the following:

- **Model 1:** Frequent users, summer period;
- **Model 2:** Frequent users, non-summer period;
- **Model 3:** Occasional users, summer period;
- **Model 4:** Occasional users, non-summer period.

As applications of the first-year lagged vkt as an instrumental variable lead to invalid GMM models, with adjustment of the instrumental lagged variable, this thesis used the two-year lagged *vkt* variable to achieve valid models.

6.5.1.1. GMM DIFF and GMM SYS: frequent motorway users

Table 6.12. shows the results obtained for frequent motorway users when using the GMM DIFF and GMM SYS methods applied for Model 1 and Model 2.

Table 6.12.

Separated models GMM (Model 1 and Model 2): frequent motorway users

	Model 1 Frequent users, summer period		**Model 2 Frequent users, non-summer period**	
Variable	GMM DIFF	GMM SYS	GMM DIFF	GMM SYS
vkt_{t-2}	-0.6378*	1.0103***	-0.1834	0.9835***
toll	-0.3413	-0.0689	0.1520	0.0332
fuel	0.3613*	-0.2447	0.1865	-0.4847
gdp_cro	3.2989***	-0.0343	2.3598**	0.1735
Observations	378	882	378	882
AR(1)	0.4981	0.0253	0.4144	0.0000
AR(2)	0.9920	0.1352	0.3425	0.0342
Sargan	0.6321	0.0012	0.2796	0.0088
Wald test	0.0000	0.0000	0.0000	0.0000

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . P < 0.1.*
t-2 is two-years lagged variable

Note: Developed by the author based on collected data.

Prior to discussion of the results, it is worth noting that the variation in the number of observations across OLS, WLS, GMM DIFF, and GMM SYS arises from the distinct data processing mechanism in each estimation method. As indicated in Chapter 6, the reduced OLS and WLS models retain the full sample (640 observations) as they do not require transformation. However, GMM DIFF reduces the sample size to 378 observations due to first-differencing, which removes the first time period for each panel unit, resulting in a loss of data. In comparison, GMM SYS expands the sample size to 882 observations by adding both the first-differenced and level equations. These differences emphasise the need for careful selection of estimation techniques based on model validity and data constraints.

- *GMM DIFF tests: Model 1 and Model 2*

The tests for Model 1 and Model 2 showed differences in the validity of the instruments and the presence of autocorrelation, which are critical for assessing the reliability of the estimations. In both models, the Sargan tests showed a p-value higher than 0.05, indicating that the models do not suffer from over-identification issues, thus supporting the validity of the chosen instruments. However, the AR(1) p-values are unexpectedly high, as the first-order serial correlation is expected to be significant (p-value < 0.05). The AR(2) results in both models reported p-values above 0.05, suggesting the absence of second-order autocorrelation and supporting instrument validity. The results of the Wald test in both models showed a highly significant p-value, thus confirming the statistical significance of the parameters used in the models.

- *GMM SYS tests: Model 1 and Model 2*

Regarding the usage of the GMM SYS method, the diagnostic tests for Model 1 and Model 2 indicated potential concerns regarding instrument validity and autocorrelation in the estimations. In both models, despite Wald tests being statistically significant, the Sargan test showed p-values below 0.05, implying that the instruments may be overidentified or endogenous. Furthermore, both models exhibit significant AR(1) p-values, which aligns with the expectations since first-differencing introduces first-order serial correlation. While the p-value of AR(2) in Model 1 was above 0.05, suggesting no second-order autocorrelation and supporting the instrument validity, the significant p-value of AR(2) in Model 2 showed a test violation in the second-order autocorrelation test.

6.5.1.2. GMM DIFF and GMM SYS: occasional motorway users

When applying the GMM DIFF and GMM SYS methods to occasional motorway users, the results and tests from Model 3 and Model 4 implied a similar conclusion as those for Model 1 and Model 2.

Table 6.13.

Separated models GMM (Model 3 and Model 4): occasional motorway users

	Model 3 Occasional users, summer period		**Model 4 Occasional users, non-summer period**	
Variable	GMM DIFF	GMM SYS	GMM DIFF	GMM SYS
vkt_{t-2}	-0.7233*	1.0799***	-1.3660***	1.0106***
toll	0.0397	-0.1714***	-0.6494	0.0252
fuel	0.1376	0.0188	-0.6592.	0.3147
gdp_cro	1.3949***	-0.3722***	2.0096**	-0.0171
Observations	378	882	378	882
AR(1)	0.0311	0.0000	0.2435	0.0000
AR(2)	0.2669	0.3102	0.2298	0.5206
Sargan	0.0066	0.0156	0.6187	0.0058
Wald test	0.0003	0.0000	0.1147	0.0000

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . P < 0.1.*
t-2 is two-years lagged variable

Note: Developed by the author based on collected data.

- *GMM DIFF tests: Model 3 and Model 4*

The diagnostic results for Model 3 and Model 4 indicate discrepancies in instrument validity and autocorrelation. In Model 3, the Sargan test's significant p-value suggests that the instrument may be overidentified or endogenous, while Model 4 has an insignificant Sargan test p-value, indicating that the instrument is correctly specified and exogenous. In terms of autocorrelation, AR(1) in Model 3 is significant, which is expected due to first-differencing, while the AR(2) test is insignificant, confirming the absence of second-order autocorrelation and validating the model. In contrast, both AR(1) and AR(2) have insignificant p-values, which is unexpected given that AR(1) should be significant, thus indicating a weak instrument or insufficient variation in the data. The Wald test with significant p-value showed the statistical significance of the parameters used in the model. This suggests that the explanatory variables, as a group, do not significantly explain variations in the dependent variable.

- *GMM SYS tests: Model 3 and Model 4*

The results for Model 3 and Model 4 with application of GMM SYS showed concerns regarding instrument validity despite satisfactory autocorrelation tests. In both models, the AR(1) test p-values are highly significant, confirming the presence of first-order serial correlation. Additionally, the AR(2) test p-values are both insignificant, indicating no second-order autocorrelation, which supports the validity of the moment conditions. Even the Wald tests in both models argued for the significance of the used parameters, the Sargan test p-values in both models are significant, suggesting that the instruments may be over-identified or correlated with the error term. Since the goal is to achieve an insignificant over-identification test, both models fail to meet this requirement thus confirming the inappropriateness of using this method.

6.5.2. Fixed Effects and Random Effects

Because of the use of a panel data set, this thesis also observed the suitability of the Fixed and Random Effects methods (Hsiao, 2005, 2022; Wooldridge, 2012). A panel data models examine group individual-specific effects, time effects, or both to address the heterogeneity or individual effects that may or may not be considered (Park, 2011). By definition, Random Effect (RE) model assumes that the individual-specific effect is uncorrelated with the independent variables. It explores and estimates the average effect of the independent variable across individuals. On the contrary, the Fixed Effects (FE) model is suitable when there is a correlation between individual-specific effects and the independent variables. It examines if intercepts vary across groups or periods, does not assume independence of the independent variables, and is more general (Batarce et al., 2023).

6.5.2.1. FE and RE: frequent motorway users

As it is still common in research to apply both RE and FE methods and then formally test for statistically significant differences in the coefficients on the time-varying explanatory variables (Wooldridge, 2012), the following Table 6.14. compares the results for frequent motorway users by applying methods for summer (Model 1) and non-summer (Model 2) periods.

Table 6.14.

Separated models (Model 1 and Model 2, FE and RE): frequent motorway users

	Model 1 Frequent users, summer period		**Model 2 Frequent users, non-summer period**	
Variable	Fixed Effects	Random Effects	Fixed Effects	Random Effects
vkt_{t-1}	-0.0818	0.9899***	-0.1130*	0.9854***
toll	0.0204	0.0167	0.1129	0.0236
fuel	-0.0277	-0.8717**	-0.0267	-1.2923***
gdp_cro	1.8563***	0.1393	2.4868***	0.6380**
Observations	504	504	504	504
F-value	21.476		21.028	
Chi-square		25093.4		103916.0
Hausman test	0.0000		0.0000	

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . P < 0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

In both models, the F-values indicated the FE models as statistically significant, implying that the independent variables explained a significant percentage of the variation in the dependent variable. For RE models, the Chi-square results provide strong evidence against the null hypothesis and demonstrate that independent variables together have a statistically significant effect on the dependent variable. The Hausman test contrasted RE with FE under the null hypothesis that individual effects are uncorrelated with any regressor in the model to determine which model is valid and preferable. The approach considers using the RE estimates unless the Hausman test is rejected (Wooldridge, 2012). In the case of this thesis, a Hausman test showed p-values close to zero and caused a rejection of the null hypothesis that RE is preferred in favor of FE.

6.5.2.2. FE and RE: occasional motorway users

As demonstrated in Table 6.15., both F-values suggested FE models as statistically significant, while for RE models, the Chi-square results also confirmed strong evidence that used independent variables jointly have a statistically significant effect on the dependent variable. When comparing the results of summer and non-summer periods for occasional motorway users, the low p-values of the Hausman test also rejected the usage of RE and preferred the results of FE models.

Table 6.15.

Separated models (Model 3 and Model 4, FE and RE): occasional motorway users

	Model 3 Occasional users, summer period		**Model 4 Occasional users, non-summer period**	
Variable	Fixed Effects	Random Effects	Fixed Effects	Random Effects
vkt_{t-1}	0.3861***	1.0030***	0.0488	0.9927***
toll	0.1101	-0.0037	-0.0559	0.0572*
fuel	0.2051	-0.2778*	-0.3690	-0.0216
gdp_cro	0.0903	0.0164	0.7682**	0.0336
Observations	504	504	504	504
F-value	21.028		3.887	
Chi-square		103916		61190.3
Hausman test	0.0000		0.0000	

*p-values in parentheses; *** p < 0.001; ** p < 0.01; * p < 0.05; . P < 0.1.*
t-1 is one-year lagged variable

Note: Developed by the author based on collected data.

6.5.3. Summary

The estimated results for the GMM DIFF and GMM SYS methods across the four models reveal important insight regarding model validity and explanatory power. In the GMM DIFF estimates, all four models satisfy the AR(2) test, indicating no second-order autocorrelation and supporting the validity of the moment conditions. Even the Sargan test results confirmed no over-identification issues for Model 1, Model 2, and Model 4, the significant Sargan test p-value in Model 3 indicates concerns about instrument validity, as the null hypothesis of exogenous instrumets is rejected. Additionally, Model 4 with insignificant Wald test fails to demonstrate joint significance of explanatory variables, suggesting weak explanatory power. In contrast, the GMM SYS estimates showed issues with the Sargan tests with significant p-values in all models, indicating over-identification issues. Also, the consistent AR(1) p-values in Model 2, Model 3, and Model 4 in GMM SYS indicate potential misspecification or overfitting issues. Therefore, the GMM DIFF is preferable due to its better instrument validity in most cases, with concerns in Model 3.

The results for the FE and RE methods across the four datasets show significant heterogeneity in model fit. Model 1, Model 2, and Model 3 exhibit significant F-values, whereas the Hausman test shows a preference for the fixed effects specification. In comparison, Model 4 has a significantly lower F-value, indicating that the FE model may be less appropriate. However, the Hausman test is still highly significant, favouring FE in both Model 3 and Model 4.

In conclusion, the tests indicate that the GMM DIFF method is the most reliable for evaluating the four models, as it demonstrates instrument validity and no significant autocorrelation or over-identification issues in three models. Due to concerns about instrument validity in Model 3 and intention of this thesis to apply the same method to each model for the purpose of finding the moderating impact of seasonality and type of traveller on moroway travel demand, this thesis uses the WLS method as a baseline model for the result interpretation on the population level. This method also addresses heteroscedasticity and provides robust estimates in the presence of varying variances across observations.

6.6. Discussion of obtained results

The outcomes of this thesis provide insights about factors that impact travel demand between the summer and non-summer periods. The use of the complete model and four separate models showed that the impact of particular explanatory variables varies by type of traveller and period of the year. Further discussion provides a reflection on the research process and results obtained compared with literature findings.

The research questions from Chapter 1 focus on identifying if and how seasonality impacts motorway user behaviour between summer and non-summer periods. This thesis tests if determined explanatory variables have an impact on frequent and occasional motorway users, taking the Istrian motorway as a case study. Besides testing the impact of seasonality, the findings intend to provide new knowledge on the Croatian motorways due to the limited literature about factors influencing Croatian motorway traffic.

As demonstrated in sub-chapter 6.4., Regression results, a complete model was introduced to determine which variables influence vehicle kilometres travelled (vkt_t). To check if the period of the year and type of motorway users impacted the travel demand, this thesis introduced variables *season* and *ENC_PlusNo*. The variable *ENC_PlusNo* showed a highly significant and negative impact on vkt_t with a value of -0.0795. Although this relationship is statistically significant, the magnitude of -0.0795 suggests that the effect of type of traveller on motorway usage is relatively small. The unexpected estimate of the insignificant impact of variable *season* on travel demand is not in line with hypothesis H_7, which states that the observed period of the year has an impact on travel demand but differently for frequent and occasional motorway users. Therefore, to additionally check for H_7 and H_8, the thesis developed four models to measure the impact of seasonality and type of motorway user on travel demand:

- Model Summer: All data in summer period;
- Model Non-summer: All data in non-summer period;
- Model Frequent users: All data of frequent users from both periods;
- Model Occasional users: All data of occasional users from both periods.

Even the models showed differences in the level of significance and magnitude of explanatory variables (Table 6.7. and Table 6.8.), the Chow test was additionally conducted to identify structural differences between two datasets. Between Model Summer and Model Non-summer, the Chow test with moderate F-statistics (1.765) and significant p-value at the 5% level confirmed the the structural break between two datasets, which is in line with the hypothesis H_7. Regarding Model Frequent users and Model Occasional users, the Chow test with moderate F-statistics (1.828) and significant p-value at the 5% level confirmed the structural break between two datasets, which is in line with the hypothesis H_8.

In addition, considering that results from the complete model do not distinguish the impact of each explanatory variable on frequent and occasional users through the year, the thesis further developed four separate models to measure the impact of the used explanatory variables separately by type of motorway user combined with period of the year. The results of four separate models additionally checked the estimates from the Complete model, Model Summer, Model Non-summer, Model Frequent users, and Model Occasional users: (i) if the type of motorway user significantly impacts travel demand, and (ii) if the period of the year does not significantly impact travel demand.

As this thesis collected the data separately for summer and non-summer periods by frequency of motorway usage, the thesis constructed the models:

- Model 1: Frequent users, summer period;
- Model 2: Frequent users, non-summer period;

- Model 3: Occasional users, summer period;
- Model 4: Occasional users, non-summer period.

The following sub-chapters briefly discuss the obtained results separately by type of motorway user and if they satisfy set hypotheses.

6.6.1. Discussion on obtained results of frequent motorway users

When observing Model 1 and Model 2, the results showed that only variables vkt_{t-1} and *fuel* significantly impact vkt_t in both models. In Model 1, the vkt_{t-1} showed a positive and highly significant impact on vkt_t with a value of 0.9942, indicating that vehicle kilometres travelled in the summer of the previous year capture much of the year-to-year variation. In Model 2, the estimate of the lag variable vkt_{t-1} was also highly significant and positive, with a value of 0.9918. Therefore, the evidence showed that the traffic in the previous year significantly determines levels of the frequent motorway traffic in the current year.

Although this positive effect confirms set hypothesis H_{1a} that an increase in vehicle kilometres travelled in the previous year positively affects travel demand for frequent users in both summer and non-summer periods, it is also similar to findings in other literature that used travel variable *vkt* (Gomez & Vassallo, 2015; Gonzalez & Marrero, 2012) and *AADT* (Gomez et al., 2016; Matas & Raymond, 2003). Even expected, the values obtained in this thesis are higher than those reported in the literature. High elasticity values for vkt_{t-1} are in line with a continuous increase of Croatian motorway traffic between 2014 and 2019, with a recorded average value of +5.42% despite toll increase and tourist arrivals (+7.17% for Croatia and +5.88% for the Istrian region). The evidence shows that both frequent and occasional motorway traffic were significantly impacted by the traffic in the previous year, suggesting that past motorway traffic may help policymakers forecast future demand accurately. This finding implies that changes in traffic patterns on the Istrian motorway tend to persist over time, thus making it essential for policymakers to consider historical values and trends when defining decisions about tolling and traffic management strategies. However, since the literature used the lag variable of *vkt* and *AADT*, particular studies also calculated long-run values for each explanatory variable (Matajič et al., 2015; Odeck & Bråthen, 2008). The larger the coefficient of the lagged explanatory variable, the lower the speed of adjustment, indicating higher differences between the short-run and long-run elasticities. In the case of this thesis, due to the high impact of vkt_{t-1} on travel demand, both Model 1 and Model 2 show low speeds of adjustment, indicating high differences between the models' short-run and long-run elasticity values. This finding is unusual in the literature where long-run elasticity values were about 2 to 3 times of short-run elasticities, with referred long-run elasticities to the period of about five years (Goodwin et al., 2004) or higher (de Grange et al., 2015). It is crucial to interpret the time adjustment for this thesis with caution since the observed period refers to the period between 2014 and 2019, which limitation in data availability could affect the time adjustment of the elasticities. Even in relation to gasoline demand elasticities, Dahl and Sterner (1991) concluded that seasonal data is inappropriate and unreliable for long-run adjustment. As this thesis focuses on finding if seasonality impacts motorway travel demand separately for frequent and occasional motorway users by measuring the level of impact for each observed explanatory variable by using short-run elasticity values, the rest of the thesis focuses solely on the short-run. The obtained short-run values enable the interpretation and discussion of elasticity findings with other studies.

The fuel price estimates for frequent motorway users showed a significant and negative impact on vehicle kilometres travelled, aligning with the literature. The obtained elasticity value for the summer period was -0.2232, while during the non-summer period, the elasticity value for frequent users was -0.3797. While the non-summer elasticity is only marginally significant (p-value = 0.07), its magnitude suggests a potentially meaningful behavioural difference. These findings and differences between the two observed periods indicate that frequent user traffic is more impacted by increase in fuel prices during the non-summer period than in the summer. The new evidence aligns with hypothesis H_7 that the observed period of the year impacts travel demand. To confirm H_7, it was necessary to further observe the impact of the period of the year for occasional users. The collected historical data accompanies the findings, as during the non-summer period of 2019, the number of active ENC Plus users was lower by -9.20% than during the summer period. The results indicate reduced demand for frequent usage of the motorway in non-summer, thus demonstrating the need for increased frequent travel in the summer, possibly for private and business commitments, reducing sensitivity towards increase in fuel prices. These estimated fuel price values are slightly higher than those summarised by Goodwin et al. (2004), around -0.1 to -0.15 within a year, and elasticities for passenger traffic in Slovenia of -0.12 (Matajič et al., 2015). However, regarding the literature evidence in other countries, in the case of Spain, Gonzalez and Marrero (2012) obtained elasticities for traffic concerning fuel prices of -0.282 in the short-run, while Matas et al. (2012) showed results of -0.380, whose elasticity values are very similar to those reported in Model 1 and Model 2. Besides Spain, the estimated fuel elasticity value for the summer in Model 1 is also very close to the case of Norway, with values of -

0.26 and -0.11 (Odeck & Johansen, 2016), as well as to the result of de Grange et al. (2015) of an urban freeway in Santiago, Chile, with an elasticity value of -0.21.

In their investigation on the impact of GDP and fuel prices on trends in changes in travel demand (Bastian et al., 2016), the results from Model 1 reveal that fuel price estimates in the summer period are negative, which is consistent with findings of Sweden (-0.23). Model 2 estimates for the non-summer period are comparable to the elasticity values of France (-0.31), Australia (-0.36), and the United Kingdom (-0.37). Variations in fuel prices between nations may have distinct effects, owing to differing tax rates (Romero-Jordán et al., 2010; Small & Van Dender, 2018) and varying transportation patterns between the observed countries and motorways (Gallo, 2011).

Regarding the remaining regressors in Model 1 and Model 2, the impact of *toll* on vkt_t in both summer and non-summer periods was insignificant, which rejects the set hypothesis H_{2a} that an increase in toll prices negatively impacts the travel demand of frequent users in the summer and non-summer periods. This evidence is uncommon in the literature, which suggested the negative impact of a toll increase on travel demand (Burris & Huang, 2011; Cervero, 2012; de Grange et al., 2015; Matas & Raymond, 2003). However, these insignificant findings for the case of the Istrian motorway are not completely strange, as despite regular toll price increase between 2015 and 2019, frequent motorway traffic continued to increase by an average of +2.81% a year. This suggests that the Istrian motorway, in general, has not yet reached maximum toll price levels for frequent users until the end of 2019, after which point the toll revenues and traffic begin to fall. The discussion of occasional users further examines this topic.

Regarding testing the impact of the *gdp_cro* on vkt_t, the Croatian GDP per capita coefficient was insignificant in both Model 1 and Model 2. These results are similar to those of Fulton et al. (2000) and Gonzalez and Marrero (2012), indicating that GDP per capita increase do not impact travel demand. Generally, low values and significance for income per capita indicate that an increase in income does not correspond with increasing travel. Fulton et al. (2000) argued that insignificant impact may reflect that greater distances must be covered in rural areas, which generally have lower income levels. Considering that town of Pazin is administrative headquarter, while the City of Pula is political and economic headquarter of the Istrian county, this statement could be applicable on in terms of this thesis, due to necessity of inhabitans to regular use of the motorway for their daily activities which do not depend on the level of income. Therefore, the results for frequent motorway users reject the hypothesis H_{4a} that an increase in GDP per capita has a positive impact on the travel demand of frequent users in the summer and non-summer periods, showing there are other variables that impact travel demand.

Even if the complete model showed that variable *season* does not significantly impact vehicle kilometres travelled, the results of Model 1 and Model 2 showed that motorway user behaviour concerning fuel price varies between summer and non-summer periods. In addition, event the results in Table 6.7. showed different elasticity values of the same observed explanatory variables between seasons, the Chow test also confirmed structural differences between summer and non-summer databases. Therefore, these findings suggest that the period of the year impacts frequent motorway users and is further used in the discussion of occasional users to argue, accepting hypothesis H_7 that the observed period of the year impacts travel demand, but differently for frequent and occasional users. The estimates also showed a higher impact of fuel prices during the non-summer period, meaning higher user caution and lower flexibility when travelling during the non-summer period with lower travel demand. The expected estimations for fuel prices align with the literature, supporting hypothesis H_{3a} that an increase in fuel prices has a negative impact on the traffic levels of frequent motorway users.

6.6.2. Discussion on obtained results of occasional motorway users

For Model 3 and Model 4, the results show different elasticity values than those obtained for frequent motorway users. Model 3, which reflects the summer period results, shows that the lag variable of vehicle kilometres travelled and variable *fuel* significantly impact travel demand. The estimations indicate that the same explanatory variables impact frequent and occasional motorway user travel demand during the summer period. However, the impact differs among the types of motorway users and the period of the year.

In Model 3, the vkt_{t-1} showed a positive and highly significant impact on travel demand with a value of 1.0025, suggesting that vehicle kilometres travelled in the summer of the previous year capture much of the year-to-year variation in the summer period that this thesis aims to explain. For Model 4, the estimated value of 0.9952 also showed a positive impact of vehicle kilometres travelled in the non-summer period of the previous year on travel demand. These positive and significant impacts of lag variables align with the literature and confirm hypothesis H_{1b} that an increase in vehicle kilometres travelled in the previous year positively affects travel demand for occasional motorway users in both summer and non-summer periods. Even higher estimated impact than reported in the literature due to continuous traffic increases on the Istrian motorway from 2014 to 2019, the results are expected. Compared to frequent motorway users, occasional motorway users were additionally affected by a special temporary tolling policy measure. This measure involved a toll increase of 10% between June and September each calendar year. The increase was due to higher maintenance and operative costs for the motorway operator Bina-Istra, caused by the higher quantity of motorway traffic during this period. As shown in Figure 2.2. and Table 2.3., the motorway traffic levels increased during the years despite the application of the summer toll increase, which is in harmony with the obtained results for the impact of the lag variable of vehicle kilometres travelled on travel demand.

Regarding the impact of fuel prices on occasional motorway users during the summer period, the variable *fuel* with an estimated value of -0.2889 showed a negative and significant impact on vehicle kilometres travelled. The elasticity value suggests that fuel price increase reduces the vehicle kilometres travelled of occasional users in summer. It is worth remarking that even the coefficient showed a slightly higher impact than the frequent motorway users, a similar pattern of impact of fuel prices on travel demand during the summer is present for frequent and occasional motorway users. Although slightly higher than in Model 1 for the summer period (-0.2232), the obtained fuel price elasticity of -0.2889 in Model 3 for occasional motorway users is in line with the literature findings, which showed a negative impact of changes in fuel prices on travel demand (Gomez et al., 2016; Matas et al., 2012; Odeck & Johansen, 2016).

Furthermore, in their investigation of the impact of GDP, fuel price, and vehicle fleet on road traffic in the case of Spain by applying a dynamic panel data model, Gonzalez and Marrero (2012) estimated a short-run elasticity value of -0.282 similar to Model 3. The estimated fuel elasticity value for Model 3 also follows the findings for different countries, with short-run elasticity values of -0.26 and -0.11 for Norway (Odeck & Johansen, 2016) and -0.21 for Chile (de Grange et al., 2015). In their overview of existing literature on road traffic demand elasticities, Dunkerley et al. (2020) ranged estimated fuel price elasticities between -0.10 and -0.50. Even there is no specific procedure to apply the transferability procedure to each country (Musso et al., 2013) or common elasticities across countries (Espey, 1997), it is essential to remark that none of the existing literature differs in elasticity values by period of the year, but only on a yearly basis.

Even if the results from Model 3 are in favor of accepting hypothesis H_{3b}, the results for the non-summer period do not lead to the same conclusion. In Model 4, for the non-summer period, the variable *fuel* was insignificant. The result of Model 4 suggests that the vehicle kilometres travelled by occasional motorway users do not depend on changes in fuel prices. Therefore, this finding rejects hypothesis H_{3b} that fuel price increase negatively impacts the travel demand of occasional motorway users in summer and non-summer periods. However, due to the different elasticity values obtained between the summer and non-summer periods, this finding also argues for accepting hypothesis H_7 that the observed period of the year has an impact on travel demand but differently for frequent and occasional motorway users. The historical data for the Istrian motorway for 2014–2019 also complements these results, with 58.75% of total occasional user transactions realised during the four months of the summer period.

Changes in the traffic structure of occasional motorway users indicate that, except for fuel prices, different parameters may impact travel demand between summer and non-summer periods. Concerning that, Model 4 shows the significant and positive impact of the toll price on vehicle kilometres travelled in the non-summer period, with an estimated coefficient value of 0.0505. Although this finding is a generally uncommon in the literature, the small magnitude suggests that motorway travel demand is weakly responsive to toll price increase, and that other factors have a more significant role in moderating travel demand. The estimate rejects the hypothesis H_{2b} that an increase in toll prices negatively impacts the motorway travel demand of occasional users during the non-summer period.

Even if the extant literature base results in different samples and countries, other factors such as alternative toll-free roads, length of the tolling section, and location of the road in a tourist destination may also affect the differences in elasticity values (Matas & Raymond, 2003). The authors ranged the short-run toll elasticity values from -0.21 in the most inelastic section to -0.83 in the most elastic section. The literature also provides evidence of the negative impact of tolls on travel demand. Gibson and Carnovale (2015) found that a one percent price increase decreases entries by charged vehicles by -0.30. Boarnet et al. (2014) argued that, depending on conditions, roads with fewer essential trips, more viable alternatives, or lower congestion levels tend to have higher elasticities, typically estimated in a range between -0.10 and -0.45. The potential reason for the lack of impact of toll prices on travel demand in the summer period and the low positive impact in the non-summer period might suggest that toll prices have not reached their maximum levels until the end of 2019. It can be accompanied by the fact that, despite a summer toll increase of +10%, the Istrian motorway traffic level did not fall until the end of 2019. Instead, the Istrian motorway recorded an average yearly increase of +5.60%.

As indicated in Model 1 and Model 2, the estimated results for *gdp_cro* variable are also insignificant in both Model 3 and Model 4 for occasional motorway users. The insignificant impact of the Croatian GDP per capita variable shows that the variable is not appropriate to explain the impact of travel demand in the case of Croatia using set models. Instead, the results suggest that motorway travel demand is better explained and impacted by changes in fuel prices and vehicle kilometres travelled in the previous year. As previously mentioned, the insignificant impact of the GDP variable on travel demand is not strange in the literature (Fulton et al., 2000; Gonzalez & Marrero, 2012). Therefore, the result rejects the hypothesis H_{4b} that an increase in the Croatian GDP per capita positively impacts the motorway travel demand of occasional users.

6.6.3. Summary on discussion of obtained results

The four separate models suggest that the vehicle kilometres travelled are highly dependent on the vehicle kilometres travelled in the previous year, which variable captures much of the year-to-year variation this thesis aims to explain. The recorded continuous increase of the Istrian motorway traffic levels of both occasional and frequent motorway users between 2014 and 2019 complements these findings. This increase occured despite changes in the direct circumstances (toll price increase), and indirect circumstances (increase in GDP, tourist arrivals, and overnights). These trends may suggest Croatia as a growing market.

The results of frequent motorway users also showed that increase in fuel prices negatively impact traffic levels, which is in line with the literature, suggesting that observing this parameter is essential for policymakers when forecasting traffic levels and tolling policy. Due to literature limitations for not distinguishing the impact of variables in different periods of the year, the higher negative impact of fuel prices on motorway travel demand during the non-summer period than in the summer period provides new literature insight. The new evidence implies valuable knowledge for practice as well, particularly for practices with seasonality, where traffic structure significantly changes during the year. This finding can be further accompanied by the results of occasional motorway users, where changes in fuel prices showed a similar impact on summer travel demand but were insignificant during the non-summer period when minimally impacted by toll increase.

Therefore, the thesis suggests data separation by frequency of motorway usage and periods of the year in the presence of seasonality. In addition, the results confirm hypothesis H_7 that the observed period of the year has an impact on travel demand, as well as that user sensitivity concerning changes in explanatory variables varies depending on the type of motorway traveller (H_8). Based on the defined hypotheses and obtained results, Table 6.13. provides a summary of the set hypotheses and an overview of accepted and rejected hypotheses.

Table 6.16.

Summary of the hypotheses acceptance or rejection

Hypothesis description	Accepted/Rejected
H_{1a}: Increase in motorway travel demand in the previous year positively affects travel demand of frequent users in the summer and non-summer periods	**Accepted**
H_{1b}: Increase in motorway travel demand in the previous year positively affects travel demand of occasional users in the summer and non-summer periods	**Accepted**
H_{2a}: Increase in toll prices negatively affects travel demand of frequent users in the summer and non-summer periods	Rejected
H_{2b}: Increase in toll prices negatively affects travel demand of occasional users in summer and non-summer periods	Rejected
H_{3a}: Increase in fuel prices negatively affects travel demand of frequent users in the summer and non-summer periods	**Accepted**
H_{3b}: Increase in fuel prices negatively affects travel demand of occasional users in the summer and non-summer periods	Rejected
H_{4a}: Increase in the Croatian GDP per capita positively affects travel demand of frequent users in the summer and non-summer periods	Rejected
H_{4b}: Increase in the Croatian GDP per capita positively affects travel demand of occasional users in the summer and non-summer periods	Rejected
H_{5a}: Increase in the European Union GDP per capita positively affects travel demand of frequent users in the summer and non-summer periods	Rejected
H_{5b}: Increase in the European Union GDP per capita positively affects travel demand for occasional users in the summer and non-summer periods	Rejected
H_{6a}: Increase in tourist arrivals positively affects travel demand of frequent users in the summer and non-summer periods	Rejected
H_{6b}: Increase in tourist arrivals positively affects travel demand of occasional users in the summer and non-summer periods	Rejected
H_7: Observed period of the year has an impact on travel demand, but differently for frequent and occasional motorway users	**Accepted**
H_8: Type of motorway user has an impact on the level of how explanatory variables affect travel demand	**Accepted**

Note: Developed by the author based on obtained results.

6.7. Limitations

The collection of unique historical motorway transaction data for the Istrian motorway separately for the summer and non-summer periods was necessary due to differences in toll price policy. These differences relate to the application of a temporary toll price increase of +10% during the summer period because of higher maintenance and operative costs caused by a growth of motorway traffic. The collected data for fuel and tourism variables reflected monthly levels, so readjustments and fitting to summer and non-summer periods were not necessary. However, the GDP data were available at quarterly levels, so the readjustments of the GDP values were necessary to fit into the summer (June–September) and non-summer (January–May and October–December) periods. As detailed in sub-chapter 5.6., Data analysis method, this thesis adjusted the quarterly GDP data by using weights for the summer and non-summer periods. This adjustment was done to define the average monthly GDP per capita values for each of the observed years. The values were calculated separately for the summer and non-summer periods. Even uncommon in the literature to adjust the GDP values to the average monthly values, the determination of the average monthly GDP per capita was crucial because of the properties of this thesis and to investigate the impact of seasonality. Otherwise, due to the broader non-summer period (eight months), the GDP per capita values would be consistently higher than the summer period (four months) and impact the results. However, it is not expected for an average monthly GDP per capita to have a significant negative impact on the obtained results.

Another limitation of the thesis relates to the observed vehicle category. The thesis investigated the impact of explanatory variables on the I vehicle category (cars), which represented the share of 86.52% in traffic of occasional motorway users and 72.70% in traffic of frequent motorway users on the Istrian motorway between 2014 and 2019. Even this study uses a comprehensive sample of traffic data from the I vehicle category, it is beyond the scope of the thesis to observe how motorway users of other vehicle categories react to changes in the used explanatory variables. The investigation of such findings could imply if there are differences in motorway user sensitivity among vehicle categories as well as if other vehicle categories reached maximum toll prices, after which point the traffic levels begin to fall.

Despite the collection of unique motorway traffic data by each motorway section, as noted in sub-chapter 5.6., Data Analysis Method, this study omitted ten toll-free motorway sections not to affect the results. The omitted toll-free sections were semi-profile motorways, whose sections do not differ from the alternative roads. It is worth noting that this thesis used the traffic data of motorway sections whose traffic partly transited on omitted toll-free semi-profile motorway sections due to toll application only on complete parts of motorway sections. However, this thesis does not expect that traffic that partly transited on semi-profile sections negatively impacts the results, as semi-profile sections were toll-free.

Regarding the observed period in this thesis, the focus on collected data relates to the years from 2014 to the end of 2019. The reason for not having a more comprehensive range of observed years is limited toll and traffic data availability for motorway sections before 2014. In addition, this thesis did not use observations after 2019 to avoid using the data impacted by the COVID-19 virus, which occurred in 2020 and negatively impacted the world economy as well as motorway travel demand in Europe (ASECAP, 2021).

Since this thesis investigates whether seasonality impacts motorway travel demand by testing the impact of explanatory variables on traffic levels separately by type of traveller and period of the year, the limitation of this thesis occurs in not examining the long-run elasticity values. The estimated coefficients of the lag variable of vehicle kilometres travelled are significantly higher than the literature findings and show the low speed of the adjustment between short-run and long-run estimates, so it is essential to observe the time adjustment of explanatory variables with caution. In the literature, the long-run elasticity values are about 2 to 3 times short-run elasticities, where long-run elasticities refer to a period of about five years (Goodwin et al., 2004) or higher (de Grange et al., 2015). Therefore, this thesis focused only on the interpretation and discussion of short-run elasticity findings to understand the role of seasonality in motorway travel demand, with further suggestions to extend the observed period.

Even if it is impossible to include all the possible variables in a model (Hughes et al., 2006), Roodman (2009) emphasised that it is crucial not to specify a model with too many variables. Because of data limitations, this thesis considered other variables such as improvements to the alternative toll-free roads (Matas & Raymond, 2003), type of trip (Litman, 2019), and traffic on the alternative toll-free roads as unchanged during the observed period 2014–2019. In addition, despite the collection of the European Union GDP per capita and tourist arrivals data, due to unanticipated obstacles with a high Variance Inflation Factor (VIF) when including these two variables, this thesis omitted variables *gdp_eu* and *tourist* from the model not to impact the results. The outcome of this thesis rejected the set hypotheses for the impact of the European Union GDP per capita on motorway travel demand (H_{5a} and H_{5b}) and tourist arrivals on motorway travel demand (H_{6a} and H_{6b}), as the used set of explanatory variables cannot confirm or test their impact on motorway travel demand.

To achieve consistency and comparability across the models, this study employs a limited number of explanatory variables. Although this limitation simplifies the models and may omit variables that influence motorway travel demand, this approach provides a consistent estimation method across all models, allowing for a robust analysis of moderating impact of seasonality and type of motorway user on motorway travel demand. Expanding the set of variables may have resulted in disparities, as certain variables may be irrelevant to specific models, increasing the possibility of omitted variable bias and complicating the interpretation of results.

Despite the fact that sub-chapter 2.4., Traffic, showed continuous and similar increases in traffic levels for all motorway companies in Croatia, it is essential to note that the estimations obtained on the sample data of the Istrian motorway should be taken with caution when considering their application on the entire Croatian motorway network. The reasons for caution are potential different traffic structures at other motorway companies, different tolling policies, and toll discounts. As a supplement to the previous, even if tourist activity impacted the Croatian GDP with a share of 19.5% (Ministarstvo turizma Republike Hrvatske, 2023), tourist activity did not equally affect all regions. For example, the total share of tourist arrivals in the Istrian region was 22.91%, 18.69% for the Dalmatian region, while the Osijek-Baranja region counted 0.55% of total tourist arrivals for 2019 (Croatian Bureau of Statistics, n.d.a). To confirm the application of the results to the whole Croatian motorway network, it is necessary to obtain vehicle kilometre traffic data and toll price data for each section of the remaining motorway companies (AZM and HAC), which were unavailable for this thesis.

6.8. Conclusion

This chapter provides findings generated by modeling the quantitative data. The sub-chapter 6.3., Multicolinearity test, showed the presence of multicollinearity for *gdp_cro*, *gdp_eu*, and *tourist* variables. Therefore, the thesis excluded the latest variables, keeping the national *gdp_cro* variable aligned with the literature (Bastian et al., 2016; Gomez & Vassallo, 2015; Gonzalez & Marrero, 2012; Matas et al., 2012). Even though this chapter examined the results when using all the remaining variables in the complete model, initial results showed that the type of traveller significantly impacts motorway travel demand. However, application of the Chow tests confirmed structural differences between Model Summer and Model Non-summer, as well as between Model Frequent users and Model Occasional users, enhancing the analysis and suggesting important role of seasonality and type of motorway user in motorway travel demand.

To further test the impact of used explanatory variables and seasonality on motorway travel demand, this chapter built four models to observe differences in elasticity values between frequent and occasional motorway users in summer and non-summer periods. Based on that, not all explanatory variables showed a significant impact on motorway travel demand. Instead, the results suggest that the sensitivity of frequent and occasional motorway users concerning changes in explanatory variables depends on the type of traveller and the period of the year. Even if frequent motorway users showed higher sensitivity to changes in fuel prices during the non-summer than in the summer, this chapter showed that a negative correlation between travel demand and an increase in fuel prices is in line with the literature. Besides fuel prices, frequent motorway user traffic on the Istrian motorway is highly dependent and determined by motorway traffic in the previous year, which, although having higher estimated values, aligns with the literature.

Regarding the motorway traffic data of occasional motorway users, the chapter showed a high dependence of the Istrian motorway traffic on traffic data in the previous year. In addition, this new evidence also showed that occasional motorway user traffic is negatively impacted by the increase in fuel prices in the summer period, aligning with the literature short-run values. Although the small magnitude, the results for the non-summer period indicated a positive correlation between toll prices and motorway travel demand, which is an unusual finding in the extant literature.

Besides discussing the obtained results, their support for literature findings, and set hypotheses, the chapter also provided an overview of limitations. Except for the need to adjust the GDP per capita quarterly data to the average monthly values and keep the traffic data that partially transited over the semi-profile motorway roads, other limitations reflected non-observing remaining vehicle categories, limited number of observed years, limited number of used variables, and the omission of the EU GDP per capita and tourist arrivals variables from the models due to multicollinearity issues. Based on the previous, suggestions for future work to expand investigation and provide additional benefit for the literature and practice are discussed in Chapter 7.

CHAPTER 7. CONCLUSION

This chapter provides an overview of research questions and responses based on the identified literature and practice gaps. It emphasises the thesis contribution, limitations, and suggestions for future works. In addition, the chapter provides a brief summary of the literature gaps that served as the foundation for the determined research questions. As a final remark, the chapter emphasises the study's limitations, which suggest possible directions for extending the topic and investigation.

7.1. Summary of the research and answers to the research questions

This sub-chapter summarises the research and provides answers to research questions based on the identified literature gaps. It summarises and displays the important findings in response to predetermined research questions.

As examined in Chapter 1, sub-chapter 1.3., Problem identification and research questions, this thesis determined the following four research questions:

- **Research question 1:** Which factors significantly influence the Istrian motorway travel demand of frequent and occasional motorway users during the summer and non-summer periods?
- **Research question 2:** Which factor has the highest impact on the Istrian motorway travel demand of frequent and occasional motorway users during the summer and non-summer periods?
- **Research question 3:** How do seasonality and changes in traffic structure affect motorway travel demand of frequent and occasional motorway users?
- **Research question 4:** What are the recommendations for Croatian policymakers and countries with similar economies to Croatia to manage travel demand on tolled motorways?

To provide the answers to research questions, the use of econometric methods enabled the analysis of collected historical data related to motorway traffic, toll prices, fuel prices, GDP per capita, and the number of tourist arrivals in Croatia. To answer Research question 1, this thesis observed 8 hypotheses, where H_1, H_2, H_3, H_4, H_5, and H_6 had two sub-hypothesis, while H_7 and H_8 had only one. As the thesis investigates and tests the impact of seasonality on frequent and occasional motorway user travel demand, the motorway transactions and toll prices were collected separately by type of traveller and period of the year. Based on that, the hypotheses were defined separately by period of the year and type of traveller to test the impact of vehicle kilometres travelled in the previous year, toll prices, fuel prices, GDP per capita, and tourist arrivals on travel demand.

7.1.1. Answers to research question 1

7.1.1.1. Frequent motorway users

Regarding research question 1, "Which factors significantly influence the Istrian motorway travel demand of frequent and occasional motorway users during the summer and non-summer periods?” the results showed that frequent motorway user travel demand is significantly and positively affected by the vehicle kilometres travelled in the previous year. The results with a value of 0.9942 for the summer and 0.9918 for the non-summer period suggest that vehicle kilometres travelled in the previous year explain significant part of the year-to-year variations. Although these positive effects are consistent with findings in the literature based on annual estimates (Gomez & Vassallo, 2015; Gonzalez & Marrero, 2012; Gomez et al., 2016; Matas & Raymond, 2003), the obtained values for vehicle kilometres travelled are higher than those reported in the literature. These results with high coefficients indicate the slower speed of the adjustments and higher differences between the short-run and long-run elasticity values (Gonzalez & Marrero, 2012; Matajič et al., 2015; Odeck & Bråthen, 2008). However, the estimates in this thesis were expected given the observed continual expansion of motorway traffic levels by an average of +5.46 between 2014 and 2019 despite rising tolls. In addition, tourist arrivals also increased, with an average value of +7.17% for Croatia and +5.88% for the Istrian region.

The results for frequent motorway users revealed changes in fuel costs have a considerable and negative impact on travel demand sensitivity, whith a value of -0.2232 for the summer period and -0.3797 for the non-summer period, although the latest is found as marginally significant at the 10% level. These findings show that a 1% increase in fuel price reduces vehcile kilometres travelled by -0.22% in the summer period and with indication for higher impact of -0.38% in the non-summer period. The coefficient values and signs are consistent with previous research (Gonzalez & Marrero, 2012; Goodwin et al., 2004; Matajič et al., 2015; Matas et al., 2012), despite the lack of distinction of elasticities across periods of the year. Therefore, the estimations confirm the hypothesis H_{3a} that increases in fuel prices negatively affect travel demand for frequent motorway users in both summer and non-summer. These findings, as well as the disparities between summer and non-summer periods, show that frequent motorway users are more sensitive to fluctuations in fuel prices in the non-summer period than in the summer. It could be explained by the fact that the number of active frequent motorway users on the Istrian motorway during the non-summer period in 2019 was, on average, -9.20% lower than during the summer period, indicating an increased need for travel during the summer season, reducing sensitivity towards fuel prices.

The estimated summer and non-summer coefficients of the remaining explanatory variables showed that frequent motorway users are not sensitive to changes in toll prices and the Croatian GDP per capita. Even if findings for toll prices are uncommon with other studies (Burris & Huang, 2011; Cervero, 2012; de Grange et al., 2015; Matas & Raymond, 2003), these insignificant results are not completely strange. Despite the toll increase in all years between 2014 and 2019, the traffic of frequent motorway users increased by 65% from 2014 to 2019, meaning that toll maximums for frequent motorway users were still not reached until the end of 2019. Therefore, the results rejected the hypothesis H_{2a} that toll increases negatively impact the travel demand of frequent users in both summer and non-summer periods.

Similar to toll prices, assessing the impact of the Croatian GDP per capita on vehicle kilometres travelled revealed insignificant difference between summer and non-summer periods, implying that traffic volumes may not be sensitive to changes in the Croatian GDP per capita. Even if other studies did not distinguish beween different periods of the year, these minor effects are consistent with those of Fulton et al. (2000) and Gonzalez and Marrero (2012), demonstrating that income increases do not correspond with greater vehicle traffic. Therefore, insignificant results rejected the hypothesis that an increase in the Croatian GDP per capita has a significant and positive impact on travel demand both in the summer and non-summer periods (H_{4a}), showing a lack of user sensitivity concerning changes in domestic GDP value with the models of this thesis.

As a final remark on variables that impact travel demand, the results suggest that frequent motorway users show different sensitivity between summer and non-summer periods. The estimates indicate higher sensitivity to fuel prices in the non-summer period compared to the summer period. This suggests that there is a greater caution and lower flexibility in travelling during the non-summer period. During this time, total traffic levels were lower in the observed period from 2014 to 2019, suggesting that for frequent motorway users, the observed period of the year is an essential parameter when analysing their travel patterns. This finding is in line with hypothesis H_7, that the observed period of the year has an impact on travel demand. To confirm H_7, it was necessary to observe the impact of the period of the year for occasional users, whose findings are summarised in the following sub-chapter.

7.1.1.2. Occasional motorway users

The sensitivity of occasional motorway users who pay for tolls without toll discounts in summer and non-summer periods showed different reactions than frequent users. Regarding the traffic sensitivity concerning vehicle kilometres travelled in the previous year, the results showed a significant and positive impact with a value of 1.0025 in the summer period and 0.9952 in the non-summer period, suggesting a high impact and dependence on traffic levels in the previous year. Despite literature limitations for non-distinguishing observed motorway users as frequent and occasional, as well as by the period of the year, the identified positive impacts are in line with the literature on annual levels. A significantly higher estimated value of lag vehicle kilometres travelled than reported in the literature was expected due to the continuous traffic increase on the motorway in the period 2014–2019 (Figure 2.2.). The motorway traffic increased despite the regular toll increase, followed by temporary measures of toll increases of +10% between 1 June and 30 September of each calendar year due to higher maintenance costs and higher traffic levels and flows.

Besides travel demand sensitivity to traffic levels in the previous year, the results showed a significant and negative impact of fuel prices on motorway traffic during the summer period, with a value of -0.2889. In the non-summer period, fuel prices did not show a significant impact on traffic levels, suggesting there are other variables that impact motorway travel demand. As mentioned in the previous paragraph, even though the literature does not distinguish the estimated coefficients concerning fuel prices separately for frequent and occasional users, the result for the summer period is in line with the literature findings reported on a yearly basis. The negative relationship between travel demand and fuel prices in summer with insignificant impact during the non-summer period rejects hypothesis H_{3b} that an increase in fuel price has a significant and negative impact on the travel demand of occasional motorway users both for summer and non-summer periods. These mixed estimations could be explained by changes in traffic structure between the two periods, as, according to the data of the Croatian Bureau of Statistics between 2014 and 2019, 73.98% of total foreign tourist arrivals in Croatia were realised in the summer period (Croatian Bureau of Statistics, n.d.a).

Even estimations for occasional motorway users showed an insignificant impact of tolls on travel demand in the summer period, the results for the non-summer period estimated a significant and positive impact of tolls on vehicle kilometres travelled with a coefficient value of 0.0505. Although this finding is a generally uncommon in the literature, the small magnitude suggests that motorway travel demand is weakly responsive to toll price increase, and that other factors have a more significant role in moderating travel demand. Therefore, the result rejected the hypothesis that an increase in toll prices negatively affects travel demand for occasional users in both summer and non-summer periods (H_{2b}). A potential reason for the lack of impact of tolls in the summer or the positive impact in the non-summer period might suggest that toll prices have not reached their maximum levels until the end of 2019, after which point the traffic levels would begin to fall. It follows the fact that despite toll increases between 2014 and 2019, traffic levels did not fall but increased by an average of +5.60% yearly (HUKA, 2016; HUKA, 2018; HUKA, 2020). In addition, the insignificant impact on travel demand in the summer period also suggests that toll levels have not reached their maximum as traffic increased, despite the application of a summer toll increase of +10% only on regular toll prices. Instead, the traffic of occasional motorway users increased by 14.79% between 2014 and 2019.

As for frequent users, the Croatian GDP per capita estimations suggested an insignificant impact on travel demand in summer and non-summer periods, meaning the variable is not appropriate to explain the impact on travel demand in Croatia by this set of models. As argued in the previous sub-chapter for frequent users, this adverse finding is not strange in the literature (Fulton et al., 2000; Gonzalez & Marrero, 2012). Due to the insignificant impact on travel demand, the results reject the hypothesis that an increase in the Croatian GDP per capita positively affects travel demand for occasional users in both summer and non-summer periods (H_{4b}). The estimations suggest that the sensitivity of occasional motorway users to determined explanatory variables changes and is different between summer and non-summer periods. Only traffic levels in the previous year significantly impacted travel demand, both in the summer and non-summer periods. As the findings align with the values of frequent motorway users in general, this confirms high dependence and the relationship between the travel demand of the previous year and the existing travel demand. Besides that, this thesis showed a significant impact of fuel prices on travel demand in the summer period and a lack of user sensitivity concerning this variable in the non-summer period. A similar finding, but the opposite, is present for toll prices, whose impact is significant in the non-summer period and insignificant during the summer.

Overall, even though the Chow test confirmed structural differences between Model Summer and Model Non-summer, additional estimations of separate models (Model 1–Model 4) suggest that the observed period of the year is essential and reflects different motorway user sensitivities regarding particular factors that impact travel demand, thus accepting the hypothesis that the observed period of the year significantly impacts the travel demand of occasional and frequent motorway users (H_7). Although the Chow test confirmed structural differences between Model Frequent users and Model Occasional users, the results of separate models (Model 1–Model 4) also showed that the impacts of particular explanatory variables differ between frequent and occasional motorway users, thus accepting the hypothesis that the type of motorway user has a significant impact on motorway travel demand (H_8).

7.1.2. Answers to research question 2

Following research question 2, “Which factor has the highest impact on the Istrian motorway travel demand of frequent and occasional motorway users during the summer and non-summer periods?”, the thesis separated tests and obtained results for frequent and occasional motorway users. The results showed that for both types of motorway users, travel demand is highly affected by the traffic levels in the previous year (vkt_{t-1}). The finding is also valid for summer and non-summer periods. Except for that, the results suggested the impact of fuel prices as a variable that significantly influences travel demand in all cases, except for occasional motorway users in non-summer periods when it is insignificant. In contrast, the travel demand of occasional motorway users in the non-summer period showed sensitivity to changes in toll prices, with the lowest estimated impact on travel demand among significant variables. Therefore, the obtained results argue that the impact of each explanatory variable on travel demand is not unique but differs among the observed period of the year and type of motorway user.

7.1.3. Answers to research question 3

When considering research question 3, “How do seasonality and changes in traffic structure affect motorway travel demand of frequent and occasional motorway users?” observation of motorway traffic data in Chapter 2, Figure 2.6. graphically showed monthly fluctuations in traffic levels and indications of seasonality, especially for occasional motorway users. In addition to developed models which through Chow tests indicated structural differences between summer (Model Summer) and non-summer (Model Non-summer) data, as well as between frequent (Model Frequent users) and occasional (Model Occasional users) users, the application of collected data on traffic, tolls, fuel prices, and GDP per capita in four different models, separated by period of the year and type of traveller through four models (Model 1–Model 4), resulted in distinguished impacts on traffic levels.

Regarding the impact of seasonality on explanatory variables, Model 1 and Model 2 showed the sensitivity of frequent motorway user traffic in summer and non-summer periods. This study showed frequent motorway users as positively and significantly sensitive to vehicle kilometres travelled in the previous year. Except for that, the estimate for fuel price increases suggested a negative impact on traffic levels for this user type, while the remaining variables did not significantly impact traffic levels. Even if Chapter 2, Figure 2.5. graphically and numerically showed that the average share of monthly frequent motorway user traffic in total yearly traffic does not significantly deviate from the average value, the evidence from Model 1 and Model 2 suggested the impact of seasonality. The new evidence showed slightly lower sensitivity towards lag variable vehicle kilometres travelled in the non-summer period than in the summer period and a higher negative impact of fuel prices in the non-summer period than in the summer period. The estimations for occasional motorway users obtained in Model 3 and Model 4 can accompany these findings. Even if coefficients show a similar impact of lag vehicle kilometre travelled variables on traffic levels, the impacts of fuel and toll variables vary between summer and non-summer periods. As presented in Chapter 2, Figure 2.4., the average monthly share of occasional motorway user traffic on the Istrian motorway varies between months, with the most realised traffic during the summer. This thesis showed that fuel prices negatively impact vehicle kilometres travelled in the summer period, but it is insignificant in the non-summer period when occasional motorway users show positive sensitivity concerning changes in toll prices.

Therefore, these findings for different motorway traffic sensitivity for frequent and occasional motorway users indicate the importance of distinguishing investigation to different periods of the year and type of traveller, as not observing the seasonality may lead to incorrect conclusions.

7.1.4. Answers to research question 4

Regarding research question 4, "What are the recommendations for the Croatian policymakers and countries with similar economy to Croatia to manage travel demand on tolled motorways?" this thesis bases recommendations on collected historical data and generated results. First, the thesis recommends considering seasonality as an important factor in managing travel demand. These findings are valuable for policymakers when defining and adjusting toll levels, as the thesis showed there are other external factors than tolls that may affect travel demand. Second, an insignificant impact of tolls on motorway traffic suggests that the Istrian motorway may still not reached their maximum toll levels after which toll increase the traffic begins to fall. Third, this thesis recommends that policymakers observe the impacts of each factor on travel demand by frequency of motorway usage to take into account the specificities of different user categories over different periods of time. The sub-chapter 7.3., Contributions to practice, discusses additional findings valuable for policymakers.

7.2. Contributions to the literature

This study contributes to the literature on motorway travel demand by developing specific models for measuring the impact of vehicle kilometres travelled in the previous year, toll prices, fuel prices, and GDP per capita on vehicle kilometres travelled on the motorways. The results provide new insights into the literature and fill the literature gap by highlighting the impact of seasonality as an important factor that influences motorway travel demand. Except using historical data for each variable, including unique traffic data from the Istrian motorway, the new evidence is obtained by developing specific models to investigate the impact of seasonality by frequency of motorway usage for different periods of the year. As the research focuses on the Istrian motorway, the new evidence also fills the geographical literature gap and provides the first evidence regarding factors that impact Croatian motorway travel demand. As examined, this thesis provides four key literature contributions as follows.

First, the thesis shows that considering seasonality is an essential parameter in motorway transportation since the same type of motorway users have different reactions to changes in particular variables during the year. Except for finding a significant and positive impact of travel demand in the previous year on travel demand in the current year, the results suggested that frequent motorway users may have higher negative response to an increase in fuel prices in the non-summer period (-0.3797) than in the summer (-0.2232). The travel demand of occasional motorway users also suggested a negative response to the increase in fuel prices in the summer period (-0.2880), but insignificant during the non-summer period. These findings indicate that other variables may influence their travel demand. Unlike previous research findings (e.g., Gomez et al., 2016; Litman, 2019; Matas & Raymond, 2003; Odeck & Bråthen, 2008), the Istrian motorway toll increase in the non-summer period was found to have a positive impact on occasional motorway users (0.0505). Therefore, these findings contribute to the literature by being the first to demonstrate that motorway users differently react to changes in fuel and toll prices during the summer and non-summer periods. The existing literature estimates coefficient values on an annual basis and do not separate the impact of variables depending on seasonal traffic structure (Bakhat et al., 2017; Batarce et al., 2023; Dunkerley et al., 2020; Odeck & Bråthen, 2008).

Second, this thesis demonstrated new insight into the importance of distinct motorway users by frequency of motorway usage, as different types of motorway users have different sensitivity levels concerning explanatory variables and travelling patterns. Even if the literature distinguishes motorway user sensitivity by vehicle category, number of axles, light, and heavy vehicles (Batarce et al., 2023; Burris & Huang, 2011; Gomez & Vassallo, 2015; Gomez et al., 2016; Matajič et al., 2015), it is missing evidence of how occasional and frequent motorway ETC users react to changes in various factors in different periods of the year. To fill the literature gap, this thesis uses unique historical motorway data for the I vehicle category and develops four specific models to separately observe the impact of explanatory variables on frequent and occasional motorway user traffic.

Third, this thesis represents the first study that provides the evidence of how motorway users in the Croatian context react to changes in vehicle kilometres travelled in the previous year, toll prices, fuel prices, and GDP per capita on travel demand. The existing literature does not provide evidence of what impacts Croatian motorway travel demand. Instead, it is limited to the investigation of foreign tourism demand for Croatian destinations, price, and income elasticities (Dahl, 2012; Ferrante et al., 2018; Mervar & Payne, 2007). Even Chapter 2 indicates the presence of seasonality in Croatia, the literature evidence is limited. The extant Croatian literature provides an overview of tourism seasonality research findings (Corluka, 2018) and questions what tourism seasonality is in Croatia (Kožić, 2013). However, the literature does not observe the impact of seasonality on motorway travel demand. Although Brčić et al. (2016) defined the meaning and concept of transportation demand management in solving the complex solutions of the transport system of urban areas, the authors did not provide information to what extent specific factors affect motorway travel demand. Therefore, this study fills the literature gap by providing the first evidence of what impacts motorway travel demand in Croatia, with a specific focus on seasonality. Except for the fact that research findings contribute new knowledge to the Croatian transportation literature, studying Croatia also provides a broader understanding of the explanatory variables in economies with seasonality and GDP highly dependent on tourist activity.

Fourth, even if the results of this thesis provided the first evidence on how frequent and occasional motorway users react to changes in used explanatory variables during summer and non-summer periods, developed models also suggest the new approach in terms of observing explanatory variable data. While previous studies in the travel demand context used monthly, quarterly, and yearly data to measure the impact on travel demand (Baranzini & Weber, 2013; Bastian et al., 2016; Burris & Huang, 2011; Miller & Alberini, 2016; Odeck & Johansen, 2016), this thesis adds new knowledge for specific cases where observed periods and collected data do not necessarily cover the same time period. As a temporary measure of toll increase has been applied to the Istrian motorway during June-September, this thesis used ponders to adjust the quarterly GDP data to the average monthly value, not to impact the results for summer and non-summer periods.

7.3. Contributions to practice

Except for contributions to the literature, the findings of this thesis also provide valuable insights both for policymakers and motorway operators on how seasonality impacts motorway traffic. The new evidence showed that observed explanatory variables have different impacts on frequent and occasional motorway users, especially between summer and non-summer periods. For the Istrian motorway, the results suggest that toll levels until the end of 2019 may not reach their maximum levels, suggesting the potential for additional toll increases to maximise revenues. As detailed as examined, this thesis provides four key contributions to practice, as follows.

First, the thesis indicates the importance of considering the impact of seasonality when defining the motorway tariff policy. The research reveals the varying impact of explanatory variables such as fuel and toll prices on travel demand between summer and non-summer periods, highlighting the need for a tailored approach. These findings are valuable for defining toll levels depending on the period of the year, as the results showed there are other factors than tolls that impact motorway vehicle kilometres travelled. In essence, understanding the effects of seasonality allows policymakers to make more precise adjustments to toll levels throughout the year to optimise motorway usage and increase revenues.

Second, since tolls represent the direct cost of using the motorway, in the case of the Istrian motorway, the results suggest that for both frequent and occasional motorway users, toll levels until the end of 2019 may not reach their maximum levels. Following the evidence of motorway traffic increase from sub-chapter 2.4., Traffic, the results confirmed the insignificant impact of the toll increase on motorway travel demand, suggesting a potential for a toll increase above the temporary measure of a +10% toll increase during the summer period. In addition, the insignificant impact of the toll increase on frequent motorway user traffic levels and the positive impact on occasional users in the non-summer period also suggest the potential for regular toll increases.

Third, by separating the study of seasonality to frequent and occasional motorway users, the results demonstrated valuable insights into how different user types react to changes in used explanatory variables between summer and non-summer periods. The evidence shows that both frequent and occasional motorway traffic was significantly impacted by the traffic in the previous year, suggesting that past motorway traffic may help policymakers forecast future demand accurately. This finding implies that changes in traffic patterns on the Istrian motorway tend to persist over time, thus making it essential for policymakers to consider historical values and trends when defining decisions about tolling and traffic management strategies.

Fourth, this research suggests that for frequent motorway users, policymakers should also consider changes in fuel prices due to the negative impact on travel demand. Even if travel demand for this type of user is negatively affected by an increase in fuel prices during the whole year, the impact of fuel prices is higher in the non-summer period than in the summer period. The benefit of such observation and understanding in practice may lead policymakers and motorway operators to focus on special promotional actions in terms of ENC toll discounts, safety, and shorter travel distances to encourage drivers to use motorways instead of alternative roads. The evidence for occasional motorway users implies that an increase in fuel prices also has a negative impact on motorway traffic in the summer period but is insignificant in the non-summer implying other factors may impact travel demand. By understanding that an increase in fuel prices negatively affects motorway travel demand during the summer period, policymakers can make more informed decisions about toll pricing and other policies to manage demand throughout the year and promote efficient use of motorways.

7.4. Limitations

Although the thesis contributes to literature and practice, it also contains particular limitations summarised and addressed in this sub-chapter.

First, as unique historical motorway transaction data was used for one of the Croatian motorway operators, due to the unavailability of historical traffic data for other Croatian motorway operators, the interpretation of the obtained results for the entire Croatian motorway should be taken with caution. To supplement that, even if total traffic levels from sub-chapter 2.4., Traffic, showed a similar positive increase in traffic levels on all motorway operators in Croatia between 2014 and 2019, the application of results on the entire Croatian motorway network should be taken with caution due to different tolling policies and toll discounts. This remark is also valid due to the potential different traffic structures at other motorway operators and tourist activity whose levels vary between the counties, as demonstrated in sub-chapter 6.6., Limitations. Therefore, to test the application of the results of this thesis on the entire Croatian motorway network, it is necessary to obtain vehicle kilometre travelled data and historical toll prices for other motorway companies (AZM and HAC).

As the unique historical motorway transaction and toll price data were collected separately for summer and non-summer periods due to differences in toll pricing policy where toll prices increased by +10% during the summer periods of each year for occasional motorway users, the second limitation of this study refers to fitting the GDP per capita data to the summer and non-summer periods. The reason for that is the availability of GDP data, which is available and collected quarterly. Hence, the adjustments made by using ponders were necessary to identify GDP per capita values for summer and non-summer periods. In addition to that, since this thesis separates investigation of impacts to summer and non-summer periods, which periods do not cover the same number of months, it is essential to note the need to use average monthly GDP per capita, which approach is uncommon in the literature but acceptable since literature does not separate investigation on summer and non-summer periods. Otherwise, due to a broader non-summer period (eight months) than the summer period (four months), the GDP per capita values would be consistently higher than for the non-summer period and negatively impact results. However, even if GDP per capita values represent the average monthly value in the observed period, it is not expected to have a significant negative impact on the obtained results.

Third, this thesis investigated the impact of explanatory variables only on the I vehicle category (cars), which in the case of the Istrian motorway and Croatian road cross-boarding travels represent the most used mode of travel (on average, cars represent 86.52% of total occasional user transactions and 72.70% of total frequent user transactions, while 92.93% of total road cross-boarding travels were realised by cars). Therefore, the limitation of this thesis is related to not observing the impact of determined explanatory variables on other vehicle categories and how their vehicle kilometre travelled reacts to changes in each explanatory variable. Even if there are studies that separate the investigation of motorway user sensitivities between light and heavy vehicles (Gomez & Vassallo, 2015; Gomez et al., 2016), the investigation of other vehicle categories could imply how seasonality impacts frequent and occasional motorway users for light and heavy vehicles in summer and non-summer periods, providing valuable evidence to the literature and practice.

Fourth, another limitation of this thesis refers to non-observing transaction data of all motorway sections of the Istrian motorway as semi-profile and toll-free sections were present during the observed period 2014–2019. These ten toll-free motorway sections were excluded from the dataset so as not to impact the results. However, this thesis used other particular motorway sections whose traffic partly transited across these toll-free semi-profile motorway sections due to the application of tolls on parts of the motorway sections where the road was in complete profile and does not expect to impact the obtained results significantly.

Fifth, the limitation of this thesis also refers to unavailable motorway traffic data before 2014 due to the regime of an open tolling system and tolling procedure. The thesis does not observe the data after the year 2019 to avoid the impact of COVID-19 on the results related to pre-COVID-19 conditions. Due to the observed period and the indicated low speed of adjustment between short-run and long-run estimates, it is essential to observe the time adjustment of explanatory variables with caution, as in the literature, the long-run elasticity values are about 2 to 3 times the short-run elasticities (Goodwin et al., 2004). Therefore, this thesis focused only on the findings of short-run elasticities, while long-run elasticities could be checked in further research by extension of the observed period.

Sixth, even if the thesis attempts to test the impact of the European Union's GDP per capita and tourist arrivals, it is crucial to note their omission from the models due to the high multicollinearity issue with other variables, which limitation resulted in the impossibility of testing hypotheses about their impact on vehicle kilometres travelled through the models.

Seventh, to ensure consistency and comparability across the models, this study employs a limited set of explanatory variables. Even this limitation simplifies the models and potentially omits variables that might impact motorway travel demand, this approach allows for a uniform estimation method across all models. Expanding the set of variables could have introduced inconsistencies, as certain variables might be irrelevant to particular models, increasing the risk of omitted variable bias and complicating the interpretation of results.

7.5. Suggestions for future research

Based on the obtained results, which focused on testing the impact of seasonality on motorway travel demand in the I vehicle category, future research should focus on the remaining uninvestigated vehicle categories. By using the same explanatory variables, the new evidence should indicate if other vehicle categories react differently to changes in the same explanatory variables. These findings would provide additional benefit for the literature and practice to understand if and how seasonality impacts vehicle kilometres travelled. In the case of the Istrian motorway, sub-chapter 2.4., Traffic, suggests that travel patterns differ among vehicle categories. Such new evidence would enable policymakers to understand user sensitivities and adjust their tolling policy separately for each vehicle category.

As the sample of unique historical motorway traffic and toll price data used in this thesis relates to the Istrian motorway, the application of the obtained results to the entire Croatian motorway should be taken with caution due to differences in geographical positions, motorway user structure, tariff policy, and toll discounts. Therefore, the suggestion for future research is to collect additional traffic and toll data for the remaining Croatian motorway operators (HAC and AZM) in the I vehicle category in order to identify the similarities and differences in motorway user behaviour with the results of this thesis. The findings would provide new knowledge about motorway user habits and sensitivities concerning changes in explanatory variables on the national level. In addition, the new literature evidence would show how different tariff policies and motorway structures affect elasticity values.

Since this thesis focused on time from 2014 until the end of 2019, the suggestion for future research is also to extend the observed period after 2019 to have a broader range of data and observed periods. Extending the dataset should provide new knowledge on how motorway users react to changes in explanatory variables over a longer observed period. However, in order to eliminate the impact of the COVID-19 virus on the economy, motorway user habits, and traffic levels, it is suggested to observe the COVID-19 period separately from the post-COVID-19 period for frequent and occasional motorway users. The finding of how different motorway user types react to changes in explanatory variables in summer and non-summer periods during the presence of the virus COVID-19 would be beneficial for the literature and practice in terms of understanding what affects travel demand for different motorway user types during the pandemic period.

REFERENCES

Abrantes, P. A. L., & Wardman, M. R. (2011). Meta-analysis of UK values of travel time: An update. *Transportation Research Part A: Policy and Practice*, *45*(1), 1–17. https://doi.org/10.1016/j.tra.2010.08.003

Acutt, M. Z., & Dodgson, J. S. (1995). Cross-elasticities of demand for travel. *Transport Policy*, *2*(4), 271–277. https://doi.org/10.1016/0967-070X(95)00020-Q

Akinwande, M. O., Dikko, H. G., & Samson, A. (2015). Variance Inflation Factor: As a Condition for the Inclusion of Suppressor Variable(s) in Regression Analysis. *Open Journal of Statistics*, *5*(7), 754–767. https://doi.org/10.4236/ojs.2015.57075

Álvarez, Ó., Cantos, P., & García, L. (2007). The value of time and transport policies in a parallel road network. *Transport Policy*, *14*(5), 366–376. https://doi.org/10.1016/j.tranpol.2007.04.012

Antwi, S. K., & Kasim, H. (2015). Qualitative and Quantitative Research Paradigms in Business Research: A Philosophical Reflection Performance Management Practices in the Ghanaian local government system View project. *European Journal of Business and Management*, *7*(3), 217–226. Retrieved from https://www.researchgate.net/publication/295087782

Arellano, M., & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. *Review of Economic Studies*, *58*(2), 277–297. https://doi.org/10.2307/2297968

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29–51. https://doi.org/10.1016/0304-4076(94)01642-D

ASECAP. (n.d.). Members/Partners. Retrieved on February 1, 2019, from https://www.asecap.com/members-partners/9-en/41-croatia.html

ASECAP. (2015). Statistical Bulletin 2015. https://asecap.com/publications/statistical-bulletin-key-figures

ASECAP. (2016). Statistical Bulletin 2016. https://asecap.com/publications/statistical-bulletin-key-figures

ASECAP. (2017). Statistical Bulletin 2017. https://asecap.com/publications/statistical-bulletin-key-figures

ASECAP. (2018). Statistical Bulletin 2018. https://asecap.com/publications/statistical-bulletin-key-figures

ASECAP. (2019). Statistical Bulletin 2019. https://asecap.com/publications/statistical-bulletin-key-figures

ASECAP. (2020). Statistical Bulletin 2020. https://asecap.com/publications/statistical-bulletin-key-figures

ASECAP. (2021). Statistical Bulletin 2021. https://asecap.com/publications/statistical-bulletin-key-figures

Autocesta Zagreb-Macelj. (n.d.). O nama. Retrieved on February 1, 2019, from http://www.azm.hr/o-nama

Babyak, M. A. (2004). What you see may not be what you get: a brief, nontechnical introduction to overfitting in regression-type models. *Psychosomatic Medicine*, 66(3), 411– 421.

Bahari, S. F. (2010). Qualitative Versus Quantitative Research Strategies: Contrasting Epistemological And Ontological Assumptions. *Jurnal Teknologi*, *52*(1), 17–28. https://doi.org/10.11113/jt.v52.134

Bakhat, M., Labandeira, X., Labeaga, J. M., & López-Otero, X. (2017). Elasticities of transport fuels at times of economic crisis: An empirical analysis for Spain. *Energy Economics*, *68*, 66–80. https://doi.org/10.1016/j.eneco.2017.10.019

Baltagi, B. H. (2021). Econometric Analysis of Panel data (6th ed.) Wiley.

Banister, D. (2011). The trilogy of distance, speed and time. *Journal of Transport Geography*, *19*(4), 950–959. https://doi.org/10.1016/j.jtrangeo.2010.12.004

Baranzini, A., & Weber, S. (2013). Elasticities of gasoline demand in Switzerland. *Energy Policy*, *63*, 674–680. https://doi.org/10.1016/j.enpol.2013.08.084

Barla, P., Lamonde, B., Miranda-Moreno, L. F., & Boucher, N. (2009). Traveled distance, stock and fuel efficiency of private vehicles in Canada: price elasticities and rebound effect. 389–402. https://doi.org/10.1007/s11116-009-9211-2

Bastian, A., Börjesson, M., & Eliasson, J. (2016). Explaining "peak car" with economic variables. *Transportation Research Part A: Policy and Practice*, *88*, 236–250. https://doi.org/10.1016/j.tra.2016.04.005

Batarce, M., Basso, F., & Basso, L. (2023). The elasticity of demand on urban highways: The case of Santiago. *Transport Policy*, *133*(September 2022), 234–241. https://doi.org/10.1016/j.tranpol.2023.02.008

Becken, S., & Schiff, A. (2011). Distance Models for new Zealand International Tourists and the Role of Transport Prices. *Journal of Travel Research*, *50*(3), 303–320. https://doi.org/10.1177/0047287510362919

Belullo, A., & Križman, D. (2000). Utjecaj promjena u dohocima glavnih emitivnih zemalja na turistički promet u Hrvatskoj. *Ekonomski pregled, 51(7-8)*, 681–700.

Bhattacherjee, A. (2012). Social Science Research: Principles, Methods, and Practices. In *Pure and Applied Chemistry* (Vol. 61). https://doi.org/10.1351/pac198961091657

Biddle, C., & Schafft, K. A. (2015). Axiology and Anomaly in the Practice of Mixed Methods Work: Pragmatism, Valuation, and the Transformative Paradigm. *Journal of Mixed Methods Research*, *9*(4), 320–334. https://doi.org/10.1177/1558689814533157

Bina-Istra. (n.d.a). O projektu Istarski ipsilon. Retrieved February 1, 2019, from https://www.bina-istra.com/o-nama/

Bina-Istra. (n.d.b). ENC PAKETI. Retrieved February 1, 2019, from https://bina-istra.com/cestarina/placanje-cestarine/enc-paketi/enc-paketi

Bina-Istra. (2020). Traffic and toll data from tolling system (2014-2019). Unpublished raw data.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *87*(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Boarnet, M., Spears, S., Handy, S., & Rodier, C. (2014). Policy Brief on the Impacts of Road User Pricing on Passenger Vehicle Use and Greenhouse Gas Emissions. *California Environmental Protection Agenci, Air Resources Board*, 1–8. http://www.arb.ca.gov/cc/sb375/policies/hwycapacity/highway_capacity_brief.pdf

Bond, S., & Temple, J. (2001). *GMM Estimation of Empirical Growth Models*.

Börjesson, M., Fosgerau, M., & Algers, S. (2012). On the income elasticity of the value of travel time. *Transportation Research Part A: Policy and Practice*, *46*(2), 368–377. https://doi.org/10.1016/j.tra.2011.10.007

Brčić, D., Šimunović, L., & Slavulj, M. (2016). *Upravljanje prijevoznom potražnjom u gradovima*.

Bryman, A. and Bell, E. (2011). Business Research Methods. 3rd Edition. Retrieved from https://books.google.hr/books?hl=hr&lr=&id=J9J2DwAAQBAJ&oi=fnd&pg=PP1&dq=bryman+bell+business+research+methods&ots=GLgDk9bSJO&sig=MF6I6bTCGBvvbYA4999MqQA82x0&redir_esc=y#v=onepage&q=bryman bell business research methods&f=false

Burnham, K. P., & Anderson, D. R. (2002). Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach (2nd ed.). Springer.

Burris, M. W., & Huang, C. (2011). The short-run impact of gas prices fluctuations on toll road use. *Case Studies on Transport Policy*, *3*(2), 137–150. https://doi.org/10.1016/j.cstp.2014.12.005

Callen, T. (2008). Gross Domestic Product: An Economy's All. *Economics Concepts Explai. Finance & Development, 14-15*. https://www.imf.org/en/Publications/fandd/issues/Series/Back-to-Basics/gross-domestic-product-GDP

Cannas, R. (2012). An Overview of Tourism Seasonality: Key Concepts and Policies. *Almatourism - Journal of Tourism, Culture and Territorial Development*, *3*(5), 40–58. Retrieved from http://almatourism.unibo.it/article/view/3120

Cervero, R. (2012). Traffic impacts of variable pricing on the San Francisco-Oakland Bay Bridge, California. *Transportation Research Record*, (2278), 145–152. https://doi.org/10.3141/2278-16

Chow, G. C. (1960). Tests of equality between sets of coefficients in two linear regressions. *Econometrica: Journal of the Econometric Society,* 591-605.

Corluka, G. (2018). Tourism Seasonality – An Overview. *Journal of Business Paradigms*, *4*(1), 21–43. https://www.researchgate.net/publication/336085306_TOURISM_SEASONALITY_-_AN_OVERVIEW

Creswell, J. W. (2009). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (3rd Edition). https://doi.org/10.4324/9780203803448-9

Croatian Bureau of Statistics. (n.d.a). Dolasci i noćenja turista u komercijalnim smještajnim objektima. Retrieved on May 20, 2021, from https://web.dzs.hr/PXWeb/Menu.aspx?px_language=hr&px_type=PX&px_db=Turizam

Croatian Bureau of Statistics. (n.d.b). Transport i komunikacije. Data provided by the Ministry of Interior. Retrieved May 21, 2021, from https://web.dzs.hr/PXWeb/Menu.aspx?px_language=hr&px_db=Transport%20i%20komunikacije&rxid=310e2276-e4ac-4b46-aa57-52fee7c09aae

Croatian Bureau of Statistics. (n.d.c). Cijene. Retrieved on September 14, 2022, from https://web.dzs.hr/PXWeb/Menu.aspx?px_language=hr&px_type=PX&px_db=Cijene

CrÔtte, A., Noland, R. B., & Graham, D. J. (2010). An analysis of gasoline demand elasticities at the national and local levels in Mexico. *Energy Policy*, *38*(8), 4445–4456. https://doi.org/10.1016/j.enpol.2010.03.076

Dahl, C. A. (2012). Measuring global gasoline and diesel price and income elasticities. *Energy Policy*, *41*, 2–13. https://doi.org/10.1016/j.enpol.2010.11.055

Dahl, C., & Sterner, T. (1991). Analysing gasoline demand elasticities: a survey. *Energy Economics*, *13*(3), 203–210. https://doi.org/10.1016/0140-9883(91)90021-Q

Dargay, J. (2007). The effect of prices and income on car travel in the UK. *Transportation Research Part A: Policy and Practice*, *41*(10), 949–960. https://doi.org/10.1016/j.tra.2007.05.005

Dargay, J. M., & Clark, S. (2012). The determinants of long distance travel in Great Britain. *Transportation Research Part A: Policy and Practice*, *46*(3), 576–587. https://doi.org/10.1016/j.tra.2011.11.016

De Borger, B., & Proost, S. (2021). Road tolls, diverted traffic and local traffic calming measures: Who should be in charge? *Transportation Research Part B: Methodological*, *147*, 92–115. https://doi.org/10.1016/j.trb.2021.03.004

de Grange, L., González, F., & Troncoso, R. (2015). Estimates of price elasticity of demand for urban freeway use with high-frequency control variables: The case of Santiago, Chile. *Applied Economics*, *47*(22), 2326–2337. https://doi.org/10.1080/00036846.2015.1005825

De Jong, G., & Gunn, H. (2001). Recent Evidence on Car Cost and Time Elasticities of Travel Demand in Europe. *35*(2), 137–160. https://www.ingentaconnect.com/content/lse/jtep/2001/00000035/00000002/art00001

Directive 1999/62/EC. On the charging of heavy goods vehicles for the use of certain infrastructures. *European Parliament and Council.* Retrieved on February 5, 2019, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31999L0062

Directive 2006/38/EU. On the charging of heavy goods vehicles for the use of certain infrastructures. *European Parliament and Council.* Retrieved on February 5, 2019, from https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32006L0038

Directive 2011/76/EU. On the charging of heavy goods vehicles for the use of certain infrastructures. *European Parliament and Council.* Retrieved on February 5, 2019, from https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32011L0076

Dudovskiy, J. (2018). An Ultimate Guide to Writing a Dissertation in Business Studies: A Step-by-Step Assistance. *Research Methodology*. https://research-methodology.net/product/the-ultimate-guide-to-writing-a-dissertation-in-business-studies-a-step-by-step-assistance-january-2018-edition/

Dunkerley, F., Rohr, C., & Daly, A. (2020). Road traffic demand elasticities: A rapid evidence assessment. https://doi.org/10.7249/rr888

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2015). Management & Business Research (5th Edition). London: Sage.

Espey, M. (1997). TRAFFIC JAM: AN INTERNATIONAL STUDY OF AUTOMOBILE TRAVEL DEMAND. *REGIONAL SCIENCE: The Journal of the KSAI 76, 3*, 343–356. https://www.ptonline.com/articles/how-to-get-better-mfi-results

Eurostat. (n.d.). Main GDP aggregates per capita. Retrieved July 15, 2022, from https://ec.europa.eu/eurostat/databrowser/explore/all/all_themes

Ferrante, M., Lo Magno, G. L., & De Cantis, S. (2018). Measuring tourism seasonality across European countries. *Tourism Management*, *68*(February), 220–235. https://doi.org/10.1016/j.tourman.2018.03.015

Fleetwood, S. (2005). Ontology in organization and management studies: A critical realist perspective. *Organization*, *12*(2), 197–222. https://doi.org/10.1177/1350508405051188

Fontes, T., Pereira, S. R., Bandeira, J. M., & Coelho, M. C. (2015). Assessment of the effectiveness of fuel and toll pricing policies in motorway emissions: An ex-post analysis. *Research in Transportation Economics*, *51*, 83–93. https://doi.org/10.1016/j.retrec.2015.07.010

Fouquet, R. (2012). Trends in income and price elasticities of transport demand (1850-2010). *Energy Policy*, *50*, 62–71. https://doi.org/10.1016/j.enpol.2012.03.001

Fouquet, R. (2014). Long-run demand for energy services: Income and price elasticities over two hundred years. *Review of Environmental Economics and Policy*, *8*(2), 186–207. https://doi.org/10.1093/reep/reu002

Fuleky, P., Zhao, Q., & Bonham, C. S. (2014). Estimating demand elasticities in non-stationary panels: The case of Hawaii tourism. *Annals of Tourism Research*, *44*(1), 131–142. https://doi.org/10.1016/j.annals.2013.09.006

Fulton, L., Noland, R., Meszler, D., & Thomas, J. (2000). A Statistical Analysis of Induced Travel Effects in the U.S. Mid-Atlantic Region. *Journal of Transportation and Statistics*, *3*(1), 1–14.

Gallet, C. A., & Doucouliagos, H. (2014). The income elasticity of air travel: A meta-analysis. *Annals of Tourism Research*, *49*, 141–155. https://doi.org/10.1016/j.annals.2014.09.006

Gallo, M. (2011). A fuel surcharge policy for reducing road traffic greenhouse gas emissions.

Transport Policy, *18*(2), 413–424. https://doi.org/10.1016/j.tranpol.2010.11.003

Gibson, B., & Morgan, G. (1979). Sociological Paradigms and Organisational Analysis.

Gibson, M., & Carnovale, M. (2015). The effects of road pricing on driver behavior and air pollution. *Journal of Urban Economics*, *89*, 62–73. https://doi.org/10.1016/j.jue.2015.06.005

Gillingham, K. (2014). Identifying the elasticity of driving: Evidence from a gasoline price shock in California. *Regional Science and Urban Economics*, *47*(1), 13–24. https://doi.org/10.1016/j.regsciurbeco.2013.08.004

Giuliano, G., & Narayan, D. (2003). Another look at travel patterns and urban form: The US and Great Britain. *Urban Studies*, *40*(11), 2295–2312. https://doi.org/10.1080/0042098032000123303

Glaser, B. G., & Strauss, A. L. (1967). The discovery of Grounded Theory: Strategies for Qualitative Resarch. Chicago: Aldine.

Gomez, J., & Vassallo, J. M. (2015). Evolution over time of heavy vehicle volume in toll roads: A dynamic panel data to identify key explanatory variables in Spain. *Transportation Research Part A: Policy and Practice*, *74*, 282–297. https://doi.org/10.1016/j.tra.2015.02.017

Gomez, J., Vassallo, J. M., & Herraiz, I. (2016). Explaining light vehicle demand evolution in interurban toll roads: a dynamic panel data analysis in Spain. *Transportation*, *43*(4), 677–703. https://doi.org/10.1007/s11116-015-9612-3

Gonzalez, R. M., & Marrero, G. A. (2012). Induced road traffic in Spanish regions: A dynamic panel data model. *Transportation Research Part A: Policy and Practice*, *46*, 435–445. https://doi.org/10.1016/j.tra.2011.11.003

Goodwin, P. B. (1992). A review of new demand elasticities with special reference to short and long run effects of price changes. *Journal of transport economics and policy*, 155-169. https://jtep.org/wp-content/uploads/2021/02/Volume_XXV1_No_2_155-169.pdf

Goodwin, P., Dargay, J., & Hanly, M. (2004). Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A review. *Transport Reviews*, Vol. 24, 275–292. https://doi.org/10.1080/0144164042000181725

Graham, D. J., Crotte, A., & Anderson, R. J. (2009). A dynamic panel analysis of urban metro demand. *Transportation Research Part E: Logistics and Transportation Review*, *45*(5), 787–794. https://doi.org/10.1016/j.tre.2009.01.001

Graham, D. J., & Glaister, S. (2002). The demand for automobile fuel: A survey of elasticities. *Journal of Transport Economics and Policy*, *36*(1), 1–26.

Grisé, E., Cui, B., Turim, A., Manaugh, K., & El-Geneidy, A. (2019). The impacts of varying survey design on reported trip satisfaction. *Transportation Research Part F: Traffic Psychology and Behaviour*, *60*, 761–769. https://doi.org/10.1016/j.trf.2018.12.003

Gunter, U., & Smeral, E. (2016). The decline of tourism income elasticities in a global context. *Tourism Economics*, *22*(3), 466–483. https://doi.org/10.5367/te.2014.0431

Hanly, M., Dargay, J., & Goodwin, P. (2002). Review of income and price elasticities in the demand for road traffic. *Department for Transport, London*, 1–95. Retrieved from http://www.ucl.ac.uk/transport-studies/tsuhome.ht

Hardman, S., Chakraborty, D., & Tal, G. (2022). Estimating the travel demand impacts of semi automated vehicles. *Transportation Research Part D: Transport and Environment, 107*(November 2021), 103311. https://doi.org/10.1016/j.trd.2022.103311

Hart, C. (1998). Doing a Literature Review. https://doi.org/10.1007/BF00253969

Havranek, T., & Kokes, O. (2015). Income elasticity of gasoline demand: A meta-analysis. *Energy Economics*, *47*, 77–86. https://doi.org/10.1016/j.eneco.2014.11.004

Hayashi, K., Bentler, P. M., Yuan, K. (2007). Structural Equation Modeling. Handbook of Statistics, Vol. 27. DOI: 10.1016/S0169-7161(07)27013-0

Hensher, D. A. (1991). Electronic toll collection. *Transportation Research Part A: General, 25*(1), 9–16. https://doi.org/10.1016/0191-2607(91)90151-F

Hintermann, B., Schoeman, B., Molloy, J., Schatzmann, T., Tchervenkov, C., & Axhausen, K. W. (2023). The impact of COVID-19 on mobility choices in Switzerland. *Transportation Research Part A: Policy and Practice*, *169*, 103582, 1-24. https://doi.org/10.1016/j.tra.2023.103582

Holmgren, J. (2007). Meta-analysis of public transport demand. *Transportation Research Part A: Policy and Practice*, *41*(10), 1021–1035. https://doi.org/10.1016/j.tra.2007.06.003

Hrvatske autoceste. (n.d.). About us. Retrieved on February 1, 2019, from https://www.hac.hr/en/about-us

Hsiao, C. (2005). Invited eminent paper series, WHY PANEL DATA? *The Singapore Economic Review*, *50*(2), 143–154.

Hsiao, C. (2022). Analysis of Panel Data. Second Edition. In *Cambridge University Press*. https://doi.org/10.2307/2289407

Hughes, J. E., Knittel, C. R., & Sperling., D. (2006). Evidence of a Shift in the Short-Run Price Elasticity of Gasoline. *The Energy Journal, International Association for Energy Economics, 29*(1), 113–134. Retrieved from http://www.nber.org/papers/w12530

HUKA. (2012). National Report on Motorways 2011. http://www.huka.hr/

HUKA. (2014). National Report on Motorways 2013. http://www.huka.hr/

HUKA. (2016). National Report on Motorways 2015. http://www.huka.hr/

HUKA. (2018). National Report on Motorways 2017. http://www.huka.hr/

HUKA. (2020). National Report on Motorways 2019. http://www.huka.hr/

HUKA. (2023). National Report on Motorways 2022. http://www.huka.hr/

Hymel, K. M., & Small, K. A. (2015). The rebound effect for automobile travel: Asymmetric response to price changes and novel features of the 2000s. *Energy Economics*, *49*, 93–103. https://doi.org/10.1016/j.eneco.2014.12.016

Hymel, K. M., Small, K. A., & Dender, K. Van. (2010). Induced demand and rebound effects in road transport. *Transportation Research Part B: Methodological*, *44*(10), 1220–1241. https://doi.org/10.1016/j.trb.2010.02.007

Institut za turizam. (2020). TOMAS 2019 Stavovi i potrošnja turista u Hrvatskoj. Institut za turizam, Vrhovec 5, Zagreb.

Jelušić, A. (2017). Modelling tourist consumption to achieve economic growth and external balance: case of Croatia. Tourism and Hospitality Management, Vol. 23, No. 1, pp 87-104, https://doi.org/10.20867//thm.23.1.5

Jiwattanakulpaisarn, P., Noland, R. B., Graham, D. J., & Polak, J. W. (2009). Highway infrastructure investment and county employment growth: A dynamic panel regression analysis. *Journal of Regional Science*, *49*(2), 263–286. https://doi.org/10.1111/j.1467-9787.2008.00579.x

Jones, D. (2008). The Oxford Handbook of Organization Theory: Meta-Theoretical Perspectives. *Personnel Review*, Vol. 37, pp. 258–240. https://doi.org/10.1108/00483480810850560

Jou, R. C., Chiou, Y. C., Chen, K. H., & Tan, H. I. (2012). Freeway drivers' willingness-to-pay for a distance-based toll rate. *Transportation Research Part A: Policy and Practice*, *46*(3), 549–559. https://doi.org/10.1016/j.tra.2011.11.012

Kamolson, S. (2007). Fundamentals of quantitative research Suphat Sukamolson, Ph.D. Language Institute Chulalongkorn University. *Language Institute*, 20. Retrieved from http://www.culi.chula.ac.th/e-Journal/bod/Suphat Sukamolson.pdf%5Cnhttp://isites.harvard.edu/fs/docs/icb.topic1463827.files/2007_Sukamolson_Fundamentals of Quantitative Research.pdf

Kasim, H., & Antwi, S. K. (2015). Qualitative and Quantitative Research Paradigms in Business Research: A Philosophical Reflection. *European Journal of Business and ManagementOnline)*, *7*(3). Retrieved from www.iiste.org

Kelemen, M. L., & Rumens, N. (2008). American Pragmatism. *An Introduction to Critical Management Research*, pp. 39–52. https://doi.org/10.5840/newscholas196236331

Kelly, E., & McGuinness, S. (2015). Impact of the Great Recession on unemployed and NEET individuals' labour market transitions in Ireland. *Economic Systems*, *39*(1), 59–71. https://doi.org/10.1016/j.ecosys.2014.06.004

Kenton, W. (2020, November 30). Seasonality: What It Means in Business and Economics, Examples. https://www.investopedia.com/terms/s/seasonality.asp

Kožić, I. (2013). Kolika je sezonalnost turizma u Hrvatskoj? *Ekonomski Vjesnik*, *26*(2), 470–480. https://www.ceeol.com/search/article-detail?id=533052

Kuhn, T. S. (1970). The Structure of Scientific Revolutions. In *The Universitiy of Chicago* (Second edition).

Lake, M., & Ferreira, L. (2002). Modelling tolls: values of time and elasticities of demand: a summary of evidence. *Physical Infrastructure Centre Research Report 02-01*, (January), 1–28.

Leduc, G. (2008). Road Traffic Data : Collection Methods and Applications. *EUR Number: Technical Note: JRC 47967*, *JRC 47967*(January 2008), 55. Retrieved from http://ftp.jrc.es/EURdoc/EURdoc/JRC47967.TN.pdf

Lee, W. H., Tseng, S. S., & Wang, C. H. (2008). Design and implementation of electronic toll collection system based on vehicle positioning system techniques. *Computer Communications*, *31*(12), 2925–2933. https://doi.org/10.1016/j.comcom.2008.05.014

Lehtonen, E., Malin, F., Louw, T., Lee, Y. M., Itkonen, T., & Innamaa, S. (2022). Why would people want to travel more with automated cars? *Transportation Research Part F: Traffic Psychology and Behaviour, 89*(May), 143–154. https://doi.org/10.1016/j.trf.2022.06.014

Levinson, D., & Chang, E. (2003). A model for optimizing electronic toll collection systems. *Transportation Research Part A: Policy and Practice*, *37*(4), 293–314. https://doi.org/10.1016/S0965-8564(02)00017-4

Li, G., Song, H., & Witt, S. F. (2005). Recent Developments in Econometric Modeling and Forecasting. *Journal of Travel Research, 44(1)* 1–29. https://www.researchgate.net/publication/30930411_Recent_Developments_in_Econometric_Modeling_and_Forecasting

Litman, B. T. (2019). Socially Optimal Transport Prices and Markets Principles, Strategies and Impacts. Retrieved from www.vtpi.orgInfo@vtpi.org

Litman, T. (2013). Changing North American vehicle-travel price sensitivities: Implications for transport and energy policy. *Transport Policy*, *28*, 2–10. https://doi.org/10.1016/j.tranpol.2012.06.010

Litman, T. (2019). Understanding transport demands and elasticities. In *Victoria Transport Policy Institute*. Retrieved from https://www.vtpi.orgInfo@vtpi.org/

Llorca, C., Ji, J., Molloy, J., & Moeckel, R. (2018). The usage of location based big data and trip planning services for the estimation of a long-distance travel demand model. Predicting the impacts of a new high speed rail corridor. *Research in Transportation Economics*, 27–36. https://doi.org/10.1016/j.retrec.2018.06.004

Lodico, M. G., Spaulding, D. T., & Voegtle, K. H. (2008). Methods in Educational Research: From Theory to Practice. *Journal of MultiDisciplinary Evaluation*, *5*(9), 82–83.

Mack, L. (2010). The philosophical underpinnings of educational research. *Polyglossia*, *19*, 5–11. Retrieved from http://www.apu.ac.jp/rcaps/uploads/fckeditor/publications/polyglossia/Polyglossia_V19_Lindsay.pdf

Mack, N., Woodsong, C., MacQueen, K. M., Guest, G., & Namey, E. (2005). *Qualitative Research Methods: A Data Collector's Field Guide*. Family Health International.

Mansfield, E. R., & Helms, B. P. (1982). Detecting Multicollinearity. *The American Statistician*, *36*(3a), 158–160. https://doi.org/10.1080/00031305.1982.10482818

Marks, I. M., & Gelder, M. G. (1965). Policy Instruments. In *British Journal of Psychiatry* (2nd ed., Vol. 111). https://doi.org/10.1192/bjp.111.479.1009-a

Matajič, M., Jagrič, T., & Bekő, J. (2015). A differentiated tolls system – an effective transport policy tool for Slovenia? *Applied Economics*, *47*(21), 2201–2217. https://doi.org/10.1080/00036846.2015.1005818

Matas, A., & Raymond, J.-L. (2003). Demand Elasticity on Tolled Motorways. *Journal of Transportation and Statistics* 6 (2/3), 91-105. Retrieved from http://www.rita.dot.gov/bts/dictionary/list.xml?search=&letter=C&page=4

Matas, A., Raymond, J.-L., & Ruiz, A. (2012). *Traffic forecasts under uncertainty and capacity constraints*. 1–17. https://doi.org/10.1007/s11116-011-9325-1

May, A. D., & Milne, D. S. (2000). Effects of alternative road pricing systems on network performance. *Transportation Research Part A: Policy and Practice, 34*(6), 407–436. https://doi.org/10.1016/S0965-8564(99)00015-4

Mcmullen, B. S., & Eckstein, N. (2012). Relationship Between Vehicle Miles Traveled and Economic Activity. (2297), 21–28. https://doi.org/10.3141/2297-03

Mervar, A., & Payne, J. E. (2007). Analysis of foreign tourism demand for Croatian destinations: Long-run elasticity estimates. *Tourism Economics*, *13*(3), 407–420. https://doi.org/10.5367/000000007781497764

Metz, D. (2010). Saturation of demand for daily travel. *Transport Reviews, 30*(5), 659–674. https://doi.org/10.1080/01441640903556361

Millard-Ball, A., & Schipper, L. (2011). Are we reaching peak travel? Trends in passenger transport in eight industrialized countries. *Transport Reviews*, *31*(3), 357–378. https://doi.org/10.1080/01441647.2010.518291

Miller, M., & Alberini, A. (2016). Sensitivity of price elasticity of demand to aggregation, unobserved heterogeneity, price trends, and price endogeneity: Evidence from U.S. Data. *Energy Policy*, *97*, 235–249. https://doi.org/10.1016/j.enpol.2016.07.031

Ministarstvo mora, prometa i infrastrukture. (2020). Od 1. siječnja Autocesta Rijeka-Zagreb d.d. i Hrvatske autoceste d.o.o. postaju jedna trtka. Retrieved on December 4, 2020, from https://mmpi.gov.hr/vijesti-8/od-1-sijecnja-autocesta-rijeka-zagreb-d-d-i-hrvatske-autoceste-d-o-o-postaju-jedna-tvrtka/22476

Ministarstvo turizma Republike Hrvatske. (2023). Turizam U Brojkama 2022. 43. https://www.htz.hr/sites/default/files/2023-07/HTZ%20TUB%20HR_%202022.pdf

Montgomery, D. C., Peck, E. A., & G., V. G. (2012). *Introduction to Linear Regression Analysis* (5th Editio). John Wiley & Sons, Inc., Hoboken, New Jersey.

Musso, A., Piccioni, C., Tozzi, M., Godard, G., Lapeyre, A., & Papandreou, K. (2013). Road Transport Elasticity: How Fuel Price Changes can Affect Traffic Demand on a Toll Motorway. *Procedia - Social and Behavioral Sciences*, *87*, 85–102. https://doi.org/10.1016/j.sbspro.2013.10.596

Nicolau, J. L., & Más, F. J. (2006). The influence of distance and prices on the choice of tourist destinations: The moderating role of motivations. *Tourism Management*, *27*(5), 982–996. https://doi.org/10.1016/j.tourman.2005.09.009

Odeck, J., & Bråthen, S. (2008). Travel demand elasticities and users attitudes: A case study of Norwegian toll projects. *Transportation Research Part A: Policy and Practice*, *42*(1), 77–94. https://doi.org/10.1016/j.tra.2007.06.013

Odeck, J., & Johansen, K. (2016). Elasticities of fuel and traffic demand and the direct rebound effects: An econometric estimation in the case of Norway. *Transportation Research Part A: Policy and Practice*, *83*, 1–13. https://doi.org/10.1016/j.tra.2015.10.003

Oltmann, C., & Boughey, C. (2012). Using critical realism as a framework in pharmacy education and social pharmacy research. *Research in Social and Administrative Pharmacy, 8*(4), 333–337. https://doi.org/10.1016/j.sapharm.2011.07.005

Ortúzar, J. de D., & Willumsen, L. G. (2011). Modelling Transport. In *Modelling Transport* (4th Editio). https://doi.org/10.1002/9781119993308

Oum, T. H. (1989). Alternative demand models and their elasticity estimates. *Journal of Transport Economics and Policy, 163 - 187*. https://www.jstor.org/stable/20052880

Oum, T. H., Waters, W. G., & Yong, J.-S. (1992). Concepts of Price Elasticities Of Transport Demand and Recent Emperical Estimates. *Journal of Transport Economics and Policy*, 139–154. https://www.jstor.org/stable/20052976

Park, M. H. (2011). Practical Guides To Panel Data Modeling: A Step by Step. *Public Management and Public Analysis Program*, 1–53.

Paulley, N., Balcombe, R., Mackett, R., et al. (5 more authors). (2006). The demand for public transport: The effects of fares, quality of service, income and car ownership. *Transport Policy*, *13*(4), 295–306. https://doi.org/10.1016/j.tranpol.2005.12.004

Peng, B., Song, H., Crouch, G. I., & Witt, S. F. (2015). A Meta-Analysis of International Tourism Demand Elasticities. *Journal of Travel Research*, *54*(5), 611–633. https://doi.org/10.1177/0047287514528283

Peters, J. R., & Kramer, J. K. (2005). Seasonal Variation in the Environmental Effects of Toll Collection: Evidence from the Garden State Parkway. *Public Works Management & Policy*, *9*(4), 287–291. https://doi.org/10.1177/1087724X05274792

Pham, H. S. T., & Tran, H. T. (2020). CSR disclosure and firm performance: The mediating role of corporate reputation and moderating role of CEO integrity. *Journal of Business Research*, *120*(August), 127–136. https://doi.org/10.1016/j.jbusres.2020.08.002

Pigou, M. A. (1929). The Economics of Welfare (3rd Edition). Edinburg: MacMillan and Co., London.

Pratt, M. G. (2008). Fitting oval pegs into round holes: Tensions in evaluating and publishing qualitative research in top-tier North American journals. In *Organizational Research Methods* (Vol. 11). https://doi.org/10.1177/1094428107303349

Pravilnik o cestarini NN 130/2013. Pravilnik o cestarini. *Ministarsto pomorstva, prometa i* *infrastrukture*. https://narodne-novine.nn.hr/clanci/sluzbeni/2013_10_130_2833.html

Pravilnik o cestarini NN 122/2014. Pravilnik o izmjeni pravilnika o cestarini. *Ministarstvo pomorstva, prometa i infrastrukture*. https://narodne-novine.nn.hr/clanci/sluzbeni/2014_10_122_2342.html

Pravilnik o cestarini NN 96/2017. Pravilnik o izmjeni pravilnika o cestarini. *Ministarstvo mora, prometa i infrastrukture*. https://narodne-novine.nn.hr/clanci/sluzbeni/2017_09_96_2218.html

Pravilnik o cestarini NN 151/2022. Pravilnik o izmjenama i dopunama pravilnika o cestarini. *Ministarstvo mora, prometa i infrastrukture*. https://narodne-novine.nn.hr/clanci/sluzbeni/2022_12_151_2360.html

Romero-Jordán, D., del Río, P., Jorge-García, M., & Burguillo, M. (2010). Price and income elasticities of demand for passenger transport fuels in Spain. Implications for public policies. *Energy Policy*, *38*(8), 3898–3909. https://doi.org/10.1016/j.enpol.2010.03.010

Roodman, D. (2009). *PRACTITIONERS ' CORNER A Note on the Theme of Too Many Instruments Å*. *1*, 135–158. https://doi.org/10.1111/j.1468-0084.2008.00542.x

Sánchez, J. G. (2016). *Determining Explanatory Factors for Road Demand in Interurban Toll Roads : an Asserted Approach*. 206.

Santos, G. (2004). Road pricing. In *De Economist* (Vol. 9). https://doi.org/10.1007/BF02367282

Saunders, M., Lewis, P., & Thornhill, A. (2009). Understanding research philosophies and approaches to theory development, 122–161. https://www.researchgate.net/publication/309102603_Understanding_research_philosophies_and_approaches

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). Chapter 4: Understanding research philosophy and approaches to theory development. In *Research Methods for Business Studies (eight edition)* (8th Edition). https://www.researchgate.net/publication/330760964_Research_Methods_for_Business_Students_Chapter_4_Understanding_research_philosophy_and_approaches_to_theory_development

Schafer, A. (2000). Regularities in travel demand: an international perspective. *Journal of Transportation and Statistics*, *3*(3). https://doi.org/10.21949/1501657

Seetaram, N., Forsyth, P., & Dwyer, L. (2016). Measuring price elasticities of demand for outbound tourism using competitiveness indices. *Annals of Tourism Research*, *56*, 65–79. https://doi.org/10.1016/j.annals.2015.10.004

Shajahan, D. S. (2000). *Research Methods For Management*. http://books.google.com/books?id=6x6MAAAACAAJ&pgis=1

Sheffet, O. (2019). Differentially Private Ordinary Least Squares. *Journal of Privacy and Confidentiality*, *9*(1 Special Issue). https://doi.org/10.29012/jpc.654

Small, K. A., & Van Dender, K. (2018). Fuel efficiency and motor vehicle travel: The declining rebound effect. In *Controlling Automobile Air Pollution* (Vol. 28, pp. 421–

447). https://doi.org/10.4324/9781351161084-22

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*(July), 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Song, H., & Li, G. (2008). Tourism Demand Modelling and Forecasting A Review of Recent Research. 1–28.

Škrinjarić, T. (2011). Istraživanje inozemne turističke potražnje u Hrvatskoj primjenom analize panel podataka. *Acta turistica,* 145–173.

Tica, J., & Kožić, I. (2015). Forecasting Croatian inbound tourism demand. *Economic research-Ekonomska istraživanja, 28(1),* 1046–1062. http://dx.doi.org/10.1080/1331677X.2015.1100842

van Dender, K., & Clever, M. (2013). Recent Trends in Car Usage in Advanced Economies–Slower Growth Ahead?: Summary and Conclusions. *International Transport Forum Discussion Papers*, (2013/9). https://doi:10.1787/5k46n4121k5d-en

Wahyuni, D. (2012). The research design maze: Understanding paradigms, cases, methods and methologies. *Journal of applied management accounting research,* 10(1), 69-80.

Wang, T., & Chen, C. (2014). Impact of fuel price on vehicle miles traveled (VMT): do the poor respond in the same way as the rich? 91–105. https://doi.org/10.1007/s11116-013-9478-1

Wardman, M. (1988). A COMPARISON OF REVEALED PREFERENCE AND STATED PREFERENCE MODELS OF TRAVEL BEHAVIOUR. *Journal of Transport Economics and Policy*, *22*(1), 71–91. https://www.jstor.org/stable/20052836

Wardman, M., Chintakayala, V. P. K., & de Jong, G. (2016). Values of travel time in Europe: Review and meta-analysis. *Transportation Research Part A: Policy and Practice*, *94*, 93–111. https://doi.org/10.1016/j.tra.2016.08.019

Waters, D. (2011). Quantitative Methods for Business. In *Quantitative Methods for Business* (5th Edition). https://doi.org/10.4324/9780080474069

Wei, X., Wu, X., & Zhou, X. (2020). A self-control theory perspective on tourists' short-vacation preference: empirical evidence from China. *Asia Pacific Journal of Tourism Research, 25*(5), 560–573. https://doi.org/10.1080/10941665.2020.1742754

Wohlgemuth, N. (1997). World transport energy demand modelling. *Energy Policy*, *25*(14–15), 1109–1119. https://doi.org/10.1016/s0301-4215(97)00103-1

Wooldridge, J. M. (2010). Econometric Analysis of Cross Section and Panel data (2th Edition). MIT Press.

Wooldridge, J. M. (2012). Introductory Econometrics: A modern approach (5th Edition). In *Introductory Econometrics*. https://doi.org/10.4324/9780203157688

World Bank. (n.d.). Data. Retrieved March 13, 2021, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2019&start=1960

Xie, L., & Olszewski, P. (2011). Modelling the effects of road pricing on traffic using ERP traffic data. *Transportation Research Part A: Policy and Practice*, *45*(6), 512–522. https://doi.org/10.1016/j.tra.2011.03.006

Yang, D., & Timmermans, H. (2012). Effects of Fuel Price Fluctuation on Individual CO 2 Traffic Emissions : Empirical Findings from Pseudo Panel Data. *54*, 493–502. https://doi.org/10.1016/j.sbspro.2012.09.767

Zamparini, L., & Reggiani, A. (2007). Freight transport and the value of travel time savings: A meta-analysis of empirical studies. *Transport Reviews*, *27*(5), 621–636. https://doi.org/10.1080/01441640701322834

LIST OF TABLES

LIST OF FIGURES

APPENDIX

Factors influencing motorway traffic demand in Croatia

Ethics Review ID: ER24620014

Workflow Status: Application Approved

Type of Ethics Review Template: No human participants, human tissue or personal data

Primary Researcher / Principal Investigator

Valentino Jaksic
(Sheffield Business School)

Converis Project Application:

Q1. Is this project ii) Doctoral research

Director of Studies

Song Hanh Pham
(Sheffield Business School)

Supervisory Team

Jia Liu
(Department of Finance, Accounting and Business Systems)