TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Industrial Engineering and Management

THE ECONOMIC AND SOCIETAL BENEFIT OF 5G TELEOPERATED VEHICLES IN THE TRANSPORT AND LOGISTIC INDUSTRY: ANALYSIS OF ITS BENEFIT AND RISK

5G KAUGJUHTIMISEGA SÕIDUKITE MAJANDUSLIK JA ÜHISKONDLIK KASU TRANSPORDI- JA LOGISTIKATÖÖSTUSES: SELLE EELISTE JA RISKIDE ANALÜÜS

MASTER THESIS

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THESIS TASK

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Study programme: MARM06/18 Industrial Engineering and Management

main specialty: Industrial Engineering and Management

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Thesis topic:

(In English) The Economic and Societal benefits of 5G teleoperated vehicles in the transport and logistic industry: Analysis of its benefits and risk

(In Estonian) 5G kaugjuhtimisega sõidukite majanduslik ja ühiskondlik kasu transpordi- ja logistikatööstuses: selle eeliste ja riskide analüüs

Thesis main objectives:

1. To empirically enumerate and elucidate the benefits and risks of 5G teleoperated vehicles to business, government, and the society at large in the EU
2. To find if 5G teleoperated vehicles have significant short-run and long-run impact in terms of risk and benefit economically and societally;
3. To provide recommendations necessary for successful deployment and acceptance of 5G teleoperated vehicles for economic advancement and societal improvement.

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List of abbreviations and symbols

5Ge-TWS	5G-enabled teleoperation workstation
AI	Artificial intelligence
ANOVA	Analysis of Variance
ATM	Automated teller machines
AV	Autonomous Vehicles
BLUE	Best linear unbiased estimators
CAQDA	Computer-aided qualitative data analysis
DARPA	Defense Advanced Projects Agency
DV	Driverless vehicle
EDUTECH	Education technologies
EPC	Evolved Packet Core
ERP	Enterprise resource platform
EU	European Union
EV	Electric vehicle
FSD	Full self-driving
GDP	Gross Domestic Product
GPRS	General Packet Radio Service
HCCNS	High computing cellular network system

HCMN	High computing mobile network
HDI	Human Development Index
ICT	Information and communication technologies
IP	Internet Protocol
ISO	the International Organization for Standardization
ITRL	Integrated Transport Research Lab
ITS	Intelligent transport system
LTE	Long term evolution
MIMO	Many-input-many-output
MLR	Multiple Linear Regression
MM	Mixed method
MRM	Minimum risk maneuver
ODD	Operational Design Domain
OECD	Organization for Economic Corporation and Development
POS	Point of sales
PPP	Public-private partnership
RC	Robotic consulting
ROC	Remote Operation Centre
ROC-GW	ROC-gateway
SA	Standard Autopilot

SDT	Statistical Decision Theory
SLR	Simple Linear Regression
SMS	Short message service
SMSE	Small and medium scale enterprises
SoE	Severity of Exposure
TAC	Total annual cost
TALI	Transport and logistics Industry
TAR	Total annual revenue
TOT GDP	Total Transport Gross Domestic Product
TSD	Time series data
UAT	Users Acceptance Test
UX	User experience
VMT	Vehicle mile per travel

ABSTRACT

The study investigated the economic and societal impacts of 5G teleoperated vehicles (5G-ToV) in the Estonian transport and logistics industry. The mixed method research design was used to quantitatively analyze time series data and qualitatively extract the story behind the data. The simple regression (SLR) model was used to evaluate the individual linear relationship between 5G-ToV and variables that account for economic and societal benefits in Estonian TALI. The qualitative results showed that network capacity, investment outlay, consumer protection and other autonomous variables bore positive and empirically significant relationship with investment in 5G-ToV. It was also found out that lack of global 5G teleoperation framework could forestall acceptance and rapid deployment of the transport solution. Apart from this, 5G-ToV will drive economic, employment, and increase cross-border relationship in Estonia.

Keywords: **Teleoperation; Framework; Cross-border, 5G, Benefit; Risk**

CHAPTER ONE

1 INTRODUCTION

The European Union has cleared every doubt that the region was in any way behind in the implementation of technological innovations that can revolutionize its economy. It has immediately, not just seen the need for tech transformation in its logistic and transport industry but has gone into a twenty-nine-member agreement to power vehicles of all classes with the latest 5G technology to further strengthen human and other material haulage within any of the member state and across borders [1]. Little wonder then what the 5G technology does and what is described [1], [2].

The 5G technology is the fifth (5^{th}) generation of cellular or mobile technology that has been designed and calibrated for efficiency and high performance that has never been achieved in digital communication systems. Simply described, 5G means "5^{th} Generation". The first generation of cellular communication network technology could only guarantee voice calls in analog, which is an antique, no short message service (SMS) and no GPRS capability for browsing internet of things (IoT) for information [3]. Meanwhile, the last generation, 4G, rolled out about a decade ago had achieved so much that the world thought and described it as amazing, especially with its long-term evolution (LTE) variant. The 4^{th} generation transformed mobile data browsing with tremendous speed, it is nothing compared to what the 5G technology can do [1], [3]– [5]. This includes digital transformation of governance - in electoral systems, vendor and contract management, enterprise resource platform (ERP) – transportation and logistics – real time fleet management, instant haulage re-routing, provision of immediate weather condition data, platooning of trucks and ships with vehicle-to-everything (V2X) communications functionality that helps to maintain a fixed gap between them – in policing, security and surveillance services, agriculture extension robotic consulting (RC), and several others.

This study pinpointed the economic and societal impact that this high-performance technology could have to forestall any possible loss of benefit coverage and risk severity in the transport and logistics industry within the European Union, of which Estonia is an invested member [5]. [5] describes teleoperation is the systemic operation of an object or a fleet of objects, which could include vehicles, ships, and aircraft with respect to the transport and logistics industry, remotely from a control Centre, physically domiciled at a station or deployed on a cloud system but driven by an artificial intelligence (AI) [5]. So teleoperated vehicles (ToV) are key designs for intelligent transport systems (ITS) [4], [6] as the world experiences major transformation across all spectra that require speed and orderliness that human capabilities cannot directly offer. This technology is beginning to gain prominence after 125 years when the first vehicle was launched [7]. It is now powered by 5G mobile network technology, though grossly trailed by socio-cultural rejection and misinformation since its release and deployment in 2019 [4], [6]. Therefore, relevant governmental agencies, R & D of technology giants in ToV cum all engineering and economics unit of academic ivory towers, especially, have tasked themselves to best understand how to prepare for a future of robotics driven by advanced and a high computing cellular network system (HCCNS) like 5G.

The world over has seen, since the beginning of the industrial revolution, especially the 4th industrial revolution (4IR), fast and overwhelming innovations in information and communication technologies (ICT). Traditional schools have turned to education technologies (EDUTECH) for efficiency, communication has been sped up to improve business-to-business (B2B), customer-to-business (C2B) and government-to-business (G2B) interplay [6], [8]. Investment in financial technologies like Finacle 10x, SWIFT, Apple Pay, automated teller machines (ATM), point of sales (POS) machines, payment gateways have increased over the last three decades leading to multibillion dollars transactions [8], [9]. This research sought to measure the impact 5G powered ToV would have economically and socio-culturally. To make this main objective much clearer, the next subsection presents background to this study.

1.1 BACKGROUND

In 1925, the Houdina Radio Control Company actualized and present the first modern day driverless car, after history has it that Leonardo De Vinci actually conceived this idea many centuries before this feat [10]. Leonardo De Vinci, possibly convinced that the human brain should not be preoccupied with gears and steering wheels, created a blueprint for a self-driven or self-propelled cart, deployed a coiled upset of springs for propulsion [11]. This is evidence that the human brains can produce infinitesimal and unimaginable grandeur of innovations if less preoccupied and distracted by their past achievements. So, filled with similar concerns, the Houdina Radio Control Company launched a driverless "1926 Chandler", driving it through traffic in Broadway and Fifth Avenue with remote control signal sent from another car driven close enough for communication [11]. After this, several other automobile companies, like the Achen Motor, created driverless vehicles like the "Phantom Auto", which was not exactly teleoperated because it had to be controlled by a human from a distance. This then just served as mere comedy or entertainment through 20's and 30's as the car was showcased from city to city. The Defense Advanced Projects Agency (DARPA) held its first challenge in 2004 to kick-start demonstrations of ToV. Also, Tesla cars possess features of autopilot, but it is not guaranteed of full functionalities for driverless driving. It has what is referred to as "Standard Autopilot (SA) and Full self-driving (FSD)" with the latter providing limited So, this act left a generationally inerasable perception problem in the minds of government administrators and the society at large about the usefulness of driverless vehicles to drive prosperity in a teeming world population, which later became teleoperated through various generations of cellular network technology, including 4G LTE and now, 5G. This is a major sociocultural challenge creating acceptance problems among prospective investors and consumers. This research measures the impact of this and such challenges on the economy and on the society in Europe within the transport and logistics industry.

Transport and logistics are a twin or a two-edged sword that must cut equally deep from both ends into contribution throughput of every proactive economy that is powered by process automation [12]. This agreed with [13], whose 6-level classification of automated solutions to transport and logistics (TALI) could be a benchmark for every economy size. The study recognizes six levels of driving automation, with the lowest presented first, in relation to ODD.

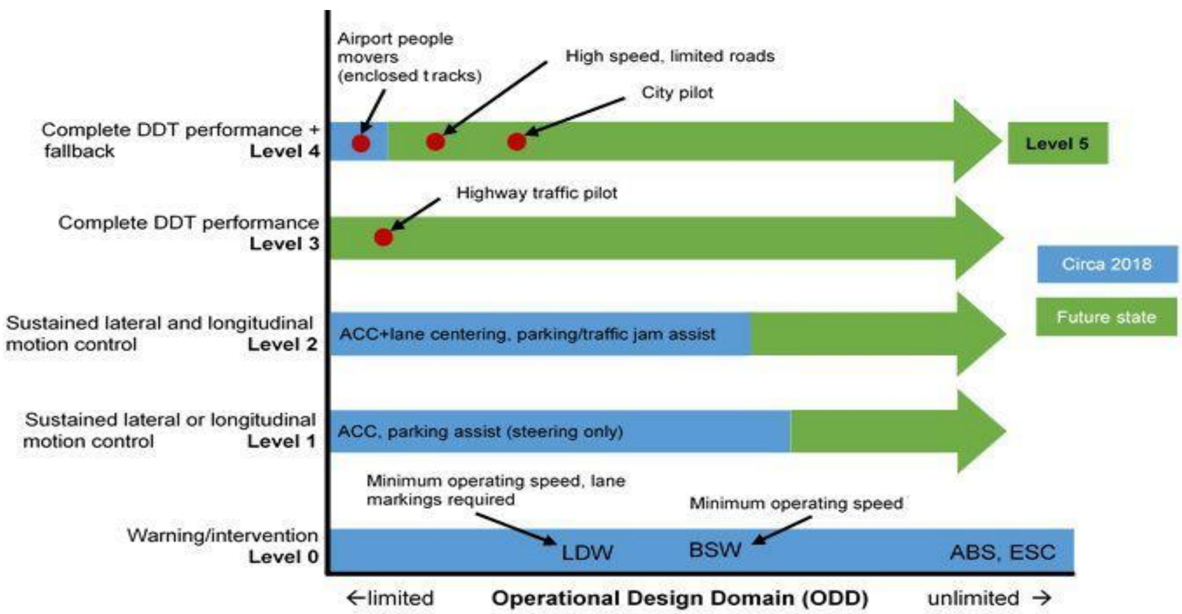


Figure 1: Relativity of ODD Orthogonality to Driving Automation Levels [13]

The levels involved in driving automation will determine the dynamic driving task (DDT) and the operational design domain (ODD) that will be built into the system. These determinants would in turn determine not just other technological requirements, but also business indicators such as revenue, risk, personnel engagement, and others. The six levels of driving automation as are:

1. No Driving Automation
2. Driver Assistance
3. Partial Driving Automation
4. Conditional Driving Automation
5. High Driving Automation
6. Full Driving Automation.

Each level implies intuitively that DDT, ODD and other support requirements will be determined by the level of automation a vehicle requires. Therefore, a sophisticated and developed country and region like Estonia and Europe respectively would rather operate, at minimum, from level 3, conditional driving automation to overcome its transport and logistics challenges.

Today, even micro cities and towns, which are experiencing urbanization but occupy narrower land space are plagued with transport and logistics challenges [12], [14], [15]. Such challenges include traffic congestion, automobile accidents and fleet mismanagement, break in fleet platooning, inability to monitor vehicular latency, and several others. On the other hand, the contribution of transport and logistics range from connecting good and services with buyers -whether at production or consumption stage -, increased employment for both skilled and unskilled labor thereby dropping crime rate to increasing the value of gross domestic product (GDP) in the society as the jobs increase, among several others. Currently, the world population is becoming explosive [14], [16]. This explosive has increased the count of megacities in the world. The United Nation defines a megacity as a city with population of 10 million people and above [17]. In the 1950s, London was the only country classified as a megacity with a population above 5 million. Now, there are 37 cities of the world with more than 10 million humans, with world population now put at approximately 8 billion people [14], [16]. London and Paris made the list from several cities in 42 European countries [17]. This simply means that most European cities are under the

10 million marks of the United Nation's definition of a megacity. This does not point off the possibility of the existence of similar challenges peculiar to megacities in Europe.

No doubts, better oversight, and faster speed for quicker delivery of goods and services are some of the criteria for future cities. Therefore, the robustness of these cities is considered to depend on the right network technology architecture that can produce efficient synchronization with teleoperated vehicles. This will mean setting a standard and x-raying device specifications required for the desired outcome, while juxtaposing it with what is obtainable as use cases of ToV today. 5G network technology is relatively new and the procedure of deployment and use cases would require ethical thorough considerations, socio-cultural stakeholders' management, and transparent orientation. This will go a long way to reduce or eliminate unfounded reasons for skepticism around acceptance and adoption. These are several other questions that need to be answered for 5G teleoperated vehicle implementation to make a meaningful impact in the transport and logistics industry. This is what this research is out to proffer 0a solution. The next subsection presents the main and sub-objectives that will be empirically pursued on this investigation.

1.2 RESEARCH OBJECTIVES

The main objective of this study is to determine the economic and societal impact of 5G teleoperated vehicles, in terms of its benefits and risks to businesses and the communities where they are deployed. To achieve this main objective, the following sub-objectives were pursued:

1. To empirically enumerate and elucidate the benefits and risks of 5G teleoperated vehicles to business, government, and the society at large in the EU.
2. To find if 5G teleoperated vehicles have significant short-run and long-run impact in terms of risk and benefit economically and societally.

3. To provide recommendations necessary for successful deployment and acceptance of 5G teleoperated vehicles for economic advancement and societal improvement.

These objectives will be pursued during the study using research questions.

1.3 RESEARCH QUESTIONS

The following are the research questions that were answered during this study:

1. What are the current states of 5G ToV and what response should the transport and logistics industry in Europe have towards its implementation?
2. What are the economic and societal benefits and risks of implementing 5G ToV in Europe, and how can we build on the benefits and mitigate the risks respectively?
3. What are the societal and technical limitations of 5G ToV in the transport and logistics industry and how can they affect acceptance and deployment respectively?

1.4 RESEARCH SIGNIFICANCE

The future of the transport and logistics industry is hanging in the balance, between the right technology and the business environment that will finance, support, regulate and accept it for consumption. The European Union, simply referred to as the Union, set directives such as the "(EU) 2019/ 534 - of 26 March 2019" [18]. There, the Union, not only expressed concerns around adoption of the 5G network technology, sought to provide balance between the benefit and risk of adopting and deploying 5G network technology. The infrastructure of value-added services such as in transport and logistics industry will have to connect to the 5G network to make driverless vehicles truly teleoperated and autonomous [15], [19]. Also, the decision on the part of ToV companies, like Tesla, on which devices to install on the vehicles to optimize the 5G network capacity of multiple-inputs-multiple-output systems from one to a large fleet function [1], [20].

This is unique research work because it focuses on Europe, where a lot has already been done on 5G network technology and electric cars but not much has been done on teleoperated vehicles powered by 5G networks. This research is significant to pinpointing the overall benefits and risks of 5G ToV in the transport and logistics industry. For example, the last set of empirical research on ToV was fragmented and centered on devices that would be required for different parts of the vehicle. They never looked at the socio-economic benefits and risks of ToV. This research is significant because it contains a blend of technical and socio-economic outlook on a region as important and as developed as the European Union. The coverage of research is across 42 European countries, apart from the 29 that signed to adopt 5G network architecture across border [1], [5], [15].

1.5 RESEARCH METHODOLOGY

The research will adopt a mixed method (MM) research design to evaluate the economic and societal impact of 5G teleoperated vehicles on the transport and logistics industry. This is necessary because 5G network was just birthed about four years ago and there is not enough secondary data to correctly establish the authenticity of the claim. The prior significant impact exists at that level across the variables. MM allows for qualitative and quantitative data analysis to be used to draw factual and scientific conclusions side-by-side [21]– [23]. MM exhausts all options for data collection, data redesign, process re-engineering, and data analysis that are to arrive at a holistic and scientific conclusion necessary for policy recommendations that can be trusted [23], [24]. It also creates new information and data to enhance scanty information on the variables being investigated.

Qualitative data analysis will in-depth interview questions (IdIQ) to authenticate the story behind the data from specialists in 5G network and teleoperated transport and logistics industry within the European Union, especially Estonia. The raw date from IdIQ will use the Atlas.ti relational experiment to codify and intelligently compare interviewees' responses to draw a conclusion. By the way, Atlas.ti is a computer-aided qualitative data analysis

(CAQDA) software that has been acclaimed as the best across board [22]. The sample in the interview will be educated and experienced experts in 5G network and ToV. The sampling methods will be judgement sampling method, which is based on some predetermined matrix of requirements. Meanwhile, quantitative data analysis will use a multiple regression model to express a multivariate function, possibly a set of double simultaneous equations to find the value of adjusted R-squared and statistical coefficients in risk and logistics regression set up. Modern tool of quantitative data analysis, STATA, will be used for the analysis. Results will be presented in descriptive statistics and clearly interpreted to capture the minds of even the simple. This research method, MM, adopted here will be based on empirical and historic success in previous similar research like [15], [25], [26]. Details of the estimation method are discussed in chapter three of this study.

CHAPTER TWO

2 LITERATURE REVIEW

This section of the research explores empirical findings of other authors across the world of teleoperated vehicles and the few in and around 5G cellular or network technology. It also covers presentations and reviews theories that are relevant to the socio-economic benefits and risks of teleoperated vehicles (ToV) in Europe and or other similar regions in terms of development and technical know-how to accommodate it in the transport and logistics industry.

2.1 THEORETICAL LITERATURE REVIEW

This section presents a theory around the evolution of the transport and logistics industry and the emergence of technology as an engine room to take the industry to an unprecedented high since the industrial revolution. In particular, the Statistical Decision Theory was dissected to provide clarity around the relationship between technology and the transport and logistics industry.

2.1.1 The Statistical Decision Theory (SDT)

The statistical decision theory (SDT) was propounded and advanced by Professor Abraham Wald in his book titled, "Statistical Decision Function" in 1951 [27]. SDT is a good fit for the transport and logistics industry because it is a theory that defines uncertainties that are resolvable with a system of complex numbers of models. In transportation, there are three major levels of uncertainties, namely, demand, technical know-how and goals [27]– [29]. Because there are uncertainties in the economic and social future around which the transport and logistics industry is built, SDT proposes a payoff matrix system to predict the optimal course of action and outcome match. SDT is also built on the premise that a sector like transport and logistics would, soon, be faced with a continually evolving technological supply and demand respectively, there is a need to determine a specific course of action. This may mean determining the optimal benefits and risks of 5G network teleoperated vehicles economically and to society [28].

To achieve this on a payoff matrix table, all alternatives benefits and risks to 5G-ToV are listed, and the corresponding uncertainties are listed. Next, we determine by calculating the utility or level of desirability of a choice and an alternative, called "actions and states". This utility value could be total annual revenue (TAR), total annual cost (TAC), Severity of Exposure (SoE) in billion Euros per annual, and other kinds of desirable actions and states, irrespective of which side of the divide, benefits, or risks [4], [6], [22], [27].

This theory establishes indirectly that 5G technology is a useful uncertainty to transport and logistics industry, whose benefits are risks are calculable once alternative to 5G ToV can be articulated and regressed against the main item, 5G ToV. It can help determine courses of actions on national or regional acquisitions plans, distribution and disposition, and sustenance, maintenance or upgrade of the transport and logistics assets [10], [11], [15], [23].

This theory has some limitations. One such is the lack of consideration on time taken for decision to be taken on the implementation of a decision [27], [30]. In the transport and logistics industry, the lower the latency of communication of the 5G network interaction to teleoperated vehicle the better for consumers and the economy generally [4]– [6], [15]. This is a benefit that is in high demand within the industry, especially for the deployment of ToV [7], [10], [31], [32]. Also, the calculations on the payoff matrix table are straightforward, but in practice, it is a lot more complicated. So, there are a few simplifications of realities that could constitute genuine challenges to the deployment of 5G teleoperated vehicles in the real world. When these come in competition against the complexities of human brains, the results could lead to some unfathomed fatalities and realization of incalculable risks within the social environment [33].

2.2 EMPIRICAL LITERATURE REVIEW

These are extractions of ideas and findings from contemporary but relevant literatures that speak to the benefits and the risks of a 5G network powered teleoperated transport and logistics industry in Europe. These ideas, investigations, methods, and findings were juxtaposed to draw a conclusion that it is worth launching an empirical investigation into the economic and societal impacts of 5G teleoperated vehicles in the transport and logistics industry.

2.2.1 General overview and history of the Transport and Logistics Industry

The European Union, hereafter referred to as the Union, possesses one of the most diverse transport and logistics industries with well above 50 land borders for conveyance of goods and passengers by air, road, sea, and railway [28]. [34], attributed the current enviable status of the European transport and logistics industry to the quality infrastructural facilities in each member nation. Humans have always been traversing all land, sea, and air for a long time now from the use of simple paddled canoes to spaceships that are run on sophisticated engines and wireless network technologies [11]. When horses and wheeled vehicles moved from military exclusives and became domesticated, the world was amazed at the amount of horsepower a nation or a family possessed to enhanced movement of goods and man, besides using them in battles.

In 1769, the need for speed and reduced latency of messages and transfer of supplies led to the invention of the "Watt Steam Engine", and by 1783, 'Claude de Jouffroy' had built the world's first steamship called the "Pyroscaphe" [11], [15], [28]. Despite the shockwave this invention sent to the world of transportation and logistics, venture capitalists and other forms of investors did not have a lot of interest in releasing money to fund further development. This is indicative of the fact that social and economic apathy has been around for a while when it comes to introduction of new technologies, not just the 5G network-powered teleoperated vehicles. To break the ice from Europe, France's 'Nicolas Joseph Cugnot', adapted the steam engine technology to a road vehicle, which resulted into the invention of the first automobile in 1769. There, vehicles on one hand and the variable engines on the other hand, interacting or communicating electromechanically. This set the stage for a series of other inventions and innovations in the transport and logistics industry the world over [29]. These included the Locomotive in 1801-1814, Locomotive Rail in 1824, Peral 1888 – electric battery-powered Spanish Navy submarine, the Wright brother's aircraft of 1903, French Cornu helicopter of 1907, and the 1957 Soviet Union Sputnik spacecraft.

These mind-blowing evolution of vehicles and transport or communication engines have revolutionized human thinking that so many things can be done better and better if the clarity of benefits are there, and we can remove, or at least reduce, the risks associated with them [35]. A sustainable transport and logistics industry is now the focal point for the Union. The priority is on the safety of communication channels across member nations, especially the twenty-nine (29) that have signed up to cross border transport and logistics benefits using the 5G network. Also, the EU has documented several directives on the architecture and procedures of every member nation must have to anticipate and prevent cyber-security breaches, internally and externally. This leads the study to break down the EU directives on 5G network technology around the risks and benefits that can be anticipated when it is fully adapted for teleoperation of driverless vehicles over considerable distance, enough to generate commercial values [4], [6].

2.3 EU DIRECTIVES

The European Union, the Union, has released several directives to member states who are to sign the cross-border agreement for 5G network on transport and logistics to be truly teleoperated [1], [18]. In summary, these directives cover several areas, which are:

1. 5G Network Architecture and ToV Infrastructural Security
2. Protection of Economic Sovereignty of the European Union
3. Public Trust and Data Security

2.3.1 Protection of Economic Sovereignty of the European Union

In terms of economics of 5G and teleoperated transport and logistics in the Union, the following directives were:

- Foreign investment in 5G Technology and in the transport infrastructure to be discouraged or closely supervised to reduce exposure to risk & maintain EU sovereignty.
- Confidentiality of use
- Screening of Federal Direct Investment on 5G technology and the terms of engagement, investment, and access

The Union requires that all foreign investments from countries who are not allies, militarily, in trade, and others, should be discouraged to prevent possible takeover or compromise of national and transnational intelligence It also directed that confidentiality use of information must cut across organizations and individuals within the organizations, private or public. Now, if foreign direct investment must happen, the third nation must be screened and monitored aggressively.

2.3.2 Public Trust and Data Security

The Union directed that, if society must accept the technology such that invested funds do not go to waste due to lack of public trust and socio-cultural 5G Network technology apathy. So, individual information, such as registered bank and log-in credentials, must be protected. Technically and organizationally, public trust must be maintained using the same standards trans-nationally [1], [28]. Also, relevant, and competent regulatory authorities must be set up and integrated across borders to make and enforce policies that will protect the interest of consumers.

2.4 OVERVIEW OF 5G TECHNOLOGY AND ITS POTENTIAL IMPACT ON THE TRANSPORT AND LOGISTICS INDUSTRY

Telepresence is summarized as the ability of an object or a supernatural being to be capable of hearing, vision, and touch without being physically impacted to a move into any of those senses [36]. In metaphysics, this process is called telekinetic, more like a psychic operation. But in teleoperation, where interactions between software and hardware take place without deployed into the same panel of a considerably long distance, cellular network technologies have proven to be the useful wizards behind everything better than other means [37]. 5G does not have a specific creator or inventor, but advancement in the previous generation of its lots [20]. It was formally launched in 2019 with outstanding features such as small cells and increased speed at 39GHz, many-input-many-output (MIMO) device interaction, reduced communication latency, and reduced power required [32], [37].

5G network communication technology also means a lot to other sectors other than transport and logistics. These include improved educational technology, research and development in medicine and pharmacology, military defense, security and policing, explosive advantages in small and medium scale enterprises (SMSE), entertainment and several others [6]. 5G mobile telecommunication network is estimated to make virtualization and interoperability of software and hardware to become seamless, even when an AI is housed away within a cloud computing system to direct the entire operation [26], [38] Road infrastructures and vehicular designs are not going to be business as usual. As it happened with the steam engine storm the world that gave birth to the first steamship, the first locomotive vehicle, and other firsts, thereby transforming the transport and logistics industry, 5G will revolutionize all sectors that have linkages to mobility [33]. This will also mean better value to the more advanced electric vehicle (EV) operators as they can sell also on low emission, low latency, shared and increased mobility corridor, and more smart jobs for younger generation of every country's population, especially in Europe.

In the transport and logistics industry, the 5G network technology will enhance digital transformation of the supply chain and distribution mechanisms that are scattered across thousands of enterprise resource platforms (ERP) today. The government 5G transport and logistics architecture will be an enviably cheap first choice for a LEAN organization [15], [25]. 5G will be an important enabler of artificial intelligence (AI) systems because it will deliver real-time data assemblage and exploration. At the same time, it will bring the cloud system to a new height by activating the distribution of computing and storage, such as edge cloud and mobile edge computing, across the entire spectrum of the infrastructure [1], [26]. With the existence of the early 5G public-private partnership (PPP) agreement signed by the EU, a country like Estonia can gain access to training materials, funds, architectural designs for a smart road, and other advantages that it offers, in other to prepare for the transport and logistics industry of the future [1]. Society will benefit as teleoperated globalization does not give room for selective development. Rural or semi-urban areas would enjoy deployment of teleoperated light train because the farms are closer there and more people who need the farm produces are in the cities. This in turn will give rise to teleoperated schools to be set up in these areas with live classes physically stationed in the cities [26], [39], [40].

2.5 BENEFITS AND RISKS OF ToV IN TRANSPORT AND LOGISTICS INDUSTRY

No doubts, with the 5th generation of mobile network technology, popularly referred to as 5G, transport and logistics industry will experience a cataclysmic exposure to new forms of cyber-attacks and security challenges that could test and question the sovereignty and strength of the European Union, either trans-nationally or nationally, depending on the size, the direction of the attacks, and forms of other risks it presents [35], [41], [42]. Many authors have written pieces of literature in and around teleoperated vehicles (ToV) to explain in titbits, as the realities unfold over the years, the range of benefits, advantages, risks open to the world, explain semi and mega-cities of the world.

2.5.1 Benefits and Advantages of Teleoperated Vehicles

A piece was written about Intelligent Transport System (ITS) in the light of 5G-ToV. The authors found out that teleoperation data collected from the Ericsson Integrated Transport Research Lab (ITRL) showed that ToV is already a possibility in a semi-urban environment with reasonable vehicular and human traffic even without connection to strong cellular network [41]. Though their data was collected while radio access on the vehicle ran on node-driven Evolved Packet Core (EPC), teleoperated transportation on the test bus has been seen to be possible with virtual 5G network. [42] drew a firm conclusion that a 5G powered teleoperated Bus could have a commercial capacity that can drive up the operator's revenue and quickly grow vehicular footprint.

In [15], the authors wrote on designing 5G architecture against the odds off teleoperated transport and logistics. The authors supported [41] that a 5G architecture will driving advantages such as network slicing, reduced network communication time or latency, and cross-border roaming [15]. This simply means that the current network architecture available for teleoperated transport and logistics will drive traversing of goods and humans from one place to another 100 times faster, even if it is across regional borders. This was closely built upon by [29], who opined that operators, government, or non-government, can reliably build business precision, drive benefit customization, and exceed client's expectation with teleoperated transport and logistic [29]. Supply chain distribution is better coordinated with teleoperation [5], [43]. Usually, logistics are associated with widespread wastages of different forms; like you never can tell when your delivery will arrive sometimes. In the process, time is wastage, gas is wasted, overtime due to drivers and assistant drivers are added to the waste. With teleoperated vehicles, driving becomes regimented and domicile at a station thousand of mile away from ToV or in an AI hosted in a 5G cloud network system [4], [10].

Teleoperated transport and logistics also has the benefit of fleet management through real-time vehicle tracking [29]. With internet of things (IoT) riding on the back of a high computing mobile network (HCMN) system like the 5G, real-time teleoperation is possible. IoT also helps aggregate and harness the power of modern software, hardware, and framework to facilitate immediate data exchanges and response through voice suite commands; button-less teleoperation transportation capable of providing on site engineers and personnel with virtual assistance [44]. Teleoperated makes it possible for the right product to be delivered to the right place, with the right total price, to the right person, in the expected condition, in the correct quantity, and the right time [43]. Economically, it was extrapolated that teleoperated transport and logistics could add as much as USD9 trillion to an economy if it optimizes the potential of the best technology available, especially 5G network [5], [37]. Other findings provided that teleoperated transport and logistics has the capacity increase autonomous revenue pool by 30% [25], [26]

2.5.2 Associated Risks of Teleoperated transported and logistics.

As pointed out by earlier reviewed authors, the benefits of teleoperation in transport and logistics industry are almost unfathomable. However, the risk associated with it as not unexpected, because investigation into the history of teleoperated technologies, especially in transport and logistics, has shown that the society seldom accept new technologies immediately without socio-cultural shades of rejections and economic draught of investors [6]. Therefore, teleoperation brings the risk of layering and integration in clandestine operations by spying and competition countries [18]. The Union believes that countries like Russian, China and the military allies must be monitored, at the very least, to private critic intelligence on transport and logistics from falling into wrong hands [37]. [40] suggests that since government can deploy underwater teleoperation logistics, especially for war and high-level research purposes, investment in the best training and technology for naval and cybersecurity against marine and submarine jacking must be given priority [40]

Apart from financial apathy and cyber-attacks on teleoperated transport and logistics infrastructures, there could be risk of other peculiar dangers in imbalanced teleoperation environments [31]. The world's navigation does not capture everywhere; there are places on the most advanced systems described as unknown roads and there are no digital footprints or landmark to identify pin-drops on maps. This exposes teleoperated transportation to the risk of theft and carjacking [31]. Also, ToV has been said to understand fixed traffic and familiar environment, like a test-bed, moving pedestrian, but has not been adapted to complex high traffic environment on high speed [45] This makes it impossible for ToV operators to receive the Estonia or EU permission to deploy in high traffic environment in order to prevent fatality and consumers are not in dire need for it too, at least, not at the moment of multiple uncertainties [45].

One of the capacities, a teleoperated transport and logistics industry would have a shared mobility. Games theory experts believe that this could pose a risk to the number of car ownership in the world. This is because, with shared mobility combined with insanely reduced use cost, individuals would rather leverage the interoperability of technology to carry on business with an available fleet of vehicles online rather than buy a car [26]. Vehicles that are owned individually will reduce by a shock while those corporately owned will slightly increase, leading to a net reduction in revenue, increased unemployment in that space, and create a perfect competition market structure in the long run [46]. Now, let us find out empirically how all of these come together within a research method or estimation framework.

2.5.3 5G-ToV Architectural Designs and Demonstrative Investment Outlay

Teleoperated driving is made possible in two scenarios; one where connectivity is powered by a dependable wireless network system to a control center with trained remote drivers and the other where the navigation system is linked to a smart road and all is integrated into an Artificial Intelligence (AI) that can ensure fail-safe delivery of vehicular movement from one location to another, including multiple stops [10]. Successful teleoperation of automated vehicles requires a minimum level of architectural designs that allow for human-machine interaction with respect to remote drivers, especially when a new network technology like the 5G provides the link between the control centers and the navigation fields, irrespective of the distance [47].

The top among many of the supportive objectives of running a teleoperated transport and logistics business will be to set up an operationally efficient teleoperated environment for the deployment of 5G-ToV and the control centers. This means a transport company, or a government is saddled with the responsibility of designing a 5G network system that can sustain a smart road, ToV, and remote driving operation [7], [15], [24]. This also means that it will be implemented in such a way as to ensure resource optimization for transport and logistics profitability and sustainability – where the arrangement is efficient enough to anchor and achieve future growth objectives without external funding or demand for technical assistance. To achieve this, [25] suggested thorough research before project developments of costume software and hardware that would be run through a user acceptance test sessions before commercial launch. They outlined a seven-step procedure for the project management user experience (UX) and outlined a typical 5G-ToV implementation research of the same; this is represented in the figure below:

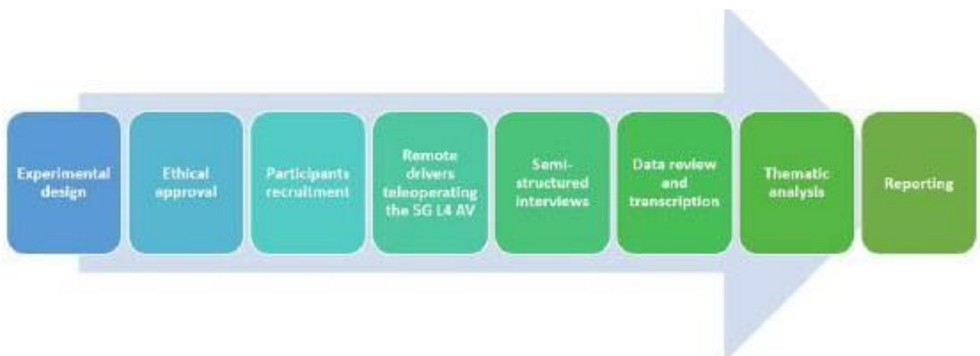


Figure 2: Research Process for Implementation of Typical 5G-ToV Project [10]

The procedure, from experimental design to reporting, was meant to acquire information from remote drivers on the best practices and the specification needs for a fail-safe 5G-ToV implementation on a large scale. Also, it will enable a government or a business to acquire long-run relationship between technical and administrative investments and benefits and risks to the economy or business profit and the society respectively. This will then ensure proper focus is given to building a formidable architecture for 5G-ToV. A typical architectural design that shows the 5G network systems setup for communication between the field and the AI or remote driving workstations is presented in Figure 3 below:

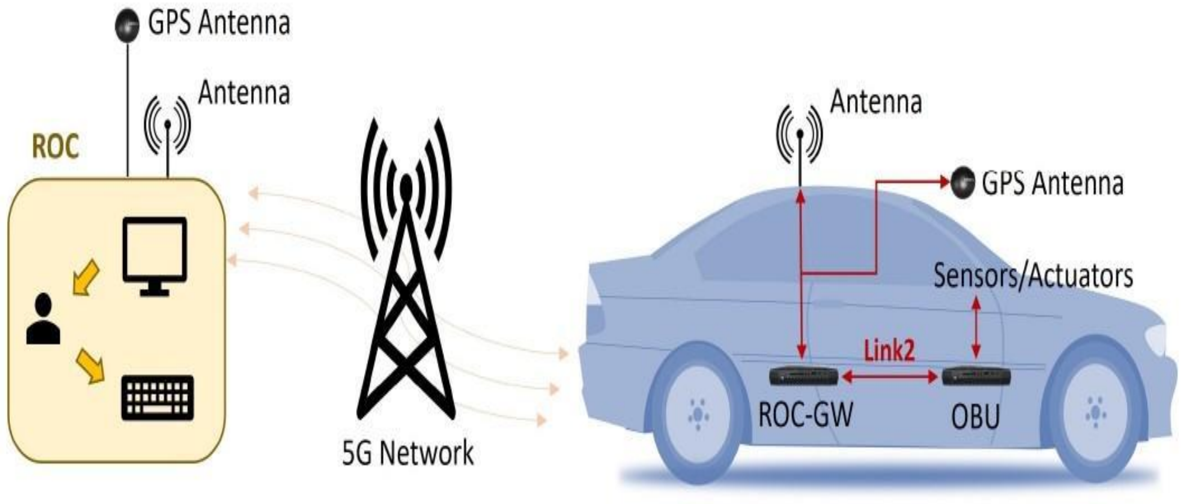


Figure 3: Overview of Teleoperation 5G-enabled Support Architecture [5]

The figure above shows an end-to-end architectural design for a typical teleoperated support system with 5G network technology as the communication channel, determining the speed of response at all levels. Devices such as sensors and actuators are used to measure and control the vehicle's speed, angles of the steering wheels, brake positioning, with four IP cameras mounted on each side of the vehicle (front, back, right, and left). The telemetry data – video, audio, and others - is received and processed at the Remote Operation Centre (ROC), which has an established interface for human operators. The On-board Unit is integrated to all cameras, actuators, and sensors to capture data on ambient and operations and make it available in formats that the actuators can easily read. This data, before it is sent to the actuators, is processed by the ROC-gateway (ROC-GW) as seen in Figure 1. The ROC-GW provides intermediate communication between the experimental vehicle and remote operation Centre (ROC) running on the 5G network infrastructure [5]. This is just to summarily explain what happens at an experimental stage of the 5G-ToV, irrespective of the type of vehicle – cargo or human carriers.

Now, all the components of the network infrastructure, the experimental vehicle, the remote operation Centre (ROC) and the On-board Units need to be regressed for economic and societal benefits and risks respectively. The investment outlay in the project, especially when it becomes aggregative across the economy, with multiple companies expanding into different areas of TALI teleoperation, will determine the long-run impact 5G-ToV will have on the economy and the people. In a study conducted by [25], [48]. This gets even bigger when all the potential investment addition to the economy and the job redistribution it will generate are included. [6], in a study titled, "5G Connected and Automated Road Mobility in the European Union", identified target audiences that will be involved in the process of development and implementation of the project. These targeted audiences are highlighted in Figure 3 below. They will determine the distribution of cost requirement and eventual profit margin for the aggregate transport and logistics industry. They constitute the interest groups that can spin the wheels of budget determination for an acceptable and economically viable 5G-ToV project.

Figure 4: 5G-ToV Project Investment and Communication Target Audience [49]

Figure 4 shows an array of communication target audience within 5G-ToV project implementation. This impliedly means that the communication lines are perfect proxies for interest groups that would be willing to provide information or investment and or both to see to the actualization of the project. The public could express concerns about the rate of accidents due to human errors, Co2 emission levels and the need for a greener earth. The industry, which is made of big corporations, SMEs, VCs, and other entrepreneurs, will be interested in a new business frontier that gives value to their funds and to society. Standard companies, policymakers, researchers, and academics will spell out ethical, legal and development issues that will determine material cost outlays across the life of the project. Finally, road operators, technology clusters, and the infrastructural requirements for 5G network will critical aspects of the project, like the Terberg autonomous heavy goods vehicle and the 5G-enabled teleoperation workstation (5Ge-TWS) in Figure 5 below.

Figure 5: Autonomous heavy goods vehicle (Left) and the 5Ge-TWS Source [10]

The ensuing section captured a major theoretical framework that has practical relevance to the application of technology in transport and logistics industry (TALI). The statistical decision theory (SDT) uses the complex number of probabilistic statistical mathematics to estimate uncertainties, just like they are experienced in TALI. This theory laid the basis for the introduction of 5G teleoperated vehicles to European TALI. This a priori expectation was tested against few but solid empirical findings, and many society network will be good for ToV in TALI but none has really tested what the benefits and risks impacts would be on the economy and in the society. This makes this current study unique and significant to the future of teleoperated TALI with 5G ToV as the process engine. This expectation will now be tested empirically to acquire a set of new useful information for policy recommendations. The test case scenario has been mentioned in chapter one. For now, it will be built on in chapter three before test procedures and results are presented and interpreted in much later chapters.

CHAPTER THREE

3 METHODOLOGY

The research adopted a mixed method (MM) research design to evaluate the economic and societal impact of 5G teleoperated vehicles on the transport and logistics industry in the short and long-run. It relies on the combination of qualitative and quantitative research designs for variable investigations. The adopted of MM was necessary because 5G network technology was just developed less than half a decade ago and there has been not enough secondary data to leverage reliably and sufficiently to establish the authenticity of the claim that a prior significant impact existed at that level with the reviewed variables. MM allows for qualitative and quantitative data analyses to be used to draw factual and scientific conclusions side-by-side [21]– [23]. MM exhausts all options for data collection, data redesign, process re-engineering, and data analysis that help to arrive at a holistic and scientific conclusion necessary for policy recommendations that can be trusted [23], [24]. It also creates new information and data to enhance scanty regime on 5G and the variables investigated in this study.

The qualitative data analysis part of the research used in-depth interview questions (IdIQ) to collect data that captured the story behind the relationship investigated from specialists in 5G network and teleoperated transport and logistics industry, both private and public sector in Estonia. For the interview, we worked with the following companies.

1. **Estonian Consumer Protection and Technical Regulatory Authority (Public Sector)** is responsible for strengthening the capacity of market regulation and safety supervision and the consumer environment.
2. **AuveTech (Private sector)** is a start-up, offering a full-scope service that enables autonomous/teleoperated vehicles, and their integration into various environments and fleet management.

3. **Cleveron (Private sector**) is the innovation leader in creating robotics/teleoperation-based parcel terminals and developing last mile click and collect pick-up solutions for retail and logistics sectors.

The raw data from IdIQ used the Atlasti's relational experiment to codify and intelligently compare interviewees' responses to draw a conclusion. Atlasti is a computer-aided qualitative data analysis software (CAQDAS) that has been acclaimed as one of the best for qualitative data analysis [22]. The sample in the interview was administered to educated and experienced experts in 5G network technologies and ToV in Estonia and the EU corridor. The sampling method was judgement sampling method, which was based on some predetermined matrix developed from some attributes these interviewees must have.

3.1 VARIABLES

In empirical research, the choice of variables to measure is akin to a good experimental design [43], [50], [51]. In this study, it was discovered that the variables to measure the impact effect of 5G-ToV on the economy and the society are both quantitative and categorical but lacked historical largeness. The quantitative variables possess data values that are continuous in nature. That is, they can be numerically reduced to fractions and or decimals without losing their meaning and usefulness. The categorical variables are those that can be grouped, ranked, or ordered. They are either ordinal, nominal or binary [52]. Therefore, to arrive at the variables to measure, the research work was broken down into a broader group of dependent and independent variables, judging from the title and the research questions. These variables are captured on Table 1 below. However, because of unavailability of adequate and reliable data on 5G teleoperated vehicles (5G-ToV) and other specific variables that could measure economic and societal benefits and risks respectively, the study adopted proxies with empirical and conceptual supports to explain the impact of

5G-ToV on the Estonian economy and societal individually. The following are the general overviews on the proxy-variables as adopted:

3.1.1 Total Inland Transport Infrastructure Investment

The investment value that adds up to 5G teleoperated vehicles, control stations, and preparation of roads, docking yards, airports, and railways for teleoperation has shifted distribution for more than two decades since the re-emergence of the hope for un-manned vehicles and provide an adequate 5G network architecture can be broadly divided into the cost of installation of 5G network, acquiring a driverless vehicle (DV) and cost of preparing the fields [6], [39], [40]. The OECD defines total inland transport and logistics investment as, "The spending on new transport construction and the improvement on the existing network" [53]. This spending covers all the transport networks from the main routes to the support routes and the European corridors. The distribution of the spending has been heavy on the technical side, which directly and indirectly had added up to making sure that 5G teleoperation in the Estonian TALI meets the standard in the European guideline [1], [18], [28].

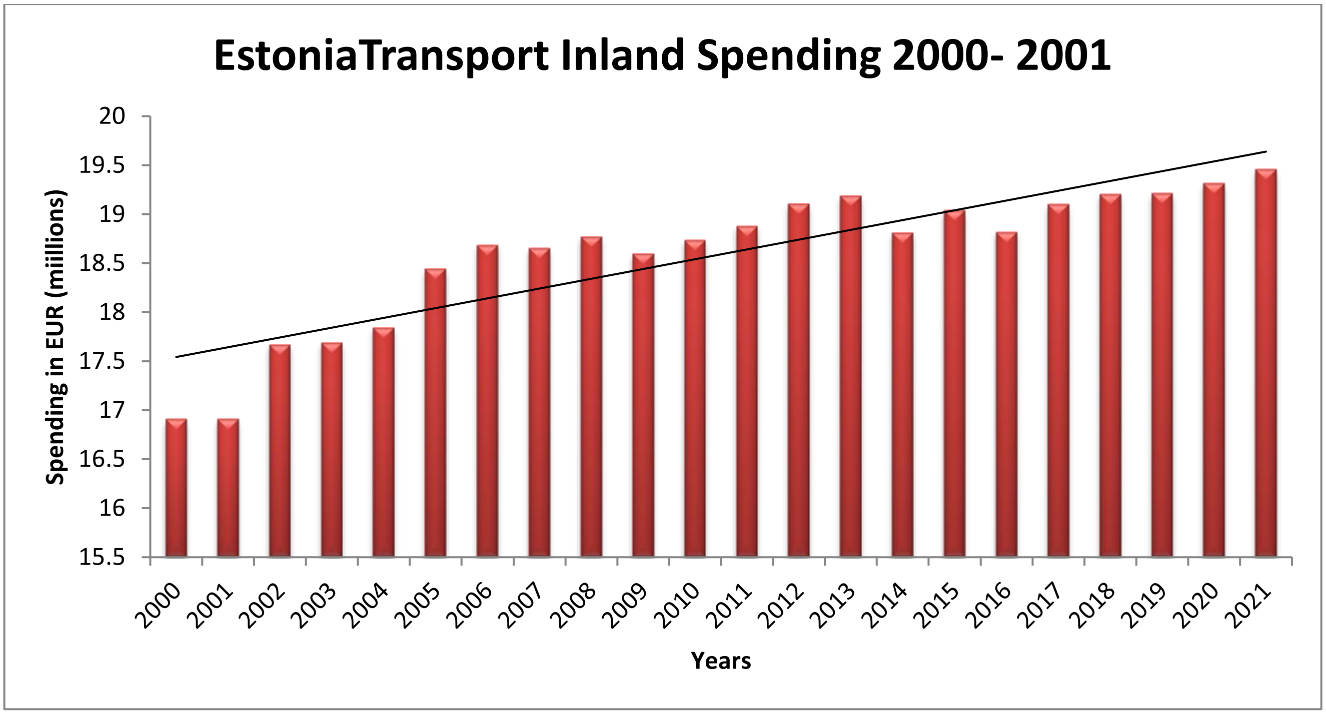


Figure 6: Estonia Transport Inland Spending 2000- 2001 [53]

Figure 6 shows that the trend of investment has been on a consistent rise from 2001, when it last consolidated. Estonia is a country of less than one and a fourth million people. The size and distribution of the inland transport investment has been more on technologies in around artificial intelligence, smart road, light rail and other that can be easily tweaked to accommodate 5G teleoperation on land, sea, rail, and air transport. This variable is a strong estimate for the actual landing cost for 5G-ToV to become commercially viable in Estonia.

3.1.2 Transport and Logistics GDP Contributions - Estonia

Every buoyant economy is backed by a strong service sector, especially a well-diversified and developed transport and logistics sector. It was not a surprise to record that the Estonian TALI contributions to GDP from 1995 to 2022 has been averaging approximately 370 million EUR, with the lowest, 178 million EUR, in the Q4 of 1995 and the highest recorded in the Q2 of 2022 at 611 million EUR.

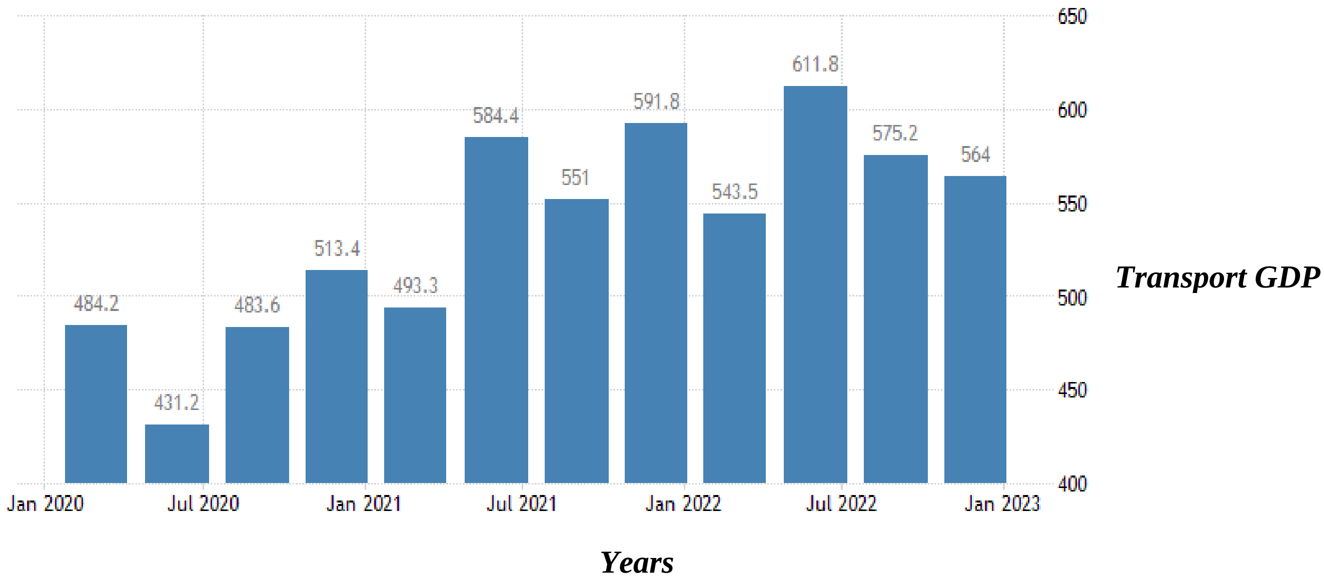


Figure 7: Transport GDP in Estonia [54]

The transport GDP is the best fit for measuring the economics benefits a country, either from the private or public sector, can derive from the 5G-ToV TALI. It provides opportunity for backward and forward linkages to other sectors of the economy such as education through research finance, agriculture, through fast and dependable movement of human and farm produces to places where they are most needed at a cheaper cost. Transport GDP makes it possible for the finance sector of the economy to gain strength as it earns inflow of foreign direct investment through services in and around the European travel corridors [6], [54].

3.1.3 Estonia – Road Accident Deaths

The number of road accident deaths worldwide has been put to about 3700 daily average and over 1.3 million in a year, not accounting for those from other forms of transportation [55]. This phenomenon has been traced to human errors in terms of unruly drivers' behavior, improper road maintenance, expired vehicle parts, porous institutional support, and other human administrative machinations, especially in third world countries.

Meanwhile, the outlook of road accident deaths has been downward trending, though with a steep curve as seen in Figure 8 below.

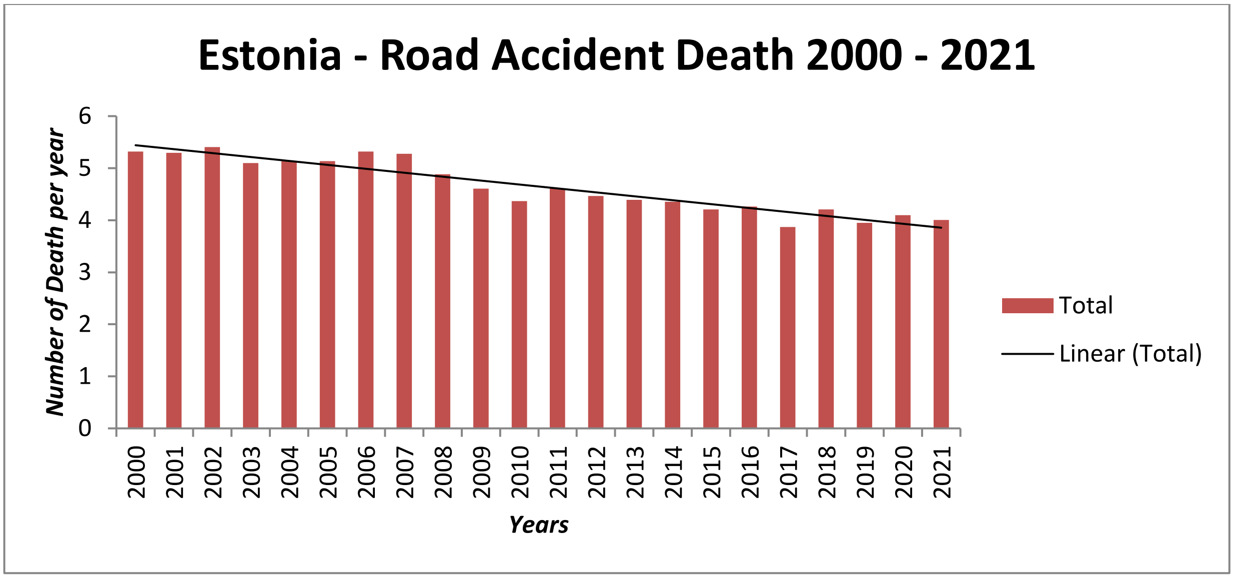


Figure 8: Road Accident in Estonia [53]

Statistically, it was recorded that most of those who died in a road accident were not in the vehicles. They were pedestrians, cyclists, and linear settlers. The introduction of teleoperation is expected to be negatively related to road accidents. That is, the better 5G-ToV becomes, the lesser deaths on the road and on any other means of transportation should be recorded. This measure is therefore a good fit to know how the Estonian societal will be more preserved than before. The figure above shows that since 2008, there has been a downward trend in road accident in Estonia but slow. This is a measure of societal benefits to that 5G teleoperated vehicle can bring to Estonia.

3.1.4 Estonia Transport Employment to Population Ratio

The ratio of employed persons in Estonia TALI to the total Estonian population is the number of individuals actively engaged from the age of 15 [56]. Over time, the introduction of technology has always been a major source of disruption; sharply cutting down most human involvements and replacing them with an automated process, like teleoperated driving. Therefore, the introduction of 5G-ToV is expected to pose some risk to jobs in the Estonian transport and logistics industry (TALI) and to the economy.

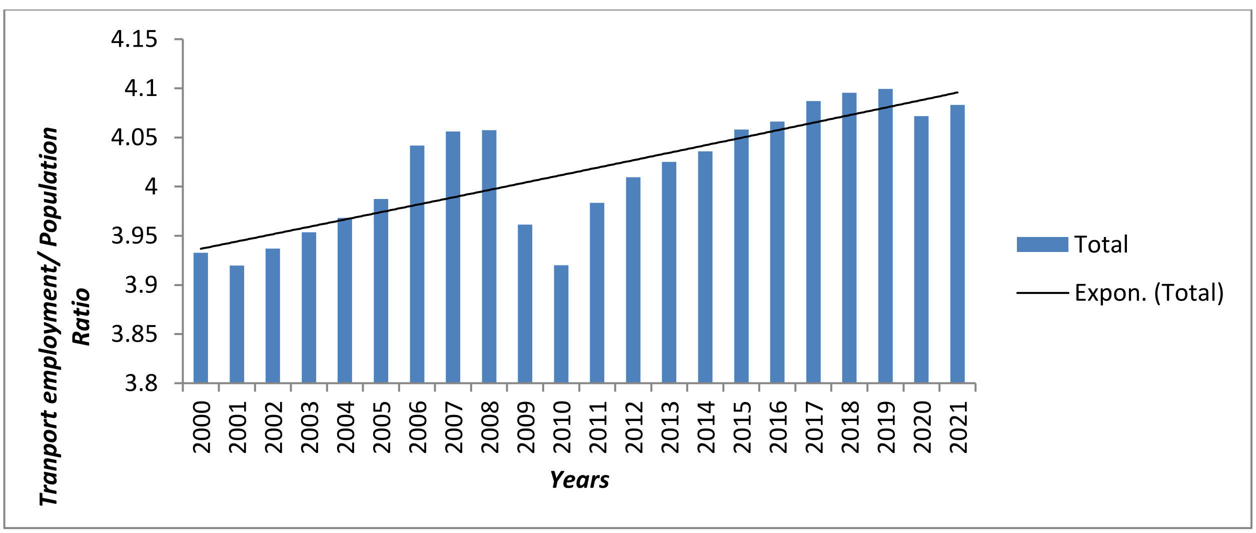


Figure 9: Transport Employment to Population Ratio in Estonia [56]

Figure 9: suggested transition from traditional transport and logistics operation into teleoperation has been creating more jobs rather tank transport employment. This is because Estonia population is educated and sizeable enough for an accelerated training on technical skills. This was evident from the sharp drop from 2008 to 2011 [8]. To overcome the financial crunch at the time, governments and companies started making smarter decisions of investing in technologies and training that would reposition them for higher competitive advantages in the future [57]. It is still a risk that technology can cause structural unemployment. Reduction of unemployment is a major goal of every economy, and the a priori expectation of this study is that 5G-ToV will first have a negative impact on transport employment and later improve. It would be a good research area to investigate the short and long run co-integration between 5G-ToV and transport unemployment. Therefore, this variable is a good measure of economic risk of 5G-ToV in Estonia.

3.1.5 Life Expectancy – a measure of 5G-ToV deployment societal risk in Estonia

Life expectancy, at birth, is a measure of how long a newborn would live if the dominant conditions at the time of its birth remain consistent throughout its life. Estonia, with Human Development Index (HDI) of 0.890 as of 2022 and a population of 1.33 million people, it can be generalized that a person born within the 21st century in Estonia had a relatively better public health system to support longer existence [14], [16].

Figure 10 below showed that the Estonian life expectancy at birth has been trending higher, estimating from year 2000. The trend line also shows a slow but steady growth in life expectancy. However, this study has the expectation that vehicle mile per travel (VMT) for elders, disable persons and children, even animals, will jump up considerably once 5G-ToV changes to tide of car usage and ownership.

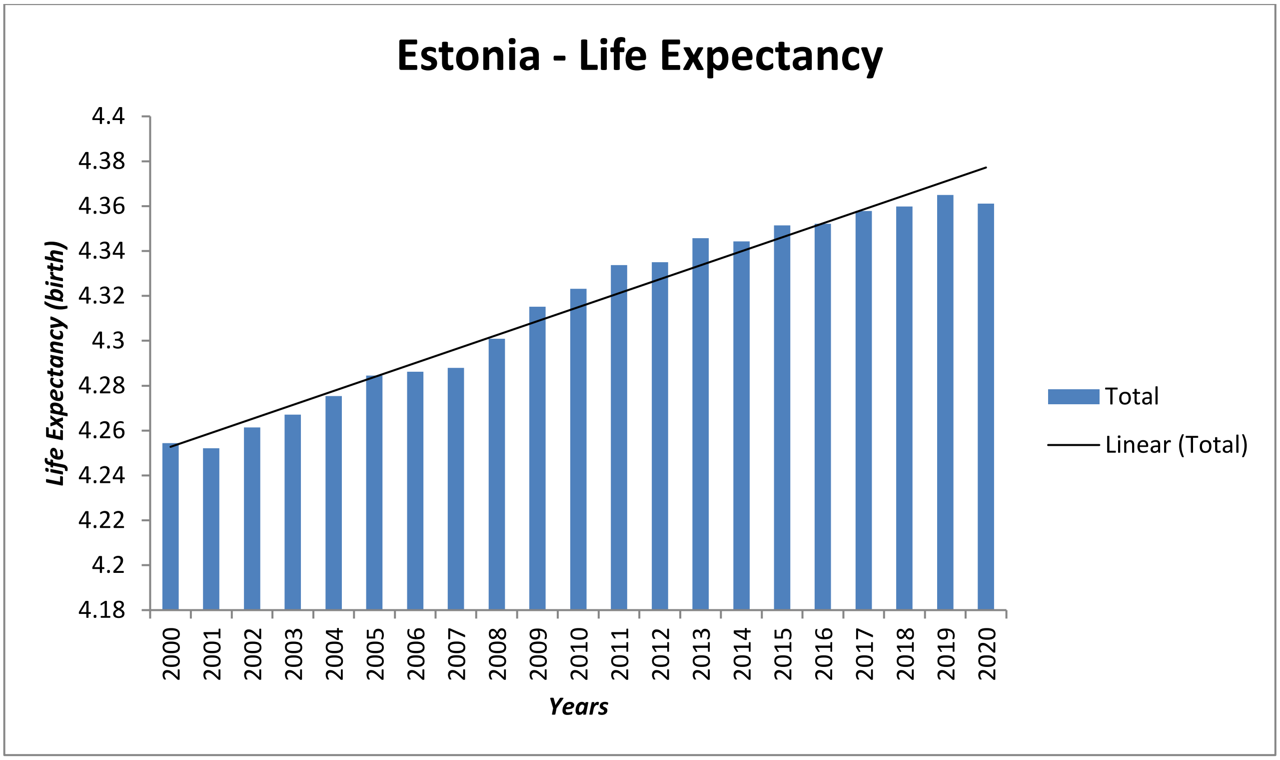


Figure 10: Estonia - Life Expectancy 2000 – 2020 [56]

The study also assumed that the cost of transportation will reduce considerably because of technology and because vehicle sharing will go up. This might create some exposure to high-tech security issues like cyber carjacking, kidnapping, cargo-diversion and theft and possible increase in homicides as well. Therefore, life expectancy is expected to be threatened but should maintain high response to changes in 5G-ToV deployment in society.

There are other variables that cannot be quantitatively described and summarized, but the qualitative section of the study captured them during the interview conducted with top three AV operators in Estonia, who are presented experts at Teleoperation and 5G network and cellular technology. Table 1 below shows all the variables that were reviewed quantitatively and qualitatively, as indicated.

Table 1: Array of Variables Reviewed

Variable	Proxies/actual measures	Measurement
economic benefits		
increased transport GDP	% transport GDP	Quantitative
reduced poverty gap	% change poverty	Quantitative
societal benefits		
increased vehicle mile travelled by disabled. Elderly and	VMT - elderly, children and disable	Quantitative descriptive
reduced road accident	road accident	Quantitative
reduced cost of transportation	cost of transport	Quantitative
Variable	**Proxies/actual measures**	**Measurement**
economic risks		
increased cost of road maintenance	road transport maintenance cost	Quantitative
reduced private vehicle ownership fuel consumption	registered vehicles/car fuel consumption	Quantitative descriptive
societal risks		
transport unemployment	transport unemployment	Quantitative
increased cyberattack	transport cyberattack	Qualitative
shortage of qualified personnel	transport % unemployment	Qualitative

Source: Developed by the author

Other variables that were qualitatively reviewed included network performance, consumer risk, investment availability, regulatory framework, and others. The theme named as others had sub-themes that were not directly related to the research but were gleaned from the interviews. They were analyzed as themes to dissect the comments of the interviewees on several sub-themes, such as:

1. 5G Deployment
2. 5G ToV Deployment Cost
3. Communication
4. Consumer Protection
5. Legal Support
6. Unemployment

In all three interviews were conducted across government agencies and private teleoperation companies in Estonia. Two of which involved a group of respondents, but their responses were taken as one under the umbrella of the organization they came from. The interviews were taken W1, W2, and W3 respectively. Each of them was under 50 minutes and were transcribed and analyzed using Google document dictation and Atlasti respectively. The results of the analysis were presented by adopting the method used by [10]

3.2 SIMPLE LINEAR REGRESSION MODEL AND DATA TYPE

Apart from the use of descriptive tables and statistical visualizations, the research adopted the Simple Linear Regression model (SLR) to investigate the impact of 5G teleoperated vehicles on the Estonian economy and its society. The SLR is one of regression analysis models which describe the relationship among variables that are fitted along a trend line. In particular, the SLR calculates the statistical values that explain how a variable responds to changes in one variable [58]. The data used were time series data – those that trend with time; they are affected by business and fiscal decisions, by time and by seasons [59]. The SLR can be used to measure the relationship among between a predictor and a response variable. It allows a study to find out how a dependent variable responds to changes in an explanatory variable using the regression statistics that will be derived from a properly formulated model.

SLR is like the Multiple Linear Regression (MLR) model, except that the latter can take from two or more predictors to explain the behavior of one response variable [60]. They are both built on some statistical properties or assumptions. These properties or assumptions must be held for a Simple Linear Regression (SLR) model to be used [61]. The independent variable must fulfil the requirement for BLUE – best linear unbiased estimators – as summarized in the description of the assumptions below [60], [62]. These assumptions are:

- Variance of homogeneity: this is otherwise referred to as homoscedasticity, and it suggests that sample size error must remain constant or homogenous for all the independent variables. So, a test for homoscedasticity was conducted to validate this position.
    - Observation independence: This suggested that the independent variable must not be correlated.
    - Normality: the time series data used must be normally distributed to avoid a spurious regression where findings will be too perfect for reality.
    - Linearity: this is a statistical property that suggests that the line of best fit must be a straight line and not a curve. Where it is not a straight line, it could be a polynomial function – with power from 2 (quadratic function) and above. In that case, SLR will not be suitable to analysis the data. So, variables x and y must be linearly related [61], [63].

In regressions models, it has been observed that time series data might violate some of these assumptions because of inconsistent digit count. This means values such as financial data would usually run into billions while location data such as 5G latency record would be hundredth. This inconsistency culminates into outliers that eventually lead to SLR assumptions violations [61]. A generic SLR model is expressed as:

Equation 1: Generic Simple Linear Regression (SLR) Model

$$y = \propto_0 + \propto_1 X_1 + \varepsilon \quad \ldots \qquad 1$$

Where:

y **=** the dependent variable

$\propto_0$ **=** the y-axis intercepts

$\propto_1 X_1$ **=** $\propto_1$ is the regression value or coefficient for the independent variable represented as X_1

ε **=** is the error allowance within the model why estimating the value of **y**

The functions for the linear relationships determined within this study are stated below:

Equation 2a-d: Simple Linear Relationships

eB = *f*(5G-ToV proxy) ….. Economic benefits

sB = *f*(5G-ToV proxy) ….. Societal benefits

eR = *f*(5G-ToV proxy) ….. Economic risks

sR = *f*(5G-ToV proxy) ….. Societal risks

Note: eB, eR, sB, and sR have all been defined under the decision in the next subsection, and they are the dependent variables, ***Y*** while 5G-ToV is the independent variable, ***X***.

Decision Rule in Simple Linear Regression (SLR) Model

To arrive at a decision in SLR required that the three basic statistics must be computed and compared. These basic statistics are:

- The regression coefficients
- The t statistics of the whole model
- `The associated *p value* that suggested the likelihood of the occurrence of the t statistic by chance is the null hypothesis of the study was true.

Once the regression analysis was done, the values of the adjusted R^2 and the F statistics were combined with those of t-statistics and the *p values* to determine the value of the dependent variable in each model.

The models for the Simple Linear Regression analysis were built to answer research question 2 of this study that said, "**What are the economic and societal benefits and risks of implementing 5G-ToV in Europe, and how can we build on the benefits and mitigate the risks respectively?**" These models were formulated to answer the first part of the question while the other part was answered in the qualitative findings of this study. To answer this question, the null (**H_0**) and alternative (**H_1**) assumptions were developed.

H_0: 5G-ToV does not significantly determine the values of eB, eR, sB, and sR

H_1: 5G-ToV significantly determined the values of eB, eR, sB, and sR

Where:

eB = the statistical notation for total transport revenue contributed to the Estonian gross domestic product, used being as a proxy for economic benefits (eB) to Estonia.

eR = the statistical notation for Estonian transport employment to population ratio that stood as a proxy for economic risk (eR) in Estonia.

sB = the statistical notation for the Estonian road accident death, used as a proxy for societal benefits (sB) in Estonia.

sR = the statistical notation for Estonian total life expectancy from birth to death, used as a proxy for societal risks (sR) in Estonia.

3.3 Thematic Content Analysis

There are several qualitative data analyses available for adoption during this study. These include content analysis thematic analysis, discourse analysis, constant comparative analysis or grounded theory analysis, basic interpretative approach, template analysis, frame analysis, and others [64]. This study adopted thematic analysis for analyzing the interview data. This required that the study go through the following steps:

a. Data preparation and organization for analysis
b. Audio data transcription to text data for intelligible engagement
c. Data familiarization and description to identify patterns and
d. Creation of data memos to log quotation groups.
e. Create groups in the form of codes.
f. Creation of code categories and themes in line with predetermined variables
g. Using relations or relational phrases to connect themes with comments.
h. Documentation, presentation, and interpretation of qualitative research output

The first step required that the interview data be properly labelled and copied into the computer software where transcription and our analysis will take place. The software used for data preparation and transcription was Atlasti. It is a modern computer-based qualitative data analysis software that has gained the acceptance and recommendation of researchers across all fields [24], [65]. The data is then transcribed into text format for readability. Every statement and nuances recorded were studied for patterns and similarities with the predetermined variables, namely automation and its proxies and corruption and its proxies before memos and quotes were marked for analysis and grouping into yet-to-be –determined data codes. These codes are short catchphrases or words that describe a group of similar opinions across the transcript by each interviewee [65]. These codes, memos and quotations were linked intelligently using Atlasti's relational phrases such as, "support by", "continued by", "contradicted by", "expanded by", and several others to create networks of agreement and disagreement on each and all the code groups and quotation groups respectively. Having done that, the study proceeded to create an analytic discourse of the output as the result and the interpretation there-from.

The study used mixed method research design to account for limited historical data on 5G network technology and teleoperated vehicles. In-depth interviews were also used to collect data on the economic and societal benefits of 5G teleoperated vehicles in Estonia. The study used the Simple Linear Regression (SLR) model and thematic content analysis to analyze the available times data and interview data, respectively. The results of the empirical investigations were presented in chapter four.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

The study examined the economic and societal impact of 5G teleoperated vehicles on the Estonian transport and logistics industry (TALI). In the earlier chapters of this study, it was established that, though teleoperation had begun as far back as the 19^{th} century, societal acceptance was low because a driverless car was seen as a mere entertainment at a time. Therefore, large commercial deployments were not economically viable at the time and acceptance is still very low. This low acceptance over the years has made it impossible for teleoperation data to be on the open access database. Hence, the adoption of mixed method research design to quantitatively analyze available historical data, and qualitatively find out the actual story behind what has been going on behind the scenes. The data used covered the period of 2000 – 2021, while structural breaks were observed from 2016, which the year 5G network technology was birthed before its first official launch in 2019. The time series data used for this research was done collected from the World Bank data group, the Estonia Statistics, CEIC data, OECD data, Statista,

4.1 DATA ANALYSIS

In Table 2, the time series data (TSD) of the variables reviewed were used to compute the relationship with the proxy of 5G teleoperated vehicles, which was the total inland investment on transport maintenance. The natural logarithms of the TSDs were computed to remove the possibility of econometric outliers that result in spurious regression results. These are the values presented on Table 2 with the notation beginning with "Ln", meaning, "Natural logarithm". It was established that the variables possessed the attributes of best linear unbiased estimators. This made them fit for simple linear regression data analysis.

Table 2: Time Series Data for Quantitative Analysis

Location	**Period**	**5G Proxy**	**eB**	**sB**	**sB**	**eR**	**sR**	**sR**	sR
Country	**Year**	**Ln 5G-ToV**	**LnTOT GDP**	**LnPgap**	**LnRoad accident**	**LnTot Service**	**LnTOT Unemp**	**Lne/p ratio**	**LnLifExp.**
Estonia	1993	0.0	9.1	0.0	5.8	0.0	3.5	0.0	0.0
Estonia	1994	0.0	9.1	0.0	5.9	0.0	3.8	0.0	0.0
Estonia	1995	0.0	9.1	0.0	5.8	0.0	3.6	0.0	0.0
Estonia	1996	0.0	9.2	0.0	5.4	0.0	4.0	0.0	0.0
Estonia	1997	0.0	9.3	0.0	5.6	0.0	3.9	0.0	0.0
Estonia	1998	0.0	9.4	0.0	5.6	0.0	3.9	0.0	0.0
Estonia	1999	0.0	9.4	0.0	5.4	0.0	3.9	0.0	0.0
Estonia	**2000**	16.9	9.5	0.0	5.3	0.0	3.8	3.9	4.3
Estonia	2001	16.9	9.6	0.0	5.3	0.0	3.9	3.9	4.3
Estonia	2002	17.7	9.7	0.0	5.4	0.0	4.0	3.9	4.3
Estonia	2003	17.7	9.8	0.0	5.1	0.0	3.8	4.0	4.3
Estonia	2004	17.8	9.9	0.0	5.1	0.0	3.9	4.0	4.3
Estonia	2005	18.4	10.0	0.0	5.1	0.0	4.0	4.0	4.3
Estonia	2006	18.7	10.2	0.0	5.3	0.0	3.9	4.0	4.3
Estonia	2007	18.7	10.3	0.0	5.3	0.0	3.9	4.1	4.3
Estonia	2008	18.8	10.3	0.0	4.9	3.6	3.4	4.1	4.3
Estonia	2009	18.6	10.2	0.0	4.6	3.6	3.3	4.0	4.3
Estonia	2010	18.7	10.3	0.0	4.4	3.7	3.8	3.9	4.3
Estonia	2011	18.9	10.4	0.0	4.6	3.7	4.0	4.0	4.3
Estonia	2012	19.1	10.4	0.0	4.5	3.7	4.0	4.0	4.3
Estonia	2013	19.2	10.5	-1.2	4.4	3.5	3.8	4.0	4.3
Estonia	2014	18.8	10.5	-1.3	4.4	3.5	3.8	4.0	4.3
Estonia	2015	19.0	10.6	-1.3	4.2	3.5	3.6	4.1	4.4
Estonia	2016	18.8	10.6	-1.3	4.3	3.4	3.5	4.1	4.4
Estonia	2017	19.1	10.7	-1.3	3.9	3.4	3.5	4.1	4.4
Estonia	2018	19.2	10.8	-1.3	4.2	3.4	3.2	4.1	4.4
Estonia	2019	19.2	10.9	-1.3	4.0	3.4	3.0	4.1	4.4
Estonia	2020	19.3	10.9	0.0	4.1	3.3	2.8	4.1	4.4
Estonia	2021	19.5	11.0	0.0	4.0	3.3	3.2	4.1	0.0

Source: World Bank data group, [56]

In Table 3, the regression results showed that total transport % of GDP, transport employment/population ratio, and Estonian life expectancy from birth are all positively related to spending or investment in 5G teleoperated vehicles while total road accident death is negatively related.

This is indicated by the signs of the coefficient statistics in Table 3. All the coefficients were positive except for road accident death. This means that an increase in the value of investment spending on 5G-ToV will increase transport % of GDP, transport employment/population ratio, and Estonian life expectancy from birth but will reduce road accident death. This shows that, without considering whether the value of the corresponding change is significant or not, 5G-ToV is good for economic growth – indicated by the GDP and transport employment – and also good for societal security.

However, on the same Table 3, the multiple R, R^2, and the Adjusted R^2 were well over 50% - the lowest being the R^2 of the natural logarithm of total transport employment to population ratio computed to be 58%. This means that for every one EUR spent on a 5G teleoperated vehicle, the transport employment-population ratio will increase by 0.58 units. This interpretation is applicable to other variables as well, irrespective of the direction of the relationship – positive or negative.

Table 3: Combined Simple Linear Regression Results

Variables	Coefficients	Multiple R	R Square	Adjusted R Square	Significance F	t Stat	P-value
LnTOT GDP	0.5753375	0.936795	0.877585	0.871142	4.13798E-10	11.67089945	4.13798E-10
LnRoad accident	-0.6181279	0.783973	0.614614	0.594330	2.60839E-05	-5.504651928	2.60839E-05
LnE/p ratio	0.0704534	0.766313	0.587235	0.565511	5.10562E-05	5.199139619	5.10562E-05
LnLifExp.	0.0526304	0.886905	0.786600	0.774745	1.89418E-07	8.145474449	1.89418E-07

Source: Stata 15

The research hypotheses, as restated below:

H_0: 5G-ToV does not significantly determine the values of eB, eR, sB, and sR

H_1: 5G-ToV significantly determined the values of eB, eR, sB, and sR

Where:

eB = the statistical notation for total transport revenue contributed to the Estonian gross domestic product, used being as a proxy for economic benefits (eB) to Estonia.

eR = the statistical notation for Estonian transport employment to population ratio that stood as a proxy for economic risk (eR) in Estonia.

sB = the statistical notation for the Estonian road accident death, used as a proxy for societal benefits (sB) in Estonia.

sR = the statistical notation for Estonian total life expectancy from birth to death, used as a proxy for societal risks (sR) in Estonia.

These show that if the p-value is below the critical value of 0.05, the null hypothesis can be rejected and the alternative hypothesis can be accepted. In Table 3, the p values for 5G teleoperated vehicles is low ($p < 0.05$), therefore the null hypothesis is rejected for those three variables. This simply means that investment in 5G teleoperated vehicles has statistical significance on increase in transport % GDP, transport employment/population ratio, and Estonian life expectancy from birth. Meanwhile, investment in 5G teleoperated vehicles does not have statistical significance with Estonia road accident death. This is consistent with the result of the interview conducted on consumer risk, measuring the societal risk of 5G teleoperated vehicles to Estonian.

In Table 4 below, consumers risk theme was analyzed from the interview response from industry experts within TALI, the interviewees are listed below.

W1 = **Estonian Consumer Protection and Technical Regulatory Authority**

W2 = **AuveTech**

W3 = **Cleveron**

The interview gathered response especially on accidents due to network outage, vehicle theft, and other safety concerns, the response showed that there was no concrete mitigating measure against road accidents, though may not lead to death if the accident was internal to the teleoperation activities and not from external factors, like other road users or change in route physical attributes without communications.

Other reasons that could cause such unmitigated road accidents could be sudden network loss, poor user acceptance test during process development and fear for health issues by users as a result of sudden realization that the vehicle is powered by 5G. The responses of the interviewees W1, W2, and W3 and the distribution of risk and benefit are captured as comments and status respectively

Table 4: Case 1 - Consumer Risk of 5G Teleoperated Vehicles

Case	Sub-theme	Comments	Theme	Risk	Benefits
W1	Safety of human and vehicles	Ensuring you understand the route before deployment	Consumer risk	Societal	Societal
W1	5G, cancer and consumer protection	There is no difference between the health and safety of consumers and the networks with 5G as with previous generations of network technologies. There was no proof that 5G caused cancer or any health issue. They are mere psychological conjectures among users.	Consumer Risk	Societal	Societal
W1	Consumer protection	The only risk that should be of major concern to the society and the government is the possibility of increased Co2 emission as vehicles increase because of 5G teleoperation advantages.	Consumer Risk	Societal	Societal
W2	Technical issues	The heavy funding for Estonia to support the European transport corridor makes it possible to overcome any foreseeable technical issues like head-on collisions of 5G-ToV.	Consumer Risk	Economic and Societal	Economic and Societal
W2	Transparent UAT testing will instill confidence in society.	This can be if the framework permits it.	Consumer Risk	Societal	Societal
W2	Are there agreed framework for giving communicative orientation to customers on the risks involved in using network technologies?	There is no interoperable communication on the use of network and cellular technologies. Consumer injuries secured from communication devices or network are not everyday issues. They are occasionally, and so there is no agreed framework to warn customers of the inherent risk in network usage.	Consumer Risk	Societal	Societal
W2	5G deployment in a PPP	The network use transparency;	Consumer Risk	Economic and Societal	Economic and Societal

W3	Cybersecurity	Following cybersecurity standards that all operators must comply with. It is called ISO 221464	Consumer risk	Economic and societal	Econom ic and societal
W3	Vehicle theft	No. The only protection is the video recording and other conferencing capability to report hostility.	Consumer risk	Societal	Societal

Source: Atlasti [65]

In Table 5 below, investment theme on 5G-ToV was analyzed from the interview data collected. The reason investment in 5G-ToV can maintain a positive and statistically significant relationship with employment is because of the direction of the investment. Though W1 said, "There was not enough funding to get the right persons", but knowledge-based and skill-based investment to universities make it easier for trainable personnel to be developed and acquired within the shortest period, enough to make necessary job changes structurally. The findings suggested that Europe has sufficient investment, but sales of products and teleoperated services are still very low. So, return on a huge investment encourages individuals to up-skill to be work as teleoperated engineers or drivers.

Table 5: Case 2 - Investment in 5G Teleoperated Vehicles

Case	Sub-themes	Comments	Theme	Risk	Benefits
W1	Personnel requirement - skilled staff	Not enough funding to get the right people on board.	Investment	Societal	Societal
W1	AV and job replacement	In developed countries, knowledge bridges the gap in jobs lost and job gained. It will not be a big issue here in Europe and in Estonia	Investment	Economic and Societal	Economic and Societal
W1	Sufficient investment	There is sufficient investment in Europe, but clients picking up the products is the main issue - getting money back on investment.	Investment	Economic	Economic
W2	How should the government investment?	Creating better legislation to compete with other developed countries that are advanced in AV.	Investment	Economic and Societal	Economic and Societal
W2	Investment and profit size and payment mode	The network is not very cheap, and the cost is borne by the operators. They also make good money from it. Investment and profit usually run to tens of millions.	Investment	Economic	Economic
W3	Cost of a single teleoperation and the teleoperated vehicle.	It is under 100,000.00 EUR. A car should be between 20000 and 50000 EUR.	Investment	Economic	Economic
W3	Funding	Funding the ecosystem is difficult and tight. But there is obvious interest in the project. We have strategic partners who help in securing approvals to use public roads and other infrastructures.	Investment	Economic	Economic
W3	Expansion	Depends on where our technology is accepted.	Investment	Economic	Economic

Source: Atlasti [65]

In Table 6, the network requirement and performance for 5G teleoperated vehicles was analyzed from the interview data. The responses of W1, and W2 suggested that most operators are investing in 5G-complaint vehicle architecture to leverage the advantages 5G network offers. This standardization is needed before a 5G network can be deployed. They also agreed that the efficiency of response to road accident scenarios will depend on this architecture and the strength of the network service. Such architecture requires capacities like Operation Design Domain (ODD) – which assesses the weather condition, road condition and network condition the vehicle is in at a point in time to determine and that the response of the vehicle - combined with the minimum risk maneuver (MRM), where the vehicle slows down and stops until connection is restored, is key to human and vehicle safety.

Table 6: Case 3: Network Theme on 5G Teleoperated Vehicles in Estonia

Case	Quotations	Comments	Codes	Risk	Benefits
W1	5G & autonomous	5G is not really the issue. The main development is in vehicle architecture. If the hardware is weak, the network capacity does not matter.	Network	Economic and Societal	Economic and Societal
W1	Security - loss of connection while in operation	The car will stop once the connection is lost.	Network	Economic and Societal	Economic and Societal
W1	Road accident -	The car will stop once the connection is lost.	Network	Economic and Societal	Economic and Societal
W2	Network standardization within Estonia and across neighboring countries.	This is required before deployment for any consumer usage, like on mobile phones, etc.	Network	Economic and Societal	Economic and Societal
W2	Safety: Losing network during teleoperation. Prioritizing operators for full network.	Base stations will be very close, and latency will be very low. Current frequency allows for the teleoperation drivers to make decisions very fast if the network is low or is out.	Network	Economic and Societal	Economic and Societal
W2	5G and other network management and auctioning	This is done as demands are placed on the department. However, 5G still on low demands because most operators have not up scaled their teleoperation or AV architectures to accommodate it.	Network	Economic	Economic
W3	Latency improvement	Currently running at max of 200 milliseconds but can be improved with 5G network.	Network	Economic	Economic
W3	Test on 5G	Data on 5G testing is small and very recent. There is no substantial data that can be publicly referenced for research purposes.	Network	Economic	Economic
W3	5G advantage	Robustness of connection (speed) and the infrastructure.	Network	Economic	Economic
W3	Switching 5G	Network is switching is possible between 4G and 5G	Network	Economic and societal	Economic and societal

W3	When network goes off completely	Operational Design Domain (ODD) assesses the weather condition, road condition and network condition the vehicle is in at a point in time to determine the response of the vehicle. This is combined with the minimum risk maneuver (MRM) where the vehicle slows down and stops until connection is restored. The 3rd option is a physical or manual rescue of the vehicle.	Network	Societal	Societal
W3	Sensors for safety	There are sensors that to measure distance in centimeters and obstructions in site from all four directions.	Network	Societal	Societal
W3	5G on teleoperation projects	Still on 4G network because 5G has not really developed in terms of infrastructure acquisition and deployment.	Network	Economic	Economic

Source: Atlasti [65]

Also, in Table 7, the 5G framework was analyzed from the interview data. Interviewees W1 and W1 responded that there has not been any framework developed around 5G-ToV in Estonia. Therefore, cross-border operations that will drive economic and societal growth and or incur economic and societal risks are treated case-by-case. It is what is communicated in countries within or outside Europe, where teleoperation is run, that will be adhered to and managed accordingly. Meanwhile, there is an EU framework which guides operations within the EU member states. In terms of structural unemployment export, the responses of the teleoperation companies will depend solely on the local legislation of each country of operation. Though there is no framework in Estonia for 5G, but there is one on cybersecurity. This legislation provides cover for both public and private companies cum the individuals in the society.

Table 7: Case 4: 5G-teleoperated Vehicle (5G-ToV) Framework in Estonia

Case	Quotations	Comments	Codes	Risk	Benefits
W1	Cross-border communication management	It depends on the country. Dependency is on the local communication service provider partner.	Framework	Economic and Societal	Economic and Societal
W2	Policy and legislation	There is an EU framework for teleoperation. It is case by case. The distant coverable is, 8000k for now, in principle.	Framework	Economic	Economic
W2	Exported unemployment - working from Estonia to the US, for example.	There is no direct legislation against it. Not that is known. That might be social agitations, but there is no law forbidding teleoperation drivers from a foreign country to drive vehicles in another.	Framework	Economic and societal	Economic and societal
W2	Regulatory process	There is a framework on network regulation, but none specifically for 5G now.	Framework	Economic	Economic
W2	Risk of cyberattacks	The government has developed an Act of the parliament, the Cybersecurity Act. It covers ensuring business make risk assessment and mitigate those risks.	Framework	Economic and Societal	Economic and Societal

Source: Atlasti [65]

Note that all detailed results of the data analyses conducted have been moved to the appendix of the study.

Finally, in Table 8, the data of the interview was analyzed for other factors that could express the impact the 5G teleoperated vehicle could have economically and societally in Estonia. These factors are synonymous to the intercept values of the simple regression models that were regressed under the quantitative data analysis of the study. They are important but seemingly immaterial when viewed quantitatively, but the result of the qualitative data showed that they could be material and statistically significant. These include when and how the project started, the challenges involved in the implementation of 5G-ToV, introduction of the 6 generation of network technology, creation of other jobs than teleoperation drivers, and decision on insurance indemnification in the occurrence of an accident. All of these have both economic and societal impacts from 5G teleoperated chapter four. The findings showed that total transport % GDP, transport employment/population ratio, and Estonian life expectancy from birth are all positively related to spending or investment in 5G teleoperated vehicles, while total road accident death is negatively related. This is indicated by the signs of the coefficient statistics in Table 3. All the coefficients were positive except for road accident death. This means that an increase in the value of investment spending on 5G-ToV will increase transport % GDP, transport employment/population ratio, and Estonian life expectancy from birth but will reduce road accident death. This shows that, without considering whether the value of the corresponding change is significant or not, 5G-ToV is good for economic growth – indicated by the GDP and transport employment – and good for societal security.

Also, factors such as network capacity, investment strength, and consumer protection are key qualitative variables that can contribute to economic and societal benefits and risks in Europe viz-a-viz Estonia. The most important of them is the amount of funding that can be attracted for the teleoperation business. Even more important is how the funds are distributed: across the right technologies that agree with 5G network and training of qualified personnel that can build and support the operations.

The 5G teleoperated vehicle deployment is not without limitations. The major limitation is the lack of agreement across major developed countries of the world on the best practice for 5G teleoperation. This includes in terms of job creation and export of unemployment, reduced transfer fund in terms of foreign direct investment attrition when other countries can us teleoperation as an economic incursion in another. Other limitations are how international accidents and theft cases are handled. The framework on who bears what and how the investigation is to be conducted is case-by-case and not global. One major area of further research will be the monitoring of 5G teleoperated vehicles' performances and creation of a database that captures important indicators that can be used to monitor its economic and societal benefits and risks in vehicles.

Table 8: Autonomous Variables from 5G Teleoperated (5G-ToV) Vehicle

Case	**Quotations**	**Comments**	**Codes**	**Risk**	**Benefits**
W1	How it started	AV project started as a gift to the University for her 100 years anniversary before going commercial with 20 vehicles, fully in operation in Europe and Middle East.	Others	Economic and Societal	Economic and Societal
W1	Challenge of implementation of autonomous driving.	Daily operations, vehicle management, cybersecurity, hardware, and software differences in vehicles. Network issues, irrespective of 4G or 5G.	Others	Economic and Societal	Economic and Societal
	Jobs creation	More than double in the last two years	Others	Economic and Societal	Economic and Societal
W2	New Standardization	There is already a standardization for 6G	Others	Economic and Societal	Economic and Societal
W3	Hiring the right people	It has been difficult hiring the right people. We move people upward from the middle management and areas of expertise that can be leveraged. Example is engineers that can use C++. We also sponsor engineers from year one till end to work with us to understand the technical aspect of the development.	Others	Economic and societal	Economic and societal
W3	Who is responsible for an accident?	It is the company, but mostly dependent on the details involved during the accident and the result of the investigations.	Others	Societal	Societal

Source: Atlasti [65]

The result of the mixed method research conducted in this study showed that 5G teleoperated vehicle is an important driver of economic activities in Estonia. Society also has a lot to benefit from it, while the risks are obvious but can be mitigated through enough and well-directed investment. The qualitative and quantitative aspects of the research agreed in total, but the former was more revealing than the latter. The qualitative research showed the intrinsic values of the autonomous variables that were simply described as intercepts among the Simple Linear Regression (SLR) models. It also shows that commensurate investment in teleoperated vehicles and knowledge will mitigate most of the risks associated with 5G-ToV and boost economic and societal values.

CHAPTER FIVE

5 CONCLUSION AND FUTURE WORK

The main objective of this study was to investigate the economic and societal impact of 5G teleoperated vehicles on the Estonian transport and logistics industry. To achieve this objective, the used the mixed method research designs to answer the following research questions that had earlier been stated in the first chapter:

1. What are the current states of 5G-ToV and what response should the transport and logistics industry in Europe have towards its implementation?

2. What are the economic and societal benefits and risks of implementing 5G-ToV in Europe, and how can we build on the benefits and mitigate the risks respectively?

3. What are the societal and technical limitations of 5G-ToV in the transport and logistics industry and how can they affect acceptance and deployment respectively?

The first research question was empirically answered in chapters two and three. The findings showed that the current state of 5G teleoperated vehicles provided opportunities for economic expansion and growth from the transport and logistics industry. Operators in the Estonian transport and logistics industry are gearing up to deploying 5G teleoperated vehicles, but the investment outlook is a little bleak because venture capitalist and strategic partners are keen on return. The network architecture itself was discovered not to bear much difference between the 4th generation network technologies. But the important part is the development of vehicles that can consume the capacity that 5G network technologies will release to enhance speed, car-pooling, and vehicular platooning. Also, it also was found that most countries outside EU do not have framework that guide 5G teleoperation. The operation communication then depends on what the country of service requires at a point in time until there is a global standardization.

The second and third research question was empirically answered with the analyses derived from the time series data and the interview data in chapter four. The findings showed that total transport % GDP, transport employment/population ratio, and Estonian life expectancy from birth are all positively related to spending or investment in 5G teleoperated vehicles while total road accident death is negatively related. This is indicated by the signs of the coefficient statistics in Table 3. All the coefficients were positive except for road accident death. This means that an increase in the value of investment spending on 5G-ToV will increase transport % GDP, transport employment/population ratio, and Estonian life expectancy from birth but will reduce road accident death. This shows that, without considering whether the value of the corresponding change is significant or not, 5G-ToV is good for economic growth – indicated by the GDP and transport employment – and good for societal security.

Also, factors such as network capacity, investment strength, and consumer protection are key qualitative variables that can contribute to economic and societal benefits and risks in Europe viz-a-viz Estonia. The most important of them is the amount of funding that can be attracted for the teleoperation business. Even more important is how the funds are distributed: across the right technologies that agree with 5G network and training of qualified personnel that can build and support the operations.

The 5G teleoperated vehicle deployment is not without limitations. The major limitation is the lack of agreement across major developed countries of the world on the best practice for 5G teleoperation. This includes in terms of job creation and export of unemployment, reduced transfer fund in terms of foreign direct investment attrition when other countries can us teleoperation as an economic incursion in another. Other limitations are how international accidents and theft cases are handled. The framework on who bears what and how the investigation is to be conducted is case-by-case and not global. One major area of further research will be the monitoring of 5G teleoperated vehicles' performances and creation of a database that captures important indicators that can be used to monitor its economic and societal benefits and risks in Europe.

LIST OF APPENDICES

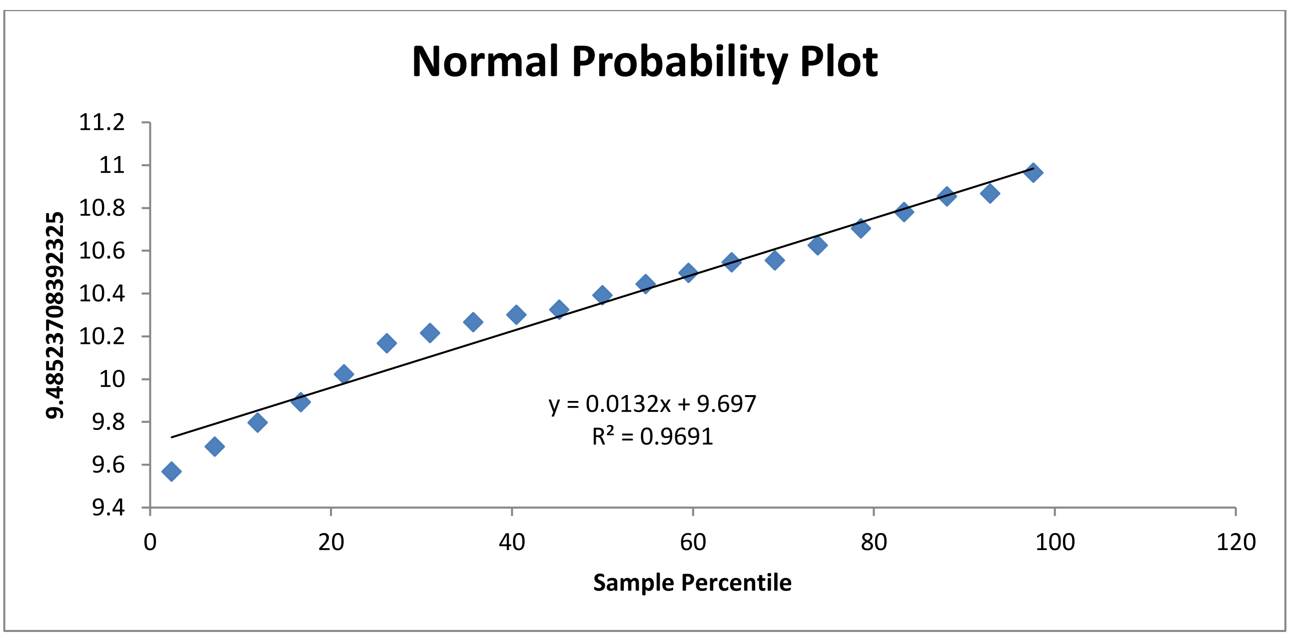
Regression Result and Normal Probability Plot: ***TOT GDP* = *α* + *β5G-ToV***

Regression Statistics	
Multiple R	0.9367951
R Square	0.8775851
Adjusted R Square	0.8711422
Standard Error	0.142079
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.7495946	2.7495946	136.20989	4.138E-10
Residual	19	0.3835426	0.0201865		
Total	20	3.1331372			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.3856551	0.9209318	-0.4187662	0.6800829	-2.3131876	1.5418774	-2.3131876	1.5418774
16.90655301	0.5753375	0.0492968	11.670899	4.138E-10	0.4721582	0.6785168	0.4721582	0.6785168



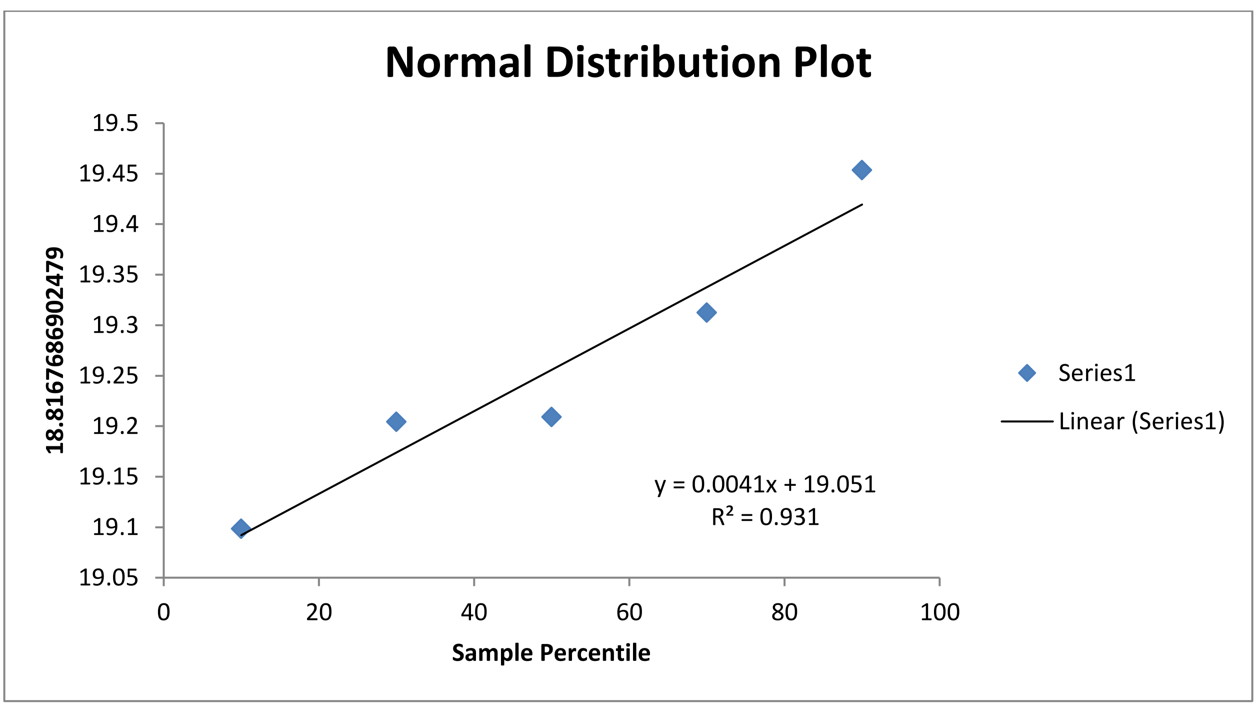
Structural Break from 2016 – the supposed year of 5G development and investment

Regression Statistics	
Multiple R	0.952756882
R Square	0.907745675
Adjusted R Square	0.876994234
Standard Error	0.047035157
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.06530462	0.06530462	29.51880071	0.012238831
Residual	3	0.006636918	0.002212306		
Total	4	0.071941538			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.128786991	2.600249791	1.972420884	0.143109026	-3.14636835	13.40394233	-3.14636835	13.40394233
10.62621851	1.303858584	0.239983364	5.433120716	0.012238831	0.540124415	2.067592752	0.540124415	2.067592752



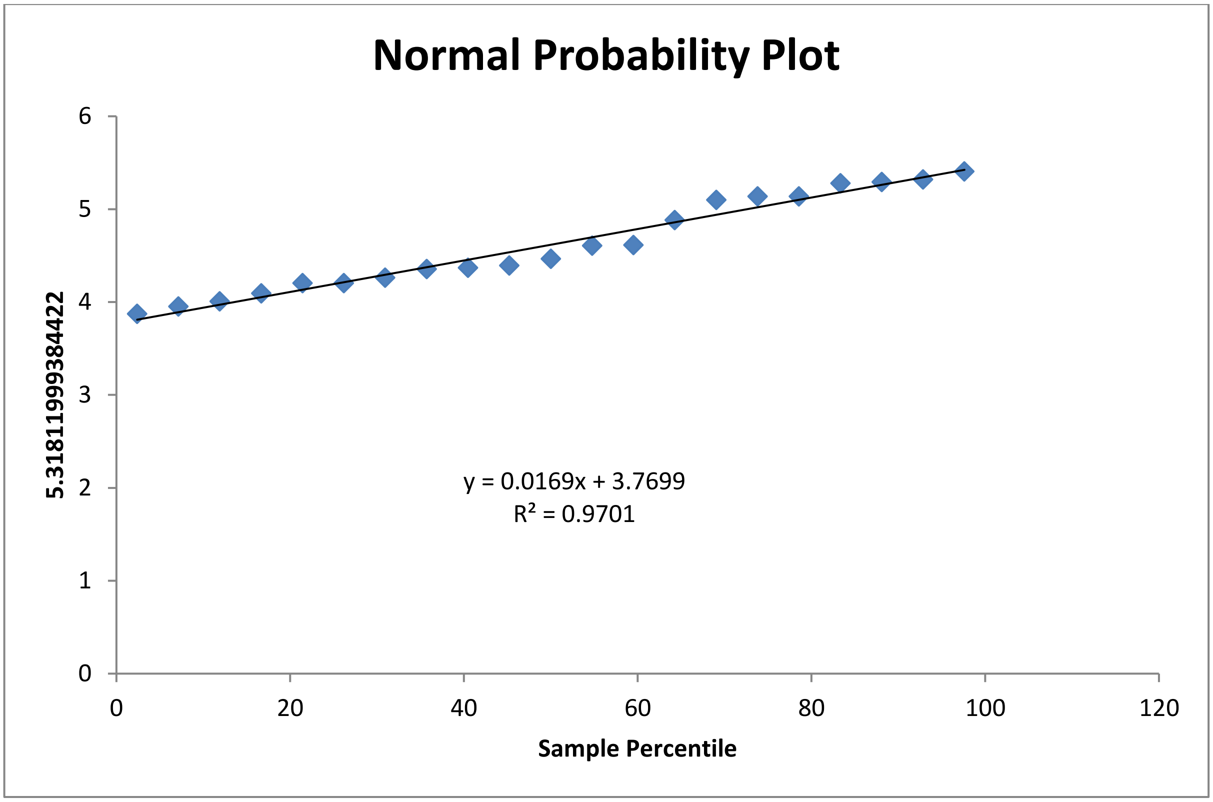
Regression Result and Normal Probability Plot: ***Road Accident= α + β5G-ToV***

Regression Statistics	
Multiple R	0.7839731
R Square	0.6146138
Adjusted R Square	0.5943303
Standard Error	0.3236384
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.1738025	3.1738025	30.301193	2.608E-05
Residual	19	1.9900949	0.1047418		
Total	20	5.1638974			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	16.157795	2.0977685	7.7023728	2.93E-07	11.767115	20.548475	11.767115	20.548475
16.906553	-0.6181279	0.1122919	-5.5046519	2.608E-05	-0.8531575	-0.3830982	-0.8531575	-0.3830982



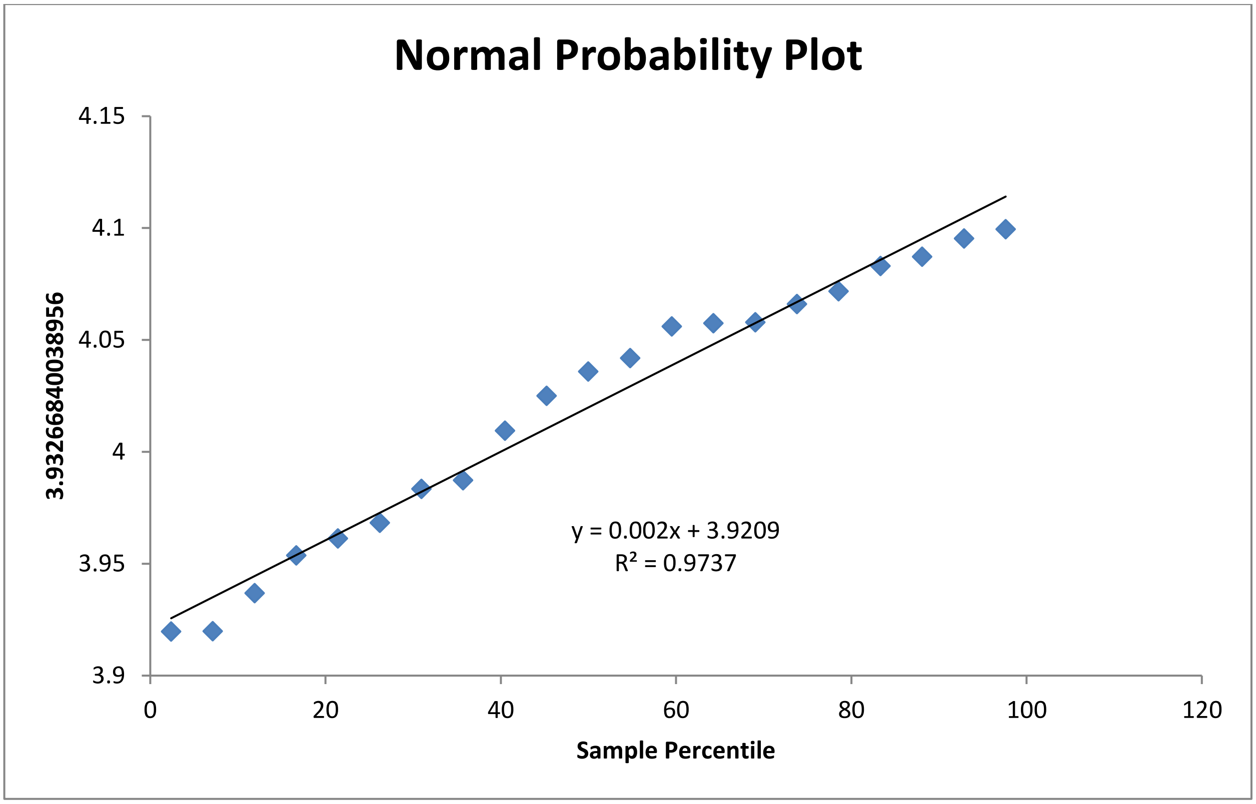
Regression Result and Normal Probability Plot: ***E/P ratio*= *α* + *β*5G-ToV**

Regression Statistics	
Multiple R	0.7663127
R Square	0.5872352
Adjusted R Square	0.5655107
Standard Error	0.0390555
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0412313	0.0412313	27.031053	5.106E-05
Residual	19	0.0289813	0.0015253		
Total	20	0.0702126			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.7044375	0.2531509	10.683103	1.797E-09	2.1745865	3.2342885	2.1745865	3.2342885
16.906553	0.0704534	0.013551	5.1991396	5.106E-05	0.0420909	0.0988159	0.0420909	0.0988159



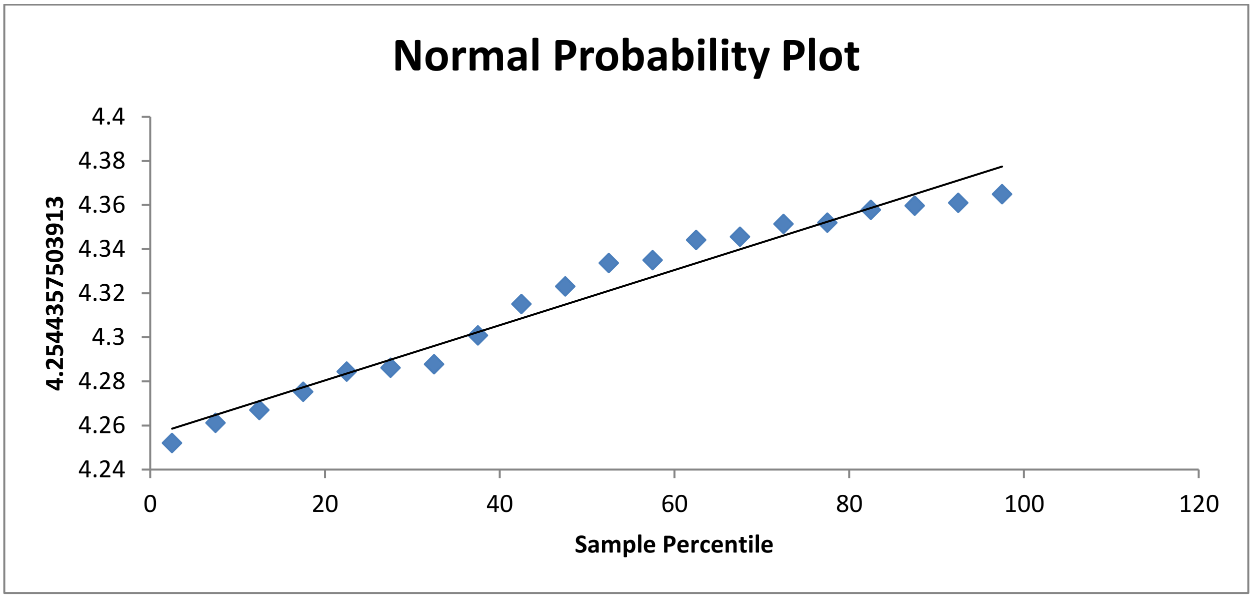
Regression Result and Normal Probability Plot: ***LifExp. = α + β5G-ToV***

Regression Statistics	
Multiple R	0.8869049
R Square	0.7866003
Adjusted R Square	0.7747447
Standard Error	0.017886
Observations	20

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0212255	0.0212255	66.34875399	1.894E-07
Residual	18	0.0057583	0.0003199		
Total	19	0.0269838			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	3.3374125	0.1204512	27.707597	3.25752E-16	3.084354	3.5904711	3.084354	3.5904711
16.906553	0.0526304	0.0064613	8.1454744	1.89418E-07	0.0390557	0.0662051	0.0390557	0.0662051



Normal Probability Plot
4.2544357503913
4.4
4.38
4.36
4.34
4.32
4.3
4.28
4.26
4.24
0
20
40
60
80
100
120
Sample Percentile

REFERENCES

[1] European Commission, '5G | Shaping Europe's digital future', Feb. 23, 2023. https://digital-strategy.ec.europa.eu/en/policies/5g (accessed Mar. 08, 2023).

[2] Eurofound, *Automation, digitalisation and platforms: implications for work and employment*. Luxembourg: Publications office of the European Union, 2018.

[3] Intel, 'What Is 5G Technology', *What You Should Know About 5G Technology*, 2023. https://www.intel.com/content/www/us/en/wireless-network/what-is-5g.html (accessed Mar. 08, 2023).

[4] Ìntel, 'Benefits of 5G Technology_ 5g Features and Advantages _ Intel.pdf', *Understanding the advantages of 5G*, 2023. https://www.intel.com/content/www/us/en/wireless-network/5g-benefits-features.html (accessed Mar. 03, 2023).

[5] G. Kakkavas *et al.*, 'Teleoperated Support for Remote Driving over 5G Mobile Communications', in *2022 IEEE International Mediterranean Conference on Communications and Networking (MeditCom)*, Athens, Greece: IEEE, Sep. 2022, pp. 280–285. doi: 10.1109/MeditCom55741.2022.9928745.

[6] STL Partners, '5G impact on transport and logistics: $280bn of benefits in 2030', *STL Partners*, Sep. 16, 2020. https://stlpartners.com/research/5g-transport/ (accessed Mar. 03, 2023).

[7] S. Gnatzig, F. Chucholowski, T. Tang, and M. Lienkamp, 'A System Design for Teleoperated Road Vehicles', 2013.

[8] E. Abad-Segura, M.-D. González-Zamar, E. López-Meneses, and E. Vázquez-Cano, 'Financial Technology: Review of Trends, Approaches and Management', *Mathematics*, vol. 8, no. 6, p. 951, Jun. 2020, doi: 10.3390/math8060951.

[9] M.-D. González-Zamar, E. Abad-Segura, E. Vázquez-Cano, and E. López-Meneses, 'IoT Technology Applications-Based Smart Cities: Research Analysis', *Electronics*, vol. 9, no. 8, p. 1246, Aug. 2020, doi: 10.3390/electronics9081246.

[10] S. Li, Y. Zhang, S. Edwards, and P. T. Blythe, 'Exploration into the Needs and Requirements of the Remote Driver When Teleoperating the 5G-Enabled Level 4 Automated Vehicle in the Real World—A Case Study of 5G Connected and Automated Logistics', *Sensors*, vol. 23, no. 2, p. 820, Jan. 2023, doi: 10.3390/s23020820.

[11] Tuan C. Nguyen, 'How a 1930's Exhibit Set the Stage For Driverless Cars', *ThoughtCo*, 2019. https://www.thoughtco.com/history-of-self-driving-cars-4117191 (accessed Mar. 09, 2023).

[12] L. M. Clements and K. M. Kockelman, 'Economic Effects of Automated Vehicles', *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2606, no. 1, pp. 106–114, Jan. 2017, doi: 10.3141/2606-14.

[13] P. Chen, 'SURFACE VEHICLE RECOMMENDED PRACTICE (R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles', Nov. 2021.

[14] Switchio, 'Population growth and public transport. What is the future of ridership?', *Intelligent Transport*, 2021. https://www.intelligenttransport.com/transport-articles/125982/population-growth-and-public-transport-what-is-the-future-of-ridership/ (accessed Mar. 09, 2023).

[15] J. M. Marquez-Barja *et al.*, 'Designing a 5G architecture to overcome the challenges of the teleoperated transport and logistics', in *2022 IEEE 19th Annual Consumer Communications & Networking Conference (CCNC)*, Jan. 2022, pp. 264–267. doi: 10.1109/CCNC49033.2022.9700565.

[16] E. S. C. ACMC, 'Countries With The Highest Youth/Young Population 2022: Top 9', *Bscholarly*, Aug. 12, 2022. https://bscholarly.com/countries-with-the-highest-youth-young-population-2022-top-9/ (accessed Dec. 02, 2022).

[17] Sharon Omondi, 'What is a Megacity?', *WorldAtlas*, Jun. 28, 2018. https://www.worldatlas.com/articles/what-is-a-megacity.html (accessed Mar. 09, 2023).

[18] J. KING, 'COMMISSION RECOMMENDATION - Cybersecurity of 5G networks', European Union, (EU) 2019/ 534, Mar. 2019.

[19] N. Goodall, 'Non-technological challenges for the remote operation of automated vehicles', *Transp. Res. Part Policy Pract.*, vol. 142, pp. 14–26, Dec. 2020, doi: 10.1016/j.tra.2020.09.024.

[20] 5GBoom, 'Who Invented 5G? What Should We Know? - Revolution in smartphones', *5gboom.net*, Jul. 10, 2020. https://5gboom.net/who-invented-5g-what-should-we-know/ (accessed Mar. 10, 2023).

[21] J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 2014.

[22] S. Almalki, ‘Integrating Quantitative and Qualitative Data in Mixed Methods Research—Challenges and Benefits’, *J. Educ. Learn.*, vol. 5, no. 3, p. 288, Jul. 2016, doi: 10.5539/jel.v5n3p288.

[23] M. Sandelowski, ‘Combining Qualitative and Quantitative Sampling, Data Collection, and Analysis Techniques in Mixed-Method Studies’, *Res. Nurs. Health*, vol. 23, no. 3, pp. 246–255, Jun. 2000, doi: 10.1002/1098-240X(200006)23:3<246::AID-NUR9>3.0.CO;2-H.

[24] B. Rittichainuwat and S. Rattanaphinanchai, ‘Applying a mixed method of quantitative and qualitative design in explaining the travel motivation of film tourists in visiting a film-shooting destination | Elsevier Enhanced Reader’, *Elsevier Ltd*, vol. 4, pp. 136-, 2015, doi: 10.1016/j.tourman.2014.06.005.

[25] J. Marquez-Barja *et al.*, *5G-Blueprint: Next Generation Connectivity for Enhanced, Safe, Efficient Transport & Logistics Invited Paper*. 2021.

[26] J. M. Marquez-Barja *et al.*, ‘Enhanced Teleoperated Transport and Logistics: A 5G Cross-Border Use Case’, in *2021 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)*, Porto, Portugal: IEEE, Jun. 2021, pp. 229–234. doi: 10.1109/EuCNC/6GSummit51104.2021.9482459.

[27] L. J. Savage, ‘The Theory of Statistical Decision’, *J. Am. Stat. Assoc.*, vol. 46, no. 253, pp. 55–67, Mar. 1951, doi: 10.1080/01621459.1951.10500768.

[28] Mathilde Carlier, ‘Transport industry in Europe - statistics and facts’, *Statista*, 2022. https://www.statista.com/topics/3671/transportation-industry-in-europe/ (accessed Mar. 11, 2023).

[29] Brisklogic, ‘Digital Transformation in Transportation and Logistics - Build digital product faster, smarter and scalable.’, *Transportation and Logistics*, Aug. 26, 2020. https://www.brisklogic.co/digital-transformation-in-transportation-and-logistics/ (accessed Mar. 12, 2023).

[30] Sven Ove Hansson, ‘Decision Theory: a brief introduction’, *Wayback Machine*, Jul. 05, 2006. https://web.archive.org/web/20060705052730/http://www.infra.kth.se/~soh/decisiontheory.pdf (accessed Mar. 12, 2023).

[31] S. Bouffouix, M. Bogaert, and S. Do, ‘A Real-Time Obstacle Avoidance Algorithm for Teleoperated Vehicles’, *IFAC Proc. Vol.*, vol. 26, no. 1, pp. 223–228, Apr. 1993, doi: 10.1016/S1474-6670(17)49303-7.

[32] G. Kakkavas *et al.*, ‘Demo Proposal: Tele-Operated Support over 4G/5G Mobile Communications’, in *2021 IEEE International Mediterranean Conference on*

Communications and Networking (MeditCom), Athens, Greece: IEEE, Sep. 2021, pp. 1–2. doi: 10.1109/MeditCom49071.2021.9647643.

[33] David Bissell, Thomas Birtchnell, Anthony Elliott, and Eric L Hsu, 'Autonomous automobilities: The social impacts of driverless vehicles', *SAGE J.*, vol. 68, no. 1, pp. 116–134, 2020, doi: https://doi.org/10.1177/0011392118816743.

[34] Statista, 'Africa: GDP by country 2021 | Statista', 2022. https://www.statista.com/statistics/1120999/gdp-of-african-countries-by-country/ (accessed Dec. 02, 2022).

[35] World Bank, 'Overview of sustainable transport', *World Bank*, 2023. https://www.worldbank.org/en/topic/transport/overview (accessed Mar. 09, 2023).

[36] S. Lichiardopol, 'A Survey on Teleoperation', *DCT Rapp.*, vol. 155, pp. 1–34, 2007.

[37] P. Pérez, J. Ruiz, I. Benito, and R. López, 'A parametric quality model to evaluate the performance of tele-operated driving services over 5G networks', *Multimed. Tools Appl.*, vol. 81, no. 9, pp. 12287–12303, Apr. 2022, doi: 10.1007/s11042-021-11251-x.

[38] C. J. Harris and R. J. C. Fraser, 'Command and Control for Intelligent Autonomous Vehicles: An Approach Emphasising Interoperability', *IFAC Proc. Vol.*, vol. 25, no. 22, pp. 43–56, Sep. 1992, doi: 10.1016/S1474-6670(17)49634-0.

[39] A. Podhurst, 'The complete guide to autonomous vehicle teleoperation', *DriveU*, Apr. 06, 2021. https://driveu.auto/blog/the-complete-guide-to-av-teleoperation/ (accessed Mar. 12, 2023).

[40] G. Bruzzone *et al.*, 'Internet-Based Teleoperation of Underwater Vehicles', *IFAC Proc. Vol.*, vol. 36, no. 4, pp. 193–198, Apr. 2003, doi: 10.1016/S1474-6670(17)36680-6.

[41] V. Berggren, A. Vulgarakis, A. Karapantelakis, and E. Fersman, '5G teleoperated vehicles for future public transport', 2017. https://www.ericsson.com/en/blog/2017/6/5g-teleoperated-vehicles-for-future-public-transport (accessed Mar. 09, 2023).

[42] Viktor Berggren *et al.*, '5G teleoperated vehicles for future public transport', 2017. https://www.ericsson.com/en/blog/2017/6/5g-teleoperated-vehicles-for-future-public-transport (accessed Mar. 11, 2023).

[43] Y. Zheng, M. J. Brudnak, P. Jayakumar, J. L. Stein, and T. Ersal, 'An Experimental Evaluation of a Model-Free Predictor Framework in Teleoperated Vehicles**This work was supported by the Automotive Research Center (ARC) in accordance with Cooperative Agreement W56HZV-14-2-0001 U.S. Army Tank Automotive Research,

Development and Engineering Center (TARDEC) Warren, MI. UNCLASSIFIED: Distribution Statement A. Approved for public release. #27479', *IFAC-Pap.*, vol. 49, no. 10, pp. 157–164, Jan. 2016, doi: 10.1016/j.ifacol.2016.07.513.

[44] T.-Mobile, 'T-Mobile for Business BrandVoice: How Can 5G Transform Transportation And Logistics?', *Forbes*, 2021. https://www.forbes.com/sites/tmobile/2021/06/07/how-can-5g-transform-transportation-and-logistics/ (accessed Mar. 03, 2023).

[45] Amit Rosenzweig, 'The success of self-driving vehicles will depend on teleoperation', *VentureBeat*, Jun. 03, 2021. https://venturebeat.com/ai/the-success-of-self-driving-vehicles-will-depend-on-teleoperation/ (accessed Mar. 12, 2023).

[46] M.-A. Fénart, R. Scherwey, and G. Python, *Switzerland's first teleoperated vehicle*. 2021.

[47] N. Slamnik-Kriještorac, S. Latré, and J. Marquez-Barja, *An optimized application-context relocation approach for Connected and Automated Mobility (CAM)*. 2021.

[48] A. Kousaridas *et al.*, 'QoS Prediction for 5G Connected and Automated Driving', *IEEE Commun. Mag.*, vol. 59, no. 9, pp. 58–64, Sep. 2021, doi: 10.1109/MCOM.110.2100042.

[49] European Union, '5G for Connected and Automated Road Mobility in the European UnioN', *5G CARMEN*, 2020. https://5gcarmen.eu/ (accessed May 02, 2023).

[50] A. C. L. Yu, 'The Role of Experimental Investigation in Understanding Sound Change', *Oxf. Handb. Online*, 2015, Accessed: Mar. 16, 2023. [Online]. Available: https://www.academia.edu/2521114/The_role_of_experimental_investigation_in_understanding_sound_change

[51] R. Katoch and S. Shilpa, 'Cointegration between Nifty 50 Spot and Future Indices: An Empirical Analysis Applying Vector Error Correction Model', *Int. J. Recent Innov. Trends Comput. Commun.*, vol. 10, pp. 168–180, Dec. 2022, doi: 10.17762/ijritcc.v10i12.5933.

[52] R. Bevans, 'Choosing the Right Statistical Test | Types & Examples', *Scribbr*, Jan. 28, 2020. https://www.scribbr.com/statistics/statistical-tests/ (accessed May 08, 2023).

[53] OECD, 'Transport - Infrastructure investment - OECD Data', *The OECD*, 2023. http://data.oecd.org/transport/infrastructure-investment.htm (accessed May 11, 2023).

[54] Trading Economics, 'Estonia GDP From Transport - 2023 Data - 2024 Forecast - 1995-2022 Historical - Chart', 2022. https://tradingeconomics.com/estonia/gdp-from-transport (accessed May 11, 2023).

[55] R. Liao, W. Liu, and Y. Yuan, 'Resilience Improvement and Risk Management of Multimodal Transport Logistics in the Post–COVID-19 Era: The Case of TIR-Based Sea–Road Multimodal Transport Logistics', *Sustainability*, vol. 15, p. 6041, Mar. 2023, doi: 10.3390/su15076041.

[56] World Bank, 'World Bank Open Data', *World Bank Open Data*, 2022. https://data.worldbank.org (accessed May 11, 2023).

[57] A. A. Ameen and K. Ahmad, 'Towards Harnessing Financial Information Systems in Reducing Corruption: A Review of Strategies', p. 11, 2012.

[58] A. Çelik, 'Testing Linear and Nonlinear Relationships Between Foreign Direct Investment and Fossil Energy Consumption in Fragile Five Countries', *Ekoist J. Econom. Stat.*, Feb. 2023, doi: 10.26650/ekoist.2023.38.1090992.

[59] Alan Anderson and David Semmelroth, 'Key Properties of a Time Series in Data Analysis', *Economics and Education*, 2016. https://www.dummies.com/article/technology/information-technology/data-science/big-data/key-properties-of-a-time-series-in-data-analysis-141265/ (accessed May 09, 2023).

[60] U. Hodeghatta and U. Nayak, 'Multiple Linear Regression', 2023, pp. 227–276. doi: 10.1007/978-1-4842-8754-5_8.

[61] Zach, 'The Four Assumptions of Linear Regression', *Statology*, Jan. 08, 2020. https://www.statology.org/linear-regression-assumptions/ (accessed May 11, 2023).

[62] Z. Patonai, R. Kicsiny, and G. Géczi, 'Multiple linear regression based model for the indoor temperature of mobile containers', *Heliyon*, vol. 8, no. 12, p. e12098, Dec. 2022, doi: 10.1016/j.heliyon.2022.e12098.

[63] Q.-H. Luu, M. F. Lau, S. P. H. Ng, and T. Y. Chen, 'Testing multiple linear regression systems with metamorphic testing', *J. Syst. Softw.*, vol. 182, p. 111062, Dec. 2021, doi: 10.1016/j.jss.2021.111062.

[64] J. N. Lester, Y. Cho, and C. R. Lochmiller, 'Learning to Do Qualitative Data Analysis: A Starting Point', *Hum. Resour. Dev. Rev.*, vol. 19, no. 1, pp. 94–106, Mar. 2020, doi: 10.1177/1534484320903890.

[65] M. J. M. Brito, C. da Silva Caram, L. C. Montenegro, L. C. Rezende, H. M. S. Rennó, and F. R. S. Ramos, 'Potentialities of Atlas.ti for Data Analysis in Qualitative Research

in Nursing', *Comput. Support. Qual. Res.*, pp. 75–84, 2017, doi: 10.1007/978-3-319-43271-7_7.