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MASTER'S THESIS DEGREE IN CIVIL ENGINEERING

THE IMPACT OF THE COVID-19 PANDEMIC ON TRANSPORTATION IN METROPOLITAN CITIES AND OUTLINING MEASURES THAT COULD HELP BUILD RESILIENCE AND SUSTAINABILITY: A CASE STUDY – BOLOGNA.

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ABSTRACT

One of the most impacted sectors of the COVID pandemic was the mobility industry, with passenger and freight transport being adversely affected. This dissertation investigates the impacts of the COVID-19 pandemic on mobility considering a study case of Bologna by analysing readily available data of public transportation (buses), vehicle and cyclist flows collected from manual passenger counts, automatic traffic and cyclist counters respectively. The timeline of the study was split in to four phases covering periods before the pandemic occurred, during the first lockdown, immediately after lockdown restrictions were lifted and post-lockdown stages. Additional data was obtained from the open access data provided by Moovit app on the usage of mobility options during the timeframe of the study. Analysis on data for the modes considered included weekly trip comparisons from 2019 and 2020, comparisons of usage during phases of the study, modal comparisons considering modal shares and percentage changes observed. Measures (policy and infrastructure wise) enacted by local government authorities in Bologna prior and during this pandemic are also examined considering the role of sustainability and resilience building. Results obtained from the case study as well as policies being employed are compared to other metropolitan cities to identify some similarities and differences to establish conclusions with recommendations suggested. It is found that Bologna experienced an overall mobility reduction of 76%, 18% and 0.5% during the phases 2, 3 and 4 respectively. Additionally, cycling was the only mode to surpass its initial levels from Phase 1 in Phase 3, showing 31% and 40% increases in usage in Phases 3 and 4. Public transportation (buses) was the most impacted during Phase 2 experiencing about 90% decrease in usage. Private transport (vehicle use) showed the most resilience reaching figures (101.4%) in Phase 4 almost identical to that recorded before the lockdown. This study recommends that policymakers should direct attention to improving active travel modes since they would play a significant role in the transport choice of users.

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CHAPTER 1 – INTRODUCTION

1.1. BACKGROUND

The COVID-19 (also known as coronavirus) outbreak started in December 2019 in Wuhan, China, and rapidly spread in many countries all over the world (e.g., Jiang et al., 2020; Lipistch et al., 2020). In March 2020, the World Health Organization declared the outbreak as a pandemic, with countries such as China, Italy, Spain and the US being hit hardest. The virus's incubation period of 2–10 days afforded ample opportunity for infected but asymptomatic travellers to export infection undetected across international borders and propagate transmission in receiving communities. By the end of May 2020, the virus (and the COVID-19 disease it causes) had spread to most countries on earth. By June 1st 2020, the WHO reported that over 6 million people had been infected worldwide and over 371,000 had died with COVID-19 (WHO, 2020).

Passenger transport within the EU Member States and between the European Union and the rest of the world were partially or entirely closed. On March 17, 2020, for the first time in its history, the European Union closed all its external borders to prevent a further spreading of the virus (European Commission 2020). This decision to temporarily restrict all non-essential travel was by no means uncontroversial, although it was very much in line with the mitigation strategies of most of the local governments: Italy introduced a national lockdown on March 9, Germany implemented school and border closures starting March 13, Spain followed on March 14, and France on March 16. By 18 March, 2020, more than 250 million people in Europe were in lockdown (European Commission 2020). Overall, the transport sector has been hit hard by the impact of COVID-19. Both passengers transport and freight suffered severe setbacks from the COVID19 crisis.

Many countries took drastic steps, such as closing schools, stores, restaurants and bars, restricting public gatherings, and stimulating or forcing work from home, to avoid social interaction and slow down the spread of the virus. These measures could all be labelled as "social distancing", and are especially efficient for diseases (such as COVID-19) which are transmitted by respiratory droplets and require a certain proximity of people (Wilder-Smith and Freedman, 2020). Transportation systems which allow the physical movement of, and enable contact among, many different people provide an enabling environment for contagion spread (Browne, A. et al, 2016). Hence in effect, travel restrictions were implemented. Several papers have looked to quantify the impact of these travel restrictions on transmissibility reductions of the virus (Fang, Wang, & Yang, 2020; H. Liu et al., 2020a). Almost immediately, people changed their daily routines and altered their household mobility and consumption patterns.

Travel demand consequently dropped due to an increased amount of working from home, e-learning, and a reduced number of public activities and events. This resulted in less car traffic – and less congestion during peak hours – and in reduced public transport ridership as well as influenced travel mode choice. Restrictions on transport also coincided with record temporary reductions in noise, road accidents and air pollution (Mahato et al. 2020, Tobias et al. 2020, Liu et al.). In Europe, passenger air traffic fell by as much as 90% (Eurocontrol, 2020) while the number of passengers using public transport declined by 80% in some cities as commuter demand evaporated and transport operators reduced their services (Bernhardt, 2020). Road transport faced several problems as well, and its efficiency plumbed. In the UK, road traffic volumes fell by as much as 73% to levels not seen since the mid-1950s as private cars remained on driveways and people adhered to government advice to remain indoors (Carrington, 2020).

In Italy, restrictions were initially applied more restrictively than other states except for China. The northern regions of Italy implemented these restrictions through the creation of limited zones called Red Zones (Zona Rossa). These measures were subsequently extended nationwide on 9 March. In these areas, movement to and from places was banned except for work, needs, and health emergencies. All sporting events and public meetings were banned, and schools, universities, and recreational facilities were closed. During the first weeks of the pandemic, Italy registered over 7300 confirmed infections, of which 366 resulted in deaths. On 11 March, restaurants and bars were closed. After 12 March, the Italian government banned all travel and forced people to stay at home. On 20 March, parks, gardens, and playgrounds were closed as well. Industries producing non-essential goods as well as non-essential services were closed on 22 March.

Lockdown measures were gradually lifted in Europe member state countries in the period from May till July of 2020; with each member country adapting specific measures to fit their situations internally. Post the pandemic, social distancing looks likely to be a part of measures in place till the near future. In terms of mobility, the role of active travel has gained prominence concurrent with the change in individual travel behaviour. Policymakers and transport planners are attempting to meet this demand by permanently (and in some cases temporarily) allocating less-used street space to cyclists and pedestrians (King and Krizek, 2020), especially at places that were previously affected by traffic congestion and did not have adequate walking and cycling infrastructure. Cities in Europe (e.g., Berlin, Vienna), North America (e.g., Philadelphia, Vancouver), and Latin America (e.g., Bogota, Mexico City) are examples of such government led interventions (Laker, 2020).

This study investigates the effects of the COVID pandemic on mobility in metropolitan cities using a case study of Bologna, the capital of the Emilia Romagna province in Italy. Public transportation data from passenger counts in buses, cyclist counts and traffic counts from major parts of the city would be analysed. Further analysis would be conducted to look at a how the pandemic has influenced the modal choices of people post COVID. It compares COVID-19 with other health risks, examines and compares policy and infrastructural changes which have been put into effect post COVID. It also recommends ways by which metropolitan cities could shape mobility plans for the future while prioritising resilience.

1.2 RESEARCH GOAL AND OBJECTIVES

The focal goal of this thesis is to research the impacts of the COVID pandemic on transportation in metropolitan cities by analysing data using a study case of Bologna. The following objectives are the driver of this thesis:

i. an analysis of data obtained from passenger in buses counts, traffic counts and bicycle count before and after the pandemic to demonstrate empirical evidence of the impacts,

ii. a background study would be conducted via a literature review into the pandemic and it's impacts in other places in the world (Italy, Europe and worldwide),

iii. The scope of this study would extend beyond a look at the obvious negative impacts of the pandemic on transportation but would also be focus on resilience and sustainable building going forward

iv. This study would also look at post-pandemic measures that are being implemented in Bologna in the transportation sector and make a comparison with other metropolitan cities (infrastructure and policy wise), and

v. outlining suggestions that could be implemented to improve efficiency and safety in the transportation sector at the metropolitan level.

1.2.1 Research Questions

To successfully meet the research objectives, suitable research questions must be asked and answered. These questions would further be grouped respectively according to a timeframe with respect to the pandemic. Below are the research questions for this study:

PRE

a. What was the outlook of the transportation prior to the pandemic?

DURING

a. How did the pandemic affect transportation/mobility in Bologna?
b. What were the impacts; on modes of transportation?

POST

a. What kind of data do we have access to indicate the impacts of the pandemic on transportation?
b. What kind of analysis can we conduct on the data and what can we infer from the results?
c. If possible, can there be access to data which indicates the shift of personal choices towards specific transportation modes?
d. What kind of measures are being taken in specific modes of transportation (case study and globally)? For example, in public transportation
e. How effective have these measures been? A look at both the good and bad examples
f. How economic and environmentally viable are these measures?
g. How are these measures equating to building resilience and sustainability going forward?

1.3. THESIS STRUCTURE/OVERVIEW

To meet the set objectives of this research, different tasks were undertaken. These tasks are grouped according to chapters as shown below:

Chapter 1: Introduction

The background of the research, objectives and an overview of the thesis are covered in this chapter.

Chapter 2: Literature Review

The extensive literature study that was carried out on the effects of the COVID-19 pandemic globally, impacts socially, economically and environmentally globally. with. This section begins with an overview of the pandemic, a look at its timeline and background and then discusses its effects. The impacts on mobility/transportation on a metropolitan city context is highlighted, and an in-depth review of literature on measures (on an infrastructure and policy level) that are being implemented globally in metropolitan cities post-pandemic in the transportation sector. It concludes with a summary of the research gap this study seeks to address.

Chapter 3: Methodology

The preferred method for obtaining data, process followed for data collection, and techniques for analysing data are discussed in this chapter.

Chapter 4: Results

Data generated from the research is presented in this chapter.

Chapter 5: Analysis and Discussion of Results

This chapter comprises detailed analysis and explanations of the results obtained from the chosen research methods. The basis for the recommended framework is discussed as well.

Chapter 6: Conclusions and Recommendations

The research effort is summarized in this chapter. Conclusions that can be drawn from the study are presented as well. The limitations of the research, recommendations, and areas for further study are also discussed.

CHAPTER 2 - LITERATURE REVIEW

2.1 INTRODUCTION

The COVID-19 (also known as coronavirus) outbreak officially started in December 2019 in Wuhan, China, and rapidly spread in many countries all over the world (Jiang et al., 2020; Lipistch et al., 2020, Wang et al.,2020). In March 2020, the World Health Organization declared the outbreak as a pandemic, with countries such as China, Italy, Spain and the US being hit hardest. By the end of May 2020, the virus (and the COVID-19 disease it causes) had spread to most countries on earth. By June 1st 2020, the WHO reported that over 6 million people had been infected worldwide and over 371,000 had died with COVID-19 (WHO, 2020). Earlier studies related to pandemics are more commonly seen in regard to the spread of flu or flu-like diseases such as the outbreak of Ebola in west Africa (Kucharski & Edmunds, 2014; Valencia et al., 2017) and the SARS pandemic (Graham, Donaldson, & Baric, 2013; Stadler et al., 2003). However, a study examined the national pandemic plans of some countries in Europe and evaluated how each of them were prepared for a potential outbreak of a pandemic influenza (Mounier-Jack & Coker, 2006). The following studies have also considered different aspects of the COVID-19 virus during its emergence such early transmission dynamics (Li et al., 2020), epidemic in other countries outside China (Holshue et al., 2020), the impact assessment (Munster et al., 2020), the forecasting of the spread (Wu, Leung, & Leung, 2020) as well as the genomic characterization (Lu et al., 2020).

On March 17, 2020, for the first time in its history, the European Union closed all its external borders to prevent a further spreading of the virus (European Commission 2020). The decision to temporarily restrict all non-essential travel was by no means uncontroversial, although it was very much in line with the mitigation strategies of most of the local governments: Italy had introduced a national lockdown on March 9, Germany had implemented school and border closures starting March 13, Spain followed on March 14, and France on March 16. By 18 March, 2020, more than 250 million people in Europe were in lockdown (European Commission 2020). These non-pharmaceutical interventions (NPIs) such as travel bans, school, and public transport closure, restriction on public gathering, stay-at-home order) were widely adopted by governments all over the world as this seemed to be the only way to slow down the spread of the virus(Ferguson et al., 2020).

Italy, as the first country in Europe to be infected as well as one of the most severely impacted by the pandemic, had studies conducted into the transmission of this virus. A study conducted by Murgante et al., attempted to investigate why the reasons why Italy was the first to be infected in Europe and what conditions could have influenced the quick spread of the virus throughout the country(Murgante, Borruso, Balletto, Castiglia, & Dettori, 2020). In another study, the epidemic risk was assessed by identifying the most vulnerable areas using a historical data series on air pollution, human mobility, winter temperature, housing concentration, health care density, population size, and age (Pluchino et al., 2020). By comparing the spatial distribution and mortality model associated with COVID-19 in Italy with various geographical, environmental, and socioeconomic variables at the provincial level, a correlation was found between the number of COVID-19 cases and the associated pollutants nitrogen and soil, especially in the Po Valley area. Both studies revealed that the highest risk occurred in some northern regions compared to central and southern Italy. Although the COVID-19 epidemic started almost simultaneously in both the north (Lombardy and Veneto) and in Lazio (central Italy) when the first cases were officially certified in early 2020, the disease spread more rapidly and with more serious consequences in regions with a higher epidemic risk.

As expected, the impacts of COVID-19 on the global economy have been unrivalled in history and researchers have investigated this (Abodunrin, Oloye, & Adesola, 2020; Igwe, 2020). Globally, stock markets collapsed by 50%. For example, in the US, COVID-19 resulted in massive unemployment rate with millions out of work soaring to 14.7% in April 2020, which was the highest rate since the Great Depression (Trading Economics, 2020). With the COVID-19 outbreak, a massive freeze in the industrial and logistical infrastructure caused a devastation throughout the global economy with an accompanying recession. Global annual GDP is expected to contract by 3-4% for 2020 (Abodunrin et al., 2020).

2.2 TRANSPORTATION AND PANDEMICS

Past studies have highlighted that human mobility and interaction patterns directly contribute to the spread of infectious diseases, particularly during pandemics (Funk et al., 2010; Rizzo et al., 2014; Yan et al., 2018; Peixoto et al., 2020). As studies have shown, persons infected with the novel coronavirus COVID-19 are contagious before showing any symptom (Javid, Weekes, and Matheson 2020; Ferretti et al. 2020). The nature of 21st century transport networks, including high-speed and high-capacity rail and intercontinental air travel are amongst the most critical platforms for the rapid spread of the infection in high-density and mixed-use urban environments (Musselwhite, Avineri, & Susilo, 2020). Thus, in general, travel restrictions are imposed during emergence of pandemics (Zhang et al., 2011; Cooley et al., 2011; Peak et al., 2018; Muley et al., 2020).

The first case of COVID-19 was reported in Wuhan, China, at the beginning of Dec. 2019, and has then quickly spread to the rest of China through airlines and high-speed rail networks during the Spring Festival travel season(Wu et al., 2020). The virus's incubation period of 2–10 days (WHO, 2020) afforded ample opportunity for infected but asymptomatic travellers to export infection undetected across international borders and propagate transmission in receiving communities. A review of previous studies suggested that air transport could accelerate and amplify the propagation of respiratory viruses, e.g.,influenza, MERS, SARS, coronavirus, (Browne et al., 2016). Consequently, in response to pandemic threats many countries would typically impose measures that restrict human mobility flows internally and externally as one of their response plans (Bajardi et al., 2011; Wang and Taylor, 2016; Charu et al., 2017). People also typically avoid public transport as these can be considered a breeding ground for viruses and places where it might be difficult to avoid contact with other passengers (Troko et al., 2011). These measures to prevent social contact and to slow down the spread of the virus, such as closing schools, shops, restaurants and bars, prohibiting public events and stimulating or imposing working from home can all be labelled as "social distancing", and are especially efficient for diseases (such as COVID-19) which are transmitted by respiratory droplets and require a certain proximity of people (Wilder-Smith and Freedman, 2020). A comparative analysis of the relationship between severity of the pandemic and lockdown measures in 88 countries using a SEM (Structural Equation Modelling) method revealed that lockdown measures have significant effects to encourage people to maintain social distancing with socioeconomic and institutional factors of urbanity and modernity also having much influence (Rahman, Thill, & Paul, 2020).

Fear of infection and perceived risk also significantly influence travel behaviors, particularly for transit use, and the influence varied based on the infected area and demographic characteristics of the people (Kim et al., 2017; Cahyanto et al., 2016). During pandemics, people perceive a higher risk for all types of trip types and avoid traveling to places where they perceive medium to high risk (Hotle et al., 2020). It therefore becomes imperative to attempt to model how the virus is spread and a number of studies have done this using different methodologies. The spreading of infectious diseases through public transportation (PT) system could also be modelled using a time-varying weighted PT encounter network (Mo et al., 2021). Results from this study supported policies which implement partial closure of public bus routes and limiting the capacity of buses could be effective in curbing the spread of the disease. Additionally, using a human movement model and data from a case study of Berlin, simulation results were presented on the infection dynamics of the virus considering various containment strategies such as relying on active transport as the only mode of transportation and shutting down work and leisure activities (Müller, Balmer, Neumann, & Nagel, 2020). The results revealed none of the containment strategies could be effective alone but would require varying combinations to slow down the rate of the spread of the virus.

Alternatively, the exogenous variations in human mobility created by lockdowns of Chinese cities during the outbreak of the Novel Coronavirus (2019-nCoV) were studied as well as the effectiveness of human mobility restrictions in the delaying and the halting of the spread of the COVID-19 pandemic examined (Fang et al., 2020). Furthermore, Lui et al. in their study indicated the effectiveness of synchronised travel restrictions in controlling the spread of the pandemic in China (H. Liu et al., 2020b). Similarly, Chinazzi et al. in their study, use a global metapopulation disease transmission model to project the impact of travel limitations on the national and international spread of the epidemic (Chinazzi et al., 2020). By analyzing a de-identified, large-scale dataset from smartphone users in Italy before and after the lockdown provided by a location intelligence and measurement platform, Cuebiq Inc, results were able to indicate the mobility trend changes during this timeframe (Pepe et al., 2020). This study provides an alternative means of measuring the impact of the lockdown on the transmission of the virus as well as offering useful insights to policy makers when required. However, as explained by Epstein et al. (2007), only international travel restrictions would not control a disease outbreak, but this could delay the spread or flatten the curve. Kraemer et al. (2020) also stated that when the outbreak is spread widely, travel restrictions are less effective. In addition, mobility restrictions might not be effective when the overall epidemic size is considered, and therefore, high- and low-risk communities should be identified (Espinoza et al., 2020). Recent studies have explained that working from home (i.e., limiting home-based work trips) and reducing consumption (i.e., limiting home-based shopping trips), limiting community contacts, and restricting international travel are effective mitigation policies (Jones et al., 2020; Yilmazkuday, 2020). Another study proposed cyclic exit strategies as another strategy to curb the spread of the virus as well as the impacts of a complete lockdown on the economy (Karin et al., 2020). Results indicate that when combined with other epidemiological measures such as contact tracing, hygiene and physical distance would help recovery of economic activities.

2.3 IMPACTS OF COVID ON TRANSPORTATION (A METROPOLITAN CITY CONTEXT)

2.3.1 Effects on Mobility

The COVID-19 pandemic has produced several unprecedented effects around the world and has adversely affected the transport sector, which has experienced a drastic reduction in passenger traffic across all different modes of transport. Both passengers transport and freight suffered severe setbacks from the COVID19 crisis.

Air transport has been one of the sectors which suffered most, as it has been one of the vehicles for the virus outbreak. The International Civil Aviation Organization predicted global passenger numbers could be 80% lower in 2020 than they were in 2019 (Air Transport Bureau, 2020) and some airlines are indicating they do not expect passenger demand to return to 2019 levels until 2022 or 2023 at the earliest (Jolly, 2020). Several airlines grounded nearly all their fleet whiles some deployed passenger aircraft as freighters. Nevertheless, even though freight forwarding was still possible in most regions in the world, it suffered from extremely limited connections. Overall, in fact, the crisis has limited the airfreight capacity between China and Europe to 40% of its original capacity (Eurocontrol, 2020). Passenger transport within the EU Member States and between the European Union and the rest of the world were partially or entirely closed as part of lockdown restrictions. In Europe, passenger air traffic fell by as much as 90% (Eurocontrol, 2020) while the number of passengers using public transport declined by 80% in some cities as commuter demand evaporated and transport operators reduced their services (Bernhardt, 2020). Road and railway transport faced several problems as well, and its efficiency plummeted due to imposed restrictions by member countries of the EU (IRU, 2020). An example was in February and March when the Brenner pass was closed to passengers' transport and health controls were put in place, queues of up to 90 kilometres in length formed on the Italian side of the border (DW, 2020).

As a result of lockdown restrictions imposed, travel demand dropped due to an increased amount of working from home, e-learning, and a reduced number of public activities and events(De Vos, 2020; Hu, 2020). People also changed their daily routines and altered their household consumption patterns. Panic buying in supermarkets was quickly replaced with overwhelming (and, in many cases, unrealised) demand for online shopping and home grocery deliveries as consumers tried to avoid going outside (Hanbury, 2020). Spill over effects included less car traffic – and less congestion during peak hours – and in reduced public transport ridership as well as influences to travel mode choice (Klein et al., 2020). In the UK, road traffic volumes fell by as much as 73% to levels not seen since the mid-1950s as private cars remained on driveways and people adhered to government advice to remain indoors (Carrington, 2020). The fear of infection and perceived risks also significantly influence travel behaviours, particularly for transit use, which is also influenced by variations based on the infected area and demographic characteristics of the people (Kim et al., 2017). During pandemics, people perceive a higher risk for all types of trip types and avoid traveling to places where they perceive medium to high risk (Hotle et al., 2020). A study conducted in Turkey concluded that one of the most adopted preventive behaviours during COVID-19 was the avoidance of public transportation (Yildirim et al., 2020). Another study conducted in Hong Kong during the early phase of COVID-19 reported that 40% of the online survey respondents answered that they would avoid public transportation (Kwok et al., 2020). Commuters that do not have other options than using public transport might try to avoid crowded buses and trains by travelling during off-peak hours. Whiles there was also a significant shift from public transport to private and non-motorized transport, a study revealed that gender, car ownership, employment status, travel distance, the primary purpose of traveling, and pandemic-related underlying factors during COVID-19 were the main influencing predictors of mode choice by commuters (Abdullah, Dias, Muley, & Shahin, 2020). Also in China, by using online surveys the phenomena of people being inclined towards using private transport was also observed as well as a growing inclination to buy new cars for those who don't already own cars (Chui, 2020).

The shutdown in industrial activity and the associated reduction in transport emissions that resulted from the COVID-19 pandemic resulted in notable improvements in local air quality in towns and cities worldwide (Monks, 2020). Huang et al. in their study also examined the effects of enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China using comprehensive in-situ measurements and chemical transport modelling(Huang et al., 2020).

2.3.2 Effects (Metropolitan city context)

With respect to investigating the spread of the corona virus pandemic in a metropolitan city context, a couple of studies have been conducted in recent times. For example, a study was conducted examining the fundamentals of the factors that may affect the spread of the novel coronavirus (COVID-19) in cities (L. Liu, 2020). It revealed that distance subway, wastewater and residential garbage are positively connected with the virus transmission while distance to the epicentre is a huge factor. This study was able to provide a highly precise estimation of the number of COVID-19 infection in Wuhan city which was very close to the officially reported number using a regression model. There remained some uncertainty on how some of these factors directly influence the transmission rate. The results, however, could be informative to policymakers on approaches to predict the local transmission of the virus.

Other studies attempt to quantify the impacts of the pandemic have had directly on various modes of mobility using different sources of data which were available. In the severely affected cities, mobility was reduced by up to 90% (Muhammad et al., 2020). In the USA, population mobility was reduced by 7.87% due to official stay-home orders. Further, a rise of the local infection rate from 0% to 0.0003% lowered the mobility by 2.31% (. A shift towards active transport from public transport is observed as a trend in most of these studies. A study conducted in in Budapest, Hungary reported that the demand for public transport decreased by approximately 80% while the car usage increased from 43% to 65% (Bucsky, 2020). Moreover, another study examined the impacts of the lockdown measures and COVID-19 related deaths on human mobility in the United Kingdom (Hadjidemetriou, Sasidharan, Kouyialis, & Parlikad, 2020). The data used was associated with human mobility trends of walking, driving and using public transport provided by Apple mobility trends reports (Apple Maps, 2020) was compared to a baseline volume of the previous year. Results indicated that human mobility was found to be reduced drastically during lockdown measures and until the end of May 2020 did not show any major fluctuations, with driving, transit and walking remaining 60%, 80% and 60% reduced compared to the same period of the previous year (i.e. 2019). Additionally, a study conducted in Switzerland revealed that the number of trips perweekday and average kilometres travelled reduced up to around 60% during the second week of March in 2020. This study further mentioned that males continued to travel more compared to females (Molloy et al., 2020).

Using datasets based on ticket validations, sales and passenger counts data, the impact of the COVID pandemic on transportation modes in the three largest regional public authorities in Sweden, namely Stockholm, Västra Götaland and Skåne was analyzed (Jenelius & Cebecauer, 2020). Results indicated a decline in public transport usage during the lockdown period and as restrictions were gradually lifted whiles cycling had increased in Stockholm relative to averages recorded in 2019. The impacts of the restrictions on city bus network in Corona in Spain were analysed (Orro, Novales, Monteagudo, Pérez-López, & Bugarín, 2020). Using data from automatic vehicle location, bus stop boarding, and smart card use, this study investigated the changes in transit ridership by line, the use of stops, the main origin–destination flows, changes in transit supply, operation time, and reliability of the city bus network. Results revealed the impact on transit ridership during the lockdown process was more significant than that on general traffic. Additionally, after restrictions were lifted, the general traffic and the shared bike system recovered a higher percentage of their previous use than the bus system. These impacts are not uniform across the bus network.

Alternatively, in a study of Sicily (Campisi et al., 2020), a city in Southern Italy, the influence of COVID-19 on changes in the use of sustainable travel modes with a comparative analysis between before and during the pandemic was also explored. The methodology involved using an online survey on a representative population of 431 individuals which was carried out during the period from March to May 2020 in the case study area. Results showed that respondents who were skeptical about safety issues with using public transportation were likely to increase their use of either walking or cycling as a mode of mobility.

2.4. SUSTAINABILITY AND RESILIENCE BUILDING POST-COVID

The COVID-19 pandemic has raised some questions about the vision of infrastructure, changing everyone’s viewpoint. Prior to the pandemic, transportation policy making faced some challenges such as the negative externality effects of transport noise, emissions, congestion and accidents(Goetz, 2019).This was to be achieved by using combinations including policy instruments, pricing mechanisms, technological interventions mainly focusing on 'top-down' Transport Demand Management, Smart Mobility, Intelligent Transport and Mobility Management approaches to transport policy (Faure & Partain, 2018). There was also growing effort by metropolitan cities all over the world to shift towards more sustainable modes of transportation (Gallo & Marinelli, 2020). Policies made were therefore likely aimed at mitigating (as far as possible given budgetary constraints and political considerations) these challenges whiles attempting to modify individual and corporate travel behaviour and simultaneously making mobility more environmentally sustainable. However, with the advent of the pandemic with its long-lasting effects, these approaches alone might be inadequate in a post-COVID world.

The priority now for most metropolitan cities would be modifying existing policies to also formulate appropriate set of policies and interventions which should emphasize on safety, resilience, efficiency and economic viability post COVID-19 (in the short term and long term) (Gallo & Marinelli, 2020). Long term impacts of COVID-19 would demand the process of making permanent changes related to smart working and other daily activities, thus reducing mobility needs and overall fossil energy consumption which would accelerate sustainability transitions in transportation. Several studies have examined resilience and sustainability in the transport sector.

CIVITAS defines sustainable transport as a set of strategies in a transportation system that have a net positive effect on the three dimensions of sustainability, namely economy, environment and society(Faure & Partain, 2018). Alternatively, the process of achieving more sustainable transportation is defined as requiring suitable establishment of four pillars: effective governance of land use and transportation; fair, efficient, stable funding; strategic infrastructure investments; and attention to neighbourhood design(Kennedy, Miller, Shalaby, MacLean, & Coleman, 2005). Urban transportation systems are always exposed to different types of disruptions such as natural events such as floods or pandemics, human-made events such as terrorist attacks and general failures as a result of system errors. The COVID-19 pandemic is a stark reminder of this. The concept of resilience in transportation infrastructure systems therefore becomes a pertinent point of discussion. Its definition is quite a broad one with different researchers with different backgrounds, perspectives and understanding offering varying definitions. However, a general definition is described as the ability of a system to resist, reduce and absorb the impacts of a disturbance (shock, interruption, or disaster), maintaining an acceptable level of service (static resilience), and restoring the regular and balanced operation within a reasonable period of time and cost (dynamic resilience) (Gonçalves & Ribeiro, 2020). In conclusion, D'Adamo et al. reported that the implementation of circular and green strategies is not explicitly aimed at improving resilience (D'Adamo & Rosa, 2020). However, their impacts are significant in terms of response and recovery, and one benefit is their positive effect on the environment and climate change, reducing the likelihood of environmental disasters. Through long-term planning, instruments such as the acquisition of public funds, and public–private partnerships, this could be achieved.

The potential effectiveness of non-pharmaceutical interventions (NPIs) such as stay-home restrictions or social distancing have already been examined by many studies as highlighted before and proven to be viable in the short-term to long-term whiles pharmaceutical interventions are to be introduced. Active transport seems to be clearly on the rise as surveys and studies highlighted previously have shown. People whiles reducing their travel trips due to COVID-19 would temporarily prefer to use active modes or cars over public transport. This will reduce the traffic volumes and affect people's well-being (De Vos, 2020). During lockdown restrictions, policymakers and transport planners stimulated walking and cycling by (temporarily) allocating less-used street space to cyclists and pedestrians (King and Krizek, 2020), prioritising places which experienced traffic congestion and did not have adequate walking and cycling infrastructure. Also, cities in Europe (e.g., Berlin, Vienna), North America (e.g., Philadelphia, Vancouver), and Latin America (e.g., Bogota, Mexico City) decided to temporarily turn car lanes into sidewalks and bike lanes (Laker, 2020). Some cities in Australia, for instance, have already started implementing automatic pedestrian crossings, so that people do not have to press a button (Laker, 2020). The desire is to implement such measures permanently where these measures turn out to be successful (i.e., resulting in large flows of active travellers). Further plans such as restricting cars from certain local streets, placing additional (pop-up) cycling parking, and reducing waiting time for pedestrians to cross roads have been suggested and being implemented by government authorities all over the world in an attempt to promote active transport (Barbarossa, 2020; Lozzi et al., 2020).

Additionally, a solution proposed in an attempt to solve the limitations of some existing transport policies was the concept of Responsible Transport in which individual citizens are aware of the effects their mobility and travel behaviour have on themselves, other people and environment, and act accordingly (Budd & Ison, 2020).For example, the study suggests ways of achieving ideal situations where an individual would consider trip purposes, consider the suitable modes of transportation and possibly substitute in-person meetings for video calls if possible.

In as much as studies and surveys have shown a growing trend towards active transport by commuters, public transportation has a huge role to play in the vision of a more sustainable transportation system. For example, a survey which was conducted in May 2020 by the UK independent transport group Transport Focus revealed that 4 in every 10 people surveyed said they were likely not to use public transport again until they felt it was safe to do so. Additionally, only 18% of respondents stated that they would be happy to resume using public transport when restrictions are lifted by the government (Transport Focus, 2020). It therefore becomes clear that public transport operators would need to reassure passengers of the safety of their operations, with measures taken such as reconfiguring the internal layout of seats and circulation spaces on buses and trains, and installing contactless door sensors, hand sanitizer dispensers and clear screens between seats to provide a physical barrier to airborne aerosols (Paton, 2020). This measures have been taken all over the world as observed in many studies (Barbarossa, 2020; Hynes & Malone, 2020; Lozzi et al., 2020; Megahed & Ghoneim, 2020).

2.5. RESEARCH GAP

There have been a lot of reports on the impacts of the pandemic on transportation modes in metropolitan cities (Aloi et al., 2020; Bucsky, 2020; Campisi et al., 2020; Jenelius & Cebecauer, 2020). Additionally, there is emerging literature considering the impacts and comparing plans for transforming mobility and transportation systems globally using similar methods however there remains a dearth in literature which combines these issues and examines them in an aggregated perspective. This study proposes to look at the specific case study of a metropolitan city (Bologna), examine the impacts of the pandemic during varying phases, compare with other study cases to identify trends or differences with these effects and critically examine policies and measures being enacted by local government authorities to build resilience in their transportation system.

CHAPTER 3 – METHODOLOGY

3.1. STUDY AREA

The case study area is Bologna which is a regional capital of the Emilia-Romagna province in North-Central Italy. It has a population of around 390,000 inhabitants and the seventh most populous city in Italy. Its metropolitan area is home to more than 1,000,000 people (Provincia di Bologna). Bologna is home to the Guglielmo Marconi International Airport, and according to statistics, the seventh busiest Italian airport for passenger traffic, about 8 million passengers handled in 2018 (www.bologna-airport.it). Additionally, Bologna Centrale railway station is one of Italy's most important train hubs thanks to the city's strategic location as a crossroad between north–south and east–west routes.

Emilia-Romagna is currently ranked third in the number of infections by regions in Italy. Bologna as well, leads in number of infected cases in the provinces in the Emilia-Romagna region (Minestero della Salute, 2020). The following tables 3.1 and 3.2 show the statistics of number of cases recorded in each province (*Data accessed on 12 October, 2020 @12:55pm).*

Table 3.1 Number of COVID-19 cases recorded in provinces of Italy (Data accessed on 12 October, 2020 @12:55pm).

Region	Number of infected cases
Lombardia	113024
Piemonte	38503
Emilia-Romagna	37681
Veneto	31503
Lazio	19890
Campania	18530
Toscana	18160
Liguria	15269
Puglia	9512
Sicilia	9294

Table 3.2 Number of COVID-19 cases recorded in cities in Emilia-Romagna Province (Data accessed on 12 October, 2020 @12:55pm).

Province	Number of Cases
Bologna	7246
Reggio Emilia	6012
Piacenza	5208
Modena	5136
Parma	4466

The city of Bologna has widely varying transportation infrastructures (neighbourhood streets, arterials, separated path non-adjoining the roadway, separated by a non-continuous barrier path, cycle track obtained from the sidewalk). The Figure 3.1 below shows a map of Bologna and the different transportation infrastructures.

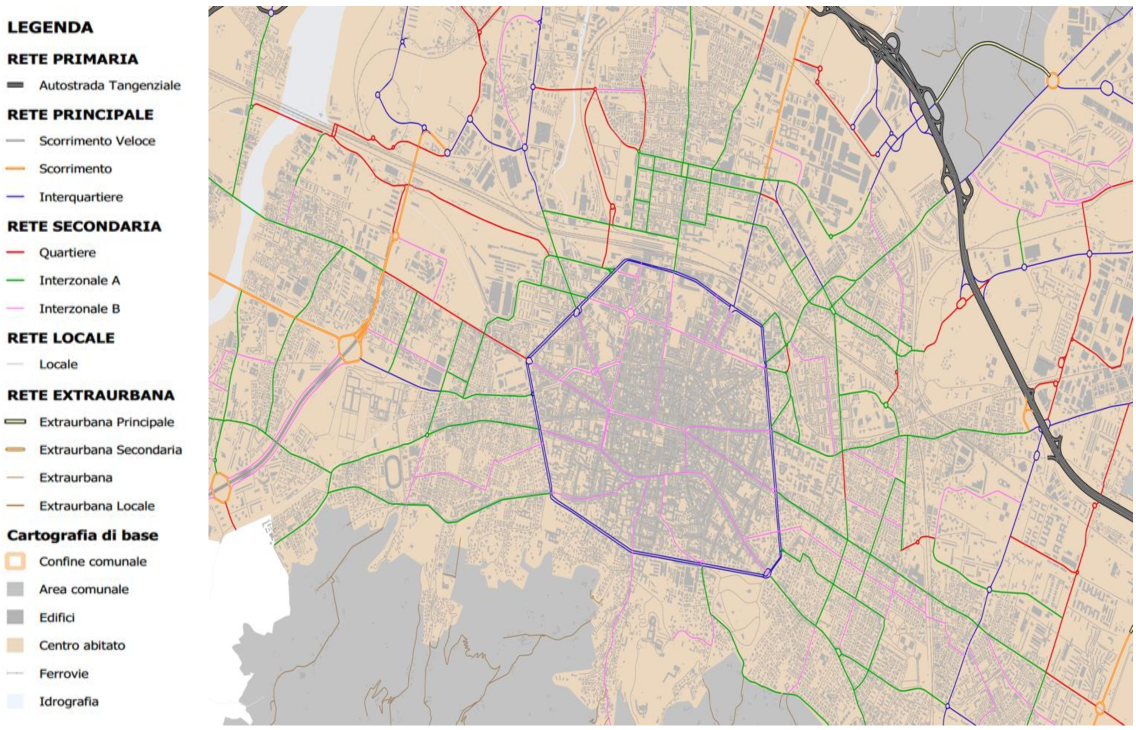

Figure 3.1 A map showing the various types of transportation infrastructure in Bologna (Biciplan di Bologna, 2018).

For example, there are 128.5 km of bicycle facilities in the city with about 43 km being off-street paths (Rupi, Poliziani, & Schweizer, 2019). The cycle network layout is composed of 13 main radial bicycle paths, connecting the suburbs to the city centre, and many other bicycle lanes linking the radials ones. Table 1 shows the length of bicycle lanes divided from roadway (in km) from 2009 to 2017 (Commune di Bologna, 2017). It can be observed that the length of bike network has increased by about 50% between the period of 2009 to 2017 as shown in the Table 3.3 below.

Table 3.3 Yearly total bicycle lane length in Bologna

	bicycle lane divided from roadway (km)
2009	86,0
2010	91,5
2011	96,5
2012	102,0
2013	107,5
2014	112,0
2015	120,5
2016	126,4
2017	128,5

The public bus operator of the city of Bologna is TPER (Transporti Passegeri Emilia Romagna). It has to run 2.2 million services every year, which cover a total of 18 million kilometers and transport 92 million passengers (Lodi, Malaguti, Stier-Moses, & Bonino, 2016). The regional government entrusts the supervision of the local transportation to a government-owned agency called SRM (http://www.srmbologna.it) which supervises the activities of TPER. TPER has a fleet of buses which serve the metropolitan area of Bologna with a number of bus lines serving areas within the city both internally and externally (https://www.tper.it/orari). These buses consist of natural gas vehicles, hybrid vehicles and electric vehicles.

3.2. DATABASES

The study in this paper aimed to investigate the frequency of use of the different modes of transport before and during the COVID-19 lockdown period and the impacts of the COVID pandemic on the mobility trends of people living in Bologna. To achieve this, it explores and analyses available mobility data from the following databases with respect to defined timeframes.

3.2.1 Bicycle Flow Count

Generally, in Italy, traffic monitoring of bicycles is rarely performed. Although several techniques and instrumental monitoring systems have been developed, few Italian cities carry out periodic and consistent monitoring of bicycle volumes. In Bologna, data are collected through manual counts of cyclists during peak commuting periods and also with automatic traffic counters.

The University of Bologna (DICAM) also performs some monitoring of the cycling flows on the main sections of the Bologna bicycle network. The monitoring period has normally been between the 15 September to 15 October each year from 2009 to 2019 (Iperbole Rete Civica, 2020). The figure shows the locations where these counts were conducted:

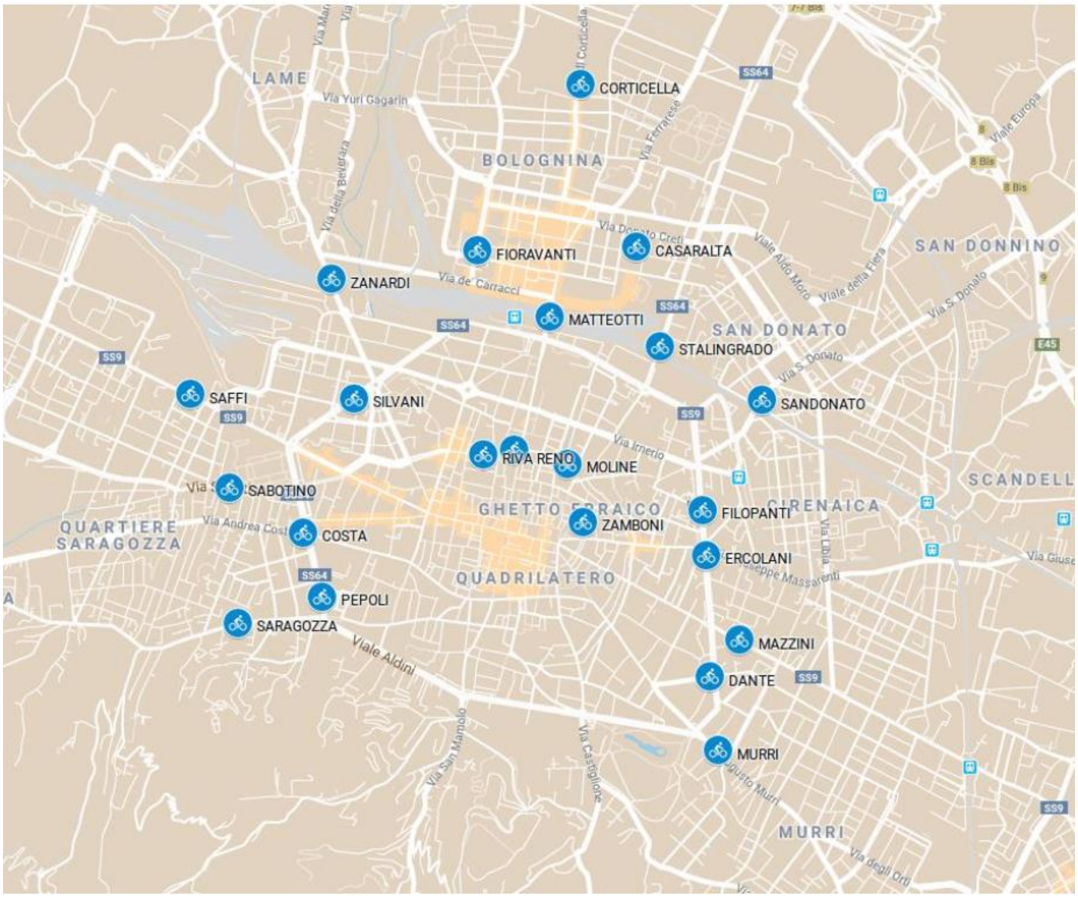

Figure 3.2 Instruments used for monitoring bike flows in Bologna (2017).

For many sections both manual and instrumental counts are conducted. The manual monitoring is normally conducted in each section for at least 2 days, from 8.30 A.M. to 10.30 A.M. and from 4.30 P.M. to 5.30 P.M. so as to include the peak hour of the morning and afternoon. Therefore, data is also collected using two kind of instruments: pneumatic and radar traffic counters, which are placed each year in different sections for at least 7 days to ensure a complete coverage from 0:00 to 24:00. However, this data was not readily made available during the time this study was conducted.

Figure 3.3 Instruments used for monitoring bike flows in Bologna.

Additionally, the commune of Bologna has over the past two years provided three permanent measuring stations with magnetic induction systems for counting cyclists passing along the tracks where they are located. Two of these devices are accompanied by a totem equipped with a display, which highlights the number of daily and annual passages on the spot. They are located along the Via Ercolani, Via Sabotino and Via San Donato with data available from the 8th of January,2018, 18th December, 2019 and 19th April, 2019 respectively (www.comune.bologna.it). For this study, data representing cyclist flows would be obtained from this source since it is open access data.
An example of the device for measuring these flows is shown in the Figure 3.4 below:

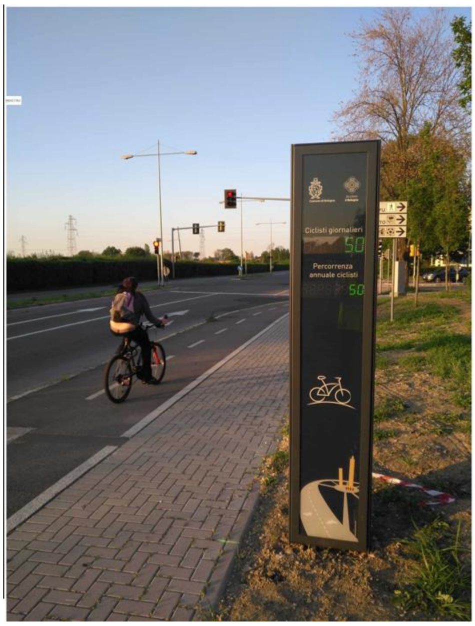

Figure 3.4 An example of a counting device.

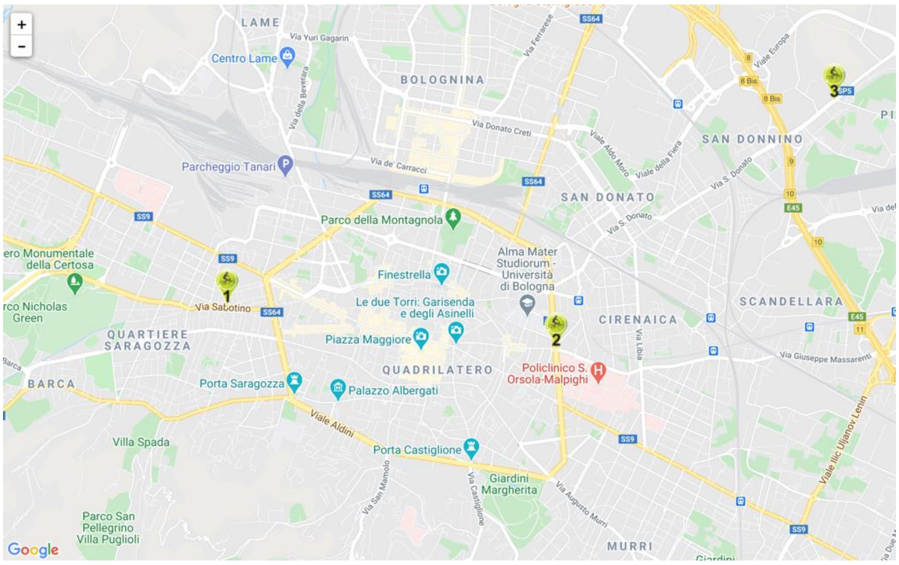

Figure 3.5 Locations of permanent counting stations owned by the commune of Bologna (Google Maps).

The data for the cyclist flows along these sections are readily made available on an online portal (https://www.eco-public.com/ParcPublic/?id=6082).

3.2.2 Passenger Count in Buses

Passenger counts in buses are rarely conducted by the transport agency and when they are done, the data is privy to the internal use of the agency. To be able to obtain this data for our case study, these counts had to be conducted manually by the students of the University of Bologna. There was some data available from previous counts conducted on 3 of the principal bus lines in the city. Counts therefore had to be scheduled to be able to establish a timeframe for comparison. The pathways for each bus line considered are illustrated in the figures 3.6, 3.7 and 3.8 below.

Table 3.4 Pathways of bus lines considered for study.

Busline	Origin	Destination
27	Corticella Stazione	Longo
13	Scala	San Ruffilo
20	Pilastro	Caselechhio Chuisa

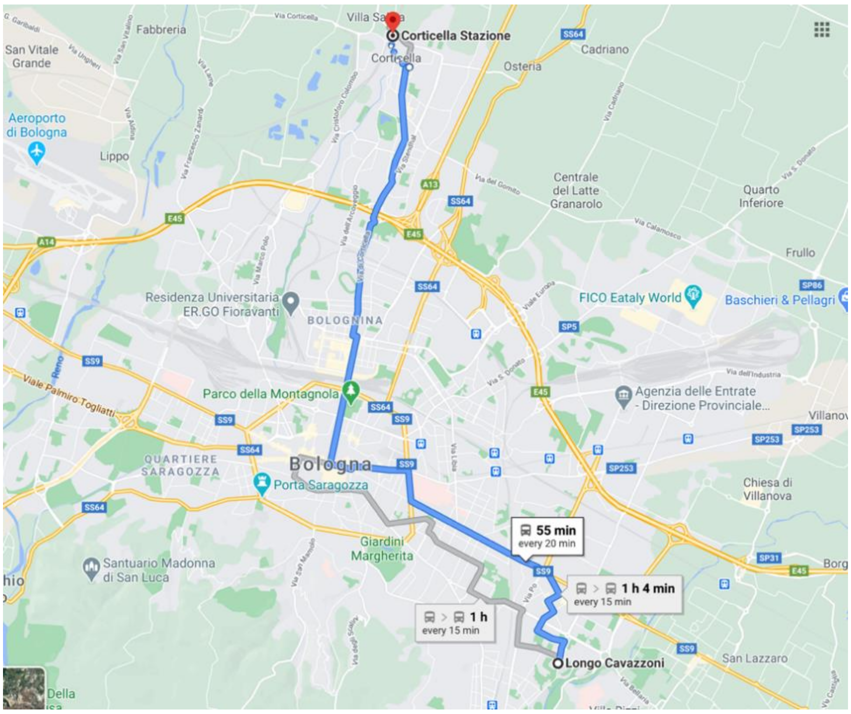

Figure 3.6 Pathway of bus line 27(Google Maps).

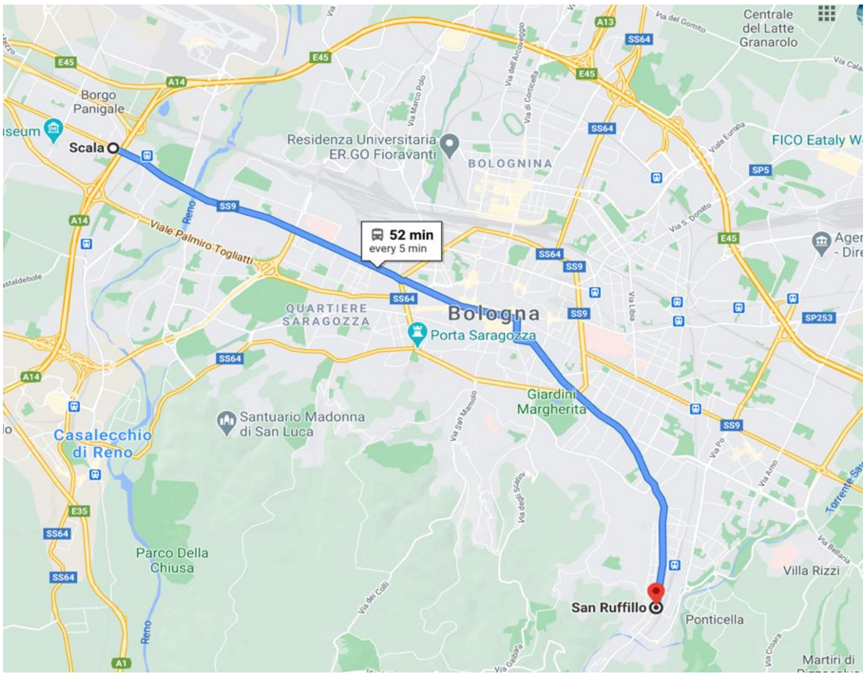

Figure 3.7 Pathway for bus line 13(Google Maps).

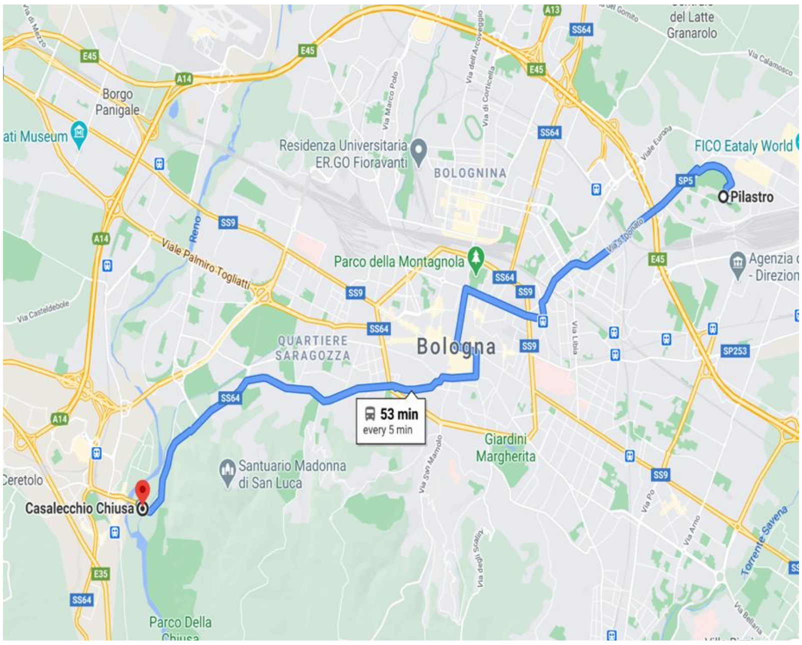

Figure 3.8 Pathway for bus line 20(Google Maps)

The counts are conducted by counting the number of passengers in the bus at the origin and then simultaneously recording those who board and descend from the bus at successive stops till the destination. It is important to note that children who were seemingly below the ages of 7 were not included since they were accompanied by their guardians. The counts could not be conducted during the lockdown phase since mobility was restricted to solely purposes of necessity. To ensure consistency with the collection of data, counts were counted on the first buses after 8 am at each origin point of the bus line.

3.2.3 Vehicle Traffic Count

The car counting devices are an integral part of the traffic light system. The counters are magnetic detectors under the road surface used to adapt the traffic light phases to the traffic flows i.e. if there are many cars on a specific branch of the traffic light then the green phase of the respective route would be prolonged. These counters are owned by the Commune of Bologna.

Figure 3.9 shows the geographical positions on the Bologna road network of inductive loops installed by the local municipality to monitor the traffic dynamics. The area under evaluation has 187 detectors that record traffic flow data in terms of the constant presence of vehicles passing over each detection site on a specific road branch. The Municipality of Bologna provides datasets containing inductive loops data, aggregated into hourly time periods and referring to 24 hours of a typical workday. The road traffic count data give a good coverage of the main city roads, including the fast-transit ringway, the main entry/exit roads to/from downtown and other several roads crossing the city centre (Caiati et al., 2016).

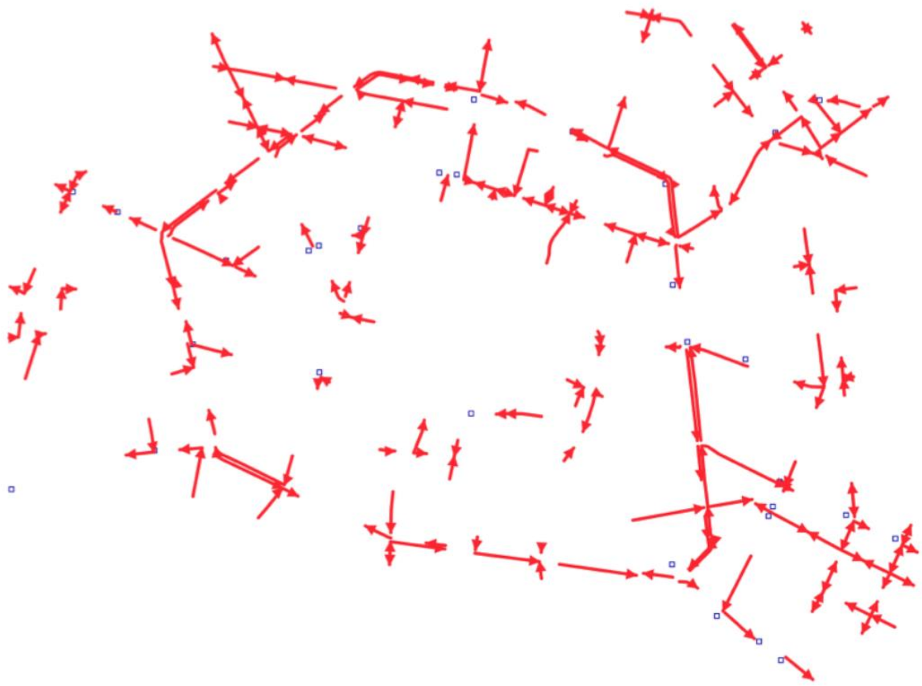

Figure 3.9 Geographical locations of traffic counters in central Bologna.

3.2.4 Auxiliary Data

Mobility service providers have published data based on geographical location data (e.g., Google COVID-19 Community Mobility Reports1), travel planner queries (e.g., Apple Mobility Trends2) or app usage (e.g., Moovit Public Transit Index).

- MOOVITAPP

This is one of the various apps which use the location of a user to give real-time arrival information for nearby public transportation services (and even docked and dockless bikeshare, ride-hailing like Uber and Lyft, and car rentals like car2go). It assists in planning trips and works in most major cities while accessing real-time arrival information on the home screens without inputting a destination, unlike Google Maps or Apple Maps. It allows open access to its data, which is updated daily, on its usage and compares it to a typical week before the outbreak began (the week prior to January 15). This study would consider the data available for the app's usage in the city of Bologna.

3.3. TIMEFRAMES

Italy had a nationwide lockdown starting on the 9th of March, 2020 with measures being loosened according to state legislation in the subsequent months of May and June, 2020. Bologna, under the Emilia-Romagna province also followed this timeline, however in order to establish some congruity based on the data available for this study, the timeframes were characterized into the following phases:

- Phase 1 - pre-lockdown (data from 2019 or before the lockdown),

Data obtained from the various modes before the effects of any restrictions imposed by the Italian government were realized. Schools, workplaces, entertainment facilities and all other services were all running normally.

- Phase 2 - during the lockdown (data from March and April, 2020)

On 11 March, restaurants and bars were closed. After 12 March, the Italian government banned all travel and forced people to stay at home. On 20 March, parks, gardens, and playgrounds were closed as well. Industries producing non-essential goods as well as non-essential services were closed on 22 March. All modes of public transportation were brought to a halt.

- Phase 3 - immediate post lockdown (data from May and June, 2020),

The Italian government launches the "Fase 2" in May which was characterized by the return to work of essential services and the ability to visit closely-related family residing in the same municipal area. "Fase 3" follows in June where non-essential services such as cinemas and museums were reopened with restrictions placed on their capacities (http://www.governo.it/it/coronavirus-misure-del-governo).

- Phase 4 - post lockdown (data from September and October,2020)

Restrictions are gradually lifted in subsequent months with schools and workplaces reopened. However, educational facilities are being run with a shift system having restrictions placed on maximum capacity. Similar schemes are applied at workplaces and varying restrictions are enforced on the opening of non-essential facilities depending on the rate of infection of the virus (http://www.governo.it/it/coronavirus-misure-del-governo).

3.4. RESEARCH APPROACH

The datasets were obtained from the various databases as discussed in .csv file formats and were analysed. The following steps in Figure 3.10 describes the general methodology applied in this study.

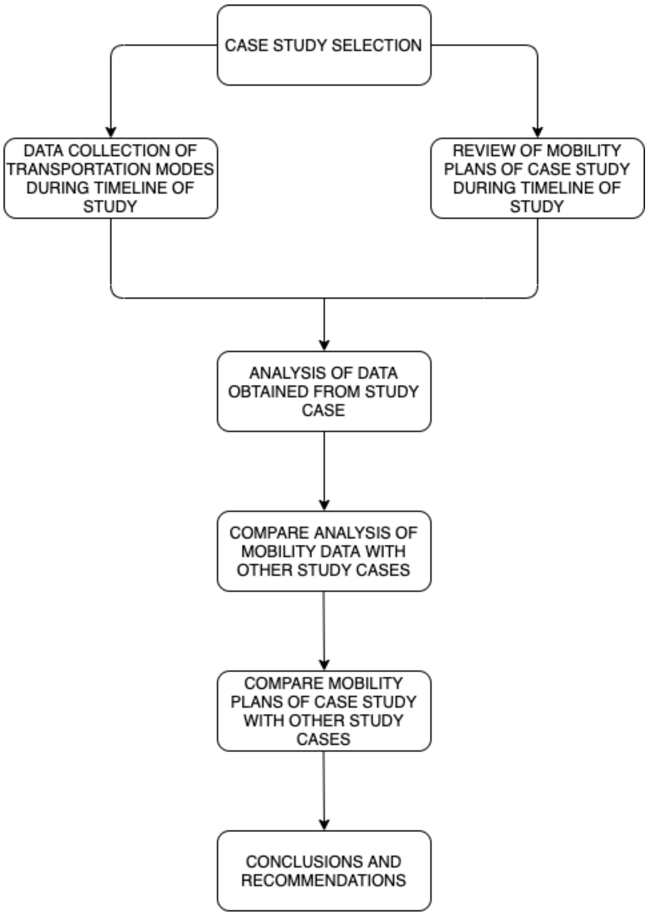

Figure 3.10 Research methodology

3.4.1 Cyclist Flows

The separate counts from the three automated counts were merged on one sheet. The date range of the data obtained was from the 22nd of April, 2019 to the 25th of October, 2020. The flows from each counter in both directions were summed for each location and a total sum of all flows was obtained for each hour of count.

1. A simple comparison of the flows with respect to the timeframe of the obtained dataset was made and the graph shown in Figure 3.11 below.

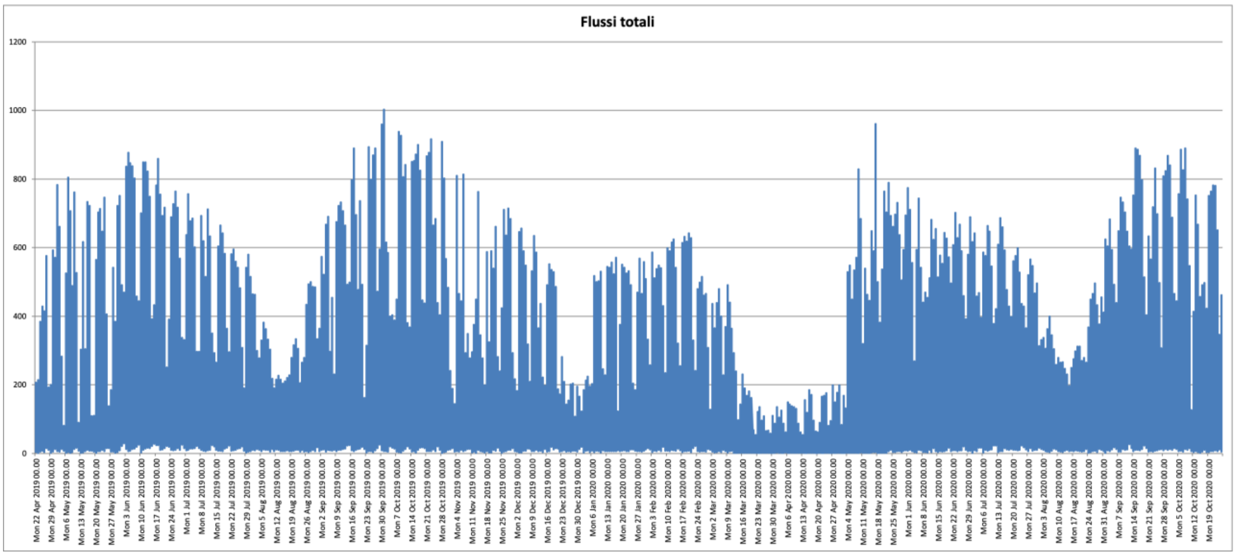

Figure 3.11 Number of weekly cyclist counts recorded from April 2019 to October 2020.

2. Secondly, a selection of the counts of weeks of the previous year (2019) were compared to the same of the current year (2020) as shown in Figure 3.12 below. An important condition to be met was that the weather conditions for that week were first checked to ensure the absence of rainy days in the data which could affect its validity.

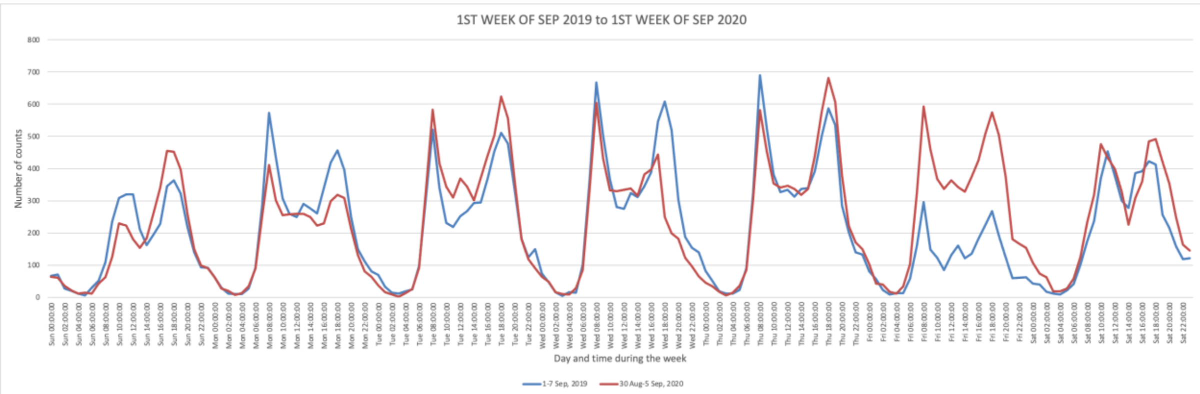

Figure 3.12 A comparison of the first weeks in September for 2019 and 2020.

3. Thirdly, a comparison of flow counts was made for the already established time frames for all modes. The sum of counts for each phase were obtained as shown in Table 3.5 and a modal comparison could be made subsequently.

Table 3.5 Sums of daily flow counts for each phase.

Phases	1	2	2	3	3	4
	02-08 Feb	15-21 Mar	19-25 Apr	15-21 Jun	05-11 Jul	04-10 Oct
Sun	2754	1258	713	5897	4441	4309
Mon	4819	2011	621	4976	6155	6945
Tues	5146	1823	1065	6546	5898	7792
Wed	5251	1817	1675	6168	7023	7710
Thurs	5135	1691	1974	7519	6857	7887
Frid	5168	1563	1957	7410	6505	7583
Sat	4133	896	970	6813	4153	6229
Sums	32406	11059	8975	45329	41032	48455

3.4.2 Bus Flows

The available datasets were recorded on the following dates:

- 25th, 26th and 27th and 28th of February, 2019
- 4th and 11th of March 2020
- 15th, 16th and 18th of June, 2020
- 7th and 9th July, 2020
- 5th, 8th and 9th of October, 2020

The following comparisons of the counts for each bus stop on the respective days were made:

1. Graphs showing the counts of passengers boarding at each stop were made for each line as shown in Figure 3.13 below.

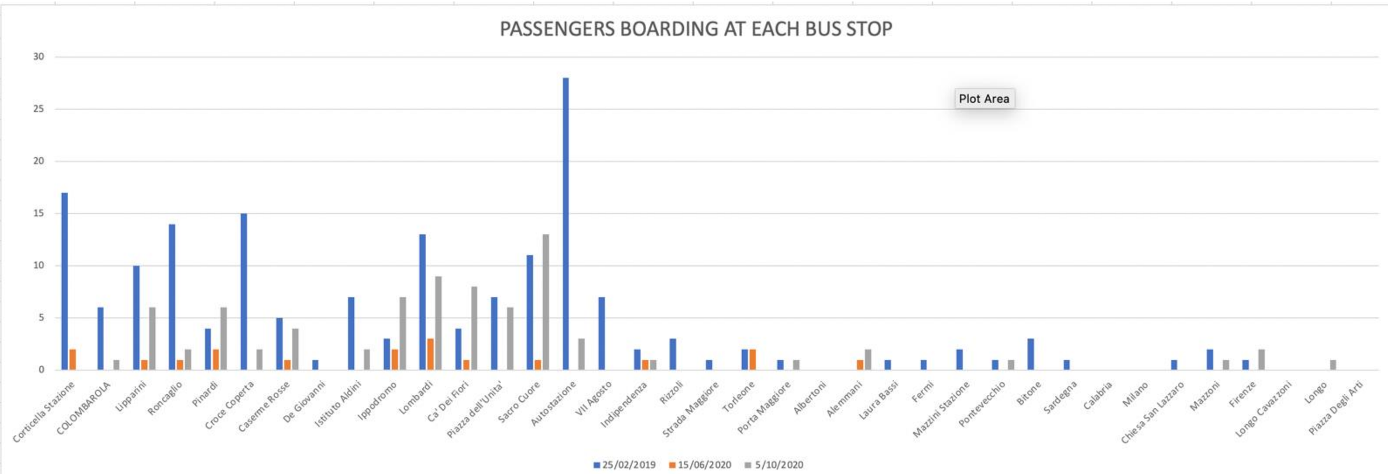

Figure 3.13 Counts for passengers boarding bus line 27.

2. Graphs showing the counts of passengers remaining onboard the bus at each stop were made for each line as shown in Figure 3.14 below.

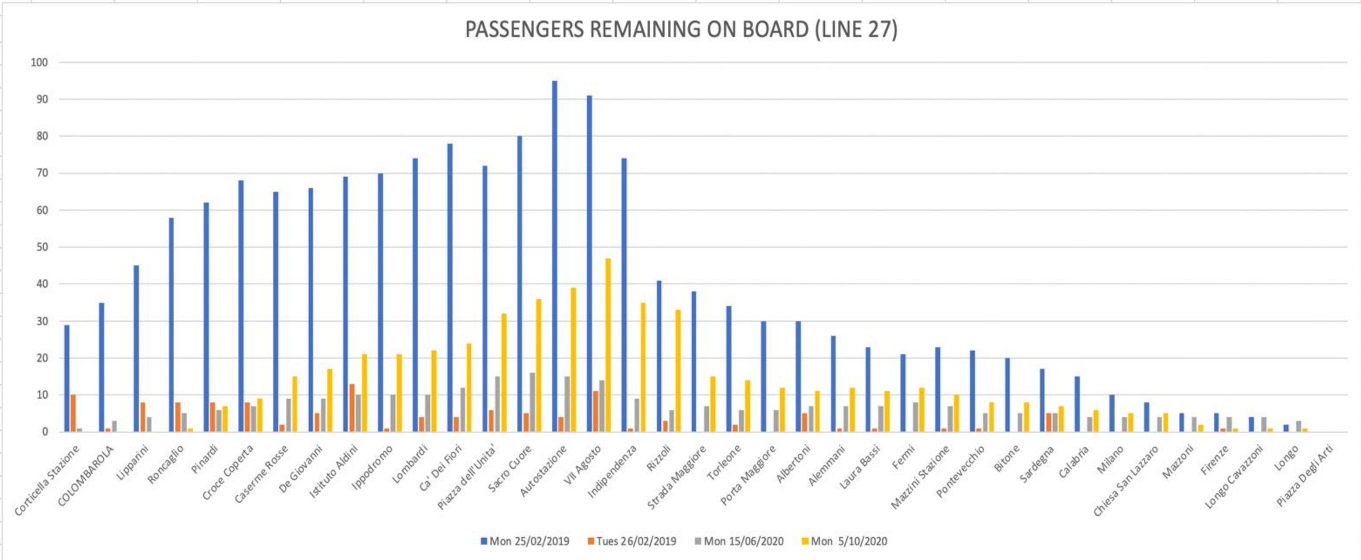

Figure 3.14 Counts for passengers remaining on board using bus line 27

3. The sums of the number of passengers boarding each bus stop on the count days were compared as shown in Table 3.6 below.

Table 3.6 Comparisons of sums of passenger counts on count days.

DATE		Mon	Mon	Mon
BUS STOPS	26/02/2020	25/02/2020	15/06/2020	5/10/2020
Corticella Stazione	10	17	2	0
COLOMBAROLA	1	6	0	1
Lipparini	8	10	1	6
Roncaglio	8	14	1	2
Pinardi	8	4	2	6
Croce Coperta	8	15	0	2
Caserme Rosse	2	5	1	4
De Giovanni	5	1	0	0
Istituto Aldini	13	7	0	2
Ippodromo	1	3	2	7
Lombardi	4	13	3	9
Ca' Dei Fiori	4	4	1	8
Piazza dell'Unita'	6	7	0	6
Sacro Cuore	5	11	1	13
Autostazione	4	28	0	3
VII Agosto	11	7	0	0
Indipendenza	1	2	1	1
Rizzoli	3	3	0	0
Strada Maggiore	0	1	0	0
Torleone	2	2	2	0
Porta Maggiore	0	1	0	1
Albertoni	5	0	0	0
Alemmani	1	0	1	2
Laura Bassi	1	1	0	0
Fermi	0	1	0	0
Mazzini Stazione	1	2	0	0
Pontevecchio	1	1	0	1
Bitone	0	3	0	0
Sardegna	5	1	0	0
Calabria	0	0	0	0
Milano	0	0	0	0
Chiesa San Lazzaro	0	1	0	0
Mazzoni	0	2	0	1
Firenze	1	1	0	2
Longo Cavazzoni	0	0	0	0
Longo	0	0	0	1
Piazza Degli Arti	0	0	0	0
	119	174	18	78
Average	146.5			

3.4.3 Vehicle Counts

The available datasets were recorded on the following dates:

- 11th and 12th of February, 2020 (when the schools were open before the lockdown)
- 25th and 26th of February, 2020 (when schools were officially closed)
- 3rd and 4th of March 2020 (when schools were officially closed)
- 21st and 22nd of April, 2020
- 5th and 7th of October, 2020

The sums of the counts of vehicles with the respective direction of flow were given as well as the accuracy of the counts. The following steps were taken for the analysis of this data:

1. A number of the counters along the routes which met the accuracy criterion of at least 80% were selected for the analysis.
2. A comparison of flow counts was made for the already established time frames for all modes. The sum of counts for each phase were obtained as shown in Table 3.7 below which allows for a modal comparison to be made subsequently.

Table 3.7 Comparison of vehicle counts from selected traffic counters during timeline of the study.

SPIRA	11-Feb	25-Feb	03-Mar	21-Apr	22-Apr	05-Oct	07-Oct
Via Marconi:Via Leopardi-Via Riva di Reno	1192	1116	1034	853	839	1145	1199
Via Marconi:Via Leopardi-Via Riva di Reno	7106	5960	6011	2160	2228	6700	7251
Via Marconi:Via Leopardi-Via Riva di Reno	2310	1956	1978	783	733	2123	2268
Via S. Donato:Via S.Nicolò di Villola-Via E. Salgari	7356	6536	6725	2196	2242	7004	7159
Via Salgari:Via S. Donato-Via Negri	1252	1159	1209	544	583	1280	1272
Via Pirandello:Via Casini-Via S. Donato	4586	3959	5240	1775	1847	5565	5569
Via del Pilastro:Via S. Donato-Via Protche	811	1177	6100	195	213	673	741
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4910	4459	4082	1471	1571	4885	5270
Via Irnerio:Via Mascarella-Via del Borgo di S. Pietro	10655	9516	9726	3164	3092	10340	11229
Via Irnerio:Via del Borgo di S. Pietro-Via Mascarella	4522	4029	4139	1568	1552	4202	4471
Via Irnerio:P.zza VIII Agosto-Via Alessandrini	3418	3125	3091	1222	1166	3282	3582
Via Irnerio:P.zza VIII Agosto-Via dell'Indipendenza	11033	9698	9872	3361	3051	11086	11611
Via Irnerio:Via Indipendenza-P.zza dell'VIII Agosto	2161	1990	2000	1011	949	1983	2106
Via dell'Indipendenza:Via dei Mille-Via S. Giuseppe	2324	1990	1798	1028	1041	1979	2142
Via dell'Indipendenza:Via dei Mille-Via Milazzo	4921	7870	4208	1848	1721	4458	4637
Via S. Felice:Via Riva di Reno-Via Pietralata	2702	2543	3279	1858	1390	2472	2895
Via S. Felice:Via Riva di Reno-Via Pietralata	4265	3736	4014	1794	1770	3868	4058
Via Saragozza:Via di Casaglia-Via F.Orioli	10783	10157	10807	3572	3523	12184	12780
Via Saragozza:Via Battaglia-Via Ruscello	902	761	781	402	402	812	842
Via Saragozza:Via Guidotti-Via Malta	10245	9362	9708	3385	3230	10148	10798
Via Emilia Ponente:Via del Triumvirato-Via del Greto	9393	8408	8331	3434	3528	8853	9134
Via Emilia Ponente:Via del Triumvirato-Via del Greto	3871	3559	3483	1526	1582	3542	3761
Via Emilia Ponente:Via del Triumvirato-Via A.Piò	12547	12085	11857	4414	4552	11808	12055
Via Emilia Ponente:Via Battindarno-Via della Ferriera	7406	6942	6723	2780	2924	6743	6743
Via Massarenti:Svincolo 11 Tang.Ovest Casalecchio S.Lazzaro-Via B.Cellini	13102	11379	11813	4514	4514	12438	12804
Via Massarenti:Via Donatello-Via Golfarelli	11494	10196	10694	4427	4334	11298	11618
Via Massarenti:Via del Parco-Via della Salita	8403	7645	7939	3369	3247	8170	8308
Via Dozza:Via Ferrara-Rot. Decorati al Valor Militare	12969	11460	11918	3534	3646	11759	12255
Via Dozza:Rot. Decorati al Valor Militare-Via Cracovia	437	383	503	306	326	709	630
Via Dozza:Via Dallolio-Via Ferrara	12544	11660	11842	3749	3779	12206	12668
Via Dozza:Via Napoli-Via Caduti e Dispersi in Guerra	8936	7189	8510	2570	2566	16669	17506
Via Dozza:Via Caduti e Dispersi in Guerra-Via Napoli	10200	9588	9912	3132	3203	2820	2276
Via Dozza:Via Due Madonne-Via M.Longhena	8735	7920	8061	2509	2583	8051	8420
Via Toscana:Via Bacchi della Lega-Via Pavese	12139	11507	11570	4651	4676	12024	12435
Via Toscana:Via Filippini-Via Fantini	7820	7026	7119	2452	2593	7547	8012
Via Toscana:Via Filippini-Via dei 7 Leoncini	7017	6483	6758	2596	2560	6660	6951
Via Toscana:Via Beethoven-Via Bellini	7260	6788	7009	2654	2654	6962	7073
Via Toscana:Via V.Bellini-Via G.S.Bach	13213	11752	12288	4875	4855	12930	13569
	264940	243069	252132	91682	91265	257378	268098

3.4.4 Moovit

The Moovit Public Transit Index indicates how people in Bologna get around each day with public transit compared to the average data in a week before the pandemic. The graph below in Figure 3.15 shows the change along a timeline.

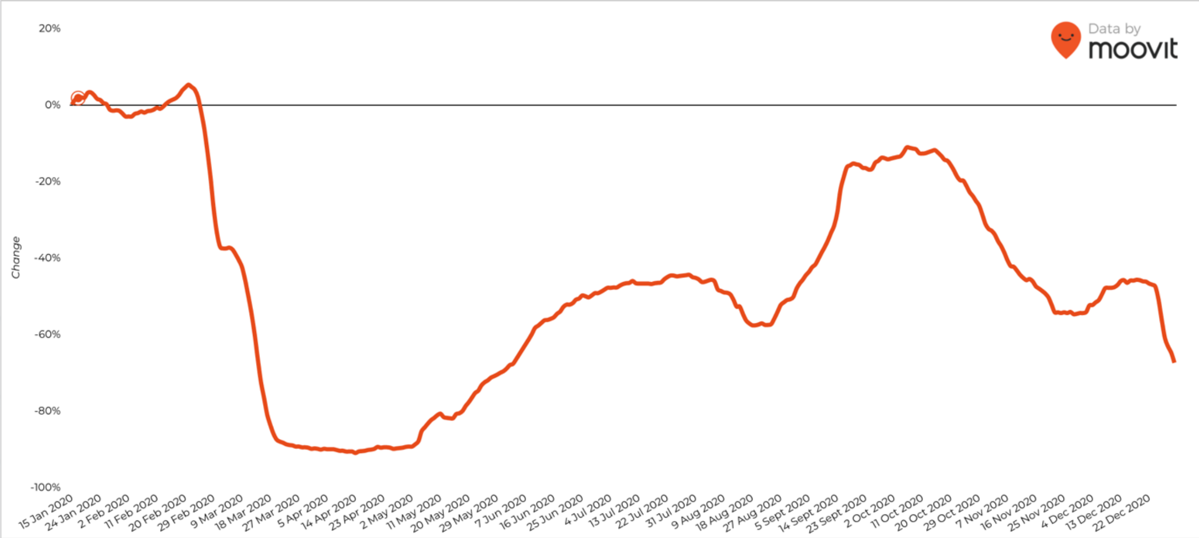

Figure 3.15 Trendline of mobility usage in Bologna during the 2020 year (MOOVIT APP).

The relative percentage changes in usage with respect to the timeframe of this study were recorded as shown in Table 3.8 below.

Table 3.8 Relative change of mobility trendline during timeline of the study (MOOVIT APP).

Phase 1	10-Feb-20	-1.30%
Phase 2	22-Apr-20	-90%
Phase 3	17-Jun-20	-54.70%
Phase 4	08-Oct-20	-11.50%

3.5. MODAL COMPARISONS

The final step of analysis was to compare the data from the various modes, namely bicycle, vehicles and buses in the established timeframes.

- For bicycles, the sum of the daily counts for specific days within the weeks of the timeframes were obtained.

Table 3.9 Sum of daily cyclist counts during timeframe of study.

	BICYCLE			
	9-15 Feb,2020	19-25 Apr, 2020	15-21 Jun, 2020	04-10 Oct,2020
Sun	2754	713	5897	4309
Mon	4819	621	4976	6945
Tues	5146	1065	6546	7792
Wed	5251	1675	6168	7710
Thurs	5135	1974	7519	7887
Frid	5168	1957	7410	7583
Sat	4133	970	6813	6229
Sums	32406	8975	45329	48455

- For bus lines, the averages of passengers who boarded the bus were summed for each phase as shown in Table 3.10. For Phase 2, since it was impossible to conduct counts during that period, the numbers for that period were estimated to be 10% of the previous phase as highlighted in yellow in Table 3.12 (assuming the same trend as observed with the data obtained from Moovit). The main reason being that, during the lockdown phase, public transportation was virtually non-existent with travel being restricted to only essential service workers.

Table 3.10 Sum of bus counts for each phase in the timeframe of the study.

	BUS		
	Line	Date	Average
PHASE 1	13	2019	123
	20	2019	64
	27	2019	147
			334
	Line	Date	Average
PHASE 2	13		
	20		
	27		
			0
	Line	Date	Average
	13	14-20 Jun, 2020	50
PHASE 3	20	14-20 Jun, 2020	57
	27	14-20 Jun, 2020	18
			125
	Line	Date	Average
	13	4-10 Oct, 20	50
PHASE 4	20	4-10 Oct, 20	41
	27	4-10 Oct, 20	78
			169

- For vehicle counts, 56 counters were selected and the sums obtained representing each phase as shown in Table 3.11. For Phase 3, data for the counts were not available so an average was taken of the counts for Phase 2 and Phase 3 as highlighted in Table 3.12.

Table 3.11 Sums of counts for vehicles during the timeline of the study.

SPIRA	11-Feb	21-Apr	14-20 Jun, 2020	07-Oct
Via Marconi:Via Leopardi-Via Riva di Reno	1192	853		1199
Via Marconi:Via Leopardi-Via Riva di Reno	7106	2160		7251
Via Marconi:Via Leopardi-Via Riva di Reno	2310	783		2268
Via S. Donato:Via S.Nicolò di Villola-Via E. Salgari	7356	2196		7159
Via Salgari:Via S. Donato-Via Negri	1252	544		1272
Via Pirandello:Via Casini-Via S. Donato	4586	1775		5569
Via del Pilastro:Via S. Donato-Via Protche	811	195		741
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4910	1471		5270
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4969	2353		5110
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4653	2445		4834
Via Irnerio:Via Mascarella-Via Centotrecento	5372	1811		5279
Via Irnerio:Via Mascarella-Via del Borgo di S. Pietro	10655	3164		11229
Via Irnerio:Via del Borgo di S. Pietro-Via Mascarella	4522	1568		4471
Via Irnerio:Via del Borgo di S. Pietro-Via Capo di Lucca	10293	3374		11279
Via Borgo San Pietro:Via Irnerio-Via Q.Majorana	1655	484		1645
Via Borgo San Pietro:Mura di Porta Galliera-Viale Masini	1713	653		2063
Via Irnerio:via Alessandrini-via Capo di Lucca	3479	1233		3586
Via Irnerio:Via del Pallone-Piazzale Baldi	8241	2641		9060
Via Irnerio:P.zza VIII Agosto-Via Alessandrini	3418	1222		3582
Via Irnerio:P.zza VIII Agosto-Via dell'Indipendenza	11033	3361		11611
Via Irnerio:Via Indipendenza-P.zza dell'VIII Agosto	2161	1011		2106
Via dell'Indipendenza:Via dei Mille-Via S. Giuseppe	2324	1028		2142
Via dell'Indipendenza:Via dei Mille-Via Milazzo	4921	1848		4637
Via S. Felice:Via Riva di Reno-Via Pietralata	2702	1858		2895
Via S. Felice:Via Riva di Reno-Via Pietralata	4265	1794		4058
Via Saragozza:Via di Casaglia-Via F.Orioli	10783	3572		12780
Via Saragozza:Via Battaglia-Via Ruscello	902	402		842
Via Saragozza:Via Guidotti-Via Malta	10245	3385		10798
Via Emilia Ponente:Via del Triumvirato-Via del Greto	9393	3434		9134
Via Emilia Ponente:Via del Triumvirato-Via del Greto	3871	1526		3761
Via Emilia Ponente:Via del Triumvirato-Via A.Piò	12547	4414		12055
Via Emilia Ponente:Via Agucchi-Via del Millario	10214	3650		10087
Via Emilia Ponente:Via Speranza-Via del Cardo	9066	3217		8563
Via Emilia Ponente:Via Battindarno-Via del Giacinto	8837	3047		8235
Via Emilia Ponente:Via Battindarno-Via della Ferriera	7406	2780		6743
Via Massarenti:Svincolo 11 Tang.Ovest Casalecchio S.Laz	13102	4514		12804
Via Massarenti:Via Donatello-Via Golfarelli	11494	4427		11618
Via Massarenti:Via del Parco-Via della Salita	8403	3369		8308
Via Massarenti:Via Crociali-Via Manfredi	10159	3915		10382
Via Massarenti:Via Venturoli-Via Libia	9564	3815		9653
Via Dozza (corsia dx):Via Cracovia-Rot. Decorati al Valor	13520	3383		13133
Via Dozza:Via Cracovia-Via Canova (S. Lazzaro)	9867	2348		9752
Via Dozza:Via Ferrara-Rot. Decorati al Valor Militare	12969	3534		12255
Via Dozza:Rot. Decorati al Valor Militare-Via Cracovia	437	306		630
Via Dozza:Via Dallolio-Via Ferrara	12544	3749		12668
Via Dozza:Via Napoli-Via Caduti e Dispersi in Guerra	8936	2570		17506
Via Dozza:Via Caduti e Dispersi in Guerra-Via Napoli	10200	3132		2276
Via Dozza:Via Due Madonne-Via M.Longhena	8735	2509		8420
Via Toscana:Via Bacchi della Lega-Via Pavese	12139	4651		12435
Via Toscana:Via Pavese-Via Bacchi della Lega	12222	4513		13032
Via Toscana:Via della Cava-Via Fantini	5053	1766		5372
Via Toscana:Via della Cava-Via Giordano Bruno	7154	2572		7338
Via Toscana:Via Filippini-Via Fantini	7820	2452		8012
Via Toscana:Via Filippini-Via dei 7 Leoncini	7017	2596		6951
Via Toscana:Via Beethoven-Via Bellini	7260	2654		7073
Via Toscana:Via V.Bellini-Via G.S.Bach	13213	4875		13569
	400971	138902	0	406501

Finally, the Table 3.11 below shows the final table obtained which shows all modes with the respective sums.

Table 3.12 Comparisons of sums of counts recorded for each mode with respect to the timeline of the study.

Phases	1	2	3	4
	9-15 Feb,2020	19-25 Apr, 2020	14-20 Jun, 2020	04-10 Oct,2020
Bicycle	32406	8975	45329	48455
Bus	334	33.4	125	169
Vehicles	400971	138902	272702	406501
Sum of modes	**433711**	**147910.4**	**318155.5**	**455125**

CHAPTER 4 – RESULTS

4.1 BICYCLES

4.1.1 Weekly Trips Comparisons

To be able to quantify the changes in volume of cycle activity as a result of the pandemic, comparisons were drawn between cycle counts recorded for the same weeks in both 2019 and 2020. In Table 4.1, the comparison between counts for the last week of April in 2019 against the same week in 2020 showed a decrease of 22027 counts. This indicates the huge decline in cyclist activities during the Phase 2 period of the study which was the lockdown period. Figure 4.1 also shows the variation in daily flow counts for each reference time period over the duration of the week.

On the other hand, for counts recorded in the Phase 3 period as shown in Table 4.2 and Figure 4.2, the sums indicated an increase of 9312 from the figures recorded in 2019 for the same period in June of both years. Similarly, for Phase 4, Tables 4.3 and 4.4 showed marginal increases of 3725 and 3852 respectively for counts recorded in the months of September and October.

The results for the various months are shown in the tables and figures below.

Table 4.13 Weekly comparison of sum of bicycle counts in last weeks of April for 2019 and 2020.

	28 Apr -4 May, 2019	26 Apr -2 May, 2020
Sun	1807	970
Mon	2196	998
Tues	6307	2035
Wed	6127	1545
Thurs	7018	1888
Frid	5737	2123
Sat	3386	992
	32578	10551
Change	-22027	

In Figure 4.1 below, it can be clearly seen that the daily counts recorded for the same period in 2019 are much higher than that recorded for 2020. In most cases, daily counts in 2020 reduced to almost a third of that recorded in 2019.

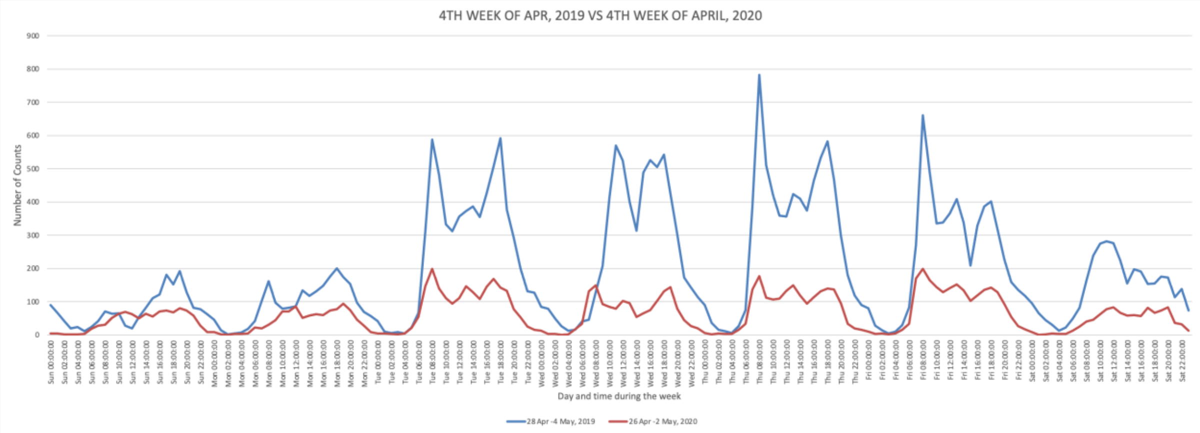

Figure 4.1 Weekly comparison of sum of bicycle counts recorded in fourth weeks of April in 2019 and 2020.

Table 4.2 Weekly comparison of sum of bicycle counts in second weeks of June in 2019 and 2020.

	7-13 Jun, 2019	9-15 Jun,2020
Sun	5507	5416
Mon	4045	6582
Tues	4801	7599
Wed	5057	7786
Thurs	5225	7747
Frid	7750	7225
Sat	6300	5642
	38685	47997
Change	9312	

In Figure 4.2 below, the trendlines indicate an increase in counts during the weekdays, that is from Monday to Friday where the trendline for 2020 shows higher count numbers. The month of June is the first indication of an upturn in bicycle counts in 2020 with respect to that recorded in 2019.

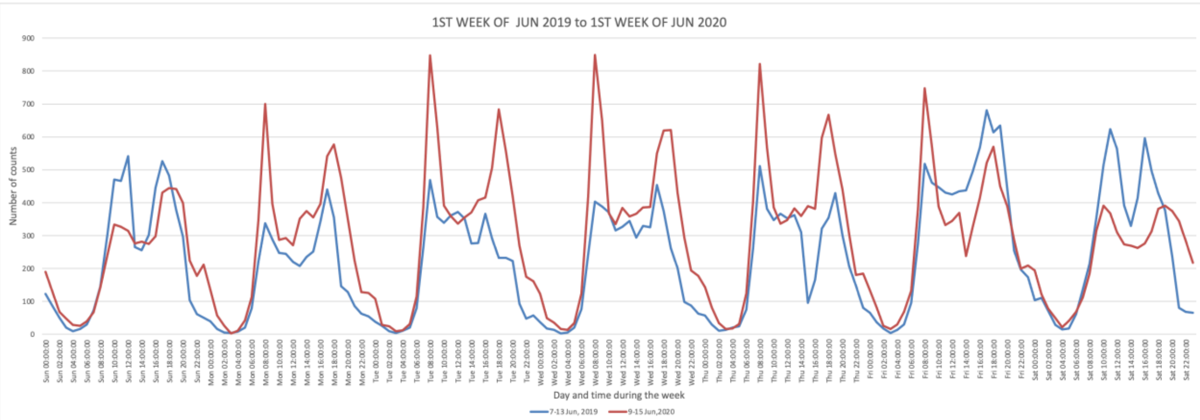

Figure 4.2 Weekly comparison of sum of bicycle counts recorded in first weeks of June in 2019 and 2020.

Table 4.3 Weekly comparison of sum of bicycle counts in the first weeks of September in 2019 and 2020.

	01-07 Sep, 2019	30 Aug - 5 Sep, 2020
Sun	3945	3920
Mon	5385	4362
Tues	5589	6434
Wed	6552	5412
Thurs	6633	6835
Frid	2785	6722
Sat	4952	5881
	35841	39566
Change	3725	

Table 4.3 above shows a total positive increase of 3725 in counts recorded in 2020 with respect to the same week in 2019. In Figure 4.3 below, the trendlines indicate a marginal increase in daily counts in 2020 with a huge increase on the counts recorded on Friday. The first week of September, therefore follows the trend of positive increase in counts similar to that of June but with a lower change.

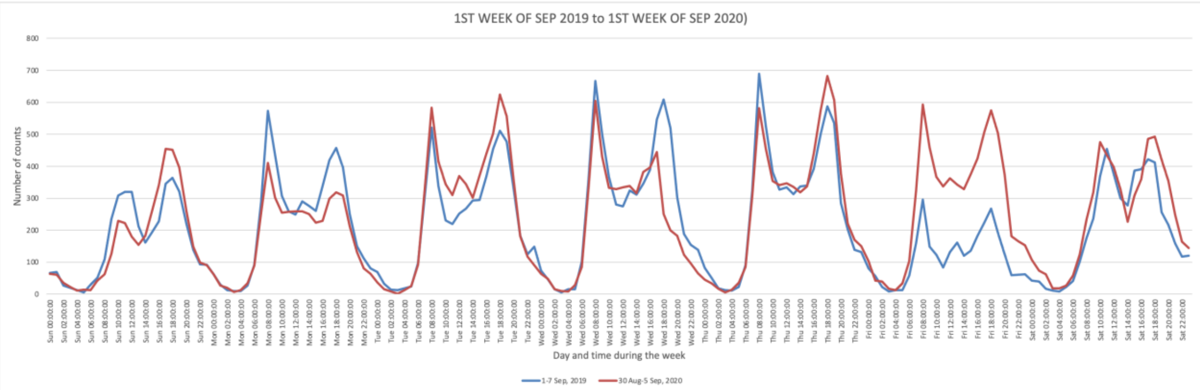

Figure 4.3 Weekly comparison of sum of bicycle counts recorded in first weeks of September in 2019 and 2020.

Table 4.4 Weekly comparison of sum of bicycle counts in the second weeks of October in 2019 and 2020.

	6-12 Oct,2019	04-10 Oct,2020
Sun	3804	4309
Mon	4264	6945
Tues	8134	7792
Wed	8059	7710
Thurs	7564	7887
Frid	7544	7583
Sat	5234	6229
	44603	48455
Change	3852	

Table 4.4 above shows a total positive increase of 3852 in counts recorded in 2020 with respect to the same week in 2019. This is similar to the change observed in September. In

Figure 4.4 below, the trendlines indicate almost same counts during Tuesday to Friday but records a marginal increase in daily counts in 2020 recorded on Saturday to Monday.

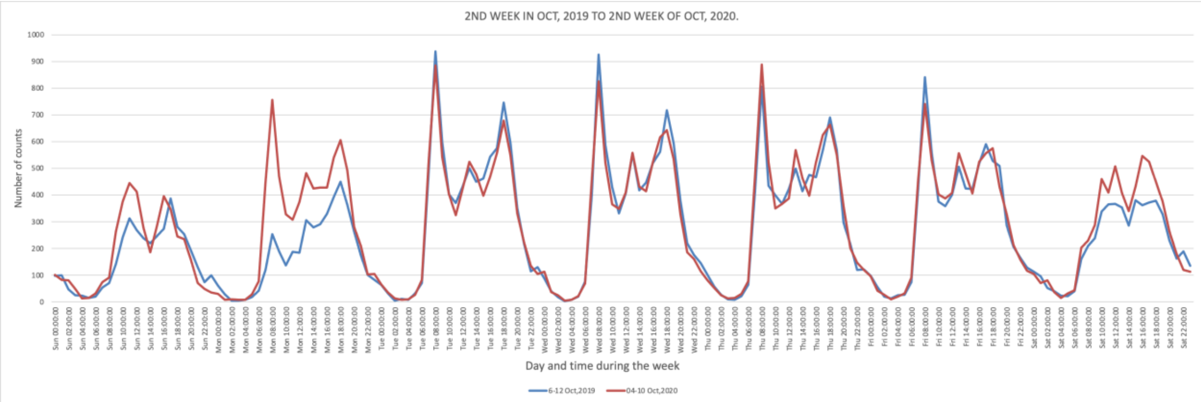

Figure 4.4 Weekly comparison of sum of bicycle counts recorded in second weeks of October in 2019 and 2020.

4.1.2 Timeframe Comparison

The comparison of the flow counts by phases shows an initial decrease in numbers in Phase 2 from numbers recorded in Phase 1. The lowest counts of 8975 were recorded in Phase 2 which was during the lockdown period whiles the highest was 48455 which was recorded in Phase 4. In June, there was a sharp increase by about 400% from the flows measured in April which signified the transition from lockdown to post-lockdown periods. Table 4.5 summarizes the flow counts during the determined timeframe with Figure 5.5 representing this data on a graph.

Table 4.5 Sum of flow counts during the timeframe of the study.

Phases	1	2	2	3	3	4
	02-08 Feb	15-21 Mar	19-25 Apr	15-21 Jun	05-11 Jul	04-10 Oct
Sun	2754	1258	713	5897	4441	4309
Mon	4819	2011	621	4976	6155	6945
Tues	5146	1823	1065	6546	5898	7792
Wed	5251	1817	1675	6168	7023	7710
Thurs	5135	1691	1974	7519	6857	7887
Frid	5168	1563	1957	7410	6505	7583
Sat	4133	896	970	6813	4153	6229
Sums	32406	11059	8975	45329	41032	48455

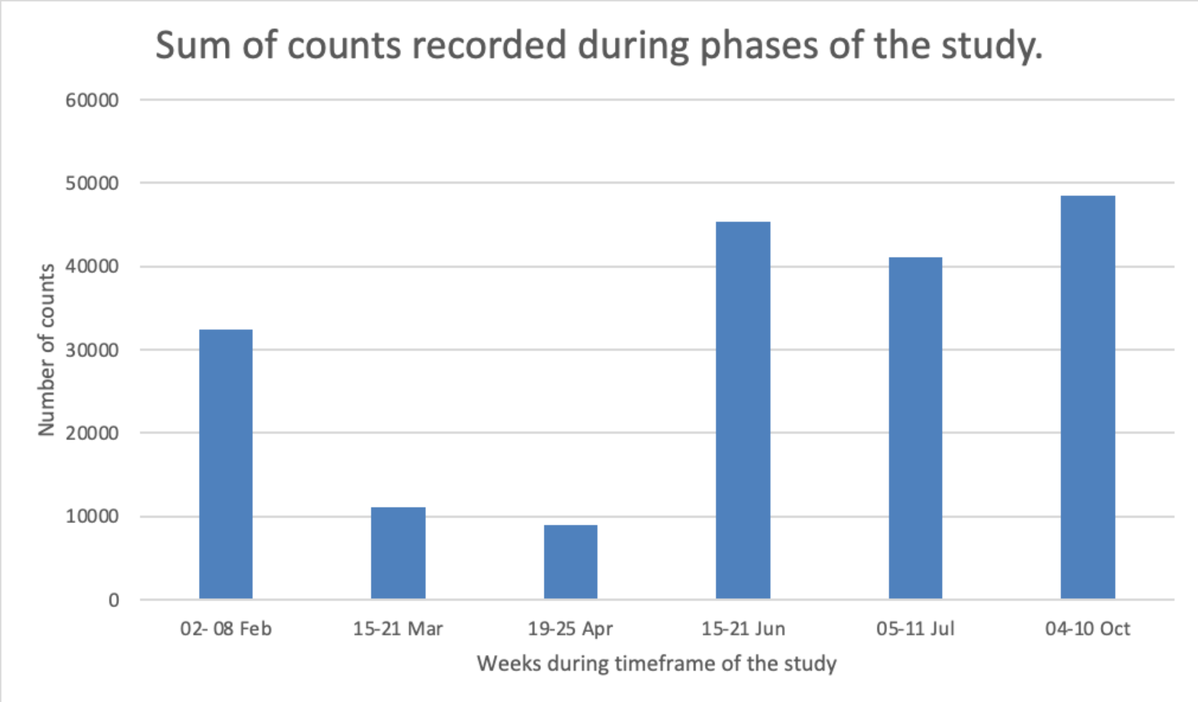

Figure 4.5 Average bicycle counts recorded during the timeframe of the study.

4.2 BUSES

4.2.1 Line 13

Table 4.6 shows the number of passengers who boarded at each bus stop on days when counts were conducted for Line 13. There were thirty-two (32) bus stops considered along with the number of passengers recorded for each of these stops.

Table 4.7 also summarizes the averages of passengers for the timeframe of the study. The average of both counts recorded in 2019 is taken as representative of the situation prior to the pandemic. Averages for the various phases aggregated for the bus stops are reported as 123, 50, 53 and 80 persons for 2019, June, July and October of 2020 respectively.

Table 4.6 Bus line 13 with the averages of the number of people who boarded on the respective dates.

LINE 13		TH	TH	TH	TH
Bus Stops	11/03/2019	28/02/2019	18/06/2020	09/07/2020	08/10/2020
SCALA	12	17	9	8	11
BORGA PANIGALE STAZIONE	2	5	2	3	7
CINTA DAZIARA TEATRI DI VITA	9	3	2	2	2
PONTELUNGO	16	13	6	7	4
BERNARDI	5	2	0	0	3
SANTA VOILA	8	8	3	3	6
BERRETTA ROSSA	6	10	3	3	3
PRATI DI CAPARA	4	0	0	0	0
OSPEDALE MAGGIORE	2	4	4	2	3
TIMAVO	6	0	1	1	2
SAFFI	3	6	0	0	3
SAN PIO V	5	2	0	2	5
PORTA SAN FELICE	5	4	0	0	4
SAN FELICE	0	5	1	1	0
UGO BASSI	15	7	5	6	5
RIZZOLI	19	12	7	4	4
PIAZZA MINGHETTI	1	3	0	0	0
GARGANELLI	0	2	0	1	0
BARACCANO	0	2	0	0	2
PORTA SANTO STEFANO	3	2	1	2	2
MURRI	1	2	0	0	0
STERLINO	0	1	3	3	1
RAGNO	1	1	1	1	1
VARTHEMA	0	4	0	0	0
CHIESA NUOVA	0	0	2	2	2
PARISIO	1	2	0	1	0
VILLA MAZZACORATI	0	3	0	0	2
CROCE DI CAMALDOLI	0	1	0	1	1
DIRETTISSIMA	0	0	0	0	1
ANGELO CUSTODE	0	1	0	0	1
SAN RUFFILO	0	0	0	0	0
PONTE SAVENA	0	0	0	0	5
	124	122	50	53	80

Table 4.714 Averages of passengers who boarded on count days.

2019 Average	Jun-20	Jul-20	Oct-20
123	50	53	80

Figure 4.6 shows the variation of the number of passengers who boarded the bus line at each specific bus stop on the count days.

With most stops, there was a reduction in numbers recorded in 2020 with respect to the same in 2019, however the last count conducted indicates an increasing trend in passenger numbers.

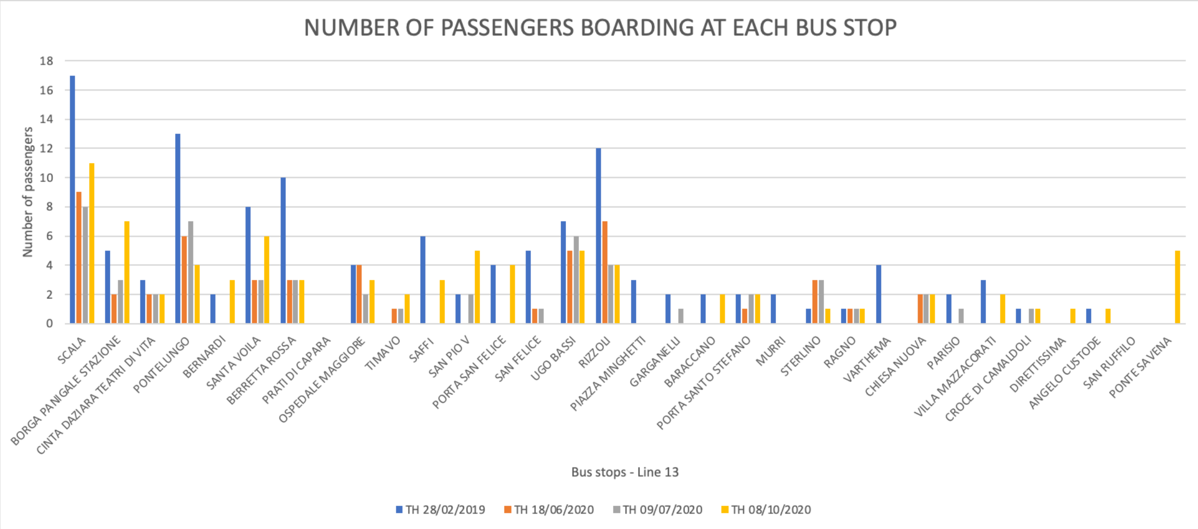

Figure 4.6 Number of passengers who boarded the bus line at each bus stop on the count days for Line 13.

4.2.2 Line 20

Table 4.8 also shows the number of passengers who boarded at each bus stop on days when counts were conducted for Line 20. There were forty (40) bus stops considered along with the number of passengers recorded for each of these stops.

Table 4.8 Averages of the number of people who boarded Bus line 20 on the respective count dates.

LINE 20	Wed	Tues	Tues	Tues
BUS STOPS	27/02/2019	16/06/2020	07/07/2020	06/10/2020
PILASTRO	10	9	7	12
NEGRI	1	0	0	2
SALGARI	0	2	2	0
CADRAINO BIVIO	3	3	3	2
SAN DONNINO	5	2	1	0
SIRENELLA	2	2	4	2
SAN DONATO	6	0	0	1
CENTRO ZANARDI	6	0	0	1
MERCATO SAN DONATO	5	8	6	2
SANT'EGIDIO	1	0	0	0
PORTA SAN DONATO	2	1	1	1
IRNERIO	1	0	0	0
SFERISTERIO	0	6	6	1
VII AGOSTO	4	2	2	8
SAN PIETRO	0	0	0	1
RIZZOLI	1	6	6	1
PIAZZA MINGHETTI	0	1	1	0
FARINI	0	2	2	0
COLLEGIO DI SPAGNA	0	2	4	1
NOSADELLA	0	2	2	0
PORTA SARAGOZZA-FRASSINAGO	0	1	1	0
PORTA SARAGOZZA-RISORGEMENTO	9	3	3	1
SAN GUISEPPE	1	0	0	0
ORSONI	1	1	1	0
VILLA BENNI	0	0	0	0
VILLA SPADA	0	0	0	0
MELONCELLO	2	0	0	2
BIVIO SAN LUCA	0	1	1	0
DELLA SPORT	0	0	0	0
FUNIVIA	4	0	1	0
DON STURZO	0	0	0	0
TREVES	7	0	1	0
MILANI	0	0	0	0
CROCE LUNA	2	0	0	1
CROCE	1	2	3	0
CASALECCHIO VILLA CHIARA	0	0	0	0
CASALECCHIO SAN MARTINO	0	0	1	0
CASALECCHIO CHUISA	4	1	0	0
CASALECCHIO CONOSCENZA	0	0	1	2
CASELECCHIO MARCONI	0	0	0	0
	78	57	60	41

Table 4.9 also summarizes the averages of passengers for the timeframe of the study. The average of both counts recorded in 2019 is taken as representative of the situation prior to the pandemic. Averages for the various phases aggregated for the bus stops are reported as 78, 57, 60 and 41 persons for 2019, June, July and October of 2020 respectively as shown in Table 4.9.

Table 4.9 Averages of passengers who boarded on count days.

2019 Average	Jun-20	Jul-20	Oct-20
78	57	60	41

Figure 4.7 shows the variation of the number of passengers who boarded the bus line at each specific bus stop on the count days. With most stops, there was a reduction in numbers

recorded in 2020 with respect to the same in 2019, however the last count conducted indicates an increasing trend of passenger numbers.

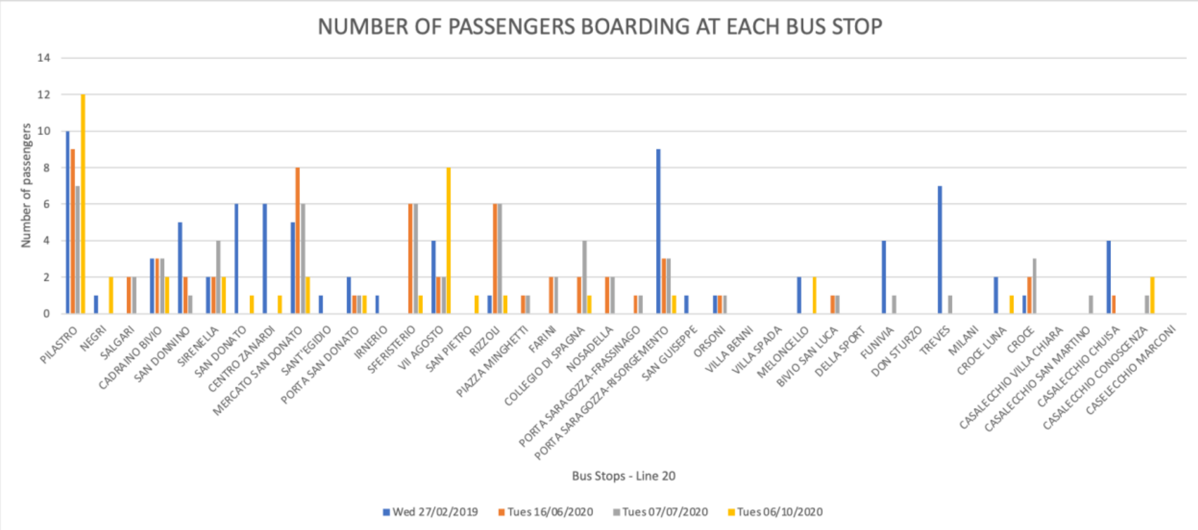

Figure 4.7 Number of passengers who boarded the bus line at each specific bus stop on the count days.

4.2.3 Line 27

Table 4.10 shows the number of passengers who boarded at each bus stop on days when counts were conducted for Line 27. There were thirty-seven (37) bus stops considered along with the number of passengers recorded for each of these stops.

Table 4.10 Bus line 27 with the averages of the number of people who boarded on the respective dates.

LINE 27	Mon		Mon	Mon
BUS STOPS	25/02/2019	26/02/2019	15/06/2020	5/10/2020
Corticella Stazione	17	10	2	0
COLOMBAROLA	6	1	0	1
Lipparini	10	8	1	6
Roncaglio	14	8	1	2
Pinardi	4	8	2	6
Croce Coperta	15	8	0	2
Caserme Rosse	5	2	1	4
De Giovanni	1	5	0	0
Istituto Aldini	7	13	0	2
Ippodromo	3	1	2	7
Lombardi	13	4	3	9
Ca' Dei Fiori	4	4	1	8
Piazza dell'Unita'	7	6	0	6
Sacro Cuore	11	5	1	13
Autostazione	28	4	0	3
VII Agosto	7	11	0	0
Indipendenza	2	1	1	1
Rizzoli	3	3	0	0
Strada Maggiore	1	0	0	0
Torleone	2	2	2	0
Porta Maggiore	1	0	0	1
Albertoni	0	5	0	0
Alemmani	0	1	1	2
Laura Bassi	1	1	0	0
Fermi	1	0	0	0
Mazzini Stazione	2	1	0	0
Pontevecchio	1	1	0	1
Bitone	3	0	0	0
Sardegna	1	5	0	0
Calabria	0	0	0	0
Milano	0	0	0	0
Chiesa San Lazzaro	1	0	0	0
Mazzoni	2	0	0	1
Firenze	1	1	0	2
Longo Cavazzoni	0	0	0	0
Longo	0	0	0	1
Piazza Degli Arti	0	0	0	0
	174	119	18	78

Table 4.11 also summarizes the averages of passengers for the timeframe of the study. The average of both counts recorded in 2019 is taken as representative of the situation prior to the pandemic (Phase 1). Averages for the various phases aggregated for the bus stops are reported as 147, 18, and 78 persons for 2019, June and October of 2020 respectively.

Table 4.1115 Averages of passengers who boarded on count days.

2019 Average	Jun-20	Jul-20	Oct-20
147	18	N/A	78

Figure 4.8 shows the variation of the number of passengers who boarded the bus line at each specific bus stop on the count days. With most stops, there was a reduction in numbers recorded in 2020 with respect to the same in 2019, however the last count conducted indicates an increasing trend of passenger numbers.

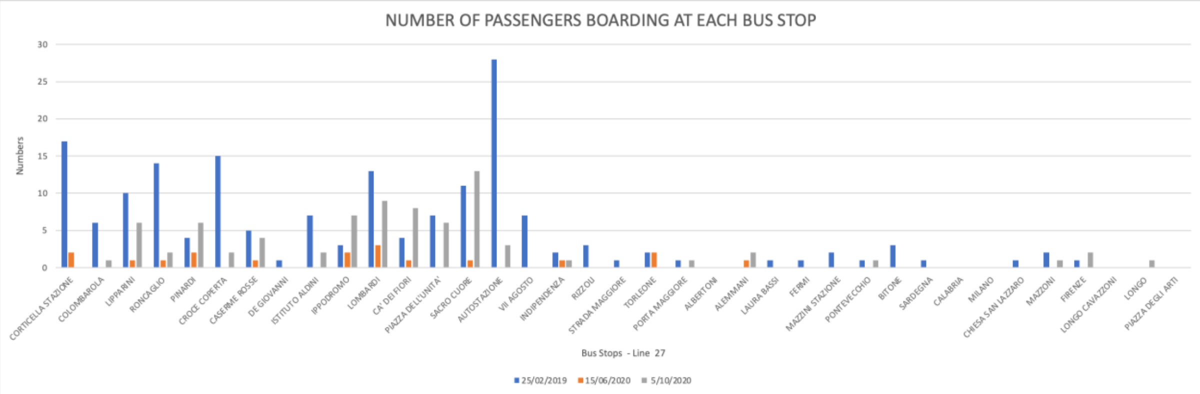

Figure 4.8 Number of passengers who boarded the bus line at each specific bus stop on the count days.

4.3 VEHICLES

Vehicle counts were summed from selected counters on count days as detailed in Table 4.12. Table 4.13 summarizes the data, indicating a decline in vehicle use along the selected routes in the weeks leading to the 3rd of March, 2020 (Phase 2). The lowest counts recorded was 138902 in 21ST of April, 2020 (Phase 2) with numbers returning to averages recorded pre-pandemic in October, 2020 (Phase 4).

Table 4.12 Selected counters and the flows recorded during the timeframe of the study.

SPIRA	11-Feb	25-Feb	03-Mar	21-Apr	22-Apr	05-Oct	07-Oct
Via Marconi:Via Leopardi-Via Riva di Reno	1192	1116	1034	853	839	1145	1199
Via Marconi:Via Leopardi-Via Riva di Reno	7106	5960	6011	2160	2228	6700	7251
Via Marconi:Via Leopardi-Via Riva di Reno	2310	1956	1978	783	733	2123	2268
Via S. Donato:Via S.Nicolò di Villola-Via E. Salgari	7356	6536	6725	2196	2242	7004	7159
Via Salgari:Via S. Donato-Via Negri	1252	1159	1209	544	583	1280	1272
Via Pirandello:Via Casini-Via S. Donato	4586	3959	5240	1775	1847	5565	5569
Via del Pilastro:Via S. Donato-Via Protche	811	1177	6100	195	213	673	741
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4910	4459	4082	1471	1571	4885	5270
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4969	4773	4898	2353	2550	4843	5110
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4653	4556	4686	2445	2446	4708	4834
Via Irnerio:Via Mascarella-Via Centotrecento	5372	4824	4669	1811	1776	5031	5279
Via Irnerio:Via Mascarella-Via del Borgo di S. Pietro	10655	9516	9726	3164	3092	10340	11229
Via Irnerio:Via del Borgo di S. Pietro-Via Mascarella	4522	4029	4139	1568	1552	4202	4471
Via Irnerio:Via del Borgo di S. Pietro-Via Capo di Lucca	10293	9327	9643	3374	3192	10307	11279
Via Borgo San Pietro:Via Irnerio-Via Q.Majorana	1655	1402	1404	484	523	1523	1645
Via Borgo San Pietro:Mura di Porta Galliera-Viale Masini	1713	1593	1538	653	605	1965	2063
Via Irnerio:via Alessandrini-via Capo di Lucca	3479	3153	3197	1233	1179	3253	3586
Via Irnerio:Via del Pallone-Piazzale Baldi	8241	7345	7369	2641	2493	8443	9060
Via Irnerio:P.zza VIII Agosto-Via Alessandrini	3418	3125	3091	1222	1166	3282	3582
Via Irnerio:P.zza VIII Agosto-Via dell'Indipendenza	11033	9698	9872	3361	3051	11086	11611
Via Irnerio:Via Indipendenza-P.zza dell'VIII Agosto	2161	1990	2000	1011	949	1983	2106
Via dell'Indipendenza:Via dei Mille-Via S. Giuseppe	2324	1990	1798	1028	1041	1979	2142
Via dell'Indipendenza:Via dei Mille-Via Milazzo	4921	7870	4208	1848	1721	4458	4637
Via S. Felice:Via Riva di Reno-Via Pietralata	2702	2543	3279	1858	1390	2472	2895
Via S. Felice:Via Riva di Reno-Via Pietralata	4265	3736	4014	1794	1770	3868	4058
Via Saragozza:Via di Casaglia-Via F.Orioli	10783	10157	10807	3572	3523	12184	12780
Via Saragozza:Via Battaglia-Via Ruscello	902	761	781	402	402	812	842
Via Saragozza:Via Guidotti-Via Malta	10245	9362	9708	3385	3230	10148	10798
Via Emilia Ponente:Via del Triumvirato-Via del Greto	9393	8408	8331	3434	3528	8853	9134
Via Emilia Ponente:Via del Triumvirato-Via del Greto	3871	3559	3483	1526	1582	3542	3761
Via Emilia Ponente:Via del Triumvirato-Via A.Piò	12547	12085	11857	4414	4552	11808	12055
Via Emilia Ponente:Via Agucchi-Via del Millario	10214	9206	9362	3650	3705	9742	10087
Via Emilia Ponente:Via Speranza-Via del Cardo	9066	8557	8347	3217	3372	8418	8563
Via Emilia Ponente:Via Battindarno-Via del Giacinto	8837	7927	7919	3047	2965	7778	8235
Via Emilia Ponente:Via Battindarno-Via della Ferriera	7406	6942	6723	2780	2924	6743	6743
Via Massarenti:Svincolo 11 Tang.Ovest Casalecchio S.Lazzaro-Via B.Cellini	13102	11379	11813	4514	4514	12438	12804
Via Massarenti:Via Donatello-Via Golfarelli	11494	10196	10694	4427	4334	11298	11618
Via Massarenti:Via del Parco-Via della Salita	8403	7645	7939	3369	3247	8170	8308
Via Massarenti:Via Crociali-Via Manfredi	10159	9165	9285	3915	3869	9624	10382
Via Massarenti:Via Venturoli-Via Libia	9564	8614	8806	3815	3731	9096	9653
Via Dozza (corsia dx):Via Cracovia-Rot. Decorati al Valor Militare	13520	12055	12591	3383	3561	12443	13133
Via Dozza:Via Cracovia-Via Canova (S. Lazzaro)	9867	8781	9193	2348	2552	9117	9752
Via Dozza:Via Ferrara-Rot. Decorati al Valor Militare	12969	11460	11918	3534	3646	11759	12255
Via Dozza:Rot. Decorati al Valor Militare-Via Cracovia	437	383	503	306	326	709	630
Via Dozza:Via Dallolio-Via Ferrara	12544	11660	11842	3749	3779	12206	12668
Via Dozza:Via Napoli-Via Caduti e Dispersi in Guerra	8936	7189	8510	2570	2566	16669	17506
Via Dozza:Via Caduti e Dispersi in Guerra-Via Napoli	10200	9588	9912	3132	3203	2820	2276
Via Dozza:Via Due Madonne-Via M.Longhena	8735	7920	8061	2509	2583	8051	8420
Via Toscana:Via Bacchi della Lega-Via Pavese	12139	11507	11570	4651	4676	12024	12435
Via Toscana:Via Pavese-Via Bacchi della Lega	12222	11519	11717	4513	4544	12482	13032
Via Toscana:Via della Cava-Via Fantini	5053	4760	4901	1766	1768	5102	5372
Via Toscana:Via della Cava-Via Giordano Bruno	7154	6435	6559	2572	2535	6718	7338
Via Toscana:Via Filippini-Via Fantini	7820	7026	7119	2452	2593	7547	8012
Via Toscana:Via Filippini-Via dei 7 Leoncini	7017	6483	6758	2596	2560	6660	6951
Via Toscana:Via Beethoven-Via Bellini	7260	6788	7009	2654	2654	6962	7073
Via Toscana:Via V.Bellini-Via G.S.Bach	13213	11752	12288	4875	4855	12930	13569
	400971	367061	378216	138902	138631	387971	406501

Table 4.13 A summary of the sum of the counts recorded by selected counters during the phases.

	11-Feb	25-Feb	03-Mar	21-Apr	22-Apr	05-Oct	07-Oct
COUNTERS	400971	367061	378216	138902	138631	387971	406501

Figure 4.9 indicates the trendline of vehicle counts along the timeline of the study whiles Figure 4.10 shows the comparison of flows measured by the counters on varying dates. Generally, it could be observed that vehicle averages showed indications of quickly returning back to normal after the lockdown phases.

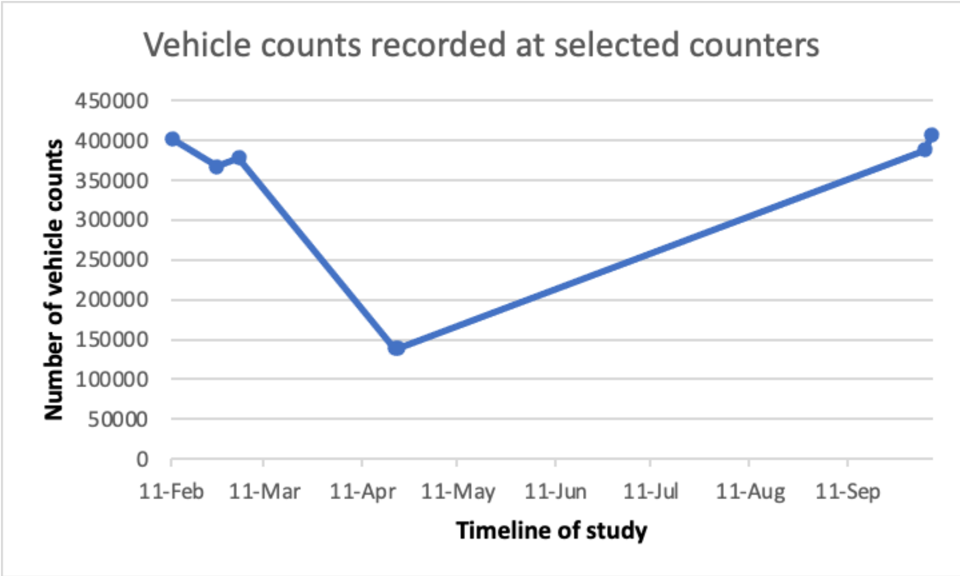

Figure 4.9 Trendline of vehicle counts along timeline of study.

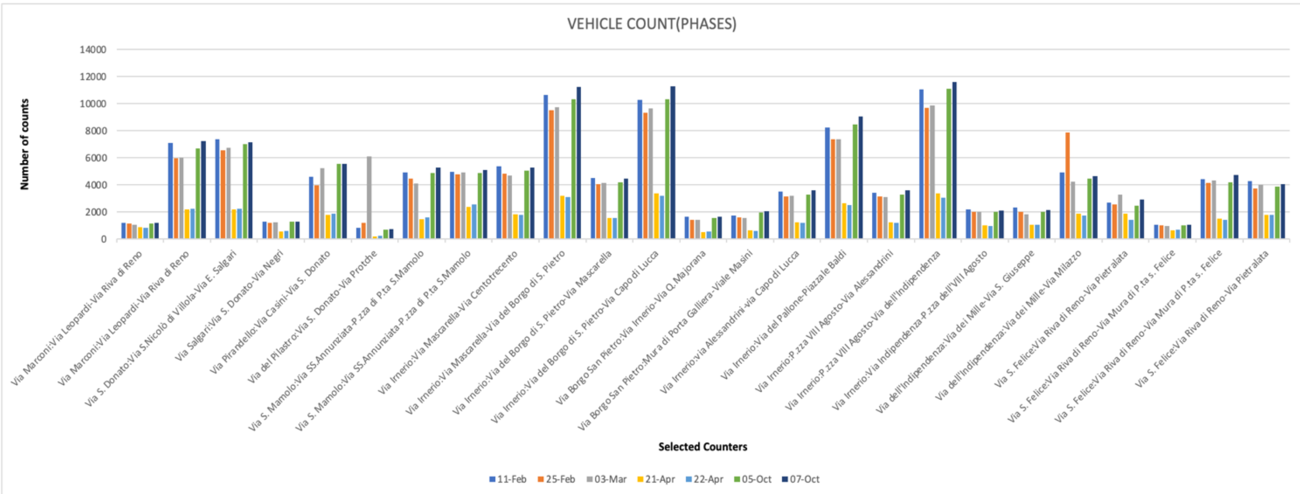

Figure 4.10 Comparison of vehicle counts recorded by selected counters on chosen dates.

4.4 MODAL COMPARISONS

4.4.1 Modal Share

According to the 2007 mobility survey of Bologna (as shown in Figure 4.11), simplified to include only three modes for this study, the aggregated picture of mobility before (including commuting) the quarantine can be seen, where 47% of urban mobility is done by motorized transport (driving or passenger), 42% by bus and 11% by cycling. It should be highlighted that there could have been some variations in the modal share since original survey in 2007 took place.

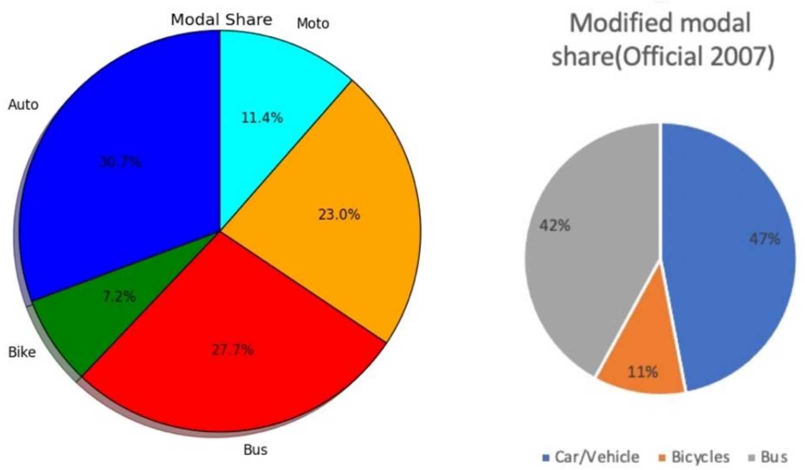

Figure 4.11 Modal share of mobility in Bologna (2007).

Table 4.14 shows the evolution of the modal shares over the period of the study with Figure 4.12 illustrating this graphically.

Table 4.14 Variations in modal splits during the timeline of the study.

Phases	1	2	3	4
MODAL SHARE	9-15 Feb,2020	19-25 Apr, 2020	14-20 Jun, 2020	04-10 Oct,2020
Bicycles	11.0%	13.4%	24.8%	19.9%
Buses	42.0%	18.5%	25.3%	25.7%
Vehicles	47.0%	71.8%	51.5%	57.7%

Bus use (public transportation) shows the biggest decrease in modal share during the study; it's usage decreases by 24% from Phase 1 to the lowest share among the modes of about 2% during Phase 2. It improves during the latter phases but never reaches its previous share in Phase 1. Vehicle use consistently remained the largest share during all the phases and was the dominant mode by far during the Phase 2 with a share of 72%. Cycling showed increase in usage over the first three phases. It had an initial share of 11% during Phase 1 which steadily increased to 24.8% in Phase 3 and a slight decrease to 19.9% in Phase 4.

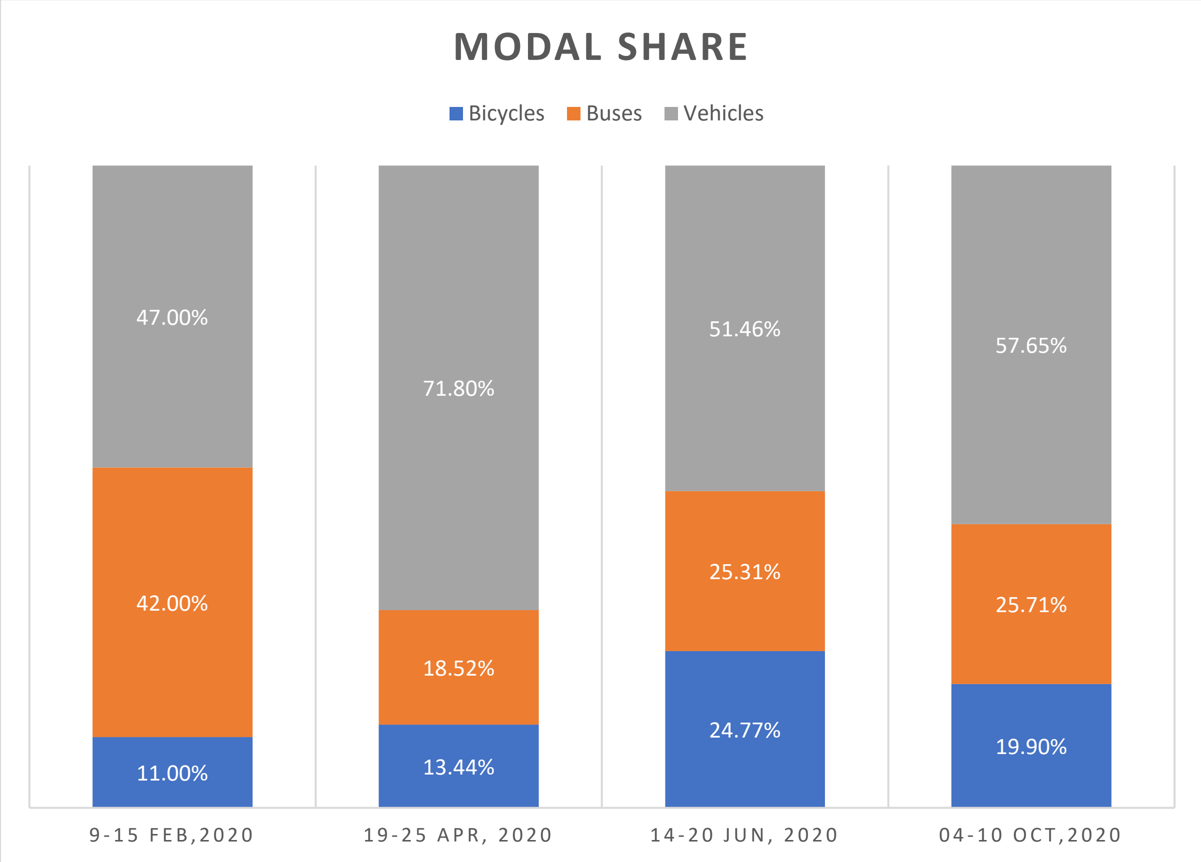

Figure 4.12 Modal share during timeline of the study.

4.4.2 Percentage Change

Percentage change describes the percentage increase or decrease in usage of a particular mode of mobility with reference to its initial usage prior to the lockdown (during Phase 1). Tables 4.15, 4.16 and 4.17 show the changes as indicated by the datasets available for Bologna and Figure 4.13 illustrates this graphically.

Table 4.15 Trendline changes in usage of mobility options across the different phases.

Phases	1	2	3	4
	9-15 Feb,2020	19-25 Apr, 2020	14-20 Jun, 2020	04-10 Oct,2020
Bicycle	1	0.277	1.399	1.495
Buslines	1	0.100	0.374	0.506
Vehicles	1	0.346	0.680	1.014
Moovit	1	0.100	0.453	0.885

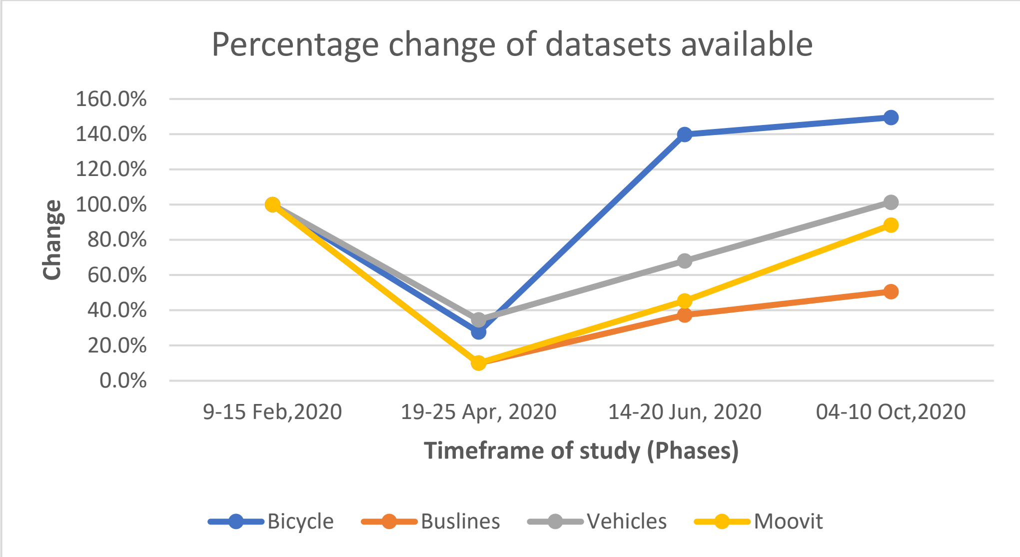

Figure 4.13 Graphical illustration of the percentage changes of mobility choices during the study.

Table 4.16 Overall mobility usage reduction in subsequent phases with respect to Phase 1.

Phases	1	2	3	4
	9-15 Feb,2020	19-25 Apr, 2020	14-20 Jun, 2020	04-10 Oct,2020
Bicycle	100.00%	-72.30%	39.88%	49.52%
Buslines	100.00%	-90.00%	-62.57%	-49.40%
Vehicles	100.00%	-65.36%	-31.99%	1.38%
Moovit	100.00%	-90.00%	-54.70%	-11.50%
		-75.89%	**-18.23%**	**0.50%**

Table 4.17 Percentage changes recorded for each phase with respect to the previous phase.

Phases	1	2	3	4
	9-15 Feb,2020	19-25 Apr, 2020	14-20 Jun, 2020	04-10 Oct,2020
Bicycle	100.00%	-72.30%	112.18%	9.65%
Buslines	100.00%	-90.00%	27.43%	13.17%
Vehicles	100.00%	-65.36%	33.37%	33.37%
Moovit	100.00%	-90.00%	35.30%	43.20%

All datasets available indicated a significant decrease in usage during Phase 2 with usage increasing in the subsequent phases. Bus use showed the largest decrease among the other modes of about 90% decline from usage recorded before the lockdown. Similarly, Moovit also recorded a 90% decrease in its usage during Phase 2. During Phase 3, all modes showed an upturn in percentages, however cycling increased the largest by around 112% and was the only mode to have an increase in usage (50%) compared to that observed before the lockdown. Vehicle use steadily rose in Phase 3 and reached figures almost close to that recorded before the lockdown.

CHAPTER 5 - DISCUSSIONS AND ANALYSIS

5.1 CASE STUDY ANALYSIS

In this section, an analysis of the results from the case study of Bologna is reported as well as a summary of the results reported. This analysis would later be used as a basis for comparisons with other study cases. Databases readily available for this study in Bologna were vehicle counts, bus passenger counts and bicycle counts as well as the online platform Moovit. All datasets available clearly demonstrated a huge decrease in usage of the various modes of transport during the lockdown period (Phase 2) as also seen all over the world. Comparisons then had to be made to find out to evaluate the impact of the pandemic on the various modes of transport. Results from this study suggested that post the lockdown phase, users were more dependent on private vehicles (i.e., cars) and cycling with public transportation(buses) showing slow signs of recovery.

The following Figures 5.1, 5.2 and 5.3 summarize the modal share and percentage changes for each mode considered in the study.

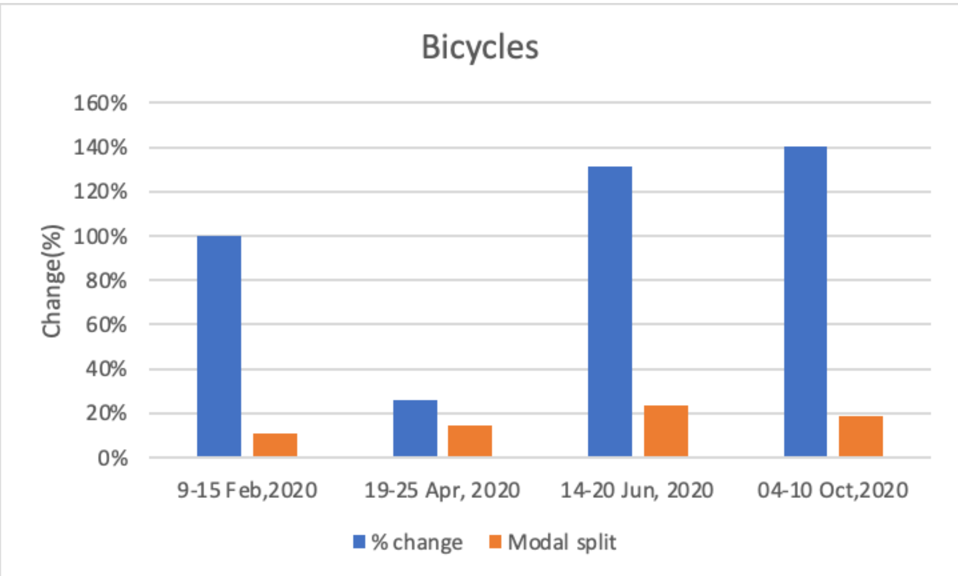

Figure 5.1 Modal split and percentage change of bicycle use during the study.

Similar to all other modes considered in this study, cycling use decreased in Phase 2 from numbers recorded in Phase 1 with a subsequent upturn in Phases 3 and 4. Averagely, after the lockdown phase (Phase 2), results indicate that the weekly counts of bicycles generally increased with respect to the same period the year before in 2019. For example, the comparison between counts for the weeks in September and October in 2019 against the same week in 2020 showed an average increase of 3788 counts. On a modal split basis, cycling showed increase in usage over the first three phases. It had an initial share of 11% during Phase 1 which steadily increased to 25% in Phase 3 and a slight decrease to 20% in Phase 4. Also, cycling use was unique in the sense that in Phase 3, it was the only mode to surpass its initial levels in Phase 1, showing 31% and 40% increases in usage in Phases 3 and 4. The results from this study could support the premise of a growing shift of users to active transportation(cycling). In light of these results, a prediction for active transport (cycling shifts) should be investigated more in detail for purposes for providing recommendations to decision-makers and local transport authorities especially with respect to provision of cycling infrastructure and expanding the existing cycling lanes length in Bologna.

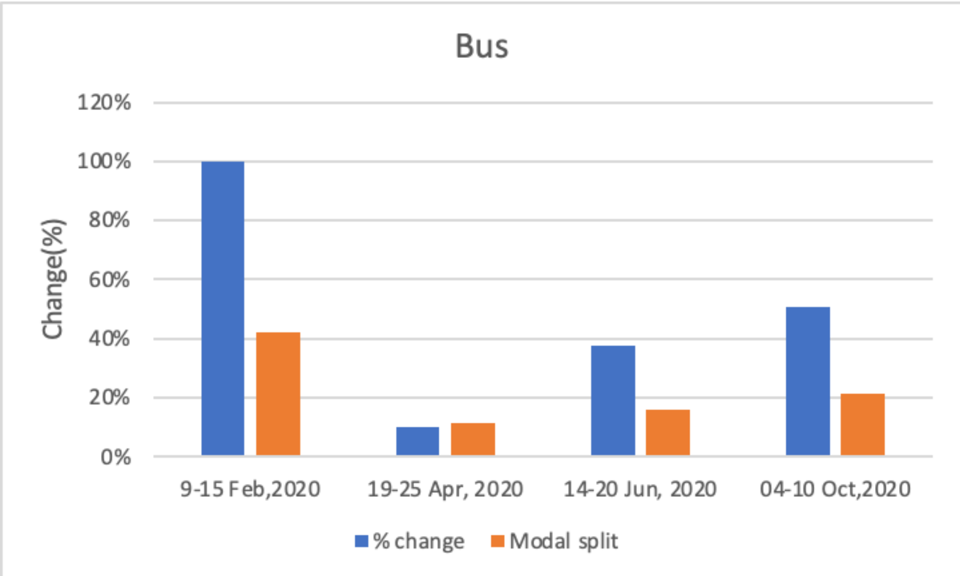

Figure 5.2 Modal split and percentage change of bus use during the study.

Public transportation(buses) was the most impacted during Phase 2 among the modes considered for this study, experiencing about 90% decrease in usage. This was mainly due to reduction of public transportation services as a result of lockdown restrictions enforced by the authorities.

Three bus lines were considered for the study, and the passenger counts recorded at bus stops along the trip journey. Collectively, the results indicate that there was a reduction in passengers boarding at selected stops in 2020 with respect to the same in 2019, however the last count conducted indicates an increasing trend in passenger numbers. Additionally, the results obtained show that bus use comparatively showed least recovery in subsequent phases after Phase 2. With respect to usage, it increases by 36% and a further 13% in Phases 3 and 4 respectively but still about 50% of its use before the lockdown phase. Similarly, with modal share, bus use showed an interesting variation during the timeframe of the study; its share decreases by 42% from Phase 1 to about 18.5% during Phase 2. It improves during the latter phases but never reaches its previous share (42%) in Phase 1. It loses most of its share to cycling. Other studies have suggested that this could be attributed to travelers' own choices because of continuing remote working conditions as well as concerns due to safety issues, anxiety, and stress levels(Hu, 2020; Pawar, Yadav, Akolekar, & Velaga, 2020). It is important to note that these arguments cannot be substantiated by only the methodology used in this study but further qualitative analysis determining road users' travel patterns, feelings, and perceptions conducted by surveys on people in Bologna could validate such premises. However, the drop in the use of public transport is a significant issue for sustainable urban transport planners and further studies could be conducted to find solutions to address the concerns raised by the users.

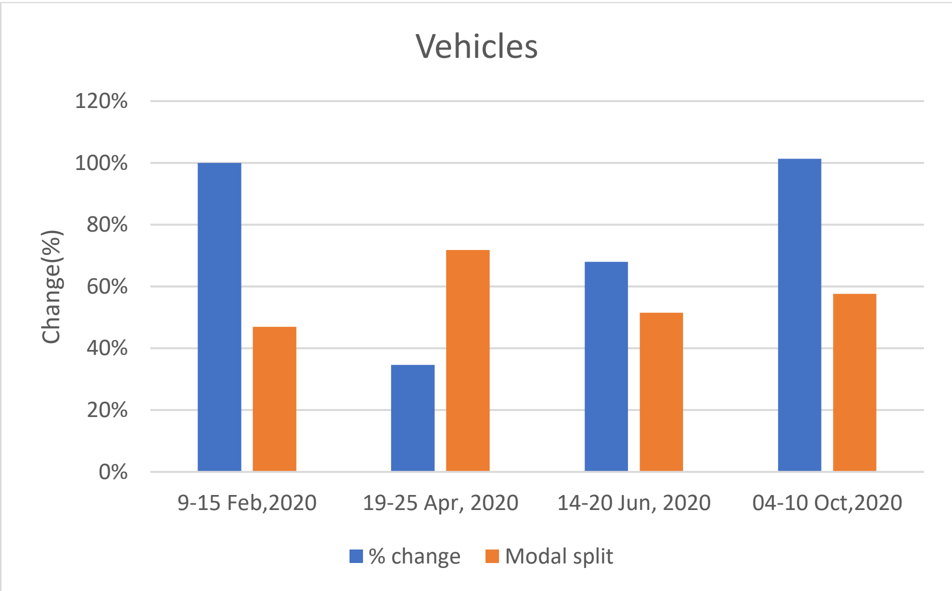

Figure 5.3 Modal split and percentage change of vehicle use during the study.

Among all modes considered for this study, private transport (vehicle use) showed the most resilience. After decreasing in Phase 2 by 65%, vehicle use steadily rose in Phase 3 by 34% and reached figures (101.4%) in Phase 4 almost identical to that recorded before the lockdown. Generally, it could be observed that vehicle averages showed indications of quickly returning back to normal after the lockdown phases. Likewise, with the modal split, vehicle use consistently remained the largest share during all the phases and was the dominant mode by far during the Phase 2 with a share of 71%. It could be clearly seen that withstanding the impacts of the COVID-19 pandemic on transport choices, vehicle use still has a significant role to play in the choice of users.

An average of the percentage changes of the modes considered for this study revealed an overall mobility reduction of 76%, 18% and 0.5% during the phases 2, 3 and 4 respectively of the study.

5.2 COMPARISONS WITH OTHER STUDY CASES

A growing number of studies targeting the impacts of COVID-19 on the travel patterns in metropolitan cities have so far been mainly based on data from mobility service providers such as Google, Apple and Moovit, for eg. (Hadjidemetriou et al., 2020; Verma et al., 2020). On the other hand, other studies have been able to evaluate other types of data provided by regional public transportation authorities. In this section, a comparison is therefore made of other case studies on the impacts of the pandemic on mobility, methods employed during and after the lockdown during COVID relative to that of Bologna.

5.2.1 Stockholm Case Study

A study was conducted to evaluate the impact of the COVID pandemic on transportation modes in the three largest regional public authorities in Sweden, namely Stockholm, Västra Götaland and Skåne (Jenelius & Cebecauer, 2020). Datasets used by the study were based on ticket validations, sales and passenger counts data. The Stockholm case study is particularly interesting because of the availability of data to be able conduct a comparison of public transport usage and other modes of transport similar to that of Bologna. Public transport system consists of four main transport modes: metro (44% of all trips), buses (39%), commuter trains (11%) and LRT/trams (6%) and calculation of daily public ridership is based on ticket validation data from the digital ticket system SL Access. This system, a tap-in only one, involves tickets which are loaded on smartphones or contactless cards being validated on the either at the entrances of the vehicles or the stations. Additionally, the evolution of bike and pedestrian flows as well as motorized road traffic in the city obtained from stationary sensors and the congestion charging system were also provided. These were evaluated as against that obtained for 2019. The following figures summarize data obtained from the study pertinent for comparisons.

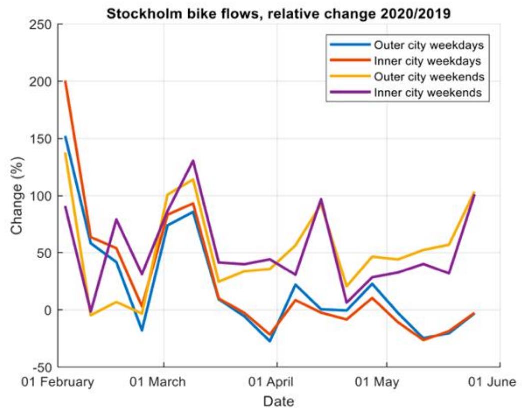

Figure 5.4 Bike flows recorded in Stockholm in 2020, relative to that recorded in 2019 (Jenelius & Cebecauer, 2020).

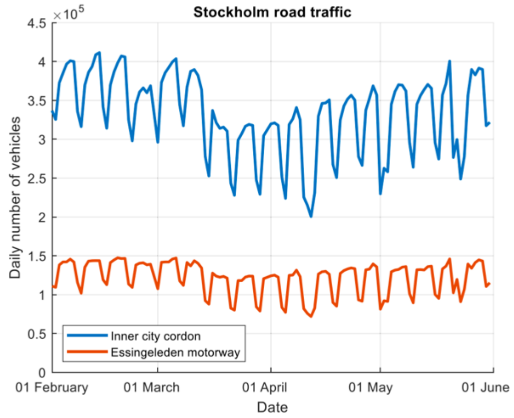

Figure 5.5 Road traffic recorded in some sections in Stockholm in 2020 (Jenelius & Cebecauer, 2020).

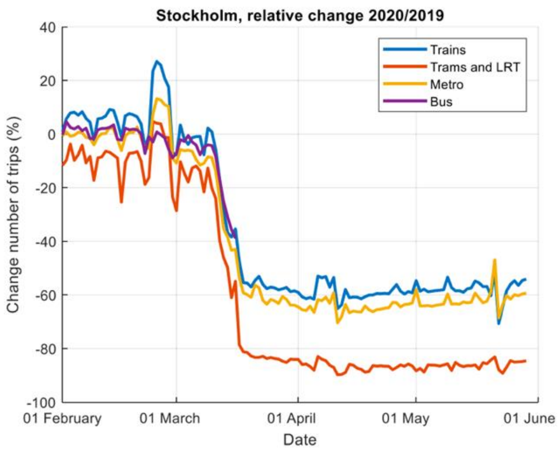

Figure 5.6 Public transport usage in Stockholm recorded in 2020 relative to averages recorded in 2019 (Jenelius & Cebecauer, 2020).

Similar to the analysis of data recorded in Bologna, Figure 5.4 shows that there was a huge decline (as much as a 200% decrease) in bike flows recorded during the Phase 2 relative to that recorded in Phase 1. Additionally, in Phase 3, bike flows in Stockholm also showed an upturn in numbers towards averages recorded in Phase 1. Also, generally, biking had increased in Stockholm relative to averages recorded in 2019 similar to the results obtained from Bologna. This trend appears to indicate a growing shift of users to active transportation. Secondly, as also observed in the case study of Bologna, road traffic flows dropped somewhat at the onset of the lockdown (Phase 2) but have since recovered to the same levels as before (Phase 1). Finally, for public transport modes, usage declined as low as 60% (in trams) as compared to almost 90% in Bologna during Phase 2 but similarly have failed to show signs yet of reaching averages in 2019 in subsequent phases.

5.2.2 Santander Case Study

In another study, the impacts of the lockdown on urban mobility in the city of Santander in Spain were analyzed (Aloi et al., 2020). Datasets used for the study were collected from traffic counters, public transport ITS, and recordings from traffic control cameras and environmental sensors which were used to make comparisons between journey flows and times before and during the lockdown. This data was used to re-estimate Origin-Destination trip matrices to obtain a preliminary analysis of how daily mobility had reduced and how the modal distribution and journey purposes have changed. This study was pertinent for our study case comparison due to the access to a modal comparison and access to public transport (bus) data. The study due to its timing however does not give data from subsequent Phases 3 and 4.

Firstly, with general motorized traffic, a strong decline was found throughout the city similar to Bologna. After lockdown was declared (Phase 2), the traffic reduced by 64%, hitting up to 78% in subsequent weeks likewise that recorded in Bologna of a reduction by about 66% in the same phase. With public transport, usage dropped by up to 93%. The dramatic fall can be seen in the Figure 5.7 below, which compares public transport trips per hour as well as per bus line before and after the lockdown restrictions. A reduction with an average of over 90% can be observed, the morning peak disappearing, and the mid-day peak being slightly maintained.

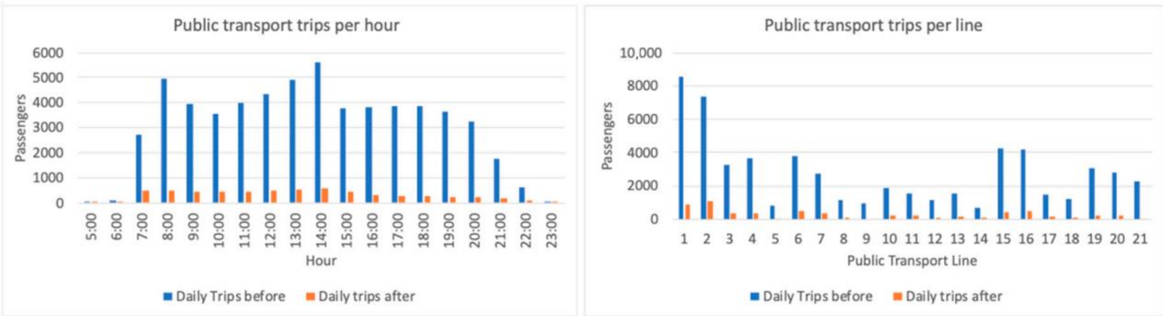

Figure 5.7 Public transport usage before and after lockdown restrictions. (Aloi et al, 2020).

With respect to modal share, urban mobility in the city of Santander is shown in Figure 5.8 below according to a 2013 mobility survey updated with traffic transit and pedestrian counts in 2018. The initial breakdown is as follows: 42% of urban mobility is done by walking, 48% by private motorized transport (driving or passenger), and 8% by bus. The remaining 2% is done by bike/scooter.

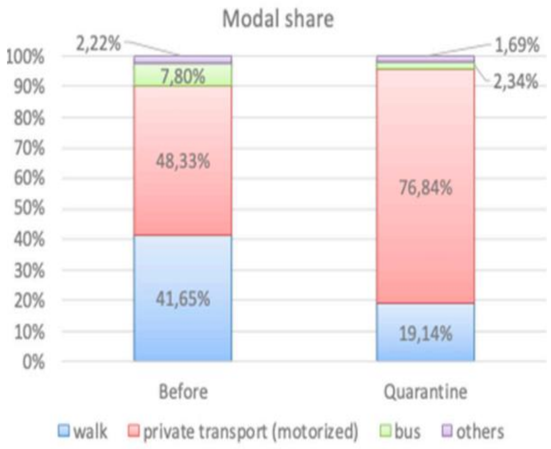

Figure 5.8 Modal share in Santander before and after the lockdown measures (Aloi et al, 2020).

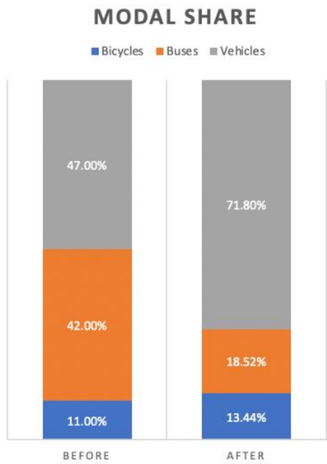

Figure 5.9 Modal share of mobility in Bologna before and after the lockdown measures.

The distribution changes significantly, as car journeys changed from 48% to 77% (it is important to clarify that the number of total car journeys is much lower during the quarantine), and public transport from 8% to 2% which was clearly inconsistent with the 23% reduction seen in Bologna. However, it is important to know the modal share of Bologna was modified with other modes of mobility such as walking ignored likely leading to a flawed basis for comparisons. For example, pedestrian journeys also showed a significant drop in their share from 42% to 19%, but the case study of Bologna provides no pedestrian data to be able to establish a baseline for comparison. From Figure 5.8, the proportion of trips using bicycles or scooters (labeled as "others") as happened with other modes of transport also decreased. However, the resulting proportional reduction was lower than the one observed for public transport or walking. This means that most people continued cycling (or using scooters) during the quarantine, which is consistent with the results observed in Bologna.

In summary, the analysis revealed an overall mobility fall of 76%, being less significant in the case of the private cars (motorized road traffic) which is consistent with a similar reduction of 77% in the case study of Bologna.

5.2.3 Other Study Cases

A study was conducted to study the impacts of the lockdown measures and COVID-19 related deaths on human mobility in the United Kingdom (Hadjidemetriou et al., 2020). The data associated with human mobility trends of walking, driving and using public transport provided by Apple mobility trends reports (Apple Maps, 2020) was compared to a baseline volume of the previous year (Fig. 5.10). The timeline of the government's measures was mapped against the human-mobility trends to study the plausible shifts in transport usage and mode choice.

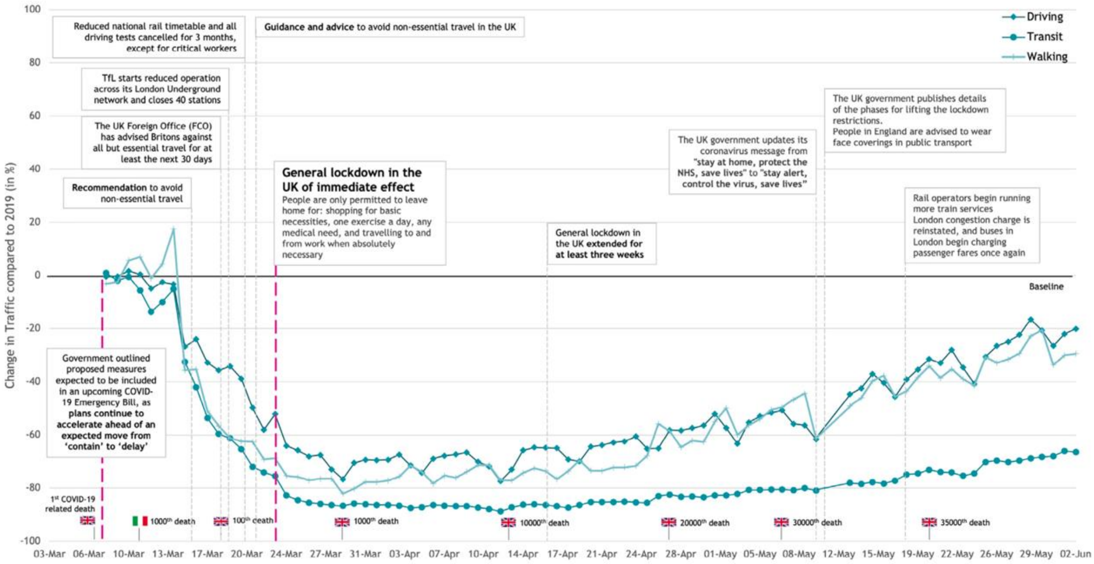

Figure 5.10 Change in Traffic of transportation modes in the UK, relative 2019/2020.

Results indicated that human mobility was found to be reduced drastically during lockdown measures (Phase 2) and until the end of May 2020 (Phase 3) did not show any major fluctuations, with driving, transit and walking remaining 60%, 80% and 60% reduced compared to the same period of the previous year (i.e. 2019). From the graph, as also with the study case of Bologna, it could be observed that driving (private car use) and walking (active transportation) were the only modes that showed signs of upturn in trend of usage.

Alternatively, in a study of Sicily (Campisi et al., 2020), a city in Southern Italy, the influence of COVID-19 on changes in the use of sustainable travel modes with a comparative analysis between before and during the pandemic was also explored. The methodology involved using an online survey on a representative population of 431 individuals which was carried out during the period from March to May 2020 in the case study area. The survey included variables, namely gender, age, city of residence, private car ownership, walking and cycling frequency before and during the pandemic, public transport use frequency for leisure activities before and during the pandemic, need for remote working, and the stress and anxiety perception of using public transport during the pandemic. The analysis begun with descriptive statistics and was followed by a correlation analysis in order to explore the characteristics of the dataset and relationship between variables. Results showed that respondents who were skeptical about safety issues with public transportation were likely to increase their use of either walking or cycling as a mode of mobility. The impacts of the restrictions on city bus network in Corona in Spain were also analysed (Orro et al., 2020). Using data from automatic vehicle location, bus stop boarding, and smart card use, this study investigated the changes in transit ridership by line, the use of stops, the main origin–destination flows, changes in transit supply, operation time, and reliability of the city bus network. Results revealed the impact on transit ridership during the lockdown process was more significant than that on general traffic. Additionally, after restrictions were lifted, the general traffic and the shared bike system recovered a higher percentage of their previous use than the bus system. There is no basis for a direct comparison with the study case of Bologna, however these studies support a common trend in other study cases of an increasing shift towards active transportation as a favored mode of mobility.

Data of general mobility trends in Italy as reported by Teralytics (Teralytics, 2020), revealed a general decrease of 30.3% in mobility in 2020 as well as a 65.7% and 31.9% in intercity and intracity mobility respectively. Total mobility trends are illustrated in the figure below.

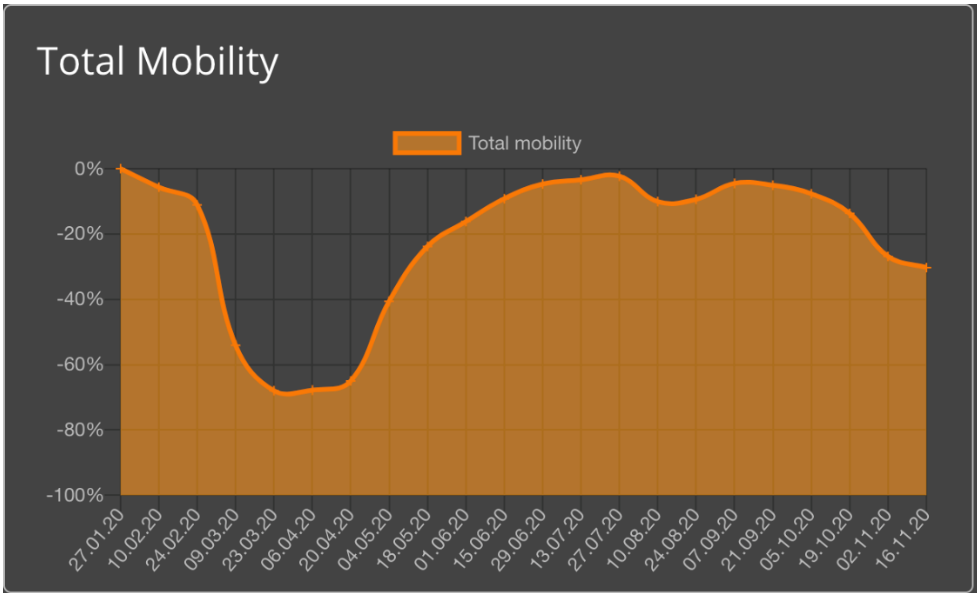

Figure 5.11 Mobility trends in Italy (Teralytics, 2020).

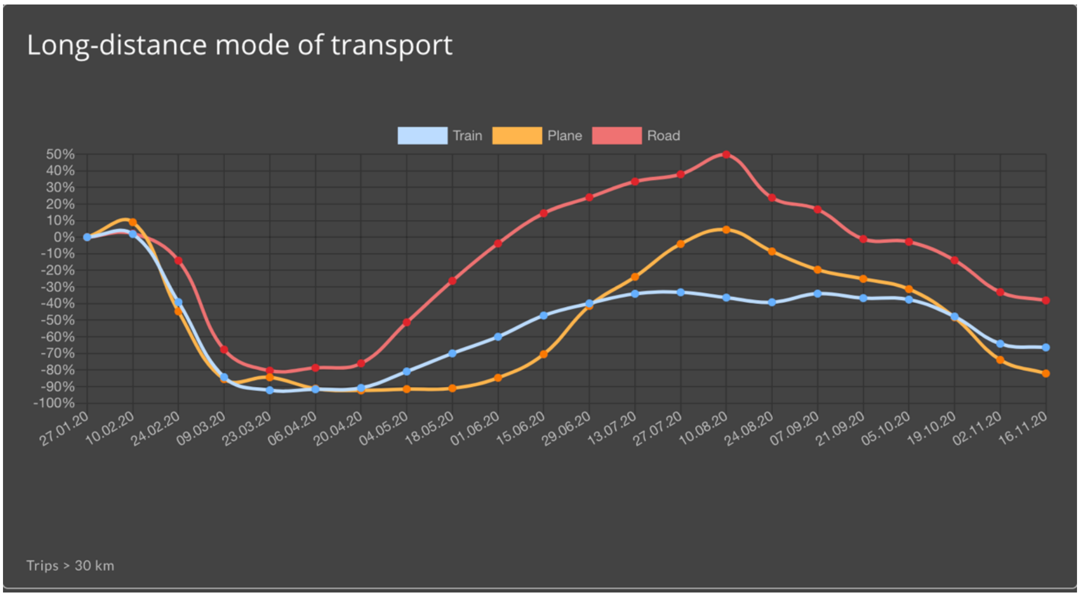

Figure 5.12 Usage of long-distance transport modes (Teralytics, 2020).

It is observed from the data that vehicle traffic by road showed the fastest and highest recovery as compared to the other modes of transport, with train use showing the least signs of recovery. Similarly, with other studies, data indicates that all modes experienced the largest decline during the Phase 2 (lockdown stage) and signs of recovery in subsequent phases.

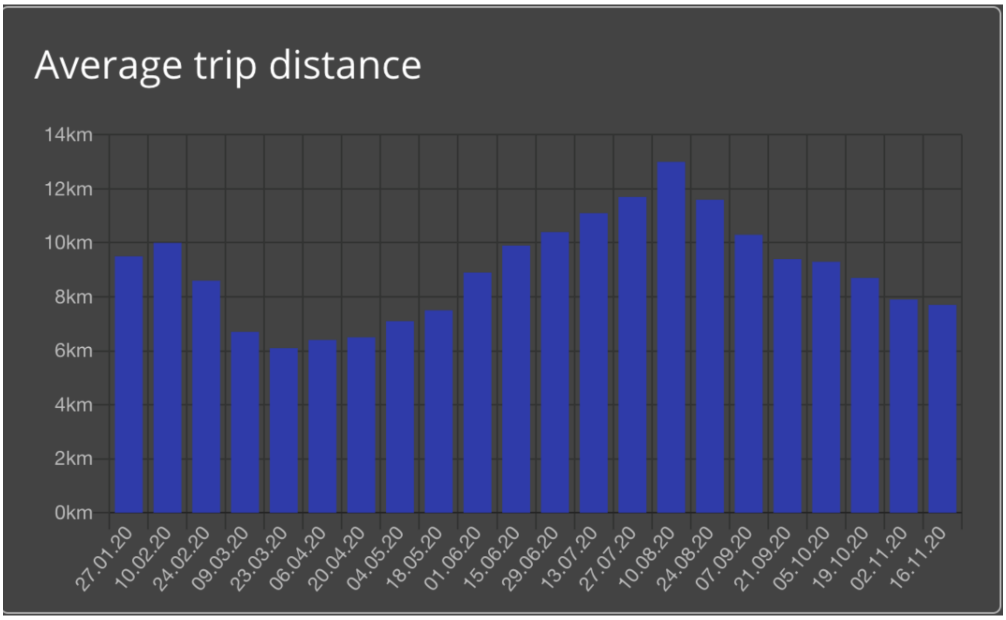

Figure 5.13 Average trip distance (Teralytics, 2020).

Finally, average trip distance was the highest during the month of August (Phase 3), with its lowest being recorded in March (Phase 2).

5.3 URBAN MOBILITY PLANS AND COVID

A review of measures and plans implemented during the lockdown stage of the COVID pandemic reveals similar strategies employed by authorities that were meant to deal with urban mobility during the emergency situation. Most of these measures were parts of bigger plans for sustainable mobility which were accelerated by the pandemic. This section would therefore review the Sustainability Urban Mobility Plan of Bologna, and discuss measures employed in emergency mobility plans rolled out by Bologna with a look at that of other study cases. It would also examine the relationship between the policy making context and the infrastructural changes required to achieve a vision of resilient mobility going forward. The timeline for evaluation would be based on the timeline of this study.

5.3.1 Phase 1 (PRE COVID)

The Sustainability Urban Mobility Plan (SUMP) of Bologna was conceptualized in 2015 to work out a collection of goals for sustainable mobility to be achieved by 2030. It consists of a vision of urban mobility for the city of Bologna as well as the Metropolitan area of Bologna which is centered on the improvement of public transport services and their integration with wide and safe networks, fit to pedestrian and cycling mobility. This would require reduction of motorized traffic and the goals for the different modes of mobility are shown in the Figure 5.14 below.

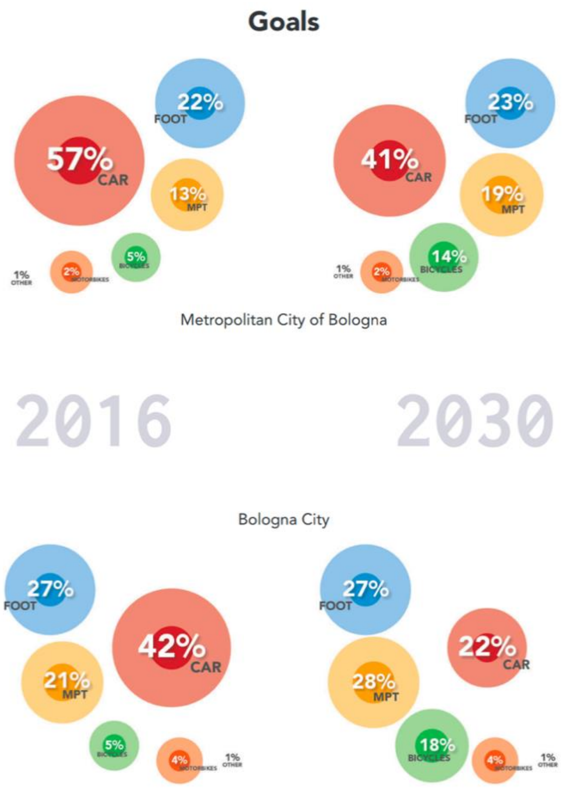

Figure 5.14 Targets outlined to be achieved according to the SUMP (https://pumsbologna.it/Obiettivi).

The SUMP is an aggregated collection of plans namely the General Urban Traffic Plan (PGTU), as well as its sectorial plans: The Sustainable Urban Logistics Plan (SULP) and the Metropolitan Bike Plan (MBP) which are geared towards achieving the goals in Bologna as shown above. An important objective SUMP aims to achieve is to reduce greenhouse gas emissions from motorized traffic by 40% by 2030. The details of the plan are summarized as follows:

1. With respect to walking, networks of sidewalks and pedestrian areas are to be increased, becoming more linear and obstacle free. The goal is to increase the distance travelled on foot by 50,000 km and pedestrian space by 20% throughout Bologna. More environmental Limited Traffic Zones (LTZ) and privileged Pedestrian Traffic Zones (PTZ) are expected to be established, with a goal to gradually introduce a maximum speed limit of 30km/h for urban residential areas.
2. Cycling is expected to become one of the main modes of transport in the metropolitan area by increasing an existing 246 km of cycling lanes by an additional 648km by 2030. An emphasis would be placed on connecting the main urban areas in the city of Bologna by these cycling lanes, hence encouraging a shift towards cycling for activity generated trips.

3. Finally, with public transportation, the goal is to improve the synchronization of the schedules of the different PT modes available therefore offering citizens more options of mobility. For example, the use of rail system is expected to boosted by the introduction of more frequent runs at the main stations as well as an introduction of tramlines interconnected with each other as well as with the railway system. Some targets are increasing distance travelled by tram, bus and trains by 2 million km and increase the number of journeys made by public transportation by 46%.

Similarly, in Italy, metropolitan cities like Milan and Florence, notable for their low private car ownership rates, high coverage of cycling lanes, capable public transport systems, pedestrian and restricted areas have also had innovative and effective mobility plans developed by their local governments (Barbarossa, 2020). These plans are quite similar to that of Bologna, with emphasis placed on providing infrastructure to encourage a shift towards active transportation as well as the use of public transportation by citizens.

5.3.2 Phases 3 & 4 (Post Lockdown Measures)

It can be deduced that cities already involved in planning processes, concerning sustainable mobility and that have already embraced strategies in favor of active mobility, such as cycling and walking, were able to improvise to cope with the impacts of pandemic on mobility. Effective programs had to developed in the medium term and implemented during phases 3 (immediate post lockdown) and 4 (post lockdown) all over the world. Bologna, for example, had its plan "Mobilità e spazio condiviso nell'emergenza" rolled out on June 8, 2020. These policies were aimed at restoration of the use of other forms of mobility and in particular the management of public transportation; the creation of an emergency network to stimulate the use of active transportation and non-congestive means of transportation.

Common measures implemented are summarized below:

Demand Management

Regarding demand management, there had not been any substantial challenges during phase 2 due to the fact that in many countries, passengers were limited to essential workers or specific categories due to restrictive measures, while all the others were asked to stay home and telework, where possible (Hu, 2020).However, in the subsequent phases, with reopening of work spaces and schools, numbers of passengers gradually increased.

Public transport Management

The overcrowding of public transport (PT) stations and vehicles possesses a high-level risk of contagion (Meyer, M. D., & Elrahman, 2019; Musselwhite et al., 2020; Nasir, Campos, Christie, & Colbeck, 2016) therefore governments and local authorities have implemented restriction measures to limit their use. This was achieved by considering two priorities:

1. The first priority was to guarantee safety and protection of staff and infrastructures. Implemented initiatives were therefore geared towards avoiding contacts between personnel and passengers, for example, by forbidding ticket sales by drivers and incentivizing e-ticketing, as well as closing front door access, thereby ensuring that people boarded at other entries. These measures were implemented globally (UITP, 2020). In Bologna, for example, drivers and personnel of public transportation services have been provided with specific training and personal protective equipment (face mask, gloves etc.).

Figure 5.15 Measures employed in Bologna according to the Emergency Plan.

2. The safety and health of passengers is another priority. Measures have also been taken with the core concern being physical distancing, requiring several transport authorities to limit the capacity of the vehicles in order to guarantee safe distances between people. For example, during Phase 3 of this study, Milan and Barcelona initially reduced occupancy of public transportation vehicles to a maximum of 25% and 50%, respectively, Ireland to 20%, Portugal to 2/3, etc.), with passengers obliged to wear personal protective equipment (Lozzi et al., 2020).

Traffic Regulation

In general, measures regulating motorized vehicle transportation in Bologna remained the same after lockdown measures were lifted. However, during Phase 2, payment for parking in the city of Bologna was temporarily suspended but resumed in Phases 3 and 4 of this study. The actions implemented since the end of April 2020 have been consistent with the original SUMP plan which seeks to promote active mobility by widening spaces for pedestrian traffic in order to guarantee social distancing and Limited Traffic Zone (LTZ) management and parking policies. In moves to encourage a shift to active travel in inter municipal trip demands, metropolitan cities globally have permanently converted carriageways meant for motor traffic to pedestrian and cyclist friendly infrastructure. For example, Seattle permanently closed 30 kilometres of streets to most vehicles, providing more space for people to walk and bike after the lockdown phase (Seattle Times, 2020). Additionally, Milan announced that 35 kilometres of streets previously used by cars would be transitioned to walking and cycling lanes after the lockdown was lifted. Brussels and Paris are also turning 40 and 50 kilometres of car lanes respectively into cycle paths (C4OKnowledgehub, 2020).

Pedestrian and Cycling infrastructure

Compared to other modes, cycling has been shown to possess the highest degree of both safety and affordability during a pandemic (Litman, 2020). This is shown in the Figure 5.16 below.

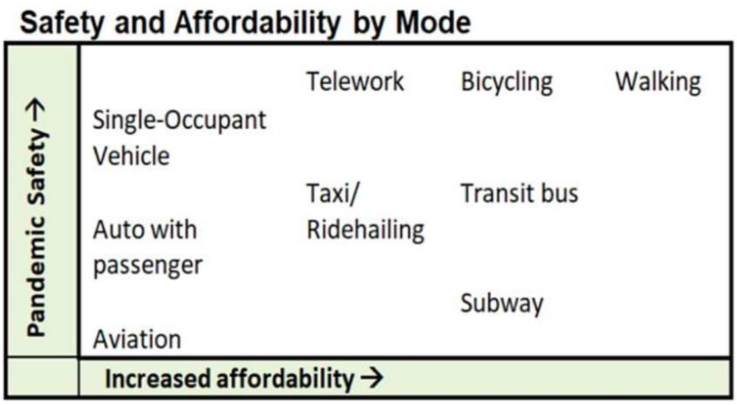

Figure 5.16 Safety and Affordability of Different Modes (Litman, 2020).

In line with the MBP under the SUMP, around 13 km of cycling lane was expected to be added in the year 2020. These interventions were already in various stages of realization, however with the emergence of the COVID pandemic, these plans were accelerated with around 10-15 km expected to be provided as emergency cycling lanes. The Figure 5.17 below shows the cycling plan of metropolitan city of Bologna with interventions planned for 2020.

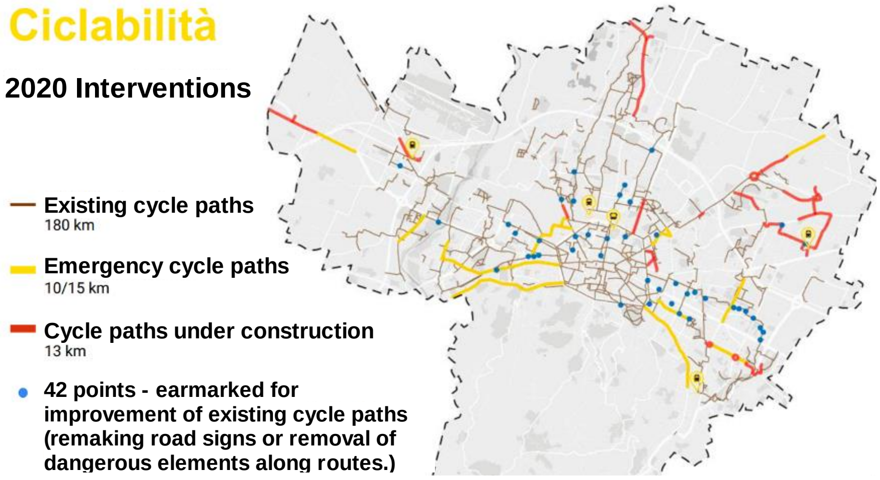

Figure 5.17 Metropolitan of Bologna cycling plan in 2020. (Mobilità e spazio condiviso nell'emergenza, 2020).

The goals of creation of new sections, as well as improvement of existing lanes were to be achieved by:

1. Creating new sections along road carriageways if possible
2. Transforming bidirectional cycling paths along sidewalks of carriageways into one direction types and adding opposite directions on the other lane where possible
3. Opening areas of preference for bicycles where possible
4. Creation of zones of 30km/h maximum speed for motorized traffic
5. Creation of bidirectional cycling paths where non exist.

An example of how these measures are envisaged to be achieved are shown in the Figure 5.18 below.

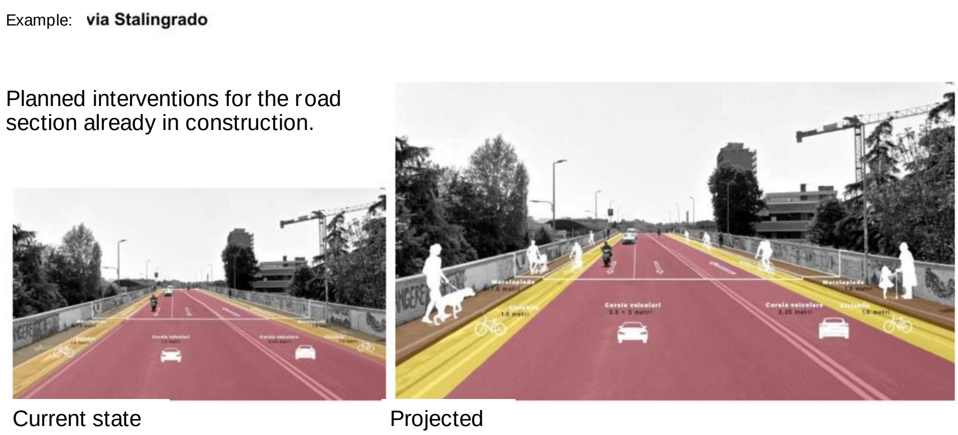

Figure 5.18 Expected transformation for the existing route in Via Stalingrado in 2020 (Mobilità e spazio condiviso nell'emergenza, 2020).

Italian cities such as Milan, Padova, Genoa and Florence have launched mobility plans with similar measures being implemented (Barbarossa, 2020). In Finland, the City of Helsinki, the

Helsinki City Transportation (HKL), decided to expedite the opening of the bike city season in an effort to mitigate the COVID-19 spread. A total of 351 stations and 3500 bikes were made available at the citizens' disposal (City of Helsinki, 2020). The London Streetspace Plan (TFL, 2020), launched by the Office of the Mayor of London entailed various measures involves a transformation of public roads aimed in order to create new walking and cycling routes along major corridors, including temporary cycle lanes. Like other mobility plans, it is expected that cycling and pedestrian spaces would be largely increased to encourage walking and cycling as people return to work. Similarly, Paris under it's "Plan Vélo" or Cycling Plan (Paris, 2020), is undergoing infrastructural changes aimed towards promoting accessibility by walking or cycling distance. Launched in 2019, it has already produced an increase of more than 50% in the use of bicycles. Some of the interventions under this plan include provision of more parking spaces, creation of express cycling lanes and cycle paths along existing metro lines. During the lockdown phase, establishment of pop-up cycle lanes were sped up to be ready by the end of lockdown.

Micromobility/Shared Riding and Other Initiatives

According to the Italian national data (Il Tempo, 2020), there has been an increase in using not only private cars but also micro mobility modes after the lockdown period. Bologna in accordance with plans enacted by the Emilia-Romagna region would support bike sharing whiles providing financial initiatives for acquiring e-bikes and folding bicycles, with discount vouchers of 300 euros and 600 euros for citizens purchasing electric bicycles and electric cargo bicycles respectively. Varying versions of such programs were also launched in different provinces of Italy (Barbarossa, 2020). The University of Bologna also launched an initiative which distributed 600 bicycles to students who applied for this program. The municipality also made available incentives in agreement with companies aimed at promoting the use of car-sharing and other micro mobility modes.

5.4. FUTURE OF URBAN MOBILITY (POST-COVID)

Whiles governments all over the world are dealing with the public health emergency crisis and consequent economic impacts of the COVID pandemic, it has been imperative to envisage what the 'new normal' would look like and how, when, and under what conditions existing restrictions and social distancing measures could be relaxed. Given the critical role transportation and mobility plays, it should be a key consideration in plans for a post-COVID world.

Prior to the pandemic, transportation policy making faced some challenges such as the negative externality effects of transport noise, emissions, congestion and accidents(Goetz, 2019).This was to be achieved by using combinations including policy instruments, pricing mechanisms, technological interventions mainly focusing on ‘top-down’ Transport Demand Management, Smart Mobility, Intelligent Transport and Mobility Management approaches to transport policy (Faure & Partain, 2018). There was also growing effort by metropolitan cities all over the world to shift towards more sustainable modes of transportation(Gallo & Marinelli, 2020). Policies made were therefore likely aimed at mitigating (as far as possible given budgetary constraints and political considerations) these challenges whiles attempting to modify individual and corporate travel behaviour and simultaneously making mobility more environmentally sustainable. However, with the advent of the pandemic with its long-lasting effects, these approaches alone might be inadequate in a post-COVID world. Therefore, it becomes necessary whiles modifying existing policies to also formulate appropriate set of policies and interventions which should emphasize on safety, efficiency and economic viability post COVID-19 (in the short term and long term) (Gallo & Marinelli, 2020). Another important objective to be considered is resilience of these transportation systems. In the face of increasing climate change, other pandemics, or extreme weather risks, the ability of these systems to mitigate the risk of disruption while being able to deliver its objective in the face of these disruptive events is paramount (Kurth et al., 2020).

This section would seek to discuss some comprehensive set of policies and interventions designed for a post COVID-19 world. They would also collectively aim to improve resiliency of transportation systems and would be summarised under the following interventions;

(i) Addressing travel demand behaviour and management;
(ii) Encouraging active travel shift;
(iii) Promotion of public transportation use;
(iv) Management of motorized traffic;
(v) Efficient, technological advancement and safe use of transportation infrastructure.

Travel Demand Behaviour and Management

A resilient approach to transport should be based on the use of new ways of managing travel demand as well as user preferences with respect to choices for mobility. In a post COVID world, it would be important to use this opportunity to promote various alternatives for mobility with respect to the nature of a desired trip. The need right now should consequently be to reorient citizens' mobility choices according to a criterion of social desirability. An example would be to promote the use of certain options for transportation according to the desired trip length as shown in the table below (Campisi et al., 2020):

Table 5.116 The correlation between distance and possible transportation choices (Campisi et al., 2020)

Distance	Transportation Modes
<3 km	pedestrian mobility—walking
3–10 km	micromobility (e-bike, hoverboard, mono-wheel)
>10 km	car + bike + micromobilitytrain + bike + micromobility
	motorcycle

With initiatives reported globally of improving infrastructure for cycle lanes, consumer behaviour has shown increasing positivity towards using micro mobility modes for trips such as grocery shopping and other domestic errands (Mckinsey, 2020). Additionally, staggering work shifts/schedules could be another way to decongest urban roads. A possible solution could be staggered cyclic shift strategy (i.e.) dividing a population into two groups of households and allowing them to travel to work on alternating weeks as a resilient approach with the occurrence of pandemics (Zong, Juan, & Jia, 2013). Other measures including promotional support, of new apps for mobility management (in the Mobility as a Service model) in the case of local public transport (such as buses, streetcars, metro, railways) and cab services, would give users access to options for a uniform transition between medium and long-distance travel between different districts or from municipalities in the metropolitan area and the rest of the region (Merkert, Bushell, & Beck, 2020). Shared mobility services such as Uber and Lyft would have a huge role to reducing the demand on public and private transportation.

The Role of Active Travel Shift

A review of literature on solutions implemented during and after lockdown measures indicate active travel as a successful choice in a vision of mobility post COVID (Campisi et al., 2020; de Haas, Faber, & Hamersma, 2020; Jenelius & Cebecauer, 2020). Active transportation has been proven to have high correlation with reduced risk of chronic conditions, premature death, and depressive symptoms while sedentary lifestyles are associated with non-communicable diseases, depression and cancer(Lee et al., 2012; Robertson, Robertson, Jepson, & Maxwell, 2012). To encourage the shift towards active travel would require gradually removing motor traffic from residential streets and extending pavements near shops, schools and parks to make walking safe and enjoyable for transit and exercise so that people can have a safer alternative to private cars and public transport. Closing roads and squares to motorized traffic when and where necessary to promote the use of active transport could be another effective measure. Bologna, for example, does not allow the access to parts of the city center by motorized traffic during weekends (CIVITAS, 2020). Additionally, innovations are needed to make cycling a mode for all purpose, age groups, and gender and longer distances, weather resistant, and safe (Budd & Ison, 2020). Consequently, these measures would improve the resilient nature of the transportation infrastructure when street space reallocation to “open streets” (streets where non-motorized modes share road space with low-speed motor vehicle traffic) since physical distancing requires wider sidewalks and paths than what exists in most urban areas(Litman, 2020; NACTO, 2020).

Promotion of Public transportation

A good public transportation (PT) system should have some combination of either Metro, Light Rapid Transit (LRT) or Bus Rapid Transit (BRT) modes. Agencies can identify the corridors for introducing new or more Bus-Priority Lanes (BPL) in situations where they exist already. Major road corridors such as ring-roads, radial roads and other arterial roads where it is feasible to introduce BPL can be identified and these roads can be properly marked (road marking) as per guidelines to ensure proper usage of BPL. The accompanying prioritization of these lanes should be enforced (Gitelman, Korchatov, & Elias, 2020; Vikovych & Zubachyk, 2015). This measure might help in reducing the travel time and encourage people to use PT. Demand management is an important aspect of PT services especially considering a resilient approach to reduce risk of spread of disease during pandemics (Müller et al., 2020). To avoid overcrowding at bus terminals, measures such as increasing the frequency of the buses could be implemented. Information on bus schedules, timetables and intervals using existing GPS on buses should be made readily available to passengers via existing apps. The emphasis would be to reduce waiting times at bus stops and terminals. Digitalization of PT systems would be crucial to improving efficiency and easy movement of people (Pettersson, 2019). Lastly, providing non-motorized transport (NMT) facilities like footpaths, cycle paths etc., around the bus stops will also encourage commuters to use public transport. Adopting policies including provision for bicycle rental facilities would smoothen mode transfer, accessibility and efficiency of PT systems(Yang et al., 2018).

Management of motorized traffic

The use of private cars, limited to authorized travel only, will have to follow progressively stricter rules depending on the areas of metropolitan cities. Through the creation of Limited Traffic Zones (LTZs), zones 30, and the reduction of carriage widths for cars where and where necessary, identifying new pedestrian areas in the central areas of the neighborhoods, would be easier to achieve (Faure & Partain, 2018). Whiles provisions are made for pedestrian and cycling infrastructure which will be invaluable as it reduces the usage of motorized vehicles, parking management is another important factor. Parking policies in metropolitan cities should be geared towards prioritizing parking management instead of the alternative of providing off-street parking spaces in order to reduce congestion. Parking management should involve stronger enforcement of on-street parking regulations as well as pricing variants imposed to discourage the use and dependance on car use in city centers (Piccioni, Valtorta, & Musso, 2017). Bologna has been quite successful with the implementation of such policies (CIVITAS, 2020). Consequently, the integration of non-motorized transit (NMT) facilities with public transport and other micro mobility modes such as slow speed electric scooters etc., would further lead to decrease in motorized mode share.

Efficient, technological advancement and safe use of transportation infrastructure

It is important that efficiency and safety remain priorities whiles building resilience of transportation infrastructure. The use of technologies such as applications (APPs) for the purchase of tickets can improve the infrastructures for safety by reducing the possibilities of hotspots for contact. This minimizes the risk of contagion and increase efficiency of the validating tickets purchased by passengers. Transportation agencies all around the world could implement Smart card or QR-based ticketing with TAP AND PAY options (if not existing) or expand coverage of these systems (if already existing). For example, Mi Muovo, a transport card which is based on a zone tariff system currently used by TPER, the transport authority in charge of the Emilia-Romagna region has been quite efficient since its introduction in Bologna. These smart cards with tap and pay options avoid queues in ticketing counters or physical contact due to exchange of cash. There are ticketing machines which are fixed at the entrances of the buses so that passengers who board are able to tap the card on the ticketing machine before taking available seats. Additionally, public transport operators and vehicle manufacturers should consider reconfiguring the internal layout of seats and circulation spaces on buses and trains, and installing contactless door sensors (Paton, 2020). Such strategies will be helpful to ensure contactless and seamless travel in public transport.

5.5 LIMITATIONS OF THE STUDY

The major constraint encountered in this study was the access to more reliable and accurate data for the bus and cyclist modes of transportation in Bologna for a comprehensive comparison and validation of observations made in this study. Additional data for cyclist modes in Bologna was envisaged to be provided by the Metropolitan Authority but could not be approved for open access before the completion of this study. Access to passenger counts conducted by the transport authority in charge of buses (TPER) would have been more accurate in representing the trend in commuter numbers during the timeline of the study. There was also a lack of recent data for the mode share in mobility in Bologna (available data was from 2007). There is likely to have been some changes to the mode share in Bologna during the 13 years that followed and should influence the accuracy of the observations made from this study.

Alternatively, an online survey to explore the changes in mobility choices based on a pre-post COVID-19 lockdown comparison could also have been conducted to validate results obtained by this study (Barbieri et al., 2020; Campisi et al., 2020). Finally, a set of policies and interventions were proposed for the future of transportation specific to a post COVID world but there seems to be a dearth in research material in this context despite the growing emergence of literature on the impacts of COVID on mobility all over the world. Future research should as well focus on improving the urban infrastructure, disease resiliency of transportation system and improve health safety of passengers (Aloi et al., 2020; Chinazzi et al., 2020; Nasir et al., 2016; Oum & Wang, 2020).

CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS

The emergence of the COVID-19 pandemic has generally impacted all aspects of life as various studies have shown (Abodunrin et al., 2020; Igwe, 2020; UITP, 2020). Similarly, the impacts on various modes of transportation both on a global and domestic levels have also been well documented (Aloi et al., 2020; Bucsky, 2020; Campisi et al., 2020).

The main purpose of this study was to demonstrate empirical evidence of the impacts of the COVID pandemic on different modes of transportation in Bologna by making comparisons with datasets obtained from the timeframes of the study. Databases considered for this study in Bologna were obtained from vehicle counts, bus passenger counts and bicycle counts as well as the online platform Moovit, observed before, during and after the pandemic. The timeframe of the study was split into 4 different phases with respect to the varying restrictions which were imposed by Italian authorities as a result of the pandemic. Results obtained from the study were analyzed and also compared with other similar case studies to identify trends and differences and attempt to interpret them.

Concluding remarks based on the results of the study could be summarized as follows below:

1. Generally, all modes of transport considered in this study, had their usage decrease in Phase 2 from numbers recorded in Phase 1 with a subsequent upturn in Phases 3 and 4. An average of the percentage changes of the modes revealed an overall mobility reduction of 76%, 18% and 0.5% during the phases 2, 3 and 4 respectively of the study.

2. Results indicate that the weekly counts of bicycles in Bologna generally increased with respect to the same period the year before in 2019. On a modal split basis, cycling showed increase in usage over the first three phases; 11%, 13%, 25% and finally 20% in Phase 4. Additionally, considering percentage change of usage, cycling was the only mode to surpass its initial levels from Phase 1 in Phase 3, showing 31% and 40% increases in usage in Phases 3 and 4.

3. Public transportation (buses) was the most impacted during Phase 2 among the modes considered for this study, experiencing about 90% decrease in usage. This was mainly attributed to the reduction of public transportation services as a result of lockdown restrictions enforced by the authorities in Italy. Collectively, the results indicate that there was a reduction in passengers boarding at selected stops in 2020 with respect to the same in 2019 whiles comparatively with other modes, bus use showed the slowest recovery in subsequent phases after Phase 2.

4. Private transport (vehicle use) showed the most resilience reaching figures (101.4%) in Phase 4 almost identical to that recorded before the lockdown. Its usage consistently remained the largest modal share during all the phases and was the dominant mode by far during the Phase 2 with a share of 71%. It could be clearly seen that withstanding the impacts of the COVID-19 pandemic on transport choices, vehicle use still has a significant role to play in the choice of users.

5. Comparison with similar studies (Aloi et al., 2020; Bucsky, 2020; Jenelius & Cebecauer, 2020) showed similar observations such as the increase in cycling with respect to usage recorded in the same period last year, as well as the overall decrease in mobility during subsequent phases. For example, public transportation experienced a decrease of 93% in Santander, Spain with a similar decrease of 90% from the case study of Bologna. Other studies possessed no basis for comparison with the study case of Bologna, however these results support a common trend in other study cases of an increasing shift towards active transportation as a favored mode of mobility.

6. Results from this study suggested that post the lockdown phase, users were more dependent on private vehicles (i.e., cars) and cycling, with public transportation(buses) showing slow signs of recovery. This could support the premise of a growing shift of users to active transportation(cycling). In light of these results, a prediction for active transport (cycling shifts) should be investigated more in detail for purposes for providing recommendations to decision-makers and local transport authorities especially with respect to provision of cycling infrastructure and expanding the existing cycling lanes length in Bologna.

7. The post lockdown recovery plan "Mobilità e spazio condiviso nell'emergenza" by Bologna shows consistency with the original Sustainability Urban Mobility Plan (SUMP) of Bologna. The measures under this policy were aimed at restoration of the use of other forms of mobility and in particular the management of public transportation; the creation of an emergency network to stimulate the use of active transportation and non-congestive means of transportation. Similar measures were implemented in other metropolitan authorities (Campisi et al., 2020).

8. With the lingering effects of the pandemic set to become a norm in the short to medium term, it is imperative to implement policies that make resilience and sustainability of transportation systems and infrastructure a priority. Measures such as encouraging active travel shift, promotion of public transportation use and management of motorized traffic are seen in the SUMP of Bologna as well as the sustainable mobility plans employed by other metropolitan cities (Barbarossa, 2020).

It is also important to note that arguments made from this study cannot be only substantiated by the methodology used in this study but further qualitative analysis determining road users' travel patterns, feelings, and perceptions done by conducting surveys on people in Bologna could validate such premises. The lack of recent data for the mode share in mobility in Bologna (available data was from 2007) was also a limitation for the accuracy of the results from this study. Also, access to more reliable and accurate data for the bus and cyclist modes of transportation in Bologna for a comprehensive comparison and validation of observations, if available, would have provided more conclusive results made in this study. Finally, this study concludes that future research should as well focus on improving the urban infrastructure, disease resiliency of transportation system and improve health safety of passengers in other metropolitan cities.

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ANNEX

ANNEX 1 – BUS COUNTS AND FIGURES.

DATE	TH	M	TH	TH	TH
Bus Stops	28/02/2019	11/03/2019	18/06/2020	09/07/2020	08/10/2020
SCALA	52	36	22	17	28
BORGA PANIGALE STAZIONE	56	38	22	17	17
CINTA DAZIARA TEATRI DI VITA	56	40	24	20	24
PONTELUNGO	67	52	24	21	22
BERNARDI	69	57	29	27	24
SANTA VOILA	71	63	29	26	24
BERRETTA ROSSA	70	66	32	29	30
PRATI DI CAPARA	70	70	34	31	32
OSPEDALE MAGGIORE	71	68	33	31	30
TIMAVO	71	72	33	29	33
SAFFI	70	72	34	30	32
SAN PIO V	68	69	33	29	33
PORTA SAN FELICE	70	71	32	30	37
SAN FELICE	71	69	32	30	38
UGO BASSI	40	59	30	28	34
RIZZOLI	39	53	25	20	30
PIAZZA MINGHETTI	34	47	21	15	18
GARGANELLI	34	42	18	12	17
BARACCANO	35	32	17	13	14
PORTA SANTO STEFANO	28	27	15	12	16
MURRI	28	28	14	12	16
STERLINO	23	17	12	11	13
RAGNO	22	15	13	12	12
VARTHEMA	24	13	11	10	10
CHIESA NUOVA	21	12	11	10	10
PARISIO	20	11	11	10	12
VILLA MAZZACORATI	18	5	11	11	11
CROCE DI CAMALDOLI	14	2	10	10	13
DIRETTISSIMA	13	1	10	11	12
ANGELO CUSTODE	12	1	8	9	13
SAN RUFFILO	10	1	5	6	13
PONTE SAVENA	10	1	2	3	5

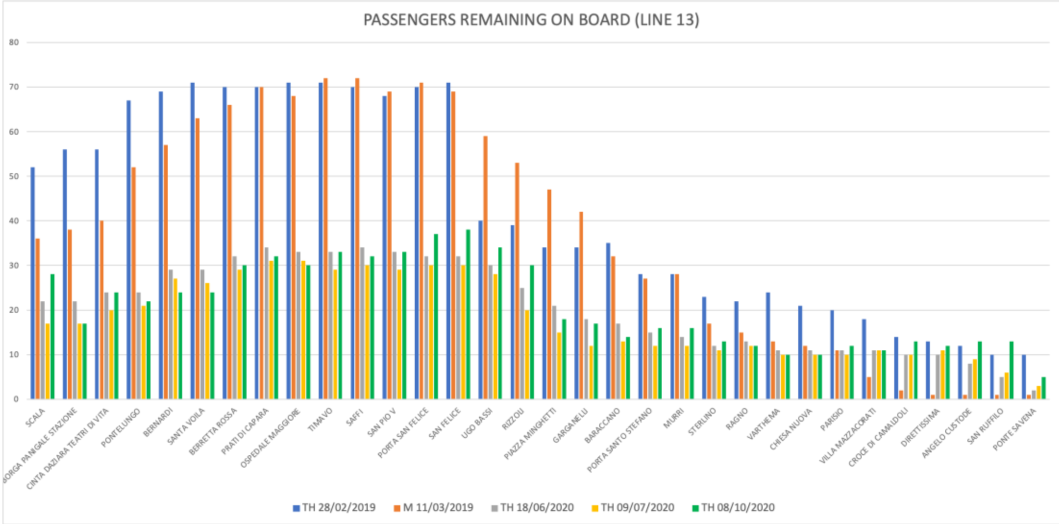
TIME-			7:59 am	8:06 am	7:59 am
LINE 20	Wed	Mon	Tues	Tues	Tues
BUS STOPS	27/02/2019	04/03/2019	16/06/2020	07/07/2020	06/10/2020
PILASTRO	10	8	9	7	12
NEGRI	11	10	9	7	14
SALGARI	11	10	9	6	16
CADRAINO BIVIO	14	12	11	8	16
SAN DONNINO	18	19	14	11	18
SIRENELLA	19	20	16	10	17
SAN DONATO	24	20	18	14	19
CENTRO ZANARDI	26	21	16	12	20
MERCATO SAN DONATO	31	24	14	10	21
SANT'EGIDIO	27	21	22	16	22
PORTA SAN DONATO	26	22	22	16	22
IRNERIO	24	18	21	14	21
SFERISTERIO	22	20	21	14	21
VII AGOSTO	21	21	26	19	20
SAN PIETRO	14	17	23	18	24
RIZZOLI	11	14	18	14	23
PIAZZA MINGHETTI	10	18	13	11	17
FARINI	9	24	11	11	14
COLLEGIO DI SPAGNA	9	25	12	11	14
NOSADELLA	9	22	14	15	13
PORTA SARAGOZZA-FRASSINAG(	9	21	16	17	12
PORTA SARAGOZZA-RISORGEMEI	13	8	17	18	12
SAN GUISEPPE	13	8	17	17	9
ORSONI	14	7	15	17	8
VILLA BENNI	14	7	15	17	8
VILLA SPADA	14	7	14	16	8
MELONCELLO	4	4	14	16	7
BIVIO SAN LUCA	4	4	14	15	8
DELLA SPORT	4	4	14	15	8
FUNIVIA	8	4	11	13	8
DON STURZO	8	5	11	12	7
TREVES	14	5	11	11	7
MILANI	14	4	11	12	7
CROCE LUNA	13	4	11	12	7
CROCE	13	5	7	8	6
CASALECCHIO VILLA CHIARA	13	5	9	10	6
CASALECCHIO SAN MARTINO	12	5	8	9	6
CASALECCHIO CHUISA	6	5	7	9	6
CASALECCHIO CONOSCENZA	4	3	2	3	4
CASELECCHIO MARCONI	0	0	0	0	0

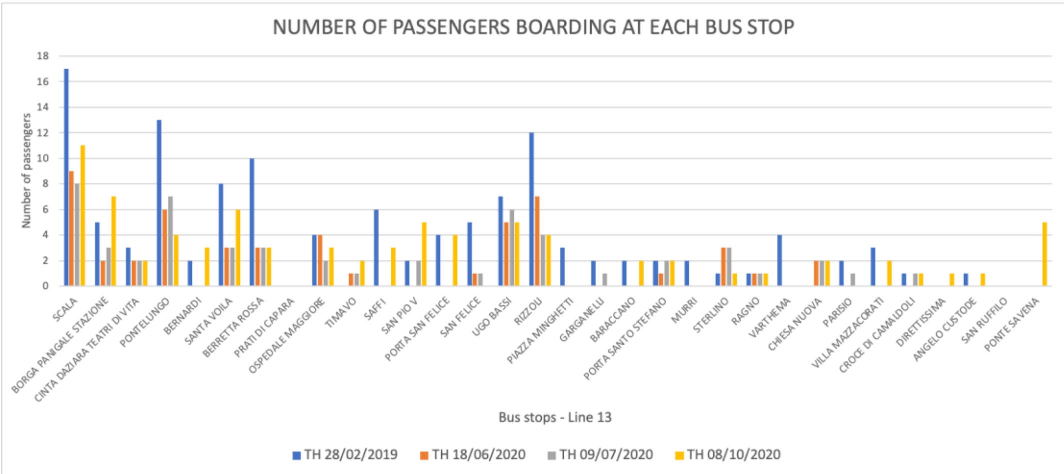
DATE	Mon	Tues	Mon	Mon
BUS STOPS	25/02/2019	26/02/2019	15/06/2020	5/10/2020
Corticella Stazione	29	23	1	0
COLOMBAROLA	35	24	3	0
Lipparini	45	32	4	0
Roncaglio	58	40	5	1
Pinardi	62	48	6	7
Croce Coperta	68	51	7	9
Caserme Rosse	65	53	9	15
De Giovanni	66	58	9	17
Istituto Aldini	69	70	10	21
Ippodromo	70	71	10	21
Lombardi	74	68	10	22
Ca' Dei Fiori	78	70	12	24
Piazza dell'Unita'	72	74	15	32
Sacro Cuore	80	73	16	36
Autostazione	95	56	15	39
VII Agosto	91	58	14	47
Indipendenza	74	49	9	35
Rizzoli	41	17	6	33
Strada Maggiore	38	13	7	15
Torleone	34	14	6	14
Porta Maggiore	30	12	6	12
Albertoni	30	15	7	11
Alemmani	26	16	7	12
Laura Bassi	23	12	7	11
Fermi	21	12	8	12
Mazzini Stazione	23	12	7	10
Pontevecchio	22	11	5	8
Bitone	20	9	5	8
Sardegna	17	13	5	7
Calabria	15	11	4	6
Milano	10	7	4	5
Chiesa San Lazzaro	8	7	4	5
Mazzoni	5	7	4	2
Firenze	5	5	4	1
Longo Cavazzoni	4	3	4	1
Longo	2	3	3	1
Piazza Degli Arti	0	0	0	0

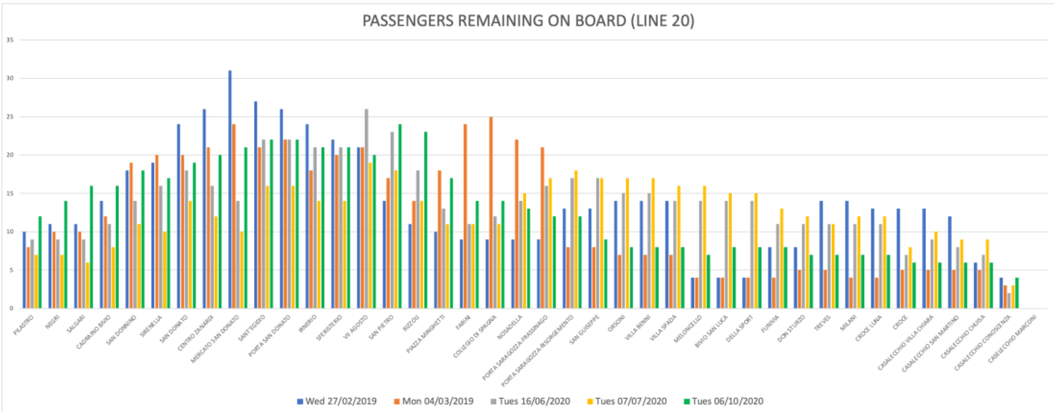
LINE 13		TH	TH	TH	TH
Bus Stops	11/03/2019	28/02/2019	18/06/2020	09/07/2020	08/10/2020
SCALA	12	17	9	8	11
BORGA PANIGALE STAZIONE	2	5	2	3	7
CINTA DAZIARA TEATRI DI VITA	9	3	2	2	2
PONTELUNGO	16	13	6	7	4
BERNARDI	5	2	0	0	3
SANTA VOILA	8	8	3	3	6
BERRETTA ROSSA	6	10	3	3	3
PRATI DI CAPARA	4	0	0	0	0
OSPEDALE MAGGIORE	2	4	4	2	3
TIMAVO	6	0	1	1	2
SAFFI	3	6	0	0	3
SAN PIO V	5	2	0	2	5
PORTA SAN FELICE	5	4	0	0	4
SAN FELICE	0	5	1	1	0
UGO BASSI	15	7	5	6	5
RIZZOLI	19	12	7	4	4
PIAZZA MINGHETTI	1	3	0	0	0
GARGANELLI	0	2	0	1	0
BARACCANO	0	2	0	0	2
PORTA SANTO STEFANO	3	2	1	2	2
MURRI	1	2	0	0	0
STERLINO	0	1	3	3	1
RAGNO	1	1	1	1	1
VARTHEMA	0	4	0	0	0
CHIESA NUOVA	0	0	2	2	2
PARISIO	1	2	0	1	0
VILLA MAZZACORATI	0	3	0	0	2
CROCE DI CAMALDOLI	0	1	0	1	1
DIRETTISSIMA	0	0	0	0	1
ANGELO CUSTODE	0	1	0	0	1
SAN RUFFILO	0	0	0	0	0
PONTE SAVENA	0	0	0	0	5
	124	122	50	53	80

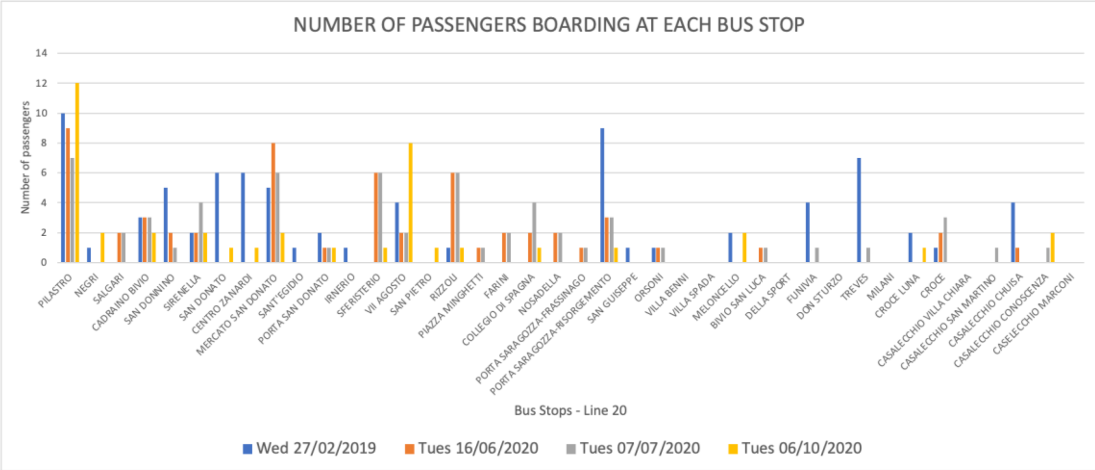
BUS STOPS	27/02/2019	16/06/2020	07/07/2020	06/10/2020
PILASTRO	10	9	7	12
NEGRI	1	0	0	2
SALGARI	0	2	2	0
CADRAINO BIVIO	3	3	3	2
SAN DONNINO	5	2	1	0
SIRENELLA	2	2	4	2
SAN DONATO	6	0	0	1
CENTRO ZANARDI	6	0	0	1
MERCATO SAN DONATO	5	8	6	2
SANT'EGIDIO	1	0	0	0
PORTA SAN DONATO	2	1	1	1
IRNERIO	1	0	0	0
SFERISTERIO	0	6	6	1
VII AGOSTO	4	2	2	8
SAN PIETRO	0	0	0	1
RIZZOLI	1	6	6	1
PIAZZA MINGHETTI	0	1	1	0
FARINI	0	2	2	0
COLLEGIO DI SPAGNA	0	2	4	1
NOSADELLA	0	2	2	0
PORTA SARAGOZZA-FRASSINAGO	0	1	1	0
PORTA SARAGOZZA-RISORGEMENTO	9	3	3	1
SAN GUISEPPE	1	0	0	0
ORSONI	1	1	1	0
VILLA BENNI	0	0	0	0
VILLA SPADA	0	0	0	0
MELONCELLO	2	0	0	2
BIVIO SAN LUCA	0	1	1	0
DELLA SPORT	0	0	0	0
FUNIVIA	4	0	1	0
DON STURZO	0	0	0	0
TREVES	7	0	1	0
MILANI	0	0	0	0
CROCE LUNA	2	0	0	1
CROCE	1	2	3	0
CASALECCHIO VILLA CHIARA	0	0	0	0
CASALECCHIO SAN MARTINO	0	0	1	0
CASALECCHIO CHUISA	4	1	0	0
CASALECCHIO CONOSCENZA	0	0	1	2
CASELECCHIO MARCONI	0	0	0	0
	78	57	60	41

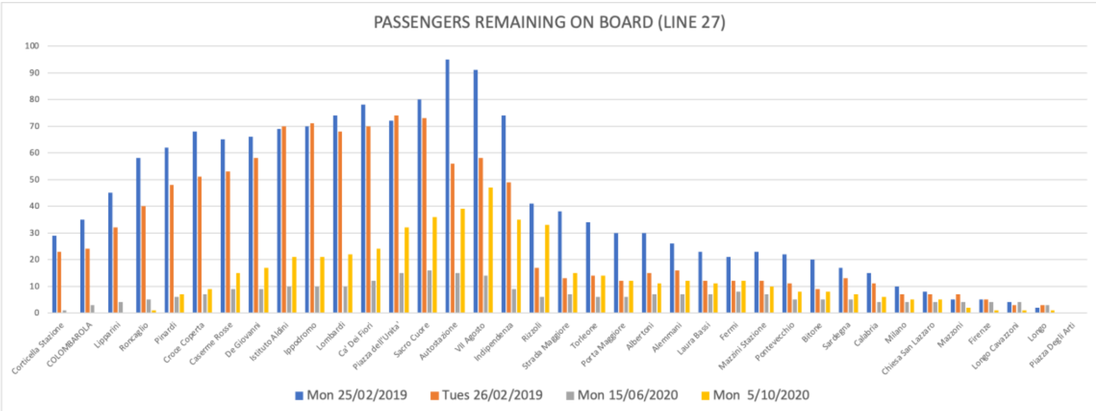
BUS STOPS	25/02/2019	26/02/2019	15/06/2020	5/10/2020
CORTICELLA STA	17	10	2	0
COLOMBAROLA	6	1	0	1
LIPPARINI	10	8	1	6
RONCAGLIO	14	8	1	2
PINARDI	4	8	2	6
CROCE COPERTA	15	8	0	2
CASERME ROSSE	5	2	1	4
DE GIOVANNI	1	5	0	0
ISTITUTO ALDINI	7	13	0	2
IPPODROMO	3	1	2	7
LOMBARDI	13	4	3	9
CA' DEI FIORI	4	4	1	8
PIAZZA DELL'UNI	7	6	0	6
SACRO CUORE	11	5	1	13
AUTOSTAZIONE	28	4	0	3
VII AGOSTO	7	11	0	0
INDIPENDENZA	2	1	1	1
RIZZOLI	3	3	0	0
STRADA MAGGIO	1	0	0	0
TORLEONE	2	2	2	0
PORTA MAGGIOR	1	0	0	1
ALBERTONI	0	5	0	0
ALEMMANI	0	1	1	2
LAURA BASSI	1	1	0	0
FERMI	1	0	0	0
MAZZINI STAZION	2	1	0	0
PONTEVECCHIO	1	1	0	1
BITONE	3	0	0	0
SARDEGNA	1	5	0	0
CALABRIA	0	0	0	0
MILANO	0	0	0	0
CHIESA SAN LAZZ	1	0	0	0
MAZZONI	2	0	0	1
FIRENZE	1	1	0	2
LONGO CAVAZZO	0	0	0	0
LONGO	0	0	0	1
PIAZZA DEGLI AR	0	0	0	0
	174	119	18	78

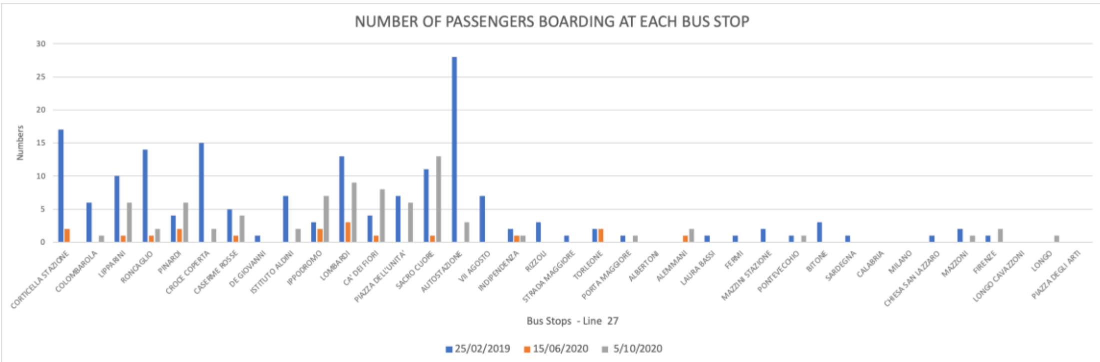

PASSENGERS REMAINING ON BOARD (LINE 13)
0
10
20
30
40
50
60
70
80
SCALA
BORGA PANIGALE STAZIONE
CINTA DAZIARA TEATRI DI VITA
PONTELUNGO
BERNARDI
SANTA VIOLA
BERRETTA ROSSA
PRATI DI CAPARA
OSPEDALE MAGGIORE
TIMAVO
SAFFI
SAN PIO V
PORTA SAN FELICE
SAN FELICE
UGO BASSI
RIZZOLI
PIAZZA MINGHETTI
GARGANELLI
BARACCANO
PORTA SANTO STEFANO
MURRI
STERLINO
RAGNO
VARTHEMA
CHIESA NUOVA
PARISIO
VILLA MAZZACORATI
CROCE DI CAMALDOLI
DIRETTISSIMA
ANGELO CUSTODE
SAN RUFFILLO
PONTE SAVENA
TH 28/02/2019
M 11/03/2019
TH 18/06/2020
TH 09/07/2020
TH 08/10/2020


NUMBER OF PASSENGERS BOARDING AT EACH BUS STOP
Number of passengers
0
2
4
6
8
10
12
14
16
18
SCALA
BORGA PANIGALE STAZIONE
CINTA DAZIARA TEATRI DI VITA
PONTELUNGO
BERNARDI
SANTA VIOLA
BERRETTA ROSSA
PRATI DI CAPARA
OSPEDALE MAGGIORE
TIMAVO
SAFFI
SAN PIO V
PORTA SAN FELICE
SAN FELICE
UGO BASSI
RIZZOLI
PIAZZA MINGHETTI
GARGANELLI
BARACCANO
PORTA SANTO STEFANO
MURRI
STERLINO
RAGNO
VARTHEMA
CHIESA NUOVA
PARISIO
VILLA MAZZACORATI
CROCE DI CAMALDOLI
DIRETTISSIMA
ANGELO CUSTODE
SAN RUFFILLO
PONTE SAVENA
Bus stops - Line 13
TH 28/02/2019
TH 18/06/2020
TH 09/07/2020
TH 08/10/2020

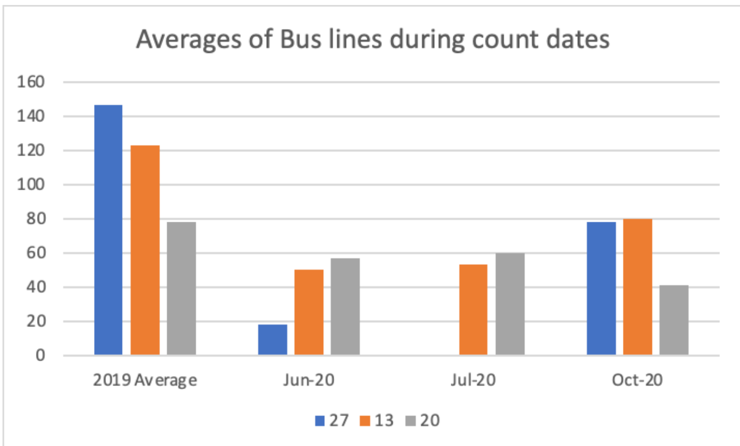

PASSENGERS REMAINING ON BOARD (LINE 20)
Wed 27/02/2019
Mon 04/03/2019
Tues 16/06/2020
Tues 07/07/2020
Tues 06/10/2020





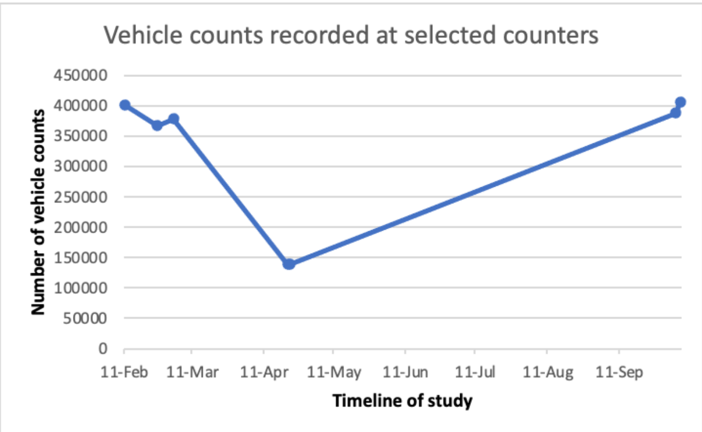


	2019 Average	Jun-20	Jul-20	Oct-20
27	147	18	N/A	78
13	123	50	53	80
20	78	57	60	41



ANNEX 2 – VEHICLE COUNTS AND FIGURES

SPIRA	11-Feb	25-Feb	03-Mar	21-Apr	22-Apr	05-Oct	07-Oct
Via Marconi:Via Leopardi-Via Riva di Reno	1192	1116	1034	853	839	1145	1199
Via Marconi:Via Leopardi-Via Riva di Reno	7106	5960	6011	2160	2228	6700	7251
Via Marconi:Via Leopardi-Via Riva di Reno	2310	1956	1978	783	733	2123	2268
Via S. Donato:Via S.Nicolò di Villola-Via E. Salgari	7356	6536	6725	2196	2242	7004	7159
Via Salgari:Via S. Donato-Via Negri	1252	1159	1209	544	583	1280	1272
Via Pirandello:Via Casini-Via S. Donato	4586	3959	5240	1775	1847	5565	5569
Via del Pilastro:Via S. Donato-Via Protche	811	1177	6100	195	213	673	741
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4910	4459	4082	1471	1571	4885	5270
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4969	4773	4898	2353	2550	4843	5110
Via S. Mamolo:Via SS.Annunziata-P.zza di P.ta S.Mamolo	4653	4556	4686	2445	2446	4708	4834
Via Irnerio:Via Mascarella-Via Centotrecento	5372	4824	4669	1811	1776	5031	5279
Via Irnerio:Via Mascarella-Via del Borgo di S. Pietro	10655	9516	9726	3164	3092	10340	11229
Via Irnerio:Via del Borgo di S. Pietro-Via Mascarella	4522	4029	4139	1568	1552	4202	4471
Via Irnerio:Via del Borgo di S. Pietro-Via Capo di Lucca	10293	9327	9643	3374	3192	10307	11279
Via Borgo San Pietro:Via Irnerio-Via Q.Majorana	1655	1402	1404	484	523	1523	1645
Via Borgo San Pietro:Mura di Porta Galliera-Viale Masini	1713	1593	1538	653	605	1965	2063
Via Irnerio:via Alessandrini-via Capo di Lucca	3479	3153	3197	1233	1179	3253	3586
Via Irnerio:Via del Pallone-Piazzale Baldi	8241	7345	7369	2641	2493	8443	9060
Via Irnerio:P.zza VIII Agosto-Via Alessandrini	3418	3125	3091	1222	1166	3282	3582
Via Irnerio:P.zza VIII Agosto-Via dell'Indipendenza	11033	9698	9872	3361	3051	11086	11611
Via Irnerio:Via Indipendenza-P.zza dell'VIII Agosto	2161	1990	2000	1011	949	1983	2106
Via dell'Indipendenza:Via dei Mille-Via S. Giuseppe	2324	1990	1798	1028	1041	1979	2142
Via dell'Indipendenza:Via dei Mille-Via Milazzo	4921	7870	4208	1848	1721	4458	4637
Via S. Felice:Via Riva di Reno-Via Pietralata	2702	2543	3279	1858	1390	2472	2895
Via S. Felice:Via Riva di Reno-Via Pietralata	4265	3736	4014	1794	1770	3868	4058
Via Saragozza:Via di Casaglia-Via F.Orioli	10783	10157	10807	3572	3523	12184	12780
Via Saragozza:Via Battaglia-Via Ruscello	902	761	781	402	402	812	842
Via Saragozza:Via Guidotti-Via Malta	10245	9362	9708	3385	3230	10148	10798
Via Emilia Ponente:Via del Triumvirato-Via del Greto	9393	8408	8331	3434	3528	8853	9134
Via Emilia Ponente:Via del Triumvirato-Via del Greto	3871	3559	3483	1526	1582	3542	3761
Via Emilia Ponente:Via del Triumvirato-Via A.Piò	12547	12085	11857	4414	4552	11808	12055
Via Emilia Ponente:Via Agucchi-Via del Millario	10214	9206	9362	3650	3705	9742	10087
Via Emilia Ponente:Via Speranza-Via del Cardo	9066	8557	8347	3217	3372	8418	8563
Via Emilia Ponente:Via Battindarno-Via del Giacinto	8837	7927	7919	3047	2965	7778	8235
Via Emilia Ponente:Via Battindarno-Via della Ferriera	7406	6942	6723	2780	2924	6743	6743
Via Massarenti:Svincolo 11 Tang.Ovest Casalecchio S.Lazzaro-Via B.Cellini	13102	11379	11813	4514	4514	12438	12804
Via Massarenti:Via Donatello-Via Golfarelli	11494	10196	10694	4427	4334	11298	11618
Via Massarenti:Via del Parco-Via della Salita	8403	7645	7939	3369	3247	8170	8308
Via Massarenti:Via Crociali-Via Manfredi	10159	9165	9285	3915	3869	9624	10382
Via Massarenti:Via Venturoli-Via Libia	9564	8614	8806	3815	3731	9096	9653
Via Dozza (corsia dx):Via Cracovia-Rot. Decorati al Valor Militare	13520	12055	12591	3383	3561	12443	13133
Via Dozza:Via Cracovia-Via Canova (S. Lazzaro)	9867	8781	9193	2348	2552	9117	9752
Via Dozza:Via Ferrara-Rot. Decorati al Valor Militare	12969	11460	11918	3534	3646	11759	12255
Via Dozza:Rot. Decorati al Valor Militare-Via Cracovia	437	383	503	306	326	709	630
Via Dozza:Via Dallolio-Via Ferrara	12544	11660	11842	3749	3779	12206	12668
Via Dozza:Via Napoli-Via Caduti e Dispersi in Guerra	8936	7189	8510	2570	2566	16669	17506
Via Dozza:Via Caduti e Dispersi in Guerra-Via Napoli	10200	9588	9912	3132	3203	2820	2276
Via Dozza:Via Due Madonne-Via M.Longhena	8735	7920	8061	2509	2583	8051	8420
Via Toscana:Via Bacchi della Lega-Via Pavese	12139	11507	11570	4651	4676	12024	12435
Via Toscana:Via Pavese-Via Bacchi della Lega	12222	11519	11717	4513	4544	12482	13032
Via Toscana:Via della Cava-Via Fantini	5053	4760	4901	1766	1768	5102	5372
Via Toscana:Via della Cava-Via Giordano Bruno	7154	6435	6559	2572	2535	6718	7338
Via Toscana:Via Filippini-Via Fantini	7820	7026	7119	2452	2593	7547	8012
Via Toscana:Via Filippini-Via dei 7 Leoncini	7017	6483	6758	2596	2560	6660	6951
Via Toscana:Via Beethoven-Via Bellini	7260	6788	7009	2654	2654	6962	7073
Via Toscana:Via V.Bellini-Via G.S.Bach	13213	11752	12288	4875	4855	12930	13569
	400971	367061	378216	138902	138631	387971	406501



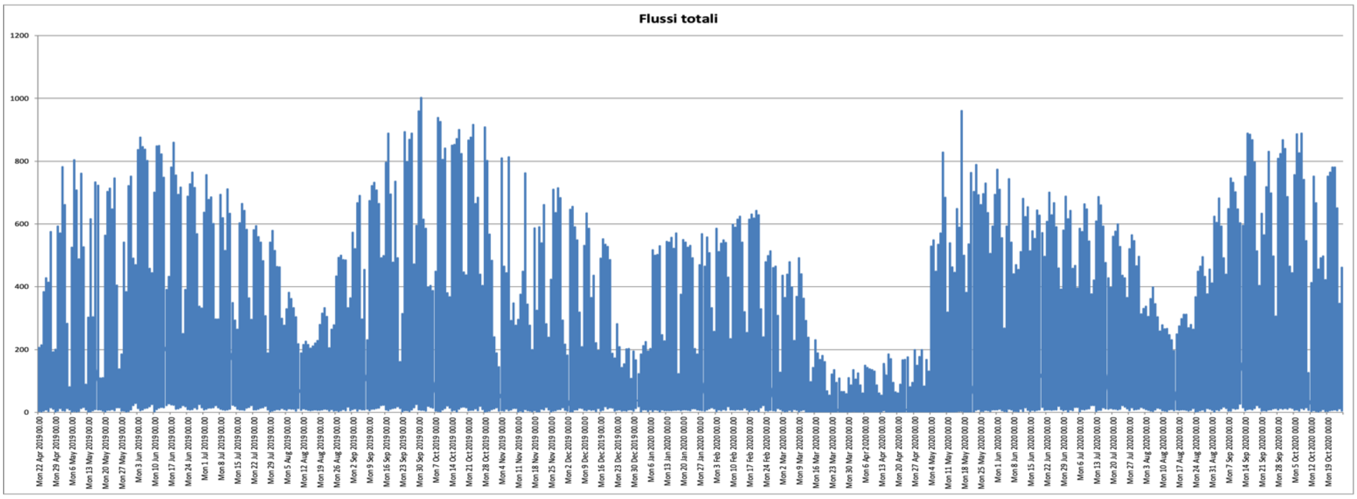
11-Feb	25-Feb	03-Mar	21-Apr	22-Apr	05-Oct	07-Oct
400971	367061	378216	138902	138631	387971	406501

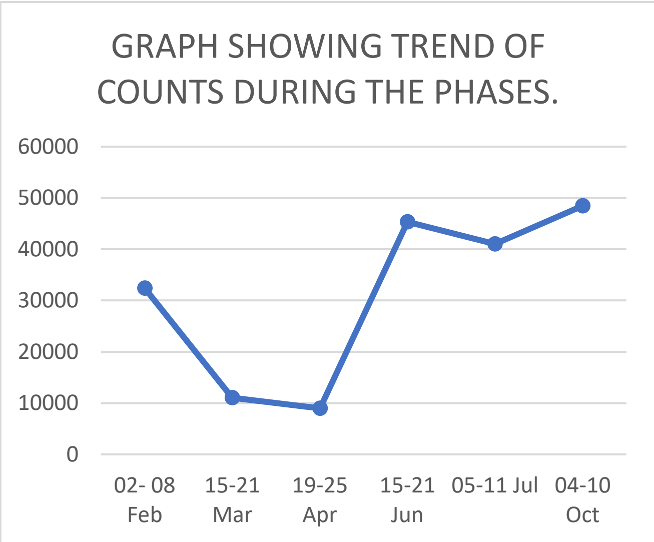
ANNEX 3 – CYCLIST COUNTS AND FIGURES.

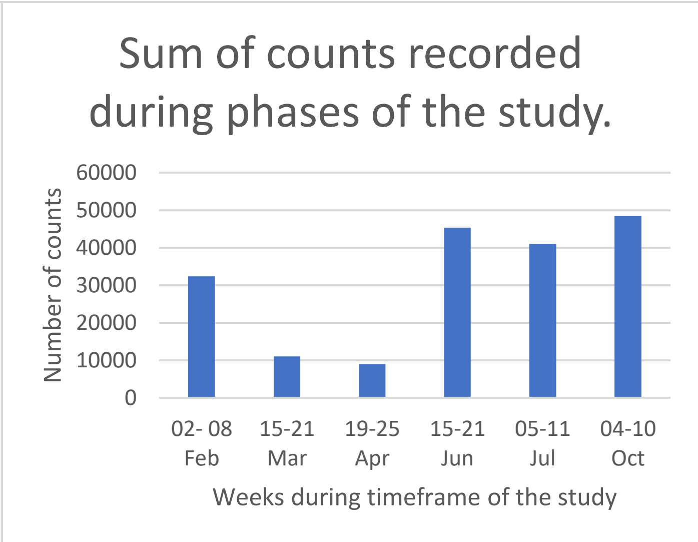
Annexes

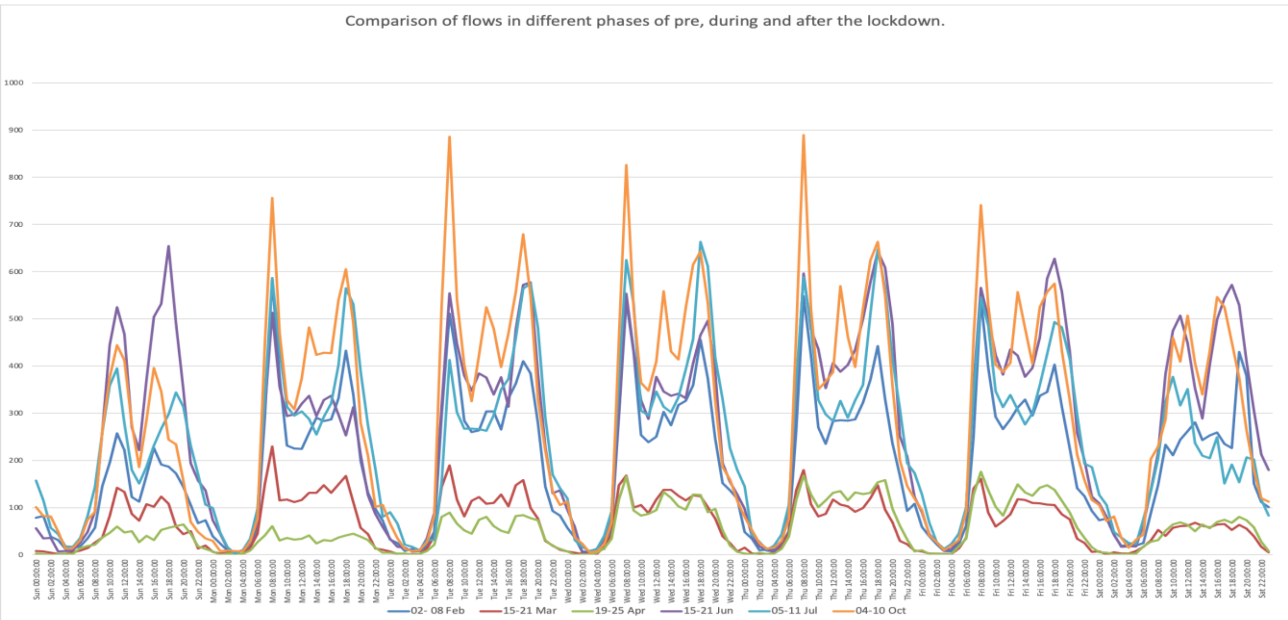
2020	02-08 Feb	15-21 Mar	19-25 Apr	15-21 Jun	05-11 Jul	04-10 Oct
Sun 00:00:00	79	8	3	56	157	101
Sun 01:00:00	82	7	2	35	115	82
Sun 02:00:00	38	4	0	36	57	81
Sun 03:00:00	31	2	1	7	44	49
Sun 04:00:00	12	3	3	8	18	13
Sun 05:00:00	14	5	2	9	17	14
Sun 06:00:00	18	9	14	26	36	31
Sun 07:00:00	35	14	19	48	82	74
Sun 08:00:00	57	26	21	92	144	91
Sun 09:00:00	146	37	37	262	260	263
Sun 10:00:00	195	82	46	444	358	375
Sun 11:00:00	257	142	60	525	395	444
Sun 12:00:00	222	133	47	467	278	412
Sun 13:00:00	122	87	50	270	180	277
Sun 14:00:00	113	72	27	222	151	186
Sun 15:00:00	168	107	40	371	187	286
Sun 16:00:00	226	102	31	504	231	396
Sun 17:00:00	191	123	53	532	267	346
Sun 18:00:00	187	108	57	654	298	244
Sun 19:00:00	172	60	61	491	344	234
Sun 20:00:00	144	44	64	350	314	157
Sun 21:00:00	105	50	45	194	231	70
Sun 22:00:00	67	13	18	157	171	48
Sun 23:00:00	73	20	12	137	106	35
Mon 00:00:00	39	6	7	73	99	29
Mon 01:00:00	24	3	0	45	47	8
Mon 02:00:00	9	4	3	13	16	9
Mon 03:00:00	4	3	3	4	3	8
Mon 04:00:00	8	2	2	10	10	7
Mon 05:00:00	17	15	9	24	34	28
Mon 06:00:00	59	45	27	71	97	77
Mon 07:00:00	293	150	41	311	335	448
Mon 08:00:00	586	230	61	513	586	756
Mon 09:00:00	378	115	30	356	436	470
Mon 10:00:00	231	117	36	294	314	328
Mon 11:00:00	225	112	32	298	295	308
Mon 12:00:00	224	116	34	320	304	374
Mon 13:00:00	258	131	41	337	288	482
Mon 14:00:00	290	131	24	294	255	424
Mon 15:00:00	283	147	31	328	292	428
Mon 16:00:00	287	131	29	337	321	427
Mon 17:00:00	332	149	37	297	402	540
Mon 18:00:00	433	167	41	253	565	605
Mon 19:00:00	340	112	45	313	531	492
Mon 20:00:00	199	57	38	213	389	280
Mon 21:00:00	131	44	31	126	274	210
Mon 22:00:00	97	13	15	87	182	102
Mon 23:00:00	72	11	4	59	80	105
Tue 00:00:00	32	7	4	34	90	66
Tue 01:00:00	25	2	3	17	66	35
Tue 02:00:00	8	1	3	15	21	12
Tue 03:00:00	12	2	1	7	17	8
Tue 04:00:00	8	2	2	8	10	10
Tue 05:00:00	19	13	8	35	30	27
Tue 06:00:00	49	39	21	88	32	83
Tue 07:00:00	295	144	80	314	153	526
Tue 08:00:00	511	189	89	554	413	886
Tue 09:00:00	416	117	66	448	302	542
Tue 10:00:00	284	81	52	380	267	402
Tue 11:00:00	260	114	45	348	267	325
Tue 12:00:00	264	122	74	384	266	423
Tue 13:00:00	304	108	80	375	263	525
Tue 14:00:00	304	110	61	340	296	479
Tue 15:00:00	265	128	51	376	350	398
Tue 16:00:00	332	103	46	314	373	469
Tue 17:00:00	363	147	82	478	459	557
Tue 18:00:00	410	158	84	572	564	679
Tue 19:00:00	384	99	78	577	575	548
Tue 20:00:00	280	77	73	385	482	331
Tue 21:00:00	145	29	31	230	291	222
Tue 22:00:00	93	20	19	130	170	134
Tue 23:00:00	83	11	12	137	141	105

2020	02-08 Feb	15-21 Mar	19-25 Apr	15-21 Jun	05-11 Jul	04-10 Oct
Wed 00:00:00	57	7	7	96	120	113
Wed 01:00:00	37	4	0	59	31	37
Wed 02:00:00	7	2	1	5	17	24
Wed 03:00:00	6	2	1	7	8	5
Wed 04:00:00	8	2	4	12	12	7
Wed 05:00:00	12	17	13	31	40	22
Wed 06:00:00	57	43	34	90	92	69
Wed 07:00:00	293	147	117	300	374	458
Wed 08:00:00	538	168	166	553	625	826
Wed 09:00:00	429	100	94	432	531	521
Wed 10:00:00	254	105	83	328	306	365
Wed 11:00:00	239	88	87	288	295	348
Wed 12:00:00	250	117	95	377	346	409
Wed 13:00:00	303	138	133	346	314	559
Wed 14:00:00	274	138	121	337	302	431
Wed 15:00:00	317	125	103	341	333	414
Wed 16:00:00	326	115	96	332	392	523
Wed 17:00:00	359	126	128	406	457	615
Wed 18:00:00	456	124	127	466	663	643
Wed 19:00:00	374	101	90	496	611	534
Wed 20:00:00	247	77	97	388	418	327
Wed 21:00:00	152	39	52	195	330	186
Wed 22:00:00	137	25	20	155	226	160
Wed 23:00:00	119	7	6	128	180	114
Thu 00:00:00	48	15	3	97	145	80
Thu 01:00:00	34	3	1	39	42	52
Thu 02:00:00	10	3	4	18	28	25
Thu 03:00:00	11	1	2	9	11	13
Thu 04:00:00	11	4	3	7	20	15
Thu 05:00:00	21	19	12	25	43	29
Thu 06:00:00	50	46	38	91	105	77
Thu 07:00:00	264	137	116	340	364	469
Thu 08:00:00	548	180	168	596	588	889
Thu 09:00:00	423	107	128	478	485	522
Thu 10:00:00	270	81	101	436	328	350
Thu 11:00:00	235	87	115	353	298	367
Thu 12:00:00	283	117	131	407	283	387
Thu 13:00:00	285	106	135	388	326	569
Thu 14:00:00	284	103	115	402	290	463
Thu 15:00:00	287	91	132	434	327	398
Thu 16:00:00	323	99	129	500	360	522
Thu 17:00:00	371	120	131	577	510	624
Thu 18:00:00	442	147	154	643	647	663
Thu 19:00:00	330	96	158	609	565	550
Thu 20:00:00	236	69	97	489	416	358
Thu 21:00:00	168	29	62	251	309	200
Thu 22:00:00	93	22	32	208	194	146
Thu 23:00:00	108	9	7	122	173	119
Fri 00:00:00	59	7	10	90	128	95
Fri 01:00:00	39	3	2	44	68	41
Fri 02:00:00	22	3	3	26	27	27
Fri 03:00:00	8	2	1	9	12	10
Fri 04:00:00	7	2	2	12	23	20
Fri 05:00:00	22	13	18	29	45	31
Fri 06:00:00	62	36	34	100	100	91
Fri 07:00:00	249	140	127	354	339	456
Fri 08:00:00	540	161	176	566	545	741
Fri 09:00:00	397	89	137	502	486	529
Fri 10:00:00	292	60	102	424	347	403
Fri 11:00:00	266	71	83	382	313	387
Fri 12:00:00	287	86	117	435	339	407
Fri 13:00:00	312	118	149	422	307	557
Fri 14:00:00	329	116	132	377	276	480
Fri 15:00:00	295	110	125	396	300	405
Fri 16:00:00	337	109	142	460	359	525
Fri 17:00:00	345	106	147	585	425	557
Fri 18:00:00	403	105	138	627	493	575
Fri 19:00:00	314	86	114	558	482	432
Fri 20:00:00	225	75	89	431	415	328
Fri 21:00:00	141	34	57	258	297	212
Fri 22:00:00	124	25	36	200	193	158
Fri 23:00:00	93	6	16	123	186	116
Sat 00:00:00	73	7	5	109	127	105
Sat 01:00:00	77	1	4	80	105	71
Sat 02:00:00	42	5	2	43	48	81
Sat 03:00:00	19	3	1	17	37	36
Sat 04:00:00	21	3	2	18	25	15
Sat 05:00:00	20	8	3	18	23	32
Sat 06:00:00	25	17	18	65	76	43
Sat 07:00:00	88	30	28	137	134	203
Sat 08:00:00	148	53	31	217	205	230
Sat 09:00:00	233	40	51	383	324	287
Sat 10:00:00	211	57	64	475	377	460
Sat 11:00:00	244	61	69	507	316	409
Sat 12:00:00	262	62	63	449	351	507
Sat 13:00:00	281	68	50	353	237	407
Sat 14:00:00	243	62	64	289	210	340
Sat 15:00:00	253	58	56	402	205	431
Sat 16:00:00	259	64	70	499	249	546
Sat 17:00:00	235	65	74	543	151	525
Sat 18:00:00	226	53	68	572	191	450
Sat 19:00:00	430	63	80	529	154	375
Sat 20:00:00	379	55	73	409	206	264
Sat 21:00:00	151	39	58	306	202	179
Sat 22:00:00	112	17	28	213	117	120
Sat 23:00:00	101	5	8	180	83	113


Flussi totali
1200
1000
800
600
400
200
0


GRAPH SHOWING TREND OF COUNTS DURING THE PHASES.
60000
50000
40000
30000
20000
10000
0
02- 08 Feb
15-21 Mar
19-25 Apr
15-21 Jun
05-11 Jul
04-10 Oct


Sum of counts recorded during phases of the study.
Number of counts
60000
50000
40000
30000
20000
10000
0
02- 08 Feb
15-21 Mar
19-25 Apr
15-21 Jun
05-11 Jul
04-10 Oct
Weeks during timeframe of the study


Comparison of flows in different phases of pre, during and after the lockdown.
1000
900
800
700
600
500
400
300
200
100
0
02- 08 Feb
15-21 Mar
19-25 Apr
15-21 Jun
05-11 Jul
04-10 Oct