Assessing the Future of Urban Mobility in Venice

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Thanks to my family for their great support.

Abstract

This project investigated the current cargo transportation system in the historical city of Venice, along with some of the possibilities for improvements. I analyzed the current cargo transportation, including the typical package delivery process in the city. Also, I presented some of the city's common problems due to the inefficiencies with the current transportation system. Finally, I proposed an underground subway system to travel around the historical city and other popular destinations in the lagoon such as Lido, Murano, the Marco Polo airport, and San Guiliano on the mainland. The proposal was presented to be developed into three different phases. I calculated the estimated travel time between each location and proposed a design for the infrastructure of the new station with two pedestrian connections. Finally, I provided the cost of the tunnel construction using two different methods: The Boring Machine Method and The Immersed Tunnel Method. Based on the research, the less expensive method is the Immersed Tunnel for approximately €7.5 billion. Further research should assess the tons of cargo the train could transport along with the passengers.

Introduction

The city of Venice faces challenges with congested streets and inefficiencies of public transportation due to over-tourism. The number of tourists in Venice has been increasing recently (Bolduc et al., 2021) except for 2020, when the worldwide pandemic forced many borders to close. While tourists have contributed to a significant portion of the city's development in the last decades, when tourists decide to embark on visits to the historical city, the daily life of residents is disturbed. The current public transportation system needs to be improved to transport visitors and residents on a timely basis. As a result, many residents chose to walk to get to their destinations.

The demand for tourists also increases the materials needed by local businesses. Whether a clothing business or a restaurant, these places need to keep an inventory of products to supply the needs of the visitors on top of the needs of the residents, this increases the tourism supply chains (Tapper et al., 2004). The current transportation system also deals with the transportation of goods and products. Since Venice is in a unique location, importing goods is more expensive than in the mainland, making it more difficult for residents to afford the cost of living. From this perspective, we have two different scenarios in the current transportation system. On one side, we need to move people from one place to another on time, and on the other, we have products to be delivered to businesses or people's homes. Because of these problems, Venice needs to consider new systems of transportation. In reimagining the public transportation system, I envision a combined strategy to transport passengers and cargo. We understand that transportation is essential and improving the resident's quality of life should be prioritized.

The objectives of this project were:

To describe the current cargo transportation system in Venice and its inefficiencies. I used desktop research to examine the types of cargo boats, packages, delivery methods, and routes. I then indicated some of the problems this presents to an already congested transportation system and some past proposals or examples from other cities that have or could be implemented. One common suggestion has been using an underwater tunnel, I envision how such a tunnel could be constructed for Venice in the future.

To analyze the possibilities for future improvements within the current system. I conducted desktop research to examine what other countries have implemented for passenger and cargo transportation, focusing on the possibility of an underwater subway system.

To visualize an underwater subway train system for Venice through maps and other graphics, along with routes and stops around the city. I relied on data from previous tunnel projects to estimate construction costs and calculated travel time savings through isochrones.

Current Cargo Transportation

As in any other city, Venetians need primary products, such as clothing, food, cleaning, household supplies, construction material, and other provisions. But how do all these products arrive at each of the sestieri or districts of Venice? Due to its geography and unique urban design around narrow streets, canals, and bridges, the transportation of its goods and products is quite different from other cities like Rome or London. Venice's system currently requires complex routes in and out of the city and around it, and the system is relatively slow, given the use of boats and hand delivery carts. Residents and businesses rely on the local transportation chains that usually take an extra step to transport the products from the mainland.

Most cargo is transported in trucks through the Ponte della Libertà (Liberty Bridge) from the mainland to Venice. Figure 3 shows the Port location where the trucks park and unload after crossing the bridge. Packages are then loaded into the boats and distributed around the city, as shown in Figure 1.

Figure 1: Cargo arrives to Venice from the mainland in trucks. (Villalobos 2022).

Figure 2: Cargo being delivered to the city using dollies. (Villalobos 2022)

Deliverers usually use dollies to carry out multiple packages to their final destination, As shown in Figure 2.

Depending on the types of cargo, the merchandise is classified as refrigerated, dry, or other such as raw material and construction supplies.

Figure 3: The Dock is situated on the Venice Port at the Tronchetto Island. (Villalobos 2022).

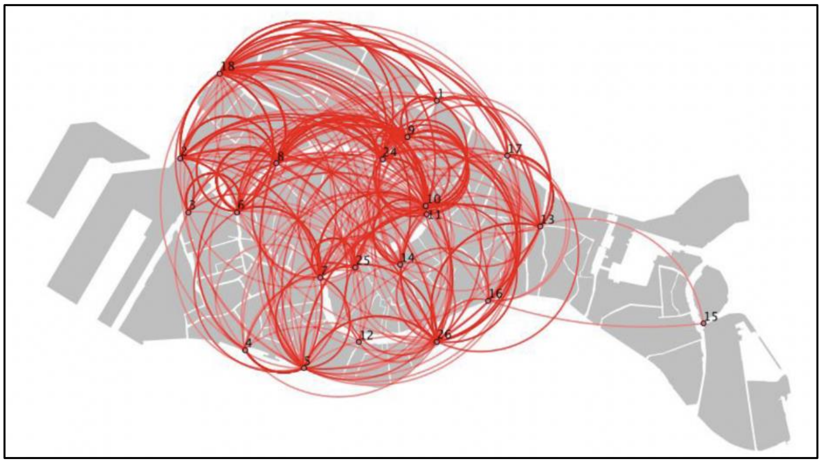


Figure 4: Current Delivery Route of Products in Venice (Goncalves 2015).

Previous research indicated that in 2015 approximately 32,000 packages were delivered throughout the city and this amount has increased over the years. Figure 4 shows the visualization of the transportation network using the current boat system (Goncalves 2015).

Licensure and Registration of Cargo Boats

For boats to distribute products and packages throughout the city, they must possess the required licenses. As Duffy et al. (2001) reported, first of all, the cargo company must be registered with the Chamber of Commerce, then designated drivers must be certified. Boats also required a shipping license and a license to register and obtain the plates for the boat. A final permit is necessary to park the boat overnight at a designated spot.

Problems with the Current System

The sheer number of cargo boats and the complex and inefficient routing system creates many problems.

Traffic

Among the social and economic problems, the city of Venice faces, traffic is no exception. Over the decades, there has been an increase in boat traffic. Cargo boats make up 36% of overall boat traffic, as shown in Figure 5.

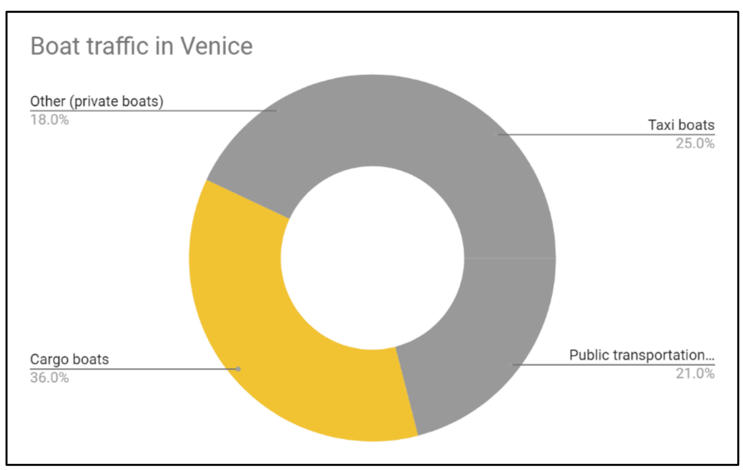


Figure 5: Percentage of Boats in Venice (Goncalves, 2015).

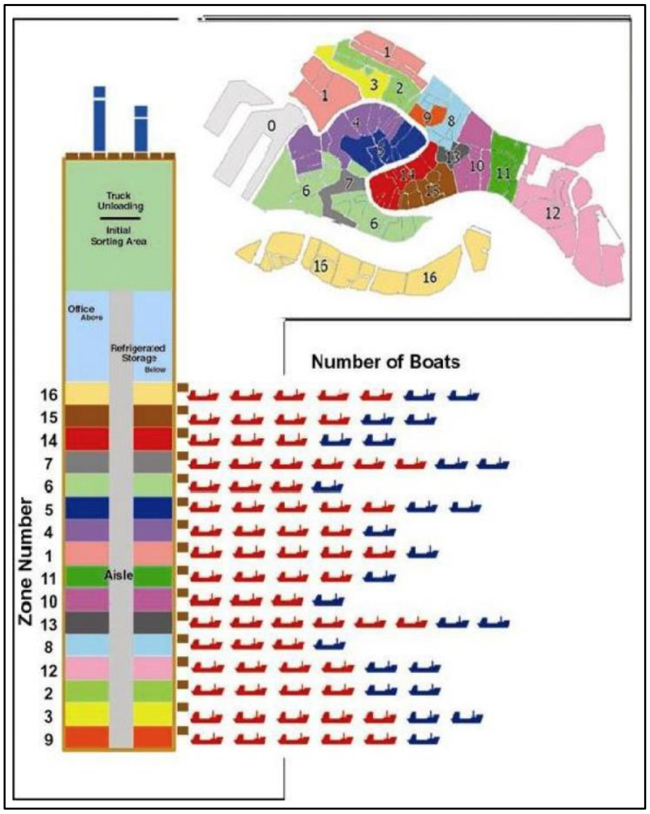


Figure 6: Number of boats in Venice (Duffy 2001).

A research study proposed in 2001 a new system of cargo delivery by location instead of only the product. This system brings goods to the warehouse and distributes them to the designated boats. Figure 6 shows that each delivery zone would have approximately five boats assigned. The number of boats for each zone was calculated based on the average cargo the zone receives daily (Duffy, 2001).

How other cities have improved transportation of people and goods: The use of tunnels

The project of an underground subway system has been implanted in other countries worldwide, especially in larger cities where traffic and congestion are the most significant problems. Some examples of subway systems are the Hooghly riverbed in India and the Ingenieurgemeinschaft Wehrhahn-Linie – IGW in Germany.

Hooghly riverbed

The underground metro station in India is recent and still under construction, which plans to run 13 meters below the Hooghly riverbed. It is planned to be open to the public by March of 2023. According to the HT Digital Stream Limited editorial, the project has cost approximately 8,600 crores (€1,101,634). The entity in charge of the project is the Kolkata Metro Rail Corporation (KMRC). The new line will connect the east and west corridors by a twin tunnel of over 500 meters, which would cut travel time. (Verma, k. 2022).

Figure 7: India's First Underwater Metro Tunnel (Verma 2022)

Ingenieurgemeinschaft Wehrhahn-Linie – IGW

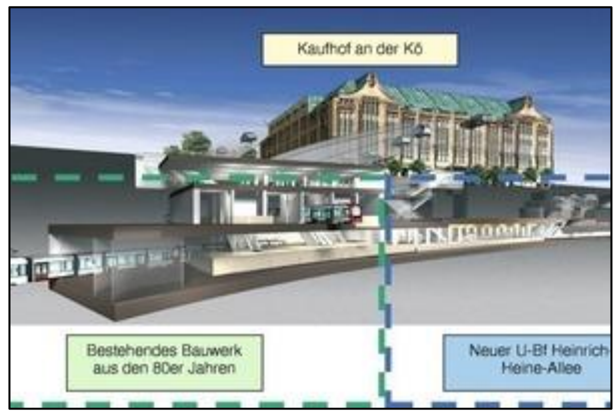


Figure 8: Station at Kaufhof an der Ko Germany (Pähler, (n.d))

Germany is also added to the countries with an innovative underground subway system. The Ingenieurgemeinschaft Wehrhahn-Linie IGW was first proposed in the early 2000s to connect Germany's eastern and southern districts. Now the subway provides transportation to more than 50,000 passengers per day (Pähler, I. (n.d.))

The IGW line runs under Düsseldorf's chic Königsallee city and the central shopping zone on Schadowstrasse an area of high traffic flow and commerce, as shown in Figure 9. The construction of the new line started in 2008, and to avoid the disruption of transportation between residents and businesses, the project was divided into two sections, southern and eastern. The tunnel was constructed in a shield-drive tunneling process, which consists of excavating and propping simultaneously, almost similar to The Boring Machine Method later discussed. On the other hand, the stations were also built using the method of cut-and-cover which consist of using an excavation equipment to dig a large trench or rectangular hole in the ground and then its covered by a concrete deck (Pähler, I. (n.d.)).

The design of this specific subway system also provided fire protection for an emergency. It has two smoke ventilation that provides natural smoke extraction at the tunnel and the stations. The eight-year program construction was finalized in February 2016, allowing passengers to reduce their time of travel (Pähler, I. (n.d.))

Envisioning an Underground Tunnel System for the Historic City of Venice.

One of the objectives of this project was to design a system capable of transporting passengers and cargo at the same time. Although the topic of a subway is familiar in Italy since most of the transportation on the mainland is by train, the mixed passenger and freight systems/cargo hitching are relatively new.

An example of this mixed system is the case in Saint-Etienne, France, as shown in Figure 10. Although this train doesn’t go underground, I envision applying the same method to the future subway system in Venice.

This system will facilitate the transportation of goods in and out of the historic city faster and easier. As stated before, Venice is in a unique location, and cargo transportation takes longer than on the mainland. The hitching method would allow cargo to arrive on time under any weather conditions.

Figure 9: Hitching innovation example in Saint-Etienne. (Mazzarino, 2019)

Further research should evaluate the costs of transporting different types of cargo, the number of tons the trains would be able to transport, and the number of passengers.

Methods for Building Underground Tunnels

I have presented the status of the current transportation system in the historical city and some of the problems the city is facing. I have also provided information on what other countries have implemented for underground train stations and I have introduced the idea of mixed passenger and cargo transportation. The project of an underground subway in Venice has been proposed since 1911. Previous researchers had also envisioned a faster and more economical system of transportation. As a visitor, I have experienced delays with the boats and the effects of over-tourism. Many residents and commuters go through the same experience daily. The new transportation system focuses on improving the quality of life for residents/commuters and increasing the population in the historical city. Although other factors such as the cost of living, over-tourism, and employment are forcing many to move out to the mainland, Venice is still the home for many others.

Before designing the future underground station and the number of trains operating, it is essential to consider the methods to construct a project of such a great magnitude. There are different types of procedures for building underground tunnels. The Umbrella Arch, the New Austrian Tunneling Method, The Boring Machine, and the Immersed Tunnel Method are some of the most known. Due to the unique location of Venice, some of these methods won’t be appropriate for the project, but I will still provide a brief description of each.

The umbrella Arch

This method works as a temporary support system during the tunnel excavation. It consists of placing the longitudinal support members, the Forepoles, the Steel Set, and the Rockbolts on the crown of the tunnel face, as shown in Figure 10 (Umbrella arch (n.d.).

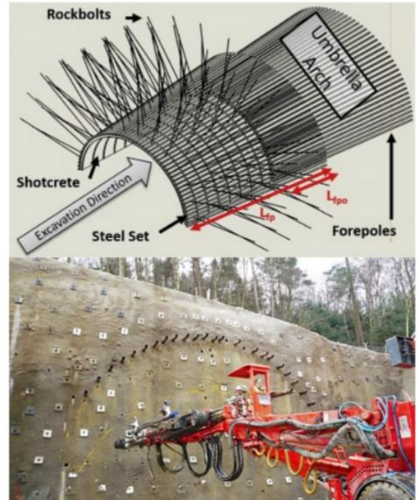


Figure 10:Umbrella Arc Method (Umbrella arch (n.d.)).

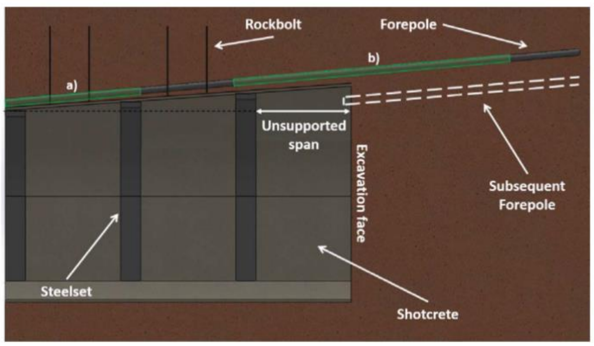


Figure 11: Umbrella Arch Diagram (Umbrella arch (n.d.)).

As the excavation progresses, the Forepoles are activated by the movement of the groundmass and carry the load away from the unsupported span, and the tunnel is created. Figure 11 shows the side diagram of the umbrella arch (Umbrella arch (n.d.)).

New Austrian Tunneling Method (NATM)

Initially developed in Austria between 1957 and 1965, this method uses the geological stress of the surrounding rock mass to stabilize the tunnel (New Austrian tunneling method (natm) (n.d.)). The NATM is also known as the sequential excavation method (SEM) or sprayed concrete lining (SCL). This excavation method creates the tunnel using the type of rock encountered in the process (Wikimedia Foundation, (n.d)). It is attractive to employ since it uses the inherent geological strength in the rock mass to hold down the tunnel (Wikimedia Foundation, (n.d)).

A great example of the SCL method is the work performed at the Elizabeth lines in the central London station. The tunnels were around 250 meters long. The SCL method was used primarily because the tunnels were short. The processes involved a layer of 75mm of sprayed concrete after excavating an area, followed by another coat of concrete, as shown in Figure 13 (Mottmac, (n.d)).

Figure 12: Sprayed Concrete (New Austrian tunneling method (natm) (n.d.)).

The boring Machine (TBM)

Another method commonly used to build underground tunnels is the boring machine, also known as "mole." This method relies on using an apparatus, as shown in Figure 13, that bores through the rocks and fills the working chamber. Depending on the type of ground, there are different types of boring machines, for example, the Slurry Pressure Balance (SPB). TBM is recommended for ground with high water pressures since it fills the working chamber with the slurry extracted, as shown in Figure 14. This boring machine typically performs 5 to 20 meters per day. Another type of TBM is the Earth Pressure Balance which transports the spoil from the excavation through the screw conveyor, as shown in Figure 14, which allows the pressure at the cutter head of the TBM to remain balanced (Tunnel boring machine (TBM) (n.d.)).

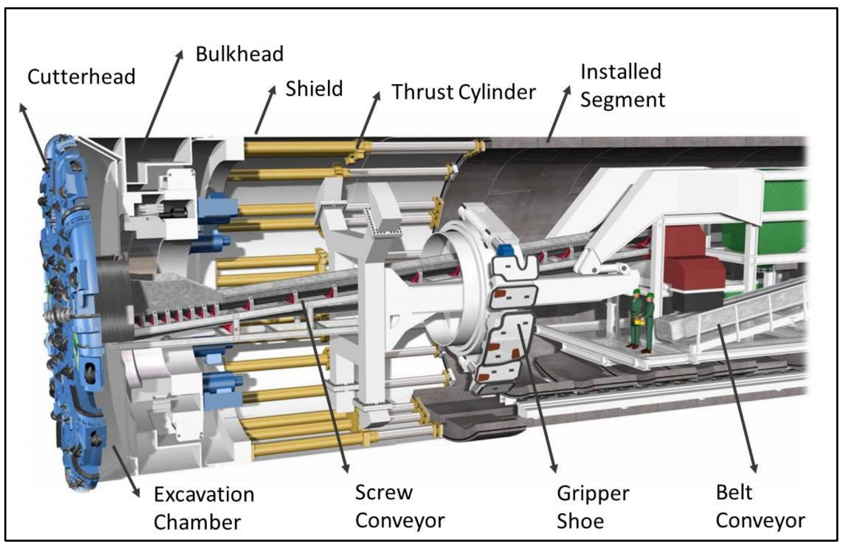


Figure 13: Boring Machine Diagram (Tunnel boring machine (TBM) (n.d.)).

The most significant disadvantage of this method is the capital cost to develop it since they are known to be expensive to construct and difficult to transport (Tunnel boring machine (TBM) (n.d.)).

The following section provides an overview of the cost of using the TBM method for constructing a tunnel in Venice.

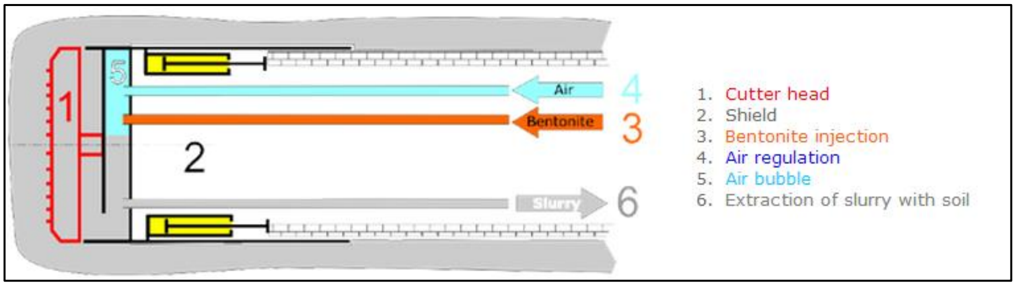


Figure 14: The Boring Machine Excavation Phase Diagram (Tunnel boring machine (TBM) (n.d.)).

Immersed Tube Tunnel

This method is commonly used for crossing a body of shallow water (Immersed tube tunnel (n.d.)). This method consists of establishing one or more casting basins as an open exaction, where the individual tunnel parts are constructed. The tunnel is developed in several segments.

The tunnel is constructed outside the water area and tested in the early stages. Then it is transported to its final destination and prepared for the immersion, as shown in figure 15.

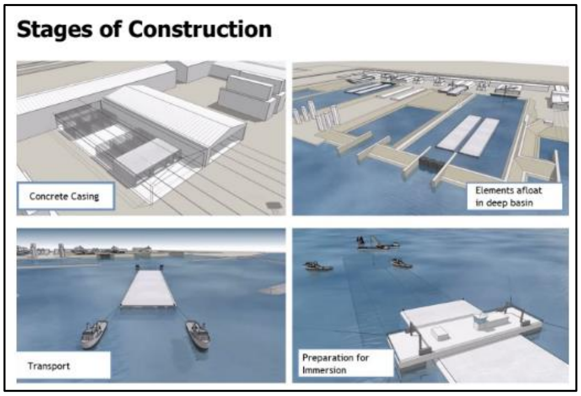


Figure 15: Immersed Tube Tunnel Stages of Construction Part 1 (Immersed tube tunnel (n.d.)).

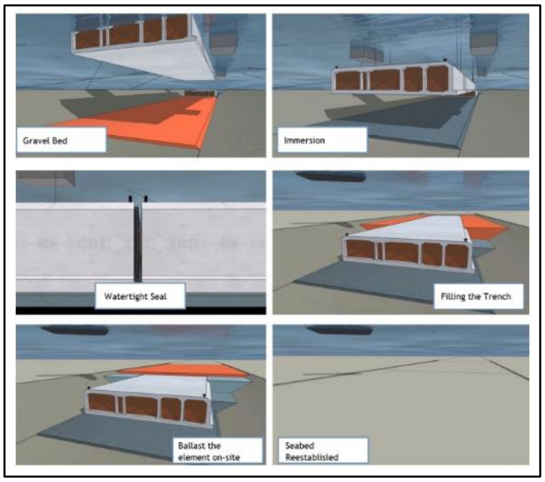


Figure 16: Immersed Tube Tunnel Stages of Construction Part 2 (Immersed tube tunnel (n.d.)).

Then, as shown in Figure 16, the tunnel is sunk into place and linked together. In some cases, additional weight might be necessary to fall the element into its final destination since each piece must get aligned to complete the sealing afterward (Wikipedia Foundation, (n.d.)).

One of the advantages of this method is the speed of construction and the minimal disruption of the river/channel (Wikipedia Foundation, (n.d.)).

One of the disadvantages of this method is that it needs a careful waterproof design around the joints since they are immersed tunnels (Immersed tube tunnel (n.d.)).

Immersed Tunnel Projects

Fehmarnbelt Fixed Link

A great example of a submerged tunnel is the project “Fehmarnbelt Fixed Link”, which will connect Germany and Denmark. As shown in Figure 17, the new tunnel will cross the Baltic Sea, connecting the Danish Island of Lolland with Fehmarn of Germany (Building Cue (n.d.)).

Figure 17: Map of the Fehmarnbelt Fixed Link. (Building Cue, (n.d.)).

One of the advantages of this new system is that once completed, it will reduce travel time between countries. The work of its construction already started in 2021, and the expected completion date is set for 2029. The immersed tunnel will have a distance of 18 km and cost approximately 10 billion dollars. Figure 18 also shows the current route, marked in blue, which takes 45 minutes to navigate between trains and ferries. The new link will cut the time to 10 minutes by vehicle and 7 minutes by train.

Figure 18: Design of the immerse tunnel between Danish Island of Lolland with Fehmarn of Germany (Fehmarn, (n.d)).

As shown in figure 18, the Fehmarnbelt Fixed Link will have separate tunnels for the vehicles and others for the train. Due to its considerable length, it is considered one of the largest infrastructure projects (Building Cue (n.d.)). The concrete ashlars will be constructed onsite in the surface area. Then the concrete ashlars will be transported, immersed, and connected under the water.

After considering some methods for building an underground tunnel, I reviewed the previous proposals presented in Venice. Brown and Raven (2022) presented a more detailed description of each proposal from 1911 – 2017. I will be reviewing the routes of each one and vizualize them in a map to reference how the 2022 proposal overlays with the most common routes proposed across the last century.

The Venice 1911 proposal consited of a connection between San Marco/San Zaccaria and Lido Quattro Fontane (Brown & Rave (2022). This route is highlighted in yellow in Figure 21.

The Venice 1933 proposal consiste of a connection from the historic city to the mainland. It was proposed as a single underground subway from Mestre to Venice and other stops including Chioggia. (Brown & Raven 2022). This route is highlighted in purple in Figure 21.

The Venice 1990 proposal included two routes, one on the mainland from Mestre to Marco Polo and a second from Mestre to the historic city. It was designed as a sublagunare once it moved into Venice. It included different stops in Trochetto, San Zaccaria, Gran Viale, Casino, and others. (Brown & Raven 2022). This route is highlighted in blue in Figure 21.

The most recent proposals have been presented in 2005 by mayor Paolo Costa and in 2017 by a group of students from Worcester Polytechnical Institute, Massachusetts, USA.

In 2005 mayor Paolo Costa proposed building an underground subway from Venice's airport on the mainland to the Venetian lagoon, this route is highlighted in white in Figure 21. For this proposal, the Italian government agreed to cost 56% of the project's 343 million euros ($448 million) investment. The rest of the cost would have been financed by private investors (The New York Times). The subway would have cut the travel time to 14 minutes, corresponding to less than half of the time it takes a person to get to Venice by boat. The proposed cost per travel was estimated to be 2 euros for residents and 6 euros for non-residents. Unfortunately, the project didn't move forward toward the next steps (The New York Times).

In 2017, students from Worcester Polytechnical Institute, Massachusetts, USA, also aimed for an underground subway system. As part of their research, they first studied the current routes of the water transportation system and the current parking spots for boats and cars.

Although their research focused on different areas of the current transportation system, they also introduced a new route for a possible underground subway system. Another highlight of their study was the creation of an online application for boat drivers/owners to reserve a parking spot. The web-based application was designed to allow boat owners to register, reserve, and pay for a boat parking spot in

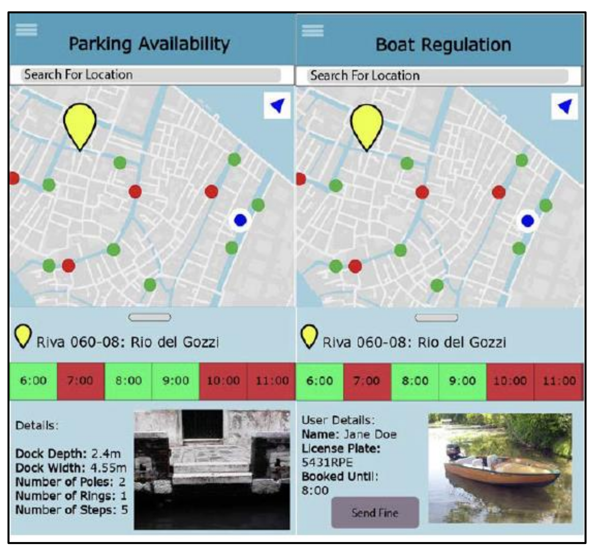


Figure 19: User view and Enforcement view of boat parking app (Bonina 2017)

advance, decreasing water congestion (Bonina et al., 2017). Figure 19 shows a preview of the online application.

As part of their research, they also provided another venue to solve the problem of congestion and traffic. The students proposed a new route for the subway system and calculated the estimate time of travel. As shown in Figure 22 the new route would go from Lido to the Piazzale Roma. This route is highlighted in red in Figure 21.

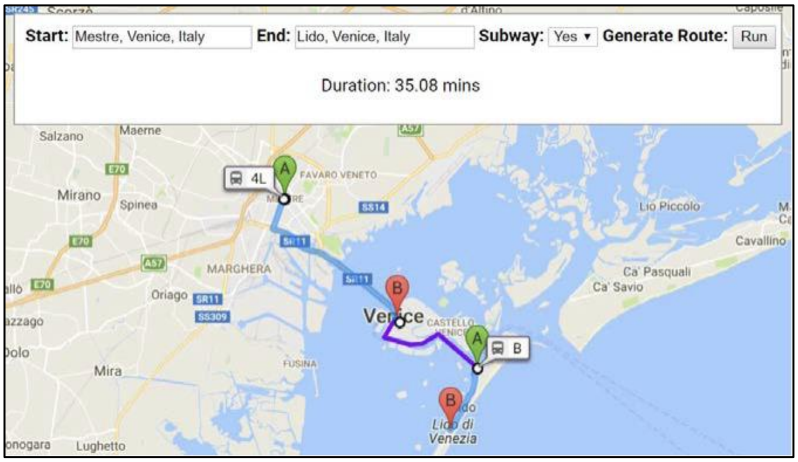


Figure 20: Subway Proposal 2017 (Bonina 2017)

According to their study, creating a subway system in Venice would cost about €201 million per kilometer. Only the route from Lido to Piazzale Roma is estimated at approximately €1.4 billion, and the extension from Piazzale Roma to Mestre could cost around €1.5 billion. (Bonina et. al., 2017).

Based on what has been proposed in the past, I created a new route for the underground tunnel. Figure 21 shows the map of Venice along with the routes that have been presented throughout the last decades.

Figure 21: Underground Subway System Routes throughout the Years (Villalobos 2022)

The 2022 proposal includes an underwater double-side tunnel that will go from the mainland to the historic city. Figure 22 shows the diagram of a cross section underground tunnel. (Bergsma, 1970).

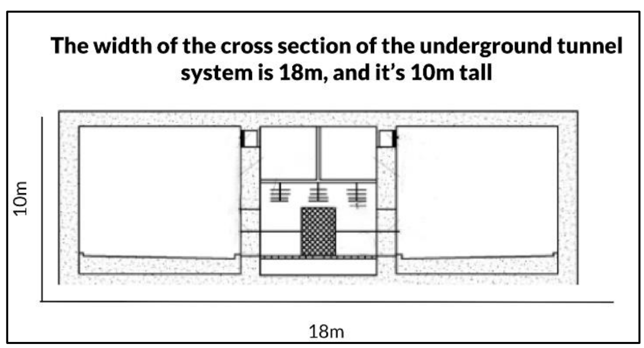


Figure 22: Diagram of a cross section of the underground tunnel system (Bergsma 1970)

Based on my research and comparing all different proposals, I came up with a route that would potentially transport passengers and cargo around the city, to Murano, to Lido, to the Marco Polo Airport and San Giuliano, as shown in figure 23. My final objective is to visualize an underground subway system and calculate the estimated cost of construction.

My proposal was reviewed during a focus group, and I received feedback from SmartDest researchers who recommended breaking the project into phases. One of the reasons for dividing the project was to prioritize the needs of residents and commuters before tourists. Creating the connection to the Marco Polo Airport would facilitate the transportation of tourists instead of the residents. Based on the feedback, I modified my proposal to be developed in phases. Figure 23 shows the color of the different stage codes. Red represents the first phase, blue represents the second phase, and green represents the project's third phase.

Figure 23: Route of New Underground Tunnel divided into phases. (Villalobos 2022)

Phase 1

This phase includes four stations: Ferrovia/Pzl Roma/Tronchetto, Palanca/Zattere, S.Marco/Giudecca, Sant'Elena/Lido S.M.E, as shown in Figure 25.

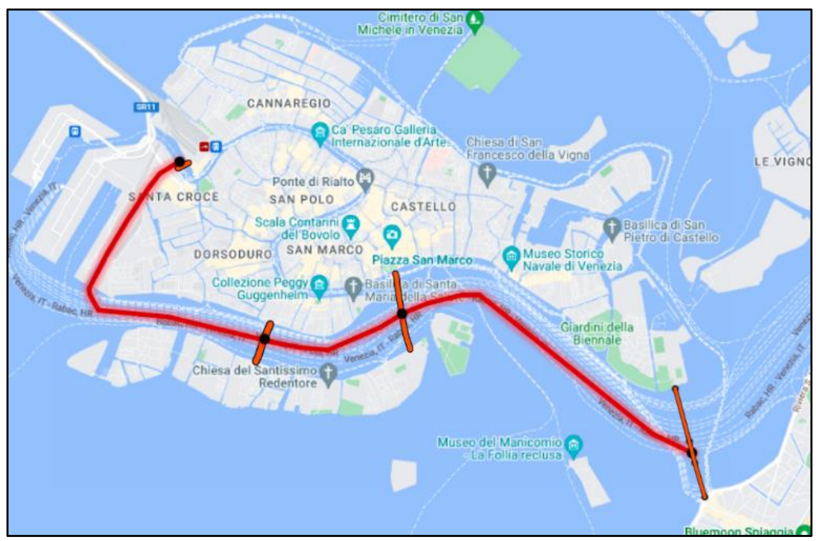


Figure 24: Underground Subway Route for Phase 1. (Villalobos 2022)

These stations will also have an underwater tunnel for pedestrians to walk across the canal. To understand the importance of this new route, I first analyzed the current travel time between Ferrovia and Lido. Figure 25 shows the approximate travel time by boat. To go from Ferrrovia to Lido, using the same route as in Phase 1, currently takes about 36 minutes per Google maps and it is highlighted in green in figure 25. To go from Ferrrovia to Lido using the northside of Venice takes approximately 53 minutes and it is highlighted in gray in figure 25. The new subway system promises that a passenger would get to Lido in around 11 minutes which is half the current time as it is highlighted in green in Table 1. The table also shows the estimated time a person would take to walk in and out of the station.

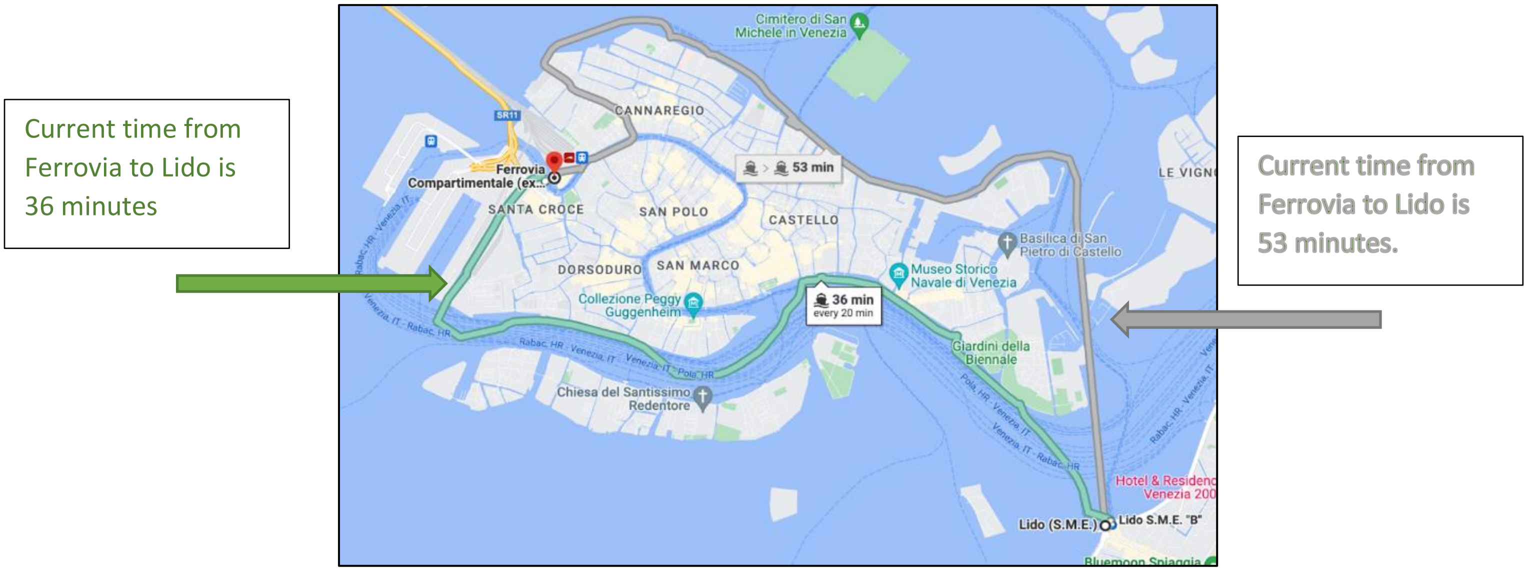


Figure 25: Current Time of Travel by Boat from Two different routes. (Villalobos 2022)

	Train Travel Times Only	1	2	3	4
	To (below) / From (right)	Ferrovia/Pzl Roma/Tronchetto	Palanca/Zattere	S. Marco/ Giudecca	Sant'Elena/Lido S.M.E.
1	Ferrovia/Pzl Roma/Tronchetto	0.0	4.0	7.0	11.0
2	Palanca/Zattere	4.0	0.0	3.0	8.0
3	S. Marco/ Giudecca	7.0	3.0	0.0	5.0
4	Sant'Elena/Lido S.M.E.	11.0	8.0	5.0	0.0

Average Walking Speed	1.42	m/s

	Walking Times Only	560.629	288.412	580.011	854.199
Access Tunnel Length (m)	To (below) / From (right)	Ferrovia/Pzl Roma/Tronchetto	Palanca/Zattere	S. Marco/ Giudecca	Sant'Elena/Lido S.M.E.
560.629	Ferrovia/Pzl Roma/Tronchetto	14.0	10.0	14.0	17.0
288.412	Palanca/Zattere	10.0	7.0	11.0	14.0
580.011	S. Marco/ Giudecca	14.0	11.0	14.0	17.0
854.199	Sant'Elena/Lido S.M.E.	17.0	14.0	17.0	21.0

Table 1: Estimated Time of Travel by Train. Phase 1 (Villalobos 2022).

To calculate the cost of construction on an underground subway system, I used the equations from the 2017 IQP proposal as a reference for the new estimate. Although these calculations have been modified with the current labor rates found in Ychart (Ychart, (n.d.)), further research must be necessary to add the increased of materials prices for future reference.

As stated before, the tunnel's construction will be divided into three phases. After receiving feedback from the focus group, members agreed to have the project structured in different stages. Members of the focus group suggested having the first phase route go around Venice as shown in figure 26 before creating a connection to Murano and the Airport. Having the subway directly connected to the airport would favor residents less than tourists. Based on the feedback received, new calculations specifically for the tunnel's first, second, and third phases were assessed using the two different types of methods which are the Boring Machine and the Immersed Tunnel method.

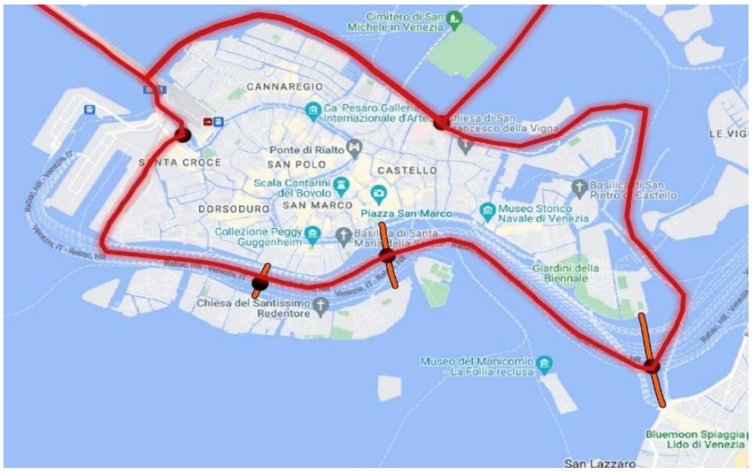


Figure 26: Route for underground subway (Villalobos 2022)

Figure 27 shows the outbound route for phase 1 and the time of travel between each stop.

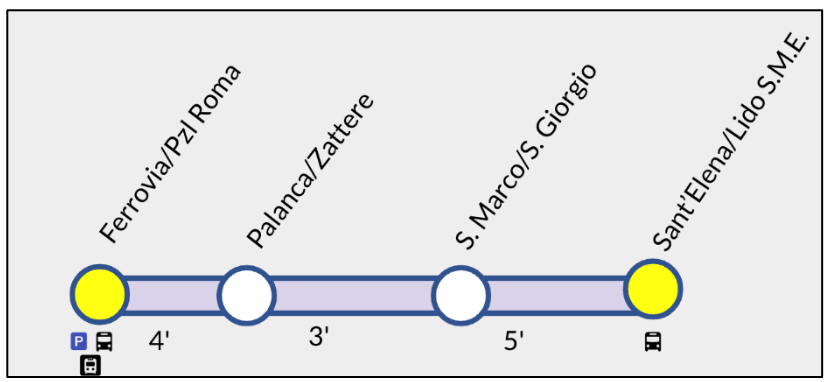


Figure 27: Outbound route for Phase 1 (Villalobos 2022)

Construction Cost Phase 1

a. The Boring Machine Method Cost Phase 1.

The boring machine is used to excavate tunnels with a circular cross section (Tunnel boring machine (n.d.)). This type of method bores through the rocks by using the disc cutters mounted in the cutter head and produces a smooth tunnel wall at the same time.

Other countries worldwide have used this method; Table 2 shows a comparison table of costs between other projects. These projects are the Berlin Subway System extension, the Naples Line 6 Extension, The Amsterdam North-South Line, The Copenhagen Circle Line, and the Paris Metro Line 14 (Bonina et al., 2017). Although I used the same format presented in the 2017 proposal, my calculations and estimates are based on the labor rates from 2022 (Ychart, (n.d.)). Using the chart of comparison, I was able to conclude that the construction cost for Phase 1 will be around €2 Billion, highlighted in green in Table 2.

Proposal	**Subway System through Venice Phase-1**									
Link	http://www.nytimes.com/2005/02/23/business/veni									
Reference	Berlin Subway System Extension		Naples Line 6 Extension		Amsterdam North-South Line		Copenhagen Circle Line		Paris Metro Line 14	
Link	http://www.spiegel.de/international/germany/14-yea		http://www.railwaygazette.com/n		https://pedestrianobservations.co		http://www.railwaygazette.com/nev		https://pedestrianobservations.com	
C_j	€320,000,000.00	euro	€107,000,000.00	euro	€3,100,000,000.00	euro	€3,100,000,000.00	euro	€1,130,000,000.00	euro
1+f	1.0133		1.014285752		1.0133		1.012903873		1.013794276	
p-j	8	years	10	years	8	years	7	years	24	years
L_p	102.8		102.8		102.8		102.8		102.8	
L_j	110.3		102.8		104.6		108.3		104.9	
Length of Track	9.018583	km	9.018583	km	9.018583	km	9.018583	km	9.018583	
Length of Access Tunnels / 2	1.1416255	km	1.1416255	km	1.1416255	km	1.1416255	km	1.1416255	km
Length of Original Facility	1.8	km	1.9	km	9.5	km	15.5	km	9	km
Cost of Track and Stations	*€1,661,046,995.86*	*euro*	*€585,290,847.51*	*euro*	*€3,215,039,872.23*	*euro*	*€1,872,882,719.51*	*euro*	*€1,541,657,509.62*	*euro*
Cost of Access Tunnels	*€210,265,138.90*	*euro*	*€74,089,572.21*	*euro*	*€406,978,735.09*	*euro*	*€237,080,555.90*	*euro*	*€195,152,112.61*	*euro*
Total Cost	*€1,871,312,134.76*	*euro*	*€659,380,419.72*	*euro*	*€3,622,018,607.32*	*euro*	*€2,109,963,275.41*	*euro*	*€1,736,809,622.23*	*euro*
# of stations	3						17			
Cost per km	177777777.8		56315789.47		326315789.5		200000000		125555555.6	
cost per million/km	177.8		56.3		326.3		200		125.6	

	Track and Stations	Access Tunnels	*Total*	Cost per km
Avg.	€1,775,183,588.94	€224,713,222.94	*€1,999,896,811.89*	€177,192,982.46
Min.	€585,290,847.51	€74,089,572.21	*€659,380,419.72*	€56,315,789.47
Max.	€3,215,039,872.23	€406,978,735.09	*€3,622,018,607.32*	€326,315,789.47
Value to use	*€1,817,000,000.00*	*€230,000,000.00*	***€2,047,000,000.00***	€182,000,000.00

Table 2: Cost of Phase 1 using the Boring Machine Method. (Villalobos 2022)

b. Immersed Tunnel Method Cost Phase 1

For this method, I also created a comparison chart with the cost of construction from different projects around the world. Table 3 shows the cost to develop an underground tunnel using the Immersed Tunnel Method in Marmaray, Izmir, and Fehmarnbelt, and the last column shows what would it be the cost in Venice. The construction cost for Phase 1 would be approximately €1.9 billion, highlighted in yellow in Table 3.

Projects Comparison Table

Reference	*Marmaray (immersed tube tunnel)*	*Izmir immersed (tube) tunnel*	Fehmarnbelt Tunnel	Venice Proplosal
Distance (Km)	14.00	7.60	18	9
Width (m)	15.3	39.8	42	15
Cost per km	$100,000,000.00	$100,000,000.00	$7,100,000,000.00	$100,000,000.00
tunnel cost	$1,400,000,000.00	$1,976,993,464.05	-	$882,352,941.18
Length of Access Tunnels / 2	-	-	-	1.1416255
Cost of Track and Stations	0	0.00	0.00	994,277,009.80
train cost	-	-	-	€16,000,000.0
Extra cost	$1,100,000,000.00	$1,100,000,000.00	-	$813,842,105.00
Total Cost (US)	$2,500,000,000.00	$3,076,993,464.05	7000000000	$1,824,119,115
Total cost Eruro		*€2,943,062,500.00*	€7,000,000,000.00	*€1,898,750,000*

Table 3: Comparison Table for the Cost of the Marmaya, Izmir, Fehmarnbelr and Venice Projects. Venice Phase 1 (Villalobos 2022)

Phase 2

Phase 2 includes three additional stations. As shown in figure 28, the train would go from Sant'Elena/Lido S.M.E. to Ospedale/F.te Nove. From Ospedale/F.te Nove to Murano. The final stop would be at the Marco Polo Airport. Then the train would loop back to Ferrovia/Pzl Roma/Tronchetto.

Currently, a boat takes one hour and 6 minutes, per Google maps to get to the airport if it follows the same route, as shown in Figure 29. This route would make the entry to the historical city more accessible to tourists. But it would also benefit medical professionals to arrive at the hospital faster. Other residents and commuters, especially airport employees, would also find this route very beneficial.

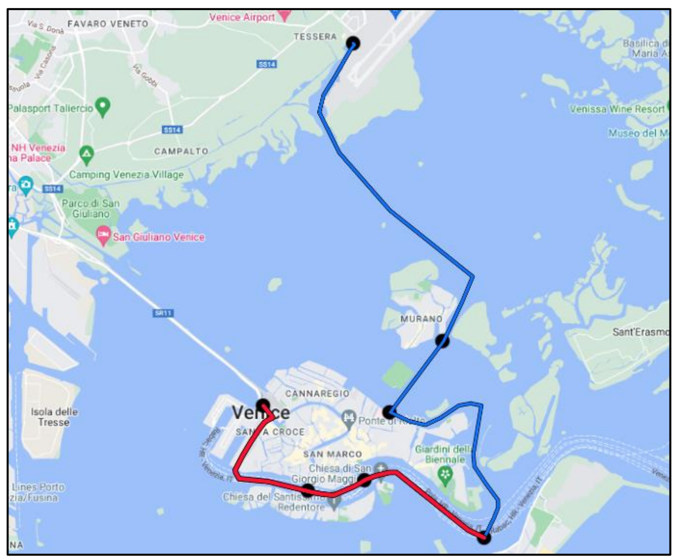


Figure 28: Underground Subway Route Phase 2. (Villalobos 2022)

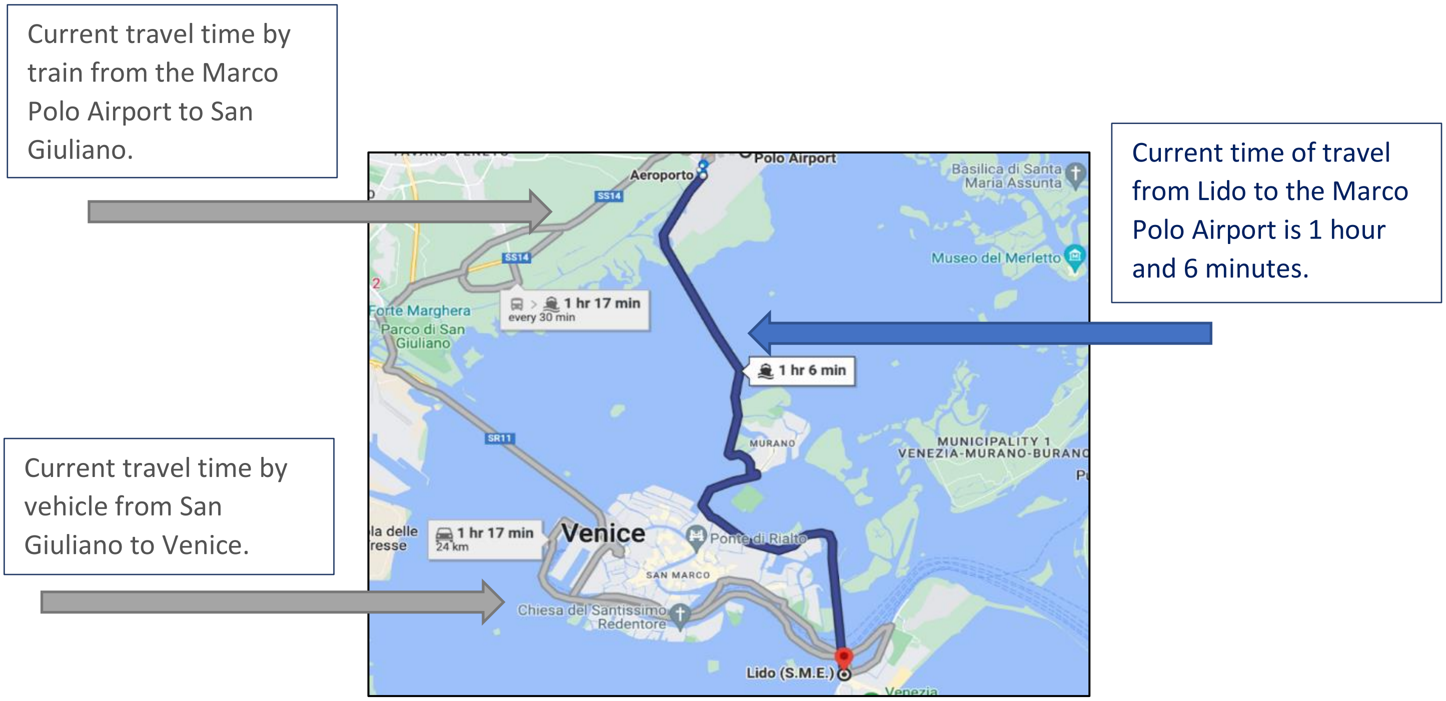


Figure 29: Current Travel Time by Boat. (Villalobos 2022)

The new underground subway system promises to impact travel time significantly. Table 4 shows the calculations for the estimated time of travel to the new stations at Ospedale, Murano and Marco Polo Airport these are highlighted in green. A passenger from the first station in Ferrovia would arrive at the airport in 26 minutes, highlighted in red. Compared to the current system, there's a difference of approximately 40 minutes.

	Train Travel Times Only	1	2	3	4	5	6	7
	To (below) / From (right)	Ferrovia/Pzl Roma/Tronchetto	Palanca/Zattere	S. Marco/ Giudecca	Sant'Elena/Lido S.M.	Ospedale/F.te Nove	Murano	AEROPORTO M:POLO
1	Ferrovia/Pzl Roma/Tronchetto	0.0	4.0	7.0	11.0	17.0	20.0	26.0
2	Palanca/Zattere	4.0	0.0	3.0	8.0	13.0	16.0	22.0
3	S. Marco/ Giudecca	7.0	3.0	0.0	5.0	10.0	13.0	19.0
4	Sant'Elena/Lido S.M.E.	11.0	8.0	5.0	0.0	6.0	9.0	15.0
5	Ospedale/F.te Nove	17.0	13.0	10.0	6.0	0.0	4.0	10.0
6	Murano	20.0	16.0	13.0	9.0	4.0	0.0	7.0
7	AEROPORTO M:POLO	26.0	22.0	19.0	15.0	10.0	7.0	0.0

Average Walking Speed 1.42 m/s

	Walking Times Only	560.629	288.412	580.011	854.199	100	151.684	100
Access Tunnel Length (m)	To (below) / From (right)	Ferrovia/Pzl Roma/Tronchetto	Palanca/Zattere	S. Marco/ Giudecca	Sant'Elena/Lido S.M.	Ospedale/F.te Nove	Murano	AEROPORTO M:POLO
560.629	Ferrovia/Pzl Roma/Tronchetto	14.0	10.0	14.0	17.0	8.0	9.0	8.0
288.412	Palanca/Zattere	10.0	7.0	11.0	14.0	5.0	6.0	5.0
580.011	S. Marco/ Giudecca	14.0	11.0	14.0	17.0	8.0	9.0	8.0
854.199	Sant'Elena/Lido S.M.E.	17.0	14.0	17.0	21.0	12.0	12.0	12.0
100	Ospedale/F.te Nove	8.0	5.0	8.0	12.0	3.0	3.0	3.0
151.684	Murano	9.0	6.0	9.0	12.0	3.0	4.0	3.0
100	AEROPORTO M:POLO	8.0	5.0	8.0	12.0	3.0	3.0	3.0

Table 4: Estimated Time of Travel by Train. Phase 2. (Villalobos 2022).

Table 4 also shows a person's time to walk in and out of the stations. It provides the estimated time of travel between each station starting from zero. For example, the first table shows that the train would take 4 minutes to go from Ospedale to Murano and then seven minutes from Murano to the airport. The time also includes 20 seconds stop for passengers to enter and exit the train.

One of the suggestions I received during the focus group was that since the train makes a stop in Ospedale, it wouldn't make sense that the train wouldn't have the possibility to continue its journey around the historical city instead of looping back. Therefore, an extension to phase 2 was later added. Figure 30 shows how from Ospedale the train would continue up north until it returns to the station in Ferrovia.

As shown in Table 5, the total distance that the train will conduct to go around the historical city is 19416.82 meters highlighted in yellow, at an acceleration of 20 m/s^2. The estimated time of travel for the trip would be 20 minutes, highlighted in green.

Figure 30: Extension of Phase 2, Connection with the Ferrovia Station. (Villalobos 2022).

	Station	Distance (m)	Arrival Time (minutes)	Departure Time (minutes)	Arrival Time (s)	Departure Time (s)	ADD distance
1	Ferrovia/Pzl Roma/Tronchetto	0	0.0	0.0	0	0	-
2	Palanca/Zattere	3712.9	3.8	4.1	229	249	-
3	S. Marco/ Giudecca	5378.2	6.7	7.0	402	422	-
4	Sant'Elena/Lido S.M.E.	9018.583	10.8	11.1	649	669	-
5	Ospedale/F.te Nove	15191.344	16.1	16.4	964	984	-
1.1	Ferrovia/Pzl Roma/Tronchetto 1.1	19416.82	20.5	20.8	1228	1248	4225.476

Station	Distance (m)	Arrival Time (minutes)	Departure Time (minutes)	Arrival Time (s)	Departure Time (s)
Ferrovia/Pzl Roma/Tronchetto 1.1	0	0.0	0.0	0	0
Ospedale/F.te Nove	4225.476	4.1	4.4	244	264
Sant'Elena/Lido S.M.E.	10398.237	9.3	9.7	559	579
S. Marco/ Giudecca	14038.62	13.4	13.8	806	826
Palanca/Zattere	15703.92	16.3	16.7	979	999
Ferrovia/Pzl Roma/Tronchetto	19416.82	20.5	20.8	1228	1248

Time in Station (s)	20	https://hypertextbook.com/facts/2006/subwaydoors.shtml
Acceleration	0.787	m/s^2
Total Distance Km	4.225476	

Table 5: Estimated Time of Travel by Train. Phase 2 Extension (Villalobos 2022).

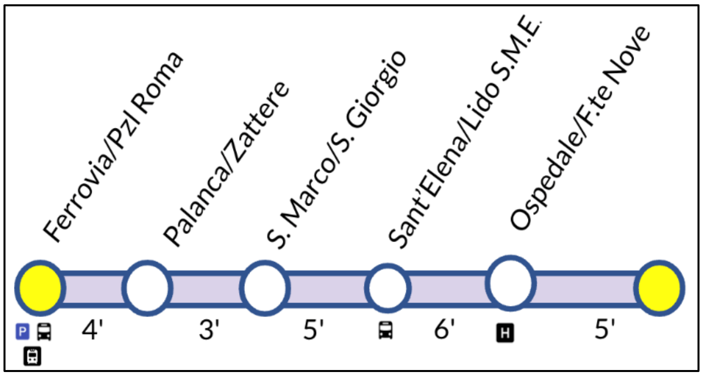


Figure 31: Outbound route for phase 2 new underground subway system (Villalobos 2022).

Figure 31 shows the outbound route for phase 2 and the time of travel between each stop.

Construction Cost Phase 2

a. The Boring Machine Method Cost Phase 2.

The cost of construction for phase 2 using the Boring Machine Method will be around €4.3 billion highlighted in green in Table 6. I used the same comparison chart from phase 1 to calculate the new cost and I modified the distance of the new route, as shown in Figure Table 6.

Proposal	**Subway System through Venice Phse-2**									
Link	http://www.nytimes.com/2005/02/23/business/veni									
Reference	Berlin Subway System Extension		Naples Line 6 Extension		Amsterdam North-South Line		Copenhagen Circle Line		Paris Metro Line 14	
Link	http://www.spiegel.de/international/germany/14-yea		http://www.railwaygazette.com/n		https://pedestrianobservations.co		http://www.railwaygazette.com/nev		https://pedestrianobservations.com	
C_j	€320,000,000.00	euro	€107,000,000.00	euro	€3,100,000,000.00	euro	€3,100,000,000.00	euro	€1,130,000,000.00	euro
1+f	1.0133		1.014285752		1.0133		1.012903873		1.013794276	
p-j	8	years	10	years	8	years	7	years	24	years
L_p	102.8		102.8		102.8		102.8		102.8	
L_j	110.3		102.8		104.6		108.3		104.9	
Length of Track	21.099866	km	21.099866	km	21.099866	km	21.099866	km	21.099866	km
Length of Access Tunnels / 2	0.125842	km	0.125842	km	0.125842	km	0.125842	km	0.125842	km
Length of Original Facility	1.8	km	1.9	km	9.5	km	15.5	km	9	km
Cost of Track and Stations	*€3,886,183,564.80*	*euro*	*€1,369,345,766.78*	*euro*	*€7,521,903,439.68*	*euro*	*€4,381,794,170.47*	*euro*	*€3,606,860,065.58*	*euro*
Cost of Access Tunnels	*€23,177,640.66*	*euro*	*€8,166,933.86*	*euro*	*€44,861,487.40*	*euro*	*€26,133,518.67*	*euro*	*€21,511,723.55*	*euro*
Total Cost	*€3,909,361,205.47*	*euro*	*€1,377,512,700.64*	*euro*	*€7,566,764,927.08*	*euro*	*€4,407,927,689.14*	*euro*	*€3,628,371,789.13*	*euro*
# of stations	3						17			
Cost per km	177777777.8		56315789.47		326315789.5		200000000		125555555.6	
cost per million/km	177.8		56.3		326.3		200		125.6	

	Track and Stations	Access Tunnels	*Total*	cost per km
Avg.	€4,153,217,401.46	€24,770,260.83	*€4,177,987,662.29*	177192982.5
Min.	€1,369,345,766.78	€8,166,933.86	*€1,377,512,700.64*	56315789.47
Max.	€7,521,903,439.68	€44,861,487.40	*€7,566,764,927.08*	326315789.5
Value to use	*€4,251,000,000.00*	*€25,000,000.00*	***€4,276,000,000.00***	182000000

Table 6: Cost of Phase 2 using the Boring Machine Method. (Villalobos 2022).

b. Immersed Tunnel Method Cost Phase 2.

For Phase 2, I calculated the cost using the same data from Table 3. I added the additional cost for the extension to the station at the hospital, the station at Murano, and its final destination to the station at the Marco Polo airport. The total cost of the new additional stations will be around €4 billion highlighted in yellow in Table 7.

Reference	*Marmaray (immersed tube tunnel)*	*Izmir immersed (tube) tunnel*	Fehmarnbelt Tunnel	Venice Proplosal
Distance (Km)	14.00	7.60	18	21
Width (m)	15.3	39.8	42	15
Cost per km	$100,000,000.00	$100,000,000.00	$7,100,000,000.00	$100,000,000.00
tunnel cost	$1,400,000,000.00	$1,976,993,464.05	-	$2,058,823,529.41
Length of Access Tunnels / 2	-	-	-	0.4245205
Cost of Track and Stations	0	0.00	0.00	2,100,443,186.27
train cost	-	-	-	€16,000,000.0
Extra cost	$1,100,000,000.00	$1,100,000,000.00	-	1.80E+09
Total Cost	$2,500,000,000.00	$3,076,993,464.05	7000000000	$3,921,074,765
		€2,943,062,500.00	€7,000,000,000.00	*€4,051,062,250*

Table 7: Comparison Table for the Cost of the Marmaya, Izmir, Fehmarnbelr and Venice Projects. Venice Phase 2 (Villalobos 2022)

Phase 3

The third phase will include a station at San Giuliano. This route is important because the city of San Giuliano also has a public parking lot for those who commute to Venice. Some people prefer to drive through the bridge to get to Venice and use the parking lot in Tronchetto. By having a station in San Giuliano, the traffic in the bridge will be reduce as well as the number of vehicles in the parking lot in Tronchetto since the underground train will have connections to different parts in Venice. Figure 32 shows in green the route of the third phase in the mainland.

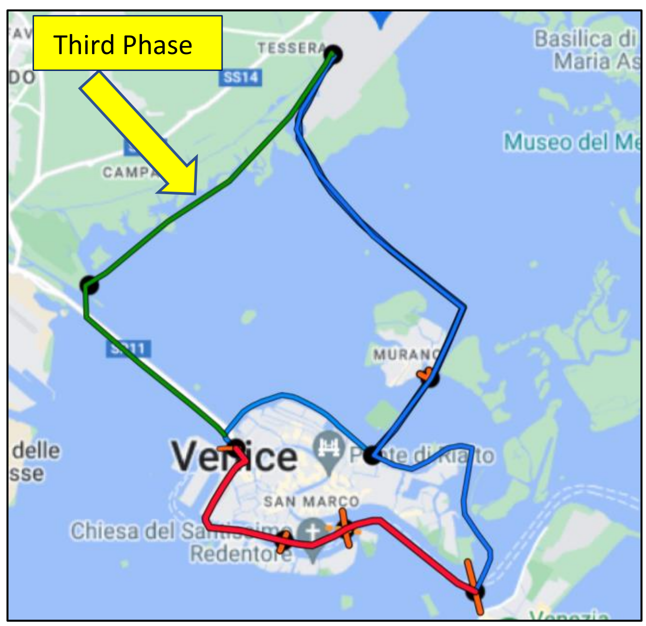
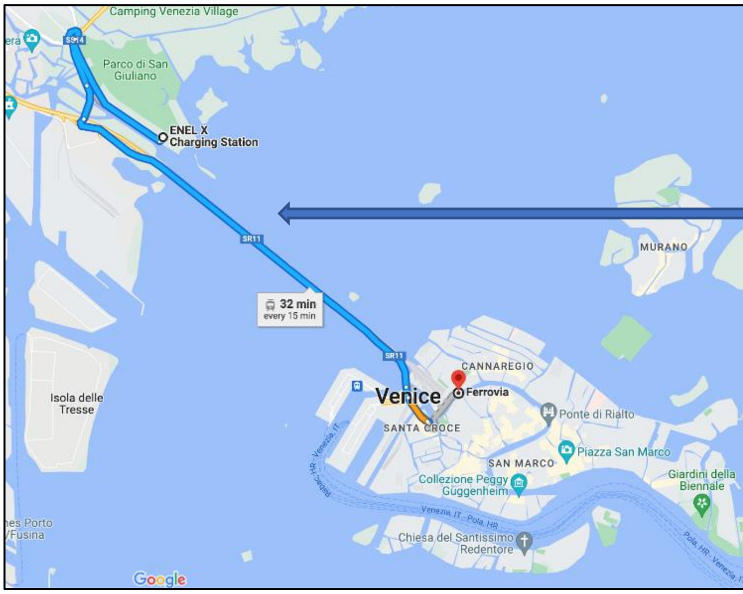


Figure 32: Underground Subway Route Phase . (Villalobos 2022)

Currently a vehicle takes around 32 minutes per Google maps to get from San Giuliano in the mainland to Ferrovia in Venice as shown in Figure 33. The new subway system promises to decrease the travel of time to around 3.9 minutes highlighted in yellow in Table 8. The approximate acceleration is 0.787 m/s^2.



The current time of travel by vehicle from San Giuliano to Venice is 32 minutes.

Figure 33: Current Travel Time by vehicle from San Giuliano to Venice is 32 minutes (Villalobos 2022).

	Station	Distance (m)	Arrival Time (minutes)	Departure Time (minutes)	Arrival Time (s)	Departure Time (s)	Add dista pahse
1	Ferrovia/Pzl Roma/Tronchett	0	0.0	0.0	0	0	-
2	Palanca/Zattere	3712.9	3.8	4.1	229	249	-
3	S. Marco/ Giudecca	5378.2	6.7	7.0	402	422	-
4	Sant'Elena/Lido S.M.E.	9018.583	10.8	11.1	649	669	-
5	Ospedale/F.te Nove	15191.344	16.1	16.4	964	984	-
6	Murano	17472.863	19.4	19.7	1164	1184	-
7	AEROPORTO M:POLO	27184.973	25.9	26.2	1554	1574	-
8	San Giuliano	33230.573	31.1	31.4	1866	1886	6045.6
9	Ferrovia/Pzl Roma/Tronchett	37059.973	35.3	35.6	2119	2139	3829.4

Station	Distance (m)	Arrival Time (minutes)	Departure	Arrival Time	Departure
Ferrovia/Pzl Roma/Tronchett	0	0.0	0.0	0	0
San Giuliano	3829.4	3.9	4.2	233	253
AEROPORTO M:POLO	9875	9.1	9.1	545	545
Murano	19587.11	15.3	15.4	916	926
Ospedale/F.te Nove	21868.629	18.4	18.4	1105	1105
Sant'Elena/Lido S.M.E.	28041.39	23.3	23.3	1400	1400
S. Marco/ Giudecca	31681.773	27.1	27.1	1627	1627
Palanca/Zattere	33347.073	29.7	29.7	1780	1780
Ferrovia/Pzl Roma/Tronchett	37059.973	33.5	33.5	2009	2009

Time in Station (s) 20 https://hypertextbook.com/facts/2006/subwaydoors.shtml

Acceleration 0.787 m/s^2

Total Distance (Km) 9.875

Table 8: Time of Travel for Phase 3. (Villalobos 2022)

Table 9 shows the estimated time of travel with the additional stations at the Marco Polo Airport, San Giuliano and back to Ferrovia which are higlighted in green. Table 9 also shows the estimated time a person would take to walk in and out of the station.

Train Travel Times Only

		1	2	3	4	5	6	7	8	9
	To (below) / From (right)	Ferrovia/Pzl Roma/Tronchetto	Palanca/Zattere	S. Marco/ Giudecca	Sant'Elena/Lid	Ospedale/F.te Nov	Murano	AEROPORTO M:POLO	San Giuliano	Stazioni Santa Lucia
1	Ferrovia/Pzl Roma/Tronchetto	0.0	4.0	7.0	11.0	17.0	20.0	26.0	32.0	36.0
2	Palanca/Zattere	4.0	0.0	3.0	8.0	13.0	16.0	23.0	28.0	32.0
3	S. Marco/ Giudecca	7.0	3.0	0.0	5.0	10.0	13.0	20.0	20.0	20.0
4	Sant'Elena/Lido S.M.E.	11.0	8.0	5.0	0.0	6.0	9.0	16.0	16.0	16.0
5	Ospedale/F.te Nove	17.0	13.0	10.0	6.0	0.0	4.0	10.0	10.0	10.0
6	Murano	20.0	16.0	13.0	9.0	4.0	0.0	7.0	7.0	7.0
7	AEROPORTO M:POLO	26.0	23.0	20.0	16.0	10.0	7.0	0.0	6.0	10.0
8	San Giuliano	32.0	28.0	25.0	21.0	16.0	12.0	6.0	0.0	5.0
9	Ferrovia/Pzl Roma/Tronchetto1.1	36.0	32.0	29.0	25.0	20.0	16.0	10.0	5.0	0.0

Average Walking Speed 1.42 m/s

Walking Times Only

		100	288.412	580.011	854.199	100	151.684	100		
	To (below) / From (right)	Ferrovia/Pzl Roma/Tronchetto	Palanca/Zattere	S. Marco/ Giudecca	Sant'Elena/Lid	Ospedale/F.te Nov	Murano	AEROPORTO M:POLO	San Giuliano	Ferrovia/Pzl Roma/Tr
485.629	Ferrovia/Pzl Roma/Tronchetto	7.0	10.0	13.0	16.0	7.0	8.0	7.0	6.0	6.0
288.412	Palanca/Zattere	5.0	7.0	11.0	14.0	5.0	6.0	5.0	4.0	4.0
580.011	S. Marco/ Giudecca	8.0	11.0	14.0	17.0	8.0	9.0	8.0	7.0	7.0
854.199	Sant'Elena/Lido S.M.E.	12.0	14.0	17.0	21.0	12.0	12.0	12.0	11.0	11.0
100	Ospedale/F.te Nove	3.0	5.0	8.0	12.0	3.0	3.0	3.0	2.0	2.0
151.684	Murano	3.0	6.0	9.0	12.0	3.0	4.0	3.0	2.0	2.0
100	AEROPORTO M:POLO	3.0	5.0	8.0	12.0	3.0	3.0	3.0	2.0	2.0
100	San Giuliano	3.0	5.0	8.0	12.0	3.0	3.0	3.0	2.0	2.0
0	Ferrovia/Pzl Roma/Tronchetto1.1	2.0	4.0	7.0	11.0	2.0	2.0	2.0	0.0	0.0

Table 9: Estimated Time of Travel Between each Station. Phase 3 (Villalobos).

Figure 34 shows the outbound route for phase 3 and the estimated time of travel between each stop.

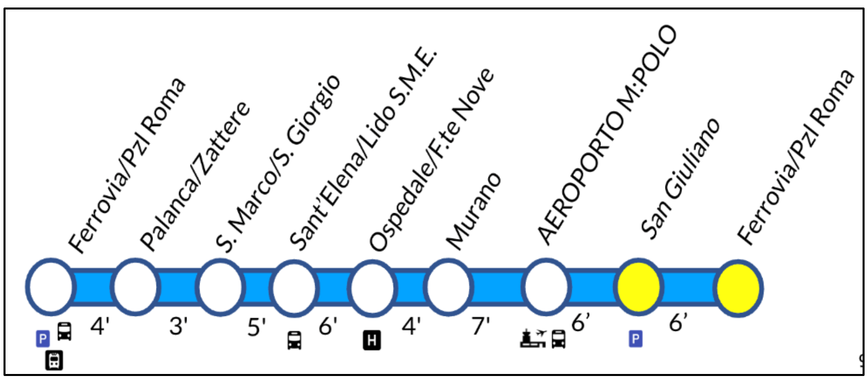


Figure 34: Outbound route for phase 3 new subway system (Villalobos 2022).

Construction Cost Phase 3

a. The Boring Machine Method Cost Phase 3.

The total cost of construction for phase 3 is approximately €2.3 billion highlighted in green in Table 10. This phase includes the connection between the station at the Marco Polo Airport, San Giuliano, and Ferrovia. Table 10 shows the comparison table with the additional kilometers of distance.

Proposal	**Subway System through Venice**									
Link	http://www.nytimes.com/2005/02/23/business/veni									
Reference	Berlin Subway System Extension		Naples Line 6 Extension		Amsterdam North-South Line		Copenhagen Circle Line		Paris Metro Line 14	
Link	http://www.spiegel.de/international/germany/14-yea		http://www.railwaygazette.com/n		https://pedestrianobservations.co		http://www.railwaygazette.com/nev		https://pedestrianobservations.com	
C_j	€320,000,000.00	euro	€107,000,000.00	euro	€3,100,000,000.00	euro	€3,100,000,000.00	euro	€1,130,000,000.00	euro
1+f	1.0133		1.014285752		1.0133		1.012903873		1.013794276	
p-j	8	years	10	years	8	years	7	years	24	years
L_p	102.8		102.8		102.8		102.8		102.8	
L_j	110.3		102.8		104.6		108.3		104.9	
Length of Track	10	km	10	km	10	km	10	km	10	km
Length of Access Tunnels / 2	0.05	km	1.1541255	km	1.1541255	km	1.1541255	km	1.1541255	km
Length of Original Facility	1.8	km	1.9	km	9.5	km	15.5	km	9	km
Cost of Track and Stations	*€1,841,804,855.44*	*euro*	*€648,983,157.89*	*euro*	*€3,564,905,786.45*	*euro*	*€2,076,692,890.12*	*euro*	*€1,709,423,209.41*	*euro*
Cost of Access Tunnels	*€9,209,024.28*	*euro*	*€74,900,801.16*	*euro*	*€411,434,867.32*	*euro*	*€239,676,422.02*	*euro*	*€197,288,891.63*	*euro*
Total Cost	*€1,851,013,879.72*	*euro*	*€723,883,959.05*	*euro*	*€3,976,340,653.78*	*euro*	*€2,316,369,312.14*	*euro*	*€1,906,712,101.03*	*euro*
# of stations	3						17			
Cost per km	177777777.8		56315789.47		326315789.5		200000000		125555555.6	
cost per million/km	177.8		56.3		326.3		200		125.6	

	Track and Stations	Access Tunnels	*Total*	cost per km
Avg.	€1,968,361,979.86	€186,502,001.28	*€2,154,863,981.14*	177192982.5
Min.	€648,983,157.89	€9,209,024.28	*€658,192,182.17*	56315789.47
Max.	€3,564,905,786.45	€411,434,867.32	*€3,976,340,653.78*	326315789.5
Value to use	*€2,015,000,000.00*	*€194,000,000.00*	***€2,209,000,000.00***	182000000

Table 10: Cost of Phase 3 using the Boring Machine Method (Villalobos 2022)

b. Immersed Tunnel Method Cost

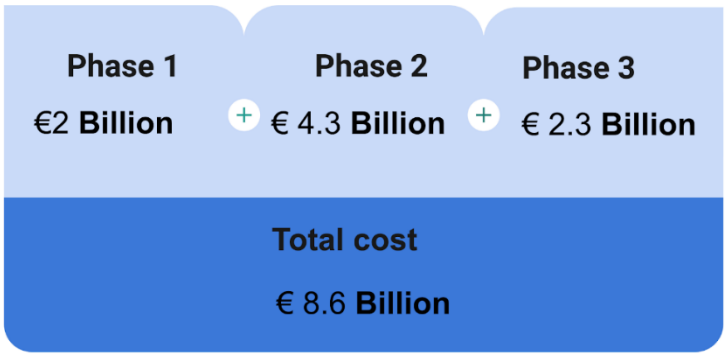
For Phase 3, I added the additional cost for the extension to the station at San Giuliano and then to the station at Ferrovia. The estimated cost of the subway system at its final phase is €1.5 billion which is highlighted in green in Table 11.

Reference	***Marmaray (immersed tube tunnel)***	***Izmir immersed (tube) tunnel***	**Fehmarnbelt Tunnel**	**Venice Proplosal**
Distance (Km)	14.00	7.60	18	10
Width (m)	15.3	39.8	42	15
Cost per km	$100,000,000.00	$100,000,000.00	$7,100,000,000.00	$100,000,000.00
tunnel cost	$1,400,000,000.00	$1,976,993,464.05	-	$980,392,156.86
Length of Access Tunnels / 2	-	-	-	0.05
Cost of Track and Stations	0	0.00	0.00	985,294,117.65
train cost	-	-	-	€0
Extra cost	$1,100,000,000.00	$1,100,000,000.00	-	7.01E+08
Total Cost (US)	$2,500,000,000.00	$3,076,993,464.05	7000000000	$1,686,720,433
Total in Eruro		*€2,943,062,500.00*	€7,000,000,000.0(	*€1,507,840,000*

Table 11: Comparison Table for the Cost of the Marmaya, Izmir, Fehmarnbelr and Venice Projects. Venice Phase 3 (Villalobos 2022).

In total, the project of developing an underground subway system that will go around the historic city with stops at Lido, Murano, the Marco Polo Airport, and San Giuliano will have an approximate cost €8.6 billion by using the Boring Machine Method, as shown in figure 35.

Figure 35: Summary of the Total Construction Cost using the Boring Machine Method. (Villalobos 2022)



The cost of the three phases using the Immersed Tube Tunnel Method will be approximately €7.5 billion, as shown in figure 36.

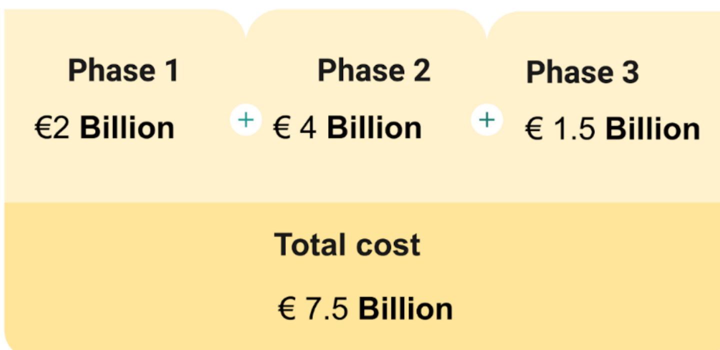


Figure 36: Summary of the Total Cost of Construction using the Immersed Tunnel Method. (Villalobos 2022)

After assesing the cost of both methods the Immersed Tunnel Method is to be considered the less expensive method to develop the underground tunnel. Both methods are effective, as it is shown in other projects around the world but the Boring Machine Method is €1.1 billion more expensive than the Immersed Tunnel Method.

Train Design

Milan has already implemented a subway train system. These trains are known to be driverless. This type of train should be considered for the new subway system in Venice since it has been proven effective and worked in larger cities such as Milan. Figure 37 shows an image of the train.

Figure 37: Train Design (Railway Pro, (n.d))

Underwater Subway Station Design.

The proposed underwater subway will have different stops around the city of Venice. This new system of transportation will offer the possibility of transporting passengers and cargo at the same time. Therefore the proposed station must accommodate the necessary space to load and unload the freight.

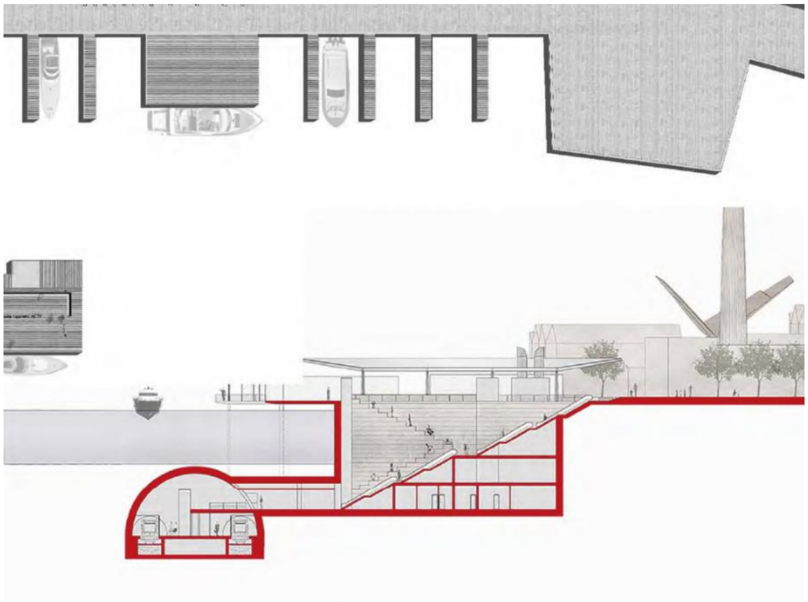


Figure 38: Original design subway station taken from thesis "Una Metropolitana sub-lagunare per Venezia" (Universita luav di Venezia 2008)

Figure 38 shows the original design for an underground station in Santa Marta, Venice. The architectural design has been published in the book "Una Metropolitana sub-lagunare per Venezia" from the univeristy Universita luav di Venezia. The structure's surface offers a theatrical look, and from inside, the station accommodates the transit of the twin trains but only has one pedestrian access to the subway. (Universita luav di Venezia 2008). Based on the design from the Universita luav di Venezia, I am proposing a two side entry station with the option to transport cargo. The idea of having two sides is to expand the station and offer greater accessibility. Figure 39 shows a sketch of this new proposal to combine cargo and passenger transportation. The idea is that while passengers depart or arrive, cargo could also be loaded or unloaded. The shipment will be placed in racks and transported up to the surface using an industrial forklift or elevator. The packages will then be placed or stored at the warehouse before starting the delivery.

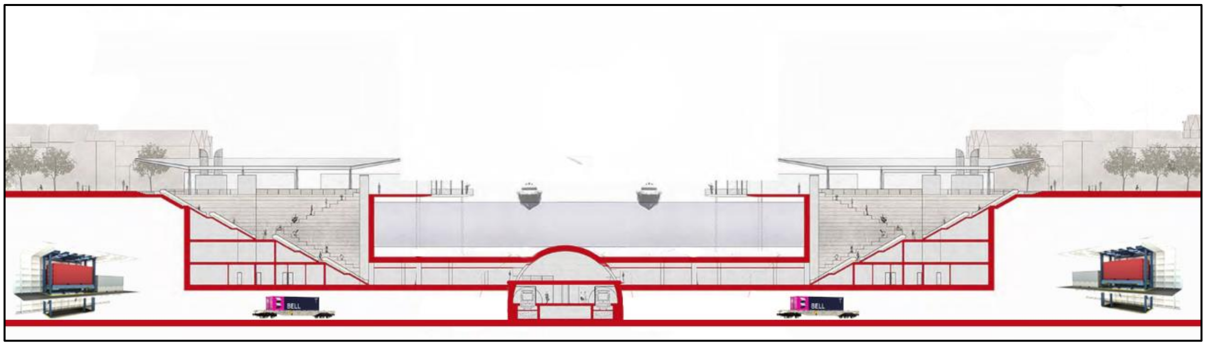


Figure 39: Design of the new station with two pedestrian connections. Adapted from the original design of the thesis "Una Metropolitana Sub-lagunare per Venezia" (Villalobos 2022).

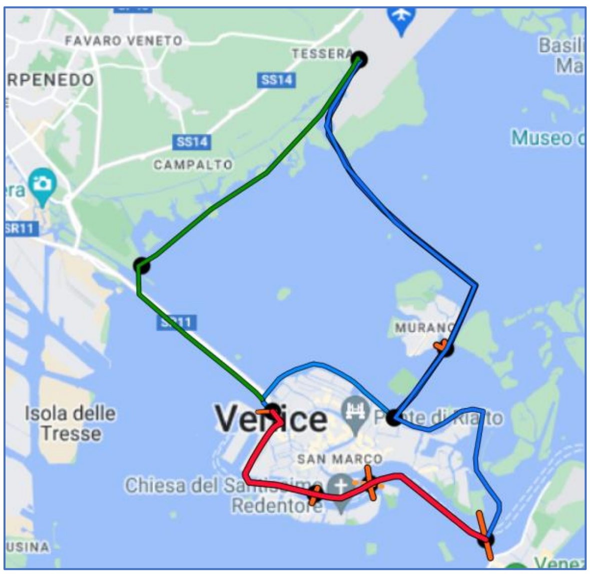


Figure 40: Route for underground subway. First proposal (Villalobos 2022).

Only certain stations will have the two pedestrian connections. Other stations will only have one side of the pedestrian entry. Figure 40 shows in red the stations with two pedestrian entries.

Conclusion

The historic city of Venice has become one of the most popular places to visit in Italy. Its unique geography and architecture make it attractive for many tourists, but Venice is also the home of many residents who appreciate the beauty of its surroundings and deserve a great place to live.

As a result of improving the quality of life of many residents and commuters of the historic city, I worked on developing a new proposal for an underwater subway transportation system in the lagoon. One of the most common problems Venetians face daily is the high boat traffic. Also, the transportation of goods and packages takes longer than it would take on the mainland. Another problem is the deterioration of the buildings due to Moto Ondoso, which is the turbulence wake force caused by motorboats. One solution to this problem is to reduce the number of boats in the canal. The subway system promises to reduce the number of boats and the money the city is currently paying to fix the damages on the canal walls (Bennet, 2013).

This paper has described the inefficiencies and the delays with the current transportation system. For example, for a passenger to go from Ferrovia to Lido, it will take about 36 minutes to arrive at their destination. The new underwater subway system will transport a passenger from Ferrovia to Lido in approximately 11 minutes.

SmartDest researchers also reviewed my proposal and suggested dividing the project into three phases. I visualized the routes for Phase 1, Phase 2, and Phase 3, along with their stops at each popular destination. I also calculated the construction cost for each phase using two different methods. The method that resulted in being the less expensive was the Immersed Tunnel method, with a total cost of approximately €7.5 billion, but further research should assess the tons of cargo the train could transport along with the passengers.

Based on what has been proposed in the past, the idea of having a *sublagunare* in the historic city of Venice is possible but it will require a significant investment from the city.

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