Urban Maintenance And Venetian Accessibility

An Interactive Qualifying Project
Submitted to the faculty of
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Authorship

This project was completed through equal contribution of all group members of the Urban Maintenance Venice Project Team. The completed book chapters were evenly divided with full team editing, reviewing, and guidance. Unless cited, the material outlined in this report and book chapters are the original work of the team.

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Abstract

The purpose of this project was to review the history and progress of urban maintenance in preparation for the Venice Project Center's 20th anniversary. Due to language barriers, knowledge about Venetian infrastructure and maintenance is largely unavailable to people outside of Italy, thus our primary focus was to produce a collection of chapters highlighting the most important aspects of urban maintenance for an English-based publication on Venice. Once this information was collected, the team explored new ways in which the data could be used to benefit the people of Venice, specifically those with mobility impairments.

As part of additional research, this project assessed the state of Island Accessibility. Inspired by the efforts of Comune di Venezia[1] and Accessible Venice[2], a Geographical Information System (GIS) map layer was created displaying each island's accessibility. This dynamic map included hotlinks for handicap itineraries provided by Accessible Venice and a color-code system to distinguish accessible vs. inaccessible islands as well as temporarily accessible islands. This interactive map, if made available on the Internet will allow each individual to access information on areas of accessibility throughout the island. This will aid in informing viewers on the resources available for mobility impaired travel.

Pedestrian traffic counts were performed and a Bridge Accessibility fieldwork form for future mobility studies was produced to analyze the impediment that bridges cause. Although tests were only performed to decide the feasibility of continuing a larger scale study of this project, initial results showed that on one island tested, 4.9% of Venetian pedestrians had mobility impairments. Specific problems and setbacks that were encountered were noted during testing in order to recommend a more accurate study be completed by future groups. A larger scale study would be completed to make assessments on areas where mobility impaired options could be beneficial. With the information, the City of Venice could make expert decisions on the implementation of these accessibility resources.

In an effort to provide visually impaired individuals with protection from hazardous areas throughout the city, an experiment was done with the automated identification of these locations, defined as "danger zones". Using data collected from 18 years of previous Interactive Qualifying Projects, additional GIS layers were created to add to the existing collection of database layers. These layers specifically identified danger zones of docks as well as the location and types of useable docks in Venice's *Centro Storico*.

Lastly, a web-based application was designed to map accessible routes around Venice. Although this application is not functional, if developed it could provide the public, including the mobility impaired community, with accurate routes to navigate the city. It will utilize the accessibility solutions implemented in the city with functions such as

[1] Cumune di Venezia, www.comune.venezia.it. Henceforth referred to as Comune Venezia.

[2] Accessible Venice, http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/1317 (Accessed October to December 2007). Henceforth referred to as Accessible Venice

"Utilize Boat Transportation" and "Minimize Number of Steps" so people with ambulatory disabilities can travel across the city with less difficulty.

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Executive Summary

With the 20th anniversary of the Venice Project Center approaching, a commemoratory publication is being produced to celebrate the great achievements made by WPI students working on their Interactive Qualifying Projects. To facilitate production, the 2007 Venice IQP teams each worked on a set of thematically related chapters. Categorized as urban maintenance, this project's goal was to create chapters about Venice's canals, bridges, docks, and utilities.

Figure 1 (top, left): This is a drained canal during the dredging stages of canal maintenance. The linings of canal walls are also restored during this process. Maintenance generally takes about six months to complete. Insula is currently in the third and final phase of their canal maintenance plan. Figure 2 (top, right): Bridges are maintained following the canal maintenance schedule. The undersides of bridges are repaired by Insula, the leader in urban maintenance. Insula has currently repaired over 200 bridges of the 473 bridges in the city of Venice. Figure 3 (bottom, left): Wooden over structures are built over stone docks throughout the city that are difficult to use according to tide levels. This is a method boaters and cargo transporters use to adapt to the unusable conditions of 32% of the 1300 docks in Venice. Figure 4 (bottom, right): Sewer pipes drain directly into the canals causing sewage to accumulate at the bottom of the canal. The holes, which are under the waterline are maintained while the canal is empty. Currently the city is discussing the implementation of a new vacuum sewer system in the historical area.

During research, it became apparent that existing databases—compiled in the process of performing urban maintenance—could be reused in new ways to benefit the handicapped within the city. While it was not originally realized that this data could be utilized towards improving the quality of life of all individuals, especially those affected by mobility and visual difficulties, the team pursued the opportunity to improve the condition of the city for these individuals by further investigating how the datasources could contribute to the following tasks:

1. **To explore the accessibility of the Venetian Islands**
2. **To determine the incidence of mobility issues at bridge crossings**
3. **To assess the impacts of docks in Venetian society**
4. **To design a web-based navigation tool accommodating all mobility levels**

Figure 5: A sample of the static maps produced by Accessible Venice and the Comune di Venezia

[3]Inspired by a manual map created to show the accessibility of Venice the group used advanced computer software to produce a newer, easily updatable, animated version of this map. The features on this new map were also verified using extensive databases to create the most up to date map. The ACTV public boat stop schedule was used to confirm and update which islands were accessible by boat stop. In some cases, team members had to locate areas in question to check if any changes had been made since the last accessibility map was distributed. Reasons for considering an island temporarily accessible had to be defined and determined also. This dynamic map was created to replace the static map produced by the Comune di Venezia which contained a color-coded island legend to indicate the degrees of accessibility, provided information on tourist terminals, and displayed the locations of accessible waterborne public transport stops and bridges with handicap facilities[4]. This dynamic map was intended to be handed over to the Comune di Venezia and the departments responsible for providing information about island accessibility to the public for interactive use on their official web page, http://www.comune.venezia.it.

[3] Accessible Venice Map, http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/1318 (Accessed January 7, 2008).

[4] Informahandicap Venezia. *Accessible Venice*. http://www.comune.venezia.it/. Last Accessed, January 8, 2008

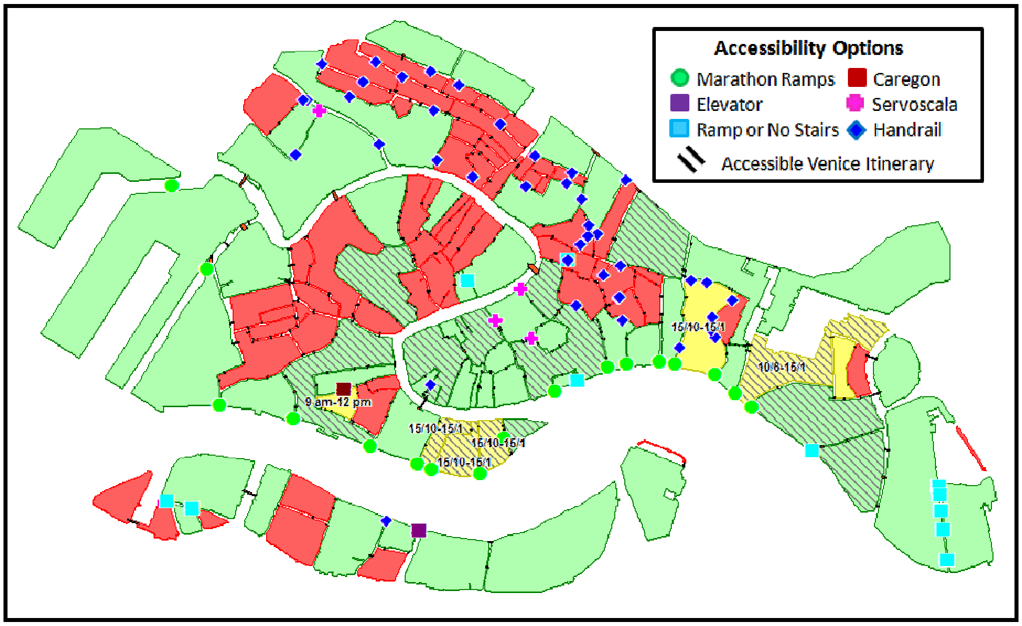

Figure 6: Using information from our database, we created a more accurate and updated accessibility map of Venice. It includes the different types of accessibility options which are labeled throughout the city.

The study of handicap accessibility of bridges consisted of three stages during which both total traffic and the number of each type of impairment were counted. The initial studies were performed on a number of types of bridges and were primarily useful to define the categories of impairments. The second stage, performed over an eleven hour period, provided data on peak walking times within the city. Finally, all 13 public bridges on the island of Tolentini were studied for one hour intervals during both previously determined peak times. Tolentini was chosen for its inaccessibility by public boat which forces impaired individuals to use bridges from one of the six surrounding islands—three of which were also inaccessible.

Using existing information collected and organized into a database exclusive to docks, several geographical information maps layers were created. Information regarding the types of docks, whether or not they were considered usable or unusable and their location and were necessary to complete these new maps. By utilizing the existing bridge and dock information to find all places where bridges are built side by side with a dock, a map pinpointing the location of these dangerous areas for visually impaired pedestrians was also produced.

The primary functions of the team in designing the web application were to first decide on the desired features that would best serve users with ambulatory disabilities and then to compile the datasets required to make those features functional. The majority of the data required to eventually create this application was already available in the form of map layers and Access databases. Additionally, creating maps to locate the various handicap accessibility solutions, such as the Vaporetti, Accessible Venice, Servoscala, and Caregòn helped to maximize the versatility of the application. Once these were accomplished, a mock-up of the interface was created.

The completion of a newer graphical map, after given to Comune di Venezia was intended to increase awareness about the measures the city has taken to improve the accessibility of the island. It includes public boat stops which make islands accessible as well as the locations of the alternative accessibility options found throughout the city. Islands on this map are also coded yellow to indicate temporary accessibility. Dates and time periods are included on these areas to allow to reader to plan around their availability. Using itineraries created by *Informahandicap*, a city department dedicated to informing the public of this work, the map was made interactive so internet users could easily access these itineraries by navigating through the map located on the City of Venice website. The goal was to assist the City of Venice in providing increased availability of information on accessibility alternatives located throughout the city.

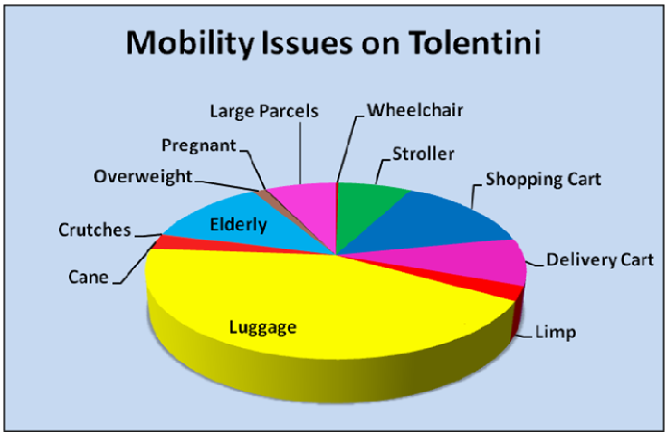

Figure 7: Mobility issues are broken up by type based on the totals of each defined issue. Luggage is the most commonly seen type noted from the preliminary tests.

Another opportunity was found in handicapped accessibility of the bridges that link the islands of Venice together. Despite the many efforts of city departments such as Accessible Venice and Plan to Eliminate Architectural Barriers[5], less than 5% of the 13 bridges examined on the test island currently meet handicap accessibility standards. After analyzing the results of each peak time tested for the bridge accessibility form, we concluded that although pedestrian traffic flow was higher in the evening, there were an increased percentage of mobility impairments during the morning hours. From 48 hours of data collection on the Island of Tolentini, it was found that 4.9% of pedestrian traffic had difficulty crossing the bridge due to a mobility impediment. Among the 22,534 pedestrians counted, a total

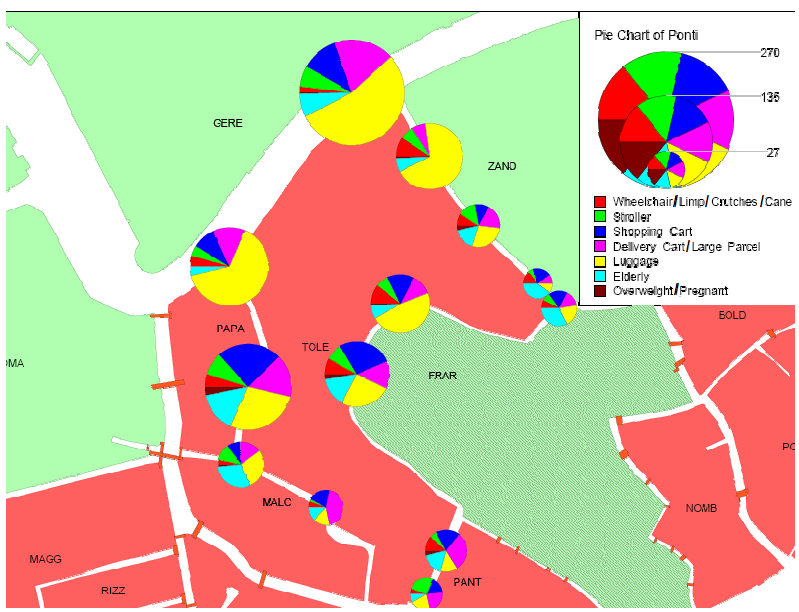

Figure 8: Using the data collected from our bridge testing on Tolentini we were able to charts the break up the different types of mobility by each individual bridge and on the island overall.

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[5] Contributi abbattimento barriere architettoniche, http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/1438 (accessed January 7, 2008). Henceforth referred to as PEBA.

of 12 different mobility impairments were recorded. The most common impairments were elderly individuals (12%), carts (23%), and those carrying luggage (43%) which accounted for 78% of the total. Mobility impairments of greater severity were also recorded. Additionally, among 1,111 observed mobility impairments, our 31 were assisted by the use of canes, 3 crossed the bridges in wheelchairs, and 2 used the assistance of crutches. Other impairments included strollers, large parcels, limps, and pregnant or overweight travelers. From this study an optimal fieldwork form was created to be used in future large-scale testing.

Using the information from the docks database[6], two new GIS layers were created, including one to map the locations of all 33% of the unusable docks in the city and one to show areas considered danger zones for individuals with visual impairments. These are valuable maps for the city to have possession of because knowing the locations of unusable docks allows them to make decisions on the need to restore them or if they should be removed or altered to make them usable. Mapping the danger zones of the city allows the city determine where gates can be restored to eliminate these hazardous areas.

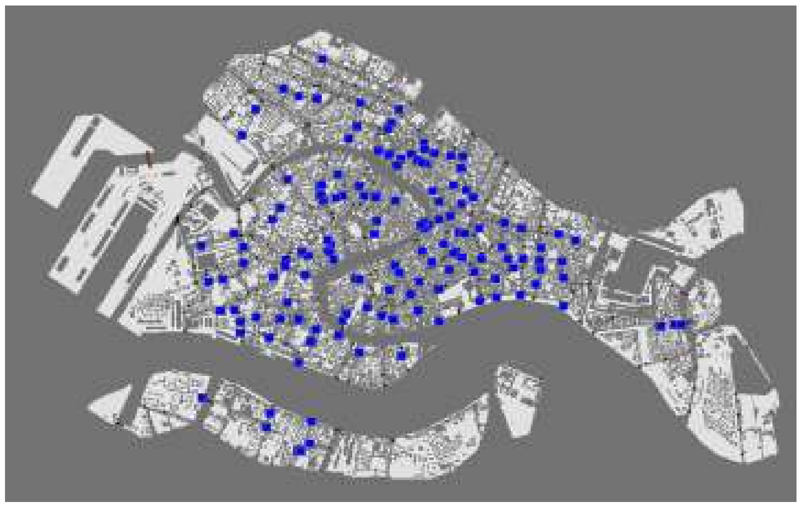

Figure 9: Map of the Danger Zones (blue squares) created using existing databases of docks and bridges.

Finally, a web-based mapping application was designed which will help both handicapped and able-bodied tourists and residents navigate the city. The features required to make the web-based application—Navigate Venice—were determined by consulting with city officials and experts who could provide suggestions on optimal features. The interface allows the user to choose several methods to produce directions within the city. They can customize their search by choosing appropriate features to meet their needs, including minimal walking distance or the option to always use the public boat transportation service. Although the team did not have sufficient computer programming skills to create a fully functional application, all the necessary data has been gathered to be added to the designed interface.

[6] EasyDocks

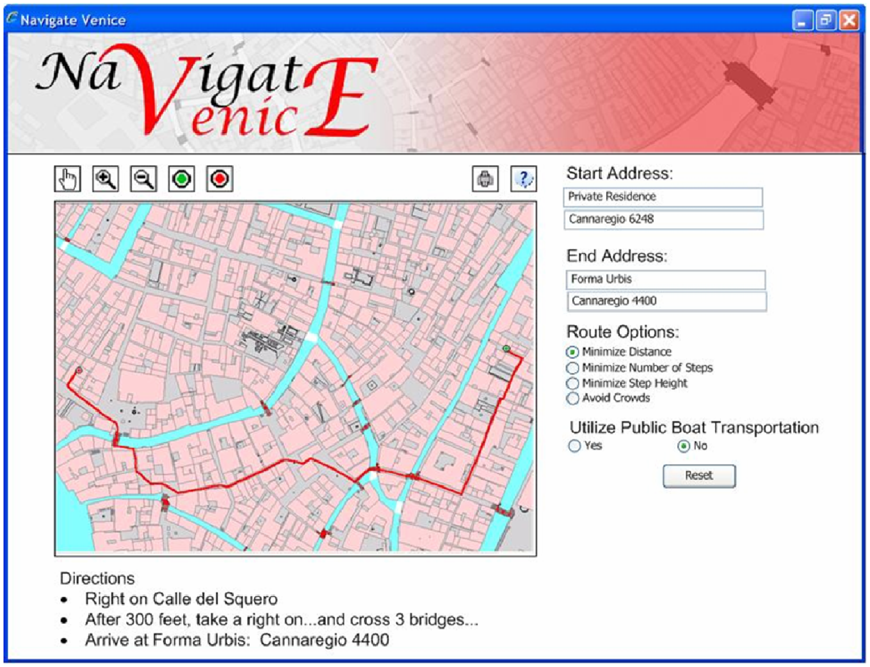

Figure 10: Navigate Venice interface showing a sample route calculation

In seeking sponsorship, it is recommended that future groups and advisors contact the City of Venice, more importantly the Accessible Venice department, to verify and coordinate further research on island accessibility. As new features are created to increase awareness about accessibility, teams can work with the city to make these features more interactive and easier to use on the Internet.

Based on the results of the pedestrian bridge testing, it was determined that a larger scale study of mobility impairments as they relate to crossing bridges in Venice would produce valuable results. The data collected from such a study could be compiled, analyzed, and relinquished to city officials for their use in making handicap accessibility upgrades.

Although the docks database does include a small amount of information about gate remnants found at docks, it is recommended that all docks are reevaluated to determine the exact number of docks that show evidence of gates. This information would be useful to because a map could be made show the accurate locations of these docks, therefore it would be easier to create a plan to attach new gates.

As a follow-up to this project, or as an MQP, it is suggested that a functional Web 2.0 application be created from the initial design to benefit the mobility impaired. This web application should utilize the accessibility solutions already present in Venice, such as the boat lines and ramps, to provide the best pathway between any two locations in the city. An application of this nature would greatly benefit Venice, its citizens, and the millions of worldwide tourists that visit each year.

Report Organization

The Interactive Qualifying Project is a study designed to use science and technology to improve society and human needs. Generally, most teams approach one specific issue for the duration of the project, with the goal of developing a solution or future recommendations that will benefit a community or organization. In the case of this year's proposal to publish a book about Venice commemorating the upcoming 20th anniversary of the Venice Project Center, the outcomes of these projects were nontraditional compared to previous IQP's. The purpose of this section is to explain and justify these differences.

The initial goal of this IQP was to research urban maintenance in Venice by constructing new resources, specifically a publication, that would provide information using extensive data collected by previous groups. Unlike distinctive IQP reports which tend to focus on the analysis of one specific topic, this report covers information included the four main areas of urban maintenance researched; canals, bridges, docks and utilities. Although these areas can all be linked by the title "Urban Maintenance," each area has the potential to be its own report.

In addition to producing chapters, issues in these areas that relate specifically to bridges and docks were exposed for further investigation. Uncovering issues that had currently been untouched by WPI students created excitement within the group. Although there was no initial intention to come to Venice with an immediate plan to produce direct results that would benefit the community, it was realized that work could be done to actually make a difference. With this, the project expanded and produced multiple levels of results in addition to the chapters for the publication. The remaining sections of the report will provide extensive detail on the background, methodology, results, conclusions, and recommendations determined upon each issue and the completion of the project.

1. Introduction

In recent years, there has been great advancement in making cities across the world more accessible to those with mobility impairments. The United States of America and the European Union have both implemented disability acts, which have greatly affected and aided the handicapped world. The Americans with Disabilities Act has enforced regulations such as the Standards for Accessible Design, which requires minimal standards for ensuring accessibility when designing and constructing a new facility of altering an existing facility[7]. By creating laws such as the Standards for Accessible Design that require public places, such as restaurants, businesses and grocery stores, to have complete access to their facilities, many countries have made great strides towards increasing the quality of life for all. From ramps to elevators, handicap accessibility has become more common worldwide and, with time, other countries will begin to adopt these procedures.

Likewise, the city of Venice, Italy has made extensive progress to adapt to these worldwide transformations. With added obstacles, such as the numerous canals, docks and bridges, the city faces certain struggles that cannot be found anywhere else in the world. Since the 13th century, Venetian bridges have transformed into one of the worlds most historical and fascinating collection of infrastructure, but these marvelous structures also cause a great impediment to pedestrians when travelling throughout the city.

Organizations within the City of Venice, such as Accessible Venice[8] and Plan to Eliminate Architectural Barriers (PEBA)[9], have worked specifically to increase the city's standard of living. Although public boat transportation allows accessibility to many of the city's islands, the bridges prohibit access to the inner islands and those islands without public boat stops. By implementations of devices, such as *servoscala* and both temporary and permanent ramps, the city has been able to renovate over 7% of Venetian bridges in the past few decades. The long-established infrastructure of the city causes great difficulty for changes to be made; therefore each bridge is handled on a case by case basis. Since there is no single solution, the city accepts and proposes new ideas frequently to make every attempt to better the community. Another area of concern that Accessible Venice has addressed is that of danger zones, which are safety hazards to those with vision impairments. Traditionally gates were present to block pedestrians from falling into canals where a dock is directly adjacent to a bridge or at the end of a street. In recent years, many of these gates have been removed by cargo and other companies, which cause a great problem to the visually impaired.

Due to Venice's great history, amendments and special permissions have been granted to avoid certain specifics of the European Union's disability act. These revisions are primarily due to the age and historic nature of the bridges and buildings, which cause them to be very difficult to modify. Venetian organizations struggle to pass ideas to revise the bridges because of the attempt to preserve the historical nature and why so many bridges are left unchanged. Though Accessible Venice has produced informational brochures and handicap itineraries for the most

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[7] US Department of Justice, "Americans with Disabilities Act" http://www.usdoj.gov/crt/ada/publicat.htm#Anchor-14210 (Accessed on 14 December 2007).

[8] Accessibe Venice

[9] PEBA

popular parts of the city, much of the information is only available in Italian and is not well publicized. Also, research has been done to locate the danger zones in Venice, but this information has not been made public and the city has not taken many measures to solve the problem.

For these reasons, our goal for this project was the following: first, explore the accessibility of Venetian Island, then to determine the incidence of mobility issues at bridge crossings, next, assess the impacts of docks in Venetian society, and lastly, to design a web-based navigation tool to accommodate those with mobility impairments. To accomplish these goals, we primarily utilized data from many different, pre-existing sources which we came across during the course of our project. Additionally, our group performed pedestrian data counts to determine what was pertinent to the success of the project. In a few cases new data was collected thorough interviews with city officials. With the help of our advisors, we were able to compile the collected data with the supplied data to produce the results for both of our goals.

2. Background

2.1. *Urban Maintenance*

A city is never designed with the capability of eliminating the need for repairs. As a city ages and adapts to the changes in its urban surroundings, repairs are certainly imminent, thus creating the need for continual maintenance. Urban Maintenance can be defined as those necessary repairs with the intent of preserving the quality of life of the affected community. Having an effective maintenance routine is imperative to protect the comfort level of the community. In Venice, urban maintenance is essential for the preservation of the city's canals, dock, utilities, and bridges.

The canals of Venice serve two primary functions that make their regular maintenance essential. They are the main mode of transportation of people, goods, and services throughout the city and they also provide an outlet for the city's sewage. Canal maintenance is a very involved process which requires major organization. A routine maintenance plan for Venice has been continuously neglected in the past. Problems have been caused by the artificial evolution of canals. Also, with the increased need of public transportation in a major tourist city such as Venice, *moto ondoso*, or wake damage, can cause extreme damage to the canal wall. *Moto ondoso* is caused by turbulence from boat motors that occur with excessive boat speeds through the canals[10]. There are also concerns with the rapid sediment buildup which causes damage to canal walls. Due to the current of the Venetian lagoon, debris and sewage constantly flow into the canals, settling at the bottom and also blocking sewage outlets.

After years of inattention, the city of Venice realized the severe effects of canal damage caused by the lack of maintenance. In 1997, to preserve their historical city, the *Comune di Venezia* created a company, *Insula S.p.A.*, to facilitate the maintenance throughout Venice. *Insula* has organized various projects on all aspects of infrastructure, including The Integrated Canal Project[11] which is a 30 year plan to repair all of the canals of Venice. They are responsible for dredging and treating the sediment accumulated on the bottom of the canals and repairing the canal wall linings. *Insula* has made significant progress completing their plan over the past ten years with the first two of three stages already complete. They continue their work to preserve the historic city and expect the completion of the Integrated Canals Project by 2025[12].

Docks are a crucial part of global infrastructure for many cities with booming economies and extensive trade power. Throughout the years, ordinary docks have been used mainly for the transportation of cargo into and out of a city, and for the transportation of people. When compared to traditional docks, the over 1600 docks[13] in Venice are diverse because of their

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[10] David Chiu, Anand Jagannath, and Emily Nodine, *Moto Ondoso Index: Accessing the Effects of Boat Traffic in the Canals of Venice*. (Worcester, MA: Worcester Polytechnic Institute, 2002). Henceforth referred to as Chiu, *Moto Ondoso*

[11] *Insula S.p.A. "*Insula: A Project for Venice: Urban Maintenance and protection of the City of Venice." Pamphlet provided by Rudj Todaro, Technical Director, Insula S.p.A. (Venice, Italy)

[12] Personal Communications. Fabio Carrera, Director Venice Project Center and Lorenzo Botazzo, Project Supervisor, *Insula S.p.A.* (Venice, Italy). Henceforth refered to as Carrera and Botazzo respectively.

[13] Forma Urbis, EasyDocks Application (Venice, Italy)

Figure 2-1: Typical Dock in Venice

complex infrastructure and configuration with canal walls. Venetian docks are built mostly of stone and brick, which is quite different than the conventional floating wooden docks in other parts of the world.

Depending on the type of docks, they can become partially impractical due to the changing of the tides, causing problems just entering or exiting the boat with the increase in algae on the steps. This has caused an increase in boat drivers pulling up alongside the dock, in effect disregarding the dock for cargo deliveries. Plans to remedy the problem include the construction of wooden over-structures protruding out into the canals rather than into the sidewalk like other docks. The over-structures make docks usable and are convenient for workers because there is usually far less algae on the wooden dock. In addition to being safer, the over-structures are usually position so that the normal high tide does cause the dock to flood. One of the downsides however, is that it affects the boat traffic passing in the area because it protrudes into the canal. With a well working docking system, and the reorganization of shipping products around the city, life in Venice should become less stressful and easier to navigate.

Figure 2-2: Example of a dock over-structure

Buried beneath the city lie complicated networks of pipes and cables. Through these flow vital resources required to keep Venice alive: the most important of which include gas, water, electricity, and sewage. Originally installed one on top of another as new technologies became available, the original utilities were highly intertwined and disorganized. Currently, *Insula S.p.A*. is in the process of "rationalizing" the system by coordinating with the utility companies to relay the networks in a more orderly manner[14].

In addition to routine maintenance, the sewer system requires a major upgrade. By far the oldest of the public utilities, the sewers have become outdated and need to be replaced. Be outputting sewage directly into the canals, the current gravity driven system, called the *fognature*, creates unsanitary conditions and causes unpleasant odors within the city. Additionally, the *fognature* has the capability of severely damaging canal walls if the outlets become blocked[15]. To remedy this situation, the city is currently investigating several proposals for new systems including a

[14] Insula

[15] Alexander P Borrelli, Matthew J. Crawfod, James W. HOrstick, and Izzettin Halil Ozbas, *Quantification of Sediment Sources in the City of Venice, Italy* (Worcester Polytechnic Institute: Worcester, MA, 1999). Henceforth referred to as Borrelli, *Sediment*.

proposal for a HIFLO vacuum sewage system created by a 1997 IQP team[16]. Unfortunately lack of funding and an unwillingness to change the system have delayed improvements for over a decade[17]. While lack of funding is a legitimate concern, it is surprising that the city is hesitant to change the system considering the incredible disruptions that have already been caused by the installation of the other utilities.

Figure 2-3: The bridges of Venice allow pedestrian and vehicular traffic to never intersect

Bridges serve as one of the world's most essential elements of both vehicular and pedestrian networks. Regardless of their design and makeup, these structures chiefly serve two main purposes: to keep two distinct flows of traffic separated at intersections and to grant traffic the ability to cross an otherwise impassable, natural barrier. Due to Venice's unique water-based transportation system, all 473 bridges[18] within the city perform both of these functions simultaneously, allowing the primarily pedestrian-based land transportation system the ability not just simply to cross the canals, but also to avoid interfering with the boat traffic that utilizes the waterways below. This allows pedestrian traffic and boat traffic to serve as two completely different entities, never interfering with one another. Only three bridges, which all connect the mainland with the islands of *Stazione Marittima*, *Piazzale Roma*, and *Tronchetto* on the western side of the city, allow motorized vehicles access to parking garages and bus lots. Bridges have served as an important piece of infrastructure throughout the history of Venice and its formation from multiple islands.

Figure 2-4: Accessible Venice Marathon Ramps constructed due to the efforts of Accessible Venice and PEBA.

Venice's history has proven that bridges have been crucial in sustaining improved quality of life. Before bridges existed in Venice, the numerous islands were separate communities with their own churches, stores, and lifestyles. At one time, landowners even used planks as access from one island to the next and charged a small toll to those who wanted to cross over. It wasn't until the 13th century that bridges were actually constructed in Venice. Once the bridges began connecting the islands, the city of Venice that we now know today

[16] Martin Felices, Lauren Goodfellow, Jay Johnston, and Sonali Maheshwary, *A Preliminary Feasibility Study of a HIFLO Vacuum Sewage System within the city of Venice, Italy (*Worcester Polytechnic Institute: Worcester, MA, 1997). Henceforth referred to as Felices, *HIFLO System*.
[17] Carrera and Botazzo
[18] Forma Urbis, EasyBridges Database (Venice, Italy). Henceforth referred to as EasyBridges

began to form into one community. There are now enough bridges in the city so that each of the 182[19] canals has at least one bridge crossing over it. This is important to note since Venetian bridges also serve a function that is unknown by most people: as a pathway and carrier for Venetian utilities. Many Venetian bridges carry pipes either underneath their pavement or on their sides. These pipes serve as connectors between islands for a number of essential items.

It was in the 1950s and 1960s that the Venetian government began to reassess the ideas of urban maintenance when floods tormented the city and its canals and bridges. The floods brought a realization to the natives that bridges would need renovations and repairs to be kept up to safe and historical standards. In order to keep the bridges intact, plans have been implemented to form a repair cycle. This cycle is based around the canal dredging schedule and is coordinated with the utility companies of Venice, so that bridges in their entirety can be maintained all at once.

2.2. *Mobility in Venice*

As there have the plans for bridge repairs, there is also the endless fight to make the bridges more handicap accessible. Accessible Venice and the Plan to Eliminate Architectural Barriers (PEBA) are two programs that are working to raise awareness of mobility issues in the city and to better the city for those with mobility and vision impairments. They are the force behind the Venice Marathon ramps remaining up from October-January, the Biennale of Contemporary Art accessibility ramp, as well as numerous additions to help those with vision problems. The city has worked to put grooved strips that run across the pavement perpendicular to some bridges so that blind and low sighted individuals can feel where bridges cross the canals. Accessible Venice has also produced brochures that include specific paths around Venice's top tourist locations for handicapped individuals, brochures on the *servoscala* that include the keys to operate the machines, information about boat shuttle services, as well as information in brail for the blind and others with vision problems[20].

Figure 2-5: Site of the Caregon

Millions of people worldwide use assistive devices due to ambulatory disabilities and physical handicaps and one area of concern in the city is handicap accessibility. There are also parents with baby carriages, tourists with suitcases and delivery men with hand-trucks who struggle to cross Venetian bridges. With the world becoming increasingly handicap accommodating, Venice still continues to move towards improving handicap accessibility. Of the 473 bridges, there are only currently 12 bridges that are handicap accessible due to ramps or because they lack stairs[21]. Additionally, there have been several other implementations to improve the comfort quality of those with this

[19] GIS Layer, *Rii*, Forma Urbis (Venice, Italy).
[20] Personal Communication, Lucia Baracco, Director, Accessible Venice (Venice, Italy: November 9, 2007). Henceforth referred to as Baracco.
[21] EasyBridges

disabilities and limitations. One bridge that has an elevator, another contains a *Caregon*[22] alongside it and there are also 4 bridges that utilize a *servoscala* for handicap individuals.[23] Although some bridges have had work done, such as the addition of handrails or small plastic ramps on each step, there are still problems present throughout the city and the city is working on improving bridges on a case by case basis.

The city also has other plans for the future of handicap accessibility throughout Venice. Some of these plans include the implementation of another mechanical *Caregon* in the city[24]. This solution along with ramps and elevators are certain examples of possible accessibility throughout the city. Since each bridge and island is unique in its own way, the city will have to treat each bridge with a case-by-case solution to better Venice's accessibility one bridge at a time.

Another area of the work in this category includes the plan to eliminate danger zones throughout Venice. A danger zone is defined as an area where a bridge and dock are located next to each other, but there is no gate blocking the dock[25]. This poses a problem because a blind or low sighted individual could walk directly into a canal since the dock is not marked or blocked. Another example of a danger zone is a street that ends with only a dock and no gate, again causing a problem to people with vision impairments. The cities work will help to implement gates throughout the city, many of which are attached to bridges that will block docks and eliminate the problems that are now present.

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[22] Carrera and Personal Communication, Enzo Cucciniello, Professor of Architecture. University of Venice. (Venice, Italy). Henceforth referred to as Cucciniello.

[23] ibid

[24] Cucciniello

[25] Carrera and Personal Communication, Lucia Baracco, Supervisor, Accessible Venice. (Venice Italy)

3. Methodology

While performing research for the publication chapters, it was noticed that the majority of infrastructure-related issues within the city are already being address; however, there are a few topics that still need attention. One such topic includes accessibility, especially as it relates to mobility and visually impaired individuals. Throughout the city, bridges and docks create architectural barriers that can limit the mobility options of some or all of Venice's pedestrians. Through the process of urban maintenance it is possible to break these barriers, thus in addition to creating the publication chapters, this team also decided to further investigate the accessibility issues caused by the city's bridges and docks. The objectives of this investigation were quadruple-fold:

1. **To explore the accessibility of the Venetian Islands**
2. **To determine the incidence of mobility issues at bridge crossings**
3. **To assess the impacts of docks in Venetian society**
4. **To design a web-based navigation tool accommodating all mobility levels**

Island Accessibility

Looking only at the bridges of Venice, the city initially seems completely inaccessible to mobility impaired individuals. However, there are many options available to help facilitate movement through the city including handicap accessible public boat transportation, ramps, lifts, and an elevator. In order to inform the mobility impaired community about these accessibility options, the *Comune di Venezia* previously created a map to distribute to the public that displayed the extent of accessibility(See Figure 5 in the Executive Summary). An automated and easily updateable Island Accessibility Map was created by our team, re-evaluating the locations of these of accessibility options. The map included new features such as the dates and hours of operation of temporarily accessible islands and the addition of hotlinks containing handicap accommodating itineraries[26] that were originally created by departments associated with the City of Venice.

Incidence of Mobility Issues

When studying bridge usage by individuals with mobility impediments, any condition— temporary or permanent—that caused the individual difficulty in crossing bridges was considered an impediment. Initially this study was spatially limited only by the bounds of the city; however, for the purposes of this feasibility study, it was beneficial to restrict data collection to the bridges connected to the island of

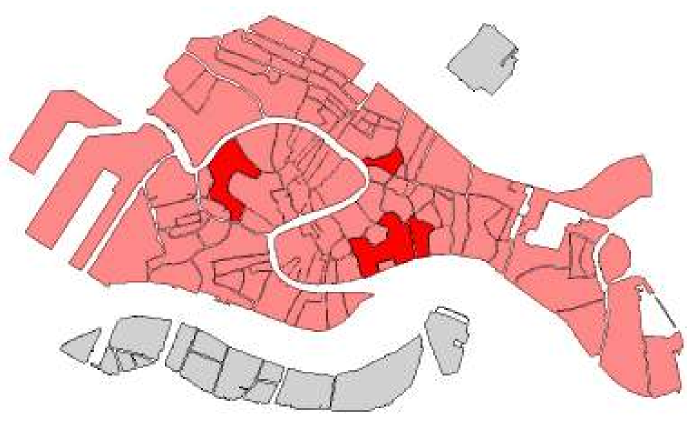

Figure 3-1: Islands in red show the locations where bridge counts were performed. Tolentini, where the majority of the data was collected, is the "C" shaped island in the western section of the city

[26] *Informahandicap* Itineraries, http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/1381 (Accessed January 8, 2008) Henceforth referred to as *Informahandicap*.

Tolintini. This island was chosen because it is inaccessible by public boat and connects to three islands that are also inaccessible, including the Island of Papadopoli which contains a kindergarten and public park, in addition to three accessible ones. Furthermore, Tolentini is home to a vaccination clinic, and is on one of the major tourist pathways though the city. Due of these factors, it was relatively certain that data collection on this island would clearly show how impaired individuals gained access to this inaccessible island. To obtain meaningful data, traffic surveys had to be performed during hours of high volume; thus, the exact timeframe for conducting surveys was one of the subjects of investigation.

Impact of Docks

Throughout Venice, docks of many different configurations and sizes have an impact on Venetian society. Primarily, docks affect cargo delivery. However, a significant percentage of the docks have become unusable because of either configuration or condition. As a first step towards remedying this issue, a map was created to locate the different types of docks throughout the city and to specifically locate the unusable ones.

Figure 3-2: Example of a Danger Zone

Docks in Venice, both usable and unusable, can create obstacles for visually impaired individuals that often go unnoticed by common pedestrians. Whenever a street ends in a bridge and dock side-by-side, individuals with vision impairments risk following the wrong wall of the street and accidentally falling off the dock when they are expecting to cross a bridge. This "danger zone" concept was first brought to our attention by Lucia Barraco from the City of Venice[27]. However, the city did not yet know the location of all the danger zones, so an easily updatable GIS layer was created, using existing data from the bridges and docks layers to map these locations. The intention was to complete the most updated danger zone map which would provide the City of Venice with the information they needed to begin the process of fixing these areas.

Web Application

Since it is unlikely that every bridge in Venice will be made handicap accessible in the near future, the team also began the process of creating a web-based application which will provide user-friendly directions on how to navigate the city. Since an individual in a wheel chair and an individual with a limp may have different concerns when traveling, this program will include multiple features that will help users avoid the architectural barriers that cause them the most difficulty. The program should likewise prove useful to for anyone planning to travel throughout the city, including unimpaired individuals.

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[27] Baracco

3.1. *To explore the accessibility of the Venetian Islands*

3.1.1. Project Approach

Several Accessibility Maps were already in existence. One, provided by Enzo Cucciniello was at least 10 years out of date. The map Enzo Cucciniello possessed used two colors to indicate areas of accessibility versus areas of inaccessibility. More advanced versions, which used a three color scheme, were provided by Lucia Baracco, which were as recent as February 2007[28]. With all the information included on the map they still remained static maps that needed to be manually updated each time there was a change. Although this map is currently available on the City of Venice webpag, it does not provide users with the ability to access interactive features.

In our initial meeting with Lucia Barraco[29] she expressed difficulty in determining the most effective way to communicate to the general public about the progress achieved in making the city more accessible. Her organization designed the first accessibility map that was distributed to the public, which was also the most updated version. Although different methods of distribution were used, such as tote bags and post cards including a picture of the map, there were still problems ensuring the information was available and easy to locate. A similar map to the one Accessible Venice made was created, verified, and updated using software that would allow it to be uploaded onto the Internet and made available to the public. The intention in producing this map was to give the City of Venice a more effective way to update the accessibility map as changes to the city were implemented. This map could be included as an interactive feature found online, such as on the Comune di Venezia official webpage.

3.1.2. Existing Data Sources

The Ponti[30] GIS layer was useful for finding the names and codes of each bridge based on their location. The Access database from EASYBridges[31] could then be used to determine if any bridges had ramps or handrails.

The Isole[32] GIS layer provided the shape and location of each island. These islands could then be color coded appropriately depending on the various mobility options.

Published timetables for the public boat system were used to determine which islands were handicap accessible by means of the *Vaporetti*.

Several Accessibility Maps were already in existence. One, provided by Enzo Cucciniello was at least 10 years out of date. Others provided by Lucia Baracco[33] were fairly recent, however they still remained static maps that must be manually updated each time there is a change.

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[28] Accessible Venice Map
[29] Baracco
[30] GIS Layer, *Ponti*, Forma Urbus. (Venice, Italy) Last updated: November 8, 2007. Henceforth referred to as *Ponti*.
[31] EasyBridges
[32] GIS Layer. *Isole*. Forma Urbis. (Venice, Italy) Last Updated: November 3, 2006. Henceforth referred to as GIS, *Isole*
[33] Accessible Venice Map

Informahandicap brochures[34], created by the City of Venice under the supervision of Lucia Baracco, are available through information kiosks throughout the city to show mobility impaired individuals the available handicap itineraries available to them through out the city.

3.1.3. Data Collection

In a few instances where the handicap accessibility of a bridge was in question, team members performed an on-sight visual inspection of the bridges in question and recorded the results.

Additionally, Enzo Cucciniello and Lucia Baracco provided information on several mobility options including the servoscala, caregon, elevator, and temporary ramps.

3.1.4. Creating the Accessibility Map

In creating the interactive Accessibility Map of Venice, our group created numerous new GIS layers for the different accessibility solutions in the city, as well as a layer showing the accessibility and temporary accessibility of each of the 125 islands. The first step in creating the Accessibility Map was to create a layer called "*Accessibilita Isole*," which followed the stoplight color scheme. This layer showed the completely accessible islands in green, the temporarily accessible islands in yellow and the inaccessible islands in red. The addition of the yellow coded islands, temporarily accessible islands replaced their orange color coded islands which indicated partially accessible islands. The change was needed to differentiate any confusion leading users to believe that only parts of the islands were accessible rather than the fact that the island is only accessible for parts of the year. This layer became the base layer for the entire map.

The next step was to create individual layers for each of the mobility solutions located throughout the city. These layers included *Caregon*, *Corrimano* (handrails), Elevator, Marathon Ramps, Ramps (or bridges with no stairs) and Servoscala. A layer was produced for each of these accessibility options by querying the bridges that contained each particular mobility aid. The query was then saved and a point was created at each bridge in the query, thus marking the bridge as accessible. For example, a query was performed for all bridges with a *servoscala*, then a pink star was placed over the bridges containing a *servoscala*. Therefore the bridge became accessible for that reason and the legend showed that a pink star referred to the presence of a servoscala.

Additionally a layer called "*Periodo*" was created to show the time period that the temporarily accessible islands were accessible, a major difference from the map Lucia possessed. For example, the islands that become accessible due to the Venice Marathon were added to the "*Periodo*" layer. Then the dates for the Venice Marathon were input to the database so that a label would appear across the temporarily accessible island, thus showing "15/10-15/1" on the island indicating accessibility from October 15 to January 15.

Next a layer called "*Itinerario*" was produced to mark the islands throughout the city with Accessible Venice itineraries[35]. It is important to note that these itineraries were not the product of our group; they were produced by the city of Venice and are available publicly throughout the

[34] *Informahandicap*
[35] *Informahandicap*

city and online. Our group only utilized the information (and properly referenced the material) to make it available in our interactive map in an attempt to help the city better communicate their existence to the general public. The islands located on the "*Itinerario*" layer were shown with a thick, black outline on the map to distinguish their locations throughout the city. Additionally the Accessible Venice itineraries were hotlinked to the map. By saving the maps in the same folders as the map layers, a hotlink could be created by locating the pictures and linking them to the "*Itinerario*" layer. Thus as a result, by using the hotlink tool, a picture of the itinerary opens in a new window when you click on an island on the "*Itinerario*" layer therefore adding an interactive component to the map.

Another important piece of information utilized for the Accessibility Map was the public boat transportation system. On Lucia Baracco's accessibility map[36], islands that were accessible by public boat were identified by a yellow circle. We attempted to add a feature on the map that would use different geometric symbols to signify the different ACTV boat lines. As the final map became overly congested with the symbols we decided to not include them in the final version of the map. By creating updatable fields on the "Pontili ACTV" layer, the stops for the public boat transportation system were entered into the database. This provides a very easy method for updating the boat lines since changes are frequently made. Once all of the data was entered and the stops were updated, queries were performed for each of the boat lines and different shapes were placed for each stop. Thus the island containing the public boat stop was marked with a different shape, which corresponds to a certain boat line, allowing travelers to identify their stops throughout the city. Again, a legend was created to easily identify the stops. This map was created in the hope that it would be constantly updated and possibly turned over to the Public Transportation system to aid them in their public awareness.

These layers were all brought together on top of the Accessibilita *Isole* layer to create a workspace in MapInfo called *Accessibilita*. This workspace, when completed, was essentially the entire, interactive Accessibility map including all layers, hotlinks and information.

3.2. *To determine the incidence of mobility issues at bridge crossings*

3.2.1. Project Approach

To begin this study, the conditions that constitute "mobility impediments" needed to be defined. Also, since various impediments are not mutually exclusive of one another, a hierarchy was required. Because other project objectives only allowed sufficient time for a feasibility study and not a fully in-depth study, it was important to know which time periods saw the greatest traffic flows. With this information, the largest possible data samples could be collected during a short period of time. Finally, the primary piece of data required for this study was the percentage of each type of mobility impaired individuals traveling over the bridges. Based on the type of impediments, it can be decided how to best modify bridges-if at all.

[36] Accessible Venice Map

3.2.2. Existing Data Sources

The main data source available on this topic was the E – term 1998 project titled *The Inventory and analysis of the Bridges and Pedestrian Traffic in Dorsoduro, San Polo, and Santa Croce Sestieri of Venice*.[37] The primary focus of this project was to catalogue the bridges, but traffic data was also collected. As part of the traffic counting, the team recorded mobility impediments; however, their categories of impediments were relatively simplistic. Also,the study was not particularly insightful as to how the bridges could be modified since that was not the goal of their traffic counting. Overall, the only useful data from the E98 project was the overall percentage of impediments to which we could compare our data.

The Ponti[38] GIS layer was useful for finding the names and codes of each bridge based on their location. The Access database from EASYBridges[39] could then be used to find the physical properties of the bridges such as number of steps, hand railings, and height of steps.

The only other potential source of data was the Accessible Venice[40] office; however, they seemed unwilling to share their data beyond letting us watch a PowerPoint presentation summarizing their work.

3.2.3. Data Collection Phases

Phase 1

The initial phase of our data collection was designed solely as a test of our field forms. Through the test, we were able to adjust our predicted mobility impediment categorizations to reflect the impediments that would actually be observed. Furthermore, though this test, we determined that only two people were required in order to observe traffic over a bridge instead of the originally predicted five. It was also found that the team member recording impediments needed to stand atop the bridge in order to observe the ambulatory patterns of pedestrians on both ramps simultaneously since some impaired individuals only have difficultly going up or going down. This test was conducted on the morning of Tuesday, October 30, 2007 for 30 minutes at each of the four bridges.

Phase 2

The second phase of this objective was designed to determine the peak time periods for both number and percentage of ambulatory impediments using both tourist and residential bridges. Additionally, this data collection helped to further refine our field form. Counts were performed every hour on the hour for a tourist bridge and every hour on the half hour for a residential bridge from 8:00 to 18:45 on Tuesday, November 6, 2007. The peak times were then verified for the Ponti Bargami on Friday, November 16, 2007 by collecting data at the bridge from 9:00 to 11:00 and from 16:00 to 18:00.

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[37] Felices, Diego, Carlos Moreno, Alexander Munoz, and Brian J. Smith, *The Inventory and analysis of the Bridges and Pedestrian Traffic in Dorsoduro, San Polo, and Santa Croce Sestieri of Venice* (Worcester MA: Worcester Polytechnic Institute, 1998).

[38] GIS, *Ponti*

[39] EasyBridges

[40] Accessibe Venice

Phase 3

During the final phase, the thirteen public bridges on the island of Tolentini were observed in order to determine which bridges carried the highest numbers and percentages of mobility impediments. Data collection was performed for one continuous hour at each bridge during both of the peak. Collection for the 16:00 to 18:00 peak occurred on Monday, November 26, 2007n and Tuesday, November 27, 2007 and collection for the 9:00 to 11:00 peak occurred on Friday, December 7, 2007 and Monday, December 10, 2007.

3.2.4. Types of Impediments

The types of impediments were broken down into several categories depending on the type of impediment and how it was counted.

Mobility Aids

Handicapped individuals seen using any of the following mobility aids were counted once towards that category of impediment.

- **Wheelchair**
- **Crutches**
- **Walker**
- **Cane**

Rolling Items

Although the following are not physical disabilities, each one creates a burden for the owner when they must be transported across a bridge. Note that, each item was counted as only one impediment, regardless of the number of people required to transport it over the bridge. This was done since, usually, only one person would be required to move the item over a handicap accessible ramp.

- **Stroller** – both the operator and passenger of the stroller are counted towards the total pedestrians, but only count once towards the impediments.
- **Luggage** – rolling type luggage that was not being carried by the owner prior to approaching the bridge. Any luggage carried by the owner was not counted since these people would not benefit from the installation of ramps
- **Shopping Cart** – a bag mounted on a dolly that is commonly utilized by Venetians for groceries
- **Delivery Cart** – any dolly or cart that can be used to transport heavy or bulky packages

Subjective Categories

The classification of individuals with the following impediments was highly subjective. In many cases, people who could be described by the following categories were unaffected by crossing bridges. As a general rule, the team only counted people falling into the following categories if they showed clear signs of duress such as heavy breathing or slow movement.

- **Limp**
- **Elderly**
- **Large Parcels** – any carried object: commonly large boxes, boards or oversized bags/objects
- **Overweight**/Pregnant**
- **Other** – is to be defined in the "Notes" section if a person crossing the bridge does not fit another category, for example someone with a mental disability with difficulty crossing the bridge

** due to the high frequency of overweight individuals that also fall under other categories, it was considered a secondary classification. In such a circumstance, the column of the primary impediment was marked with an "O" instead of a tally mark.

Supported Individuals

The following were secondary categories that were always found with one of the primary categories above. As such each was recorded in the column for the primary impediment with an appropriate letter instead of a tally mark.

- **Supported by Person, "P"**
- **Supported by Handrail, "R"**

3.2.5. Instruments

Counter – This small, hand-held counting device was used to track the total number of pedestrians to cross the bridges

Stop Watch – a timepiece was used to measure out the time intervals for the data counts

Camera – A camera was used to photograph the bridges who's traffic was under study

Figure 3-3: This style of counter was used by each team member during the data collection stages.

3.2.6. Location

The following is a list of bridges surveyed during the three stages of our project. Appendix C contains specific details, maps, and pictures of each bridge. Additionally, the full physical characteristics of each bridge can be found in the Ponti.mdb file included with this report.

Phase 1: San Marco Area

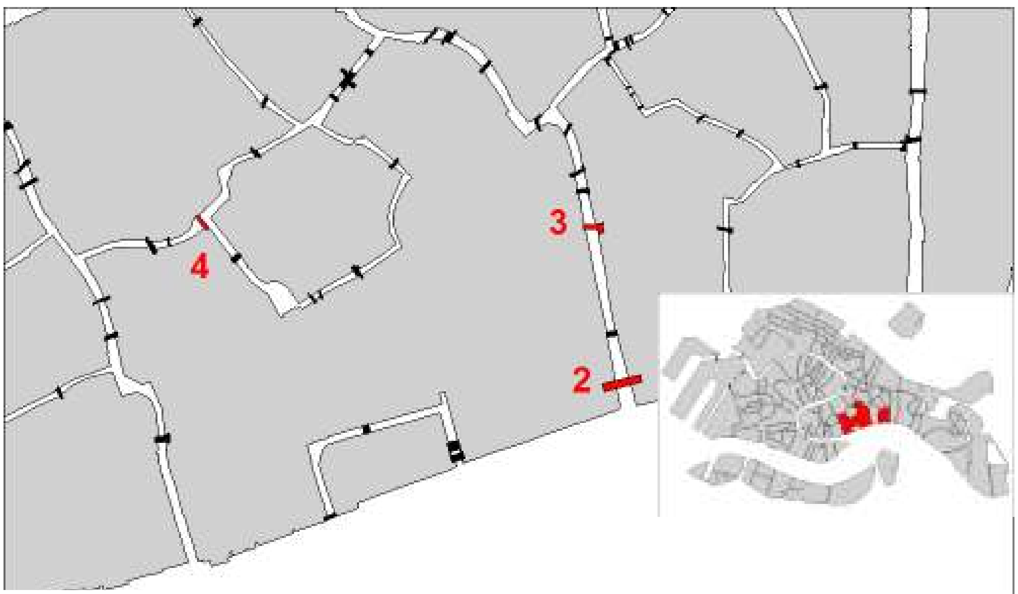

Figure 3-4: The bridges in the San Marco Area studied: 1) Ponte de la Pieta 2) Ponte de la Paglia 3) Ponte Carlo Goldoni 4) Ponte de la Canonica

Phase 2: San Cancian

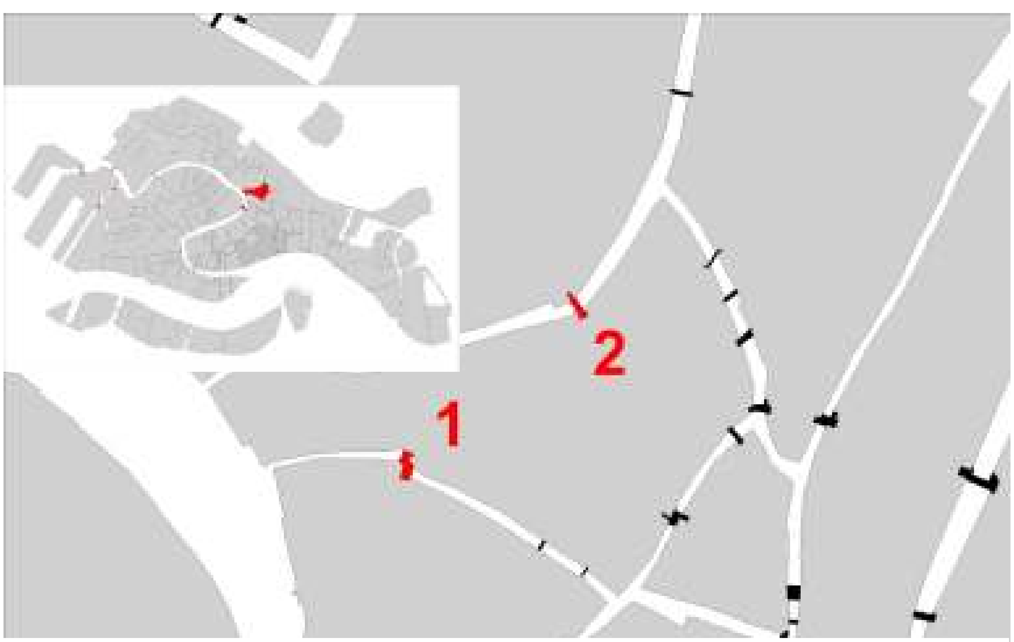

Figure 3-5: The bridges studeid on San Cancian 1) Ponte San Giovani Grisostomo 2) Ponte San Canzian

Phase 3: Tolentini

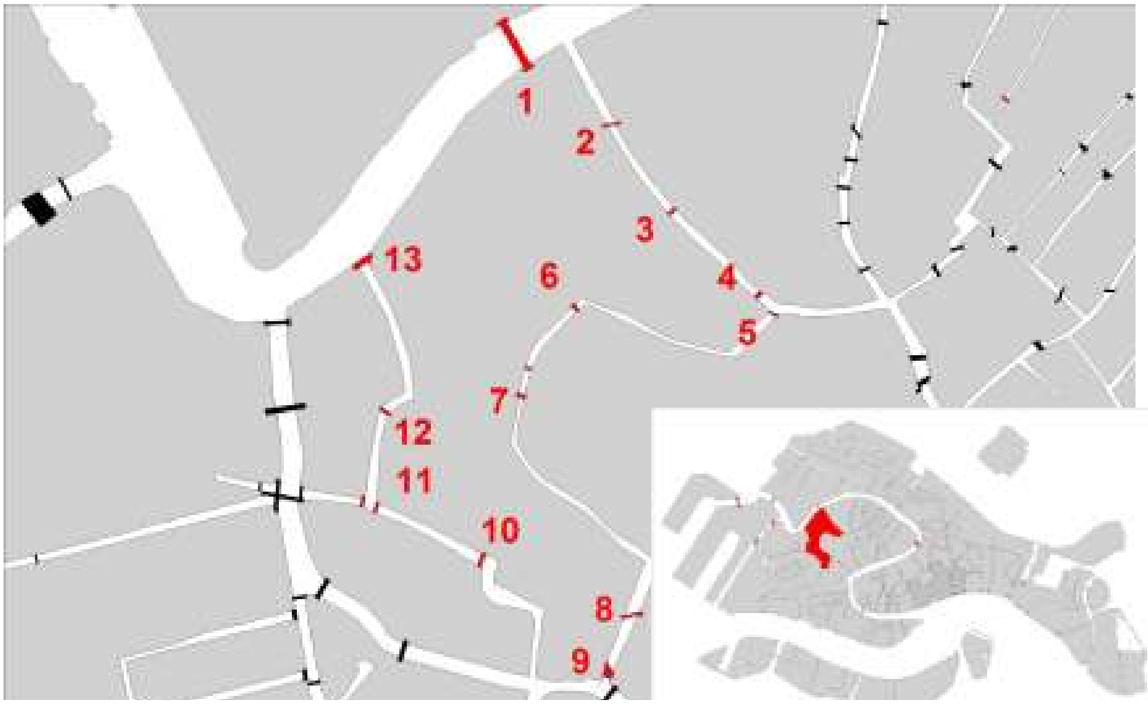

Figure 3-6: Bridges studied on the Island of Tolentini 1) Ponte degli Scalzi 2) Ponte de la Bergama 3) Ponte Cappello 4) Ponte del Cristo 5) Ponte San Pantalon 6) Ponte de Ca'Marcello 7)Ponte del Gaffaro 8)Ponte dei Tolentini 9)Ponte de la Croze

Data Collection Procedures

Based on the expected amounts of traffic over each bridge, different sized collection teams were required.

Five –Person Team

The five person procedure for high density traffic flow was only implemented for the two bridges with ramps that were surveyed during the first phase. Using this procedure, one team member stood at the bottom of each ramp and one at the bottom of each set of stairs. Each of these team members counted the pedestrians stepping off the bridge (pedestrians stepping onto the bridge were later counted by the person on the other side). The fifth team member, whose job it was to count the mobility impediments, stood in the center of the bridge near one of the railings.

Two – Person Team

The two person team for moderate density traffic flows was the most frequently used method: for the remaining two bridges of phase one, the two bridges of phase two, and many of the bridges during the third stage. For this method, both team members stood at the center of the bridge so that they could look for mobility impediments. One team member was responsible for recording those impediments while the other counted the total number of pedestrians.

Single Person Team

For the lowest density traffic flows during the third stage, a single person was capable of both counting the total pedestrians and recording the types of mobility impediments.

3.2.7. Data Archival

Data for each bridge was recorded in Excel spreadsheets. Spreadsheets for the first and second phase were simple tables that recorded the bridge, the time periods and the types of motilities. For the third phase, a multi-page spreadsheet was used. Each bridge was given its own page in which the number of impediments and totals were recorded. Then, a master page in the spreadsheet totaled all of the data from each bridge with the mobility issue across the columns and each bridge on its own row.

3.3. *To assess the impacts of docks in Venetian society*

3.3.1. Project Approach

The idea for the Danger Zone map first came from Lucia Baracco[41], who also led us to our idea for the Accessibility Map. Lucia's organization, Accessible Venice, had come up with the idea and began creating a largely-incomplete, static map of the Danger Zones located throughout the city of Venice. A Danger Zone can be defined as an area where a dock lies adjacent to a bridge with no barrier present. Thus this presents a problem to the visually impaired because if the individual was walking along the wrong side of a street with a walking stick, they would be at risk of missing the bridge and falling directly into the canal via the dock. Thus the term "danger zone" was created to help identify the problem and take action to diminish them. Again it is important to note the Ms. Baracco brought this idea to our attention and Accessible Venice did take the first steps in producing a map of these danger zones throughout Venice. Existing information from the Venice Project Centers databases was used to create GIS layers that, when linked together, formed an easily updatable map of the danger zones.

The idea for a map about Types of Docks and Usable vs. Unusable Docks was brought to our attention through our groups discussions with Professor Carrera. We were able to utilize data collected by past IQPs regarding the usability of the docks, as well as their classifications. This information was present in the EASYDocks application and available to us through the Project Center and Forma Urbis.

3.3.2. Existing Data Sources

The Rive[42] and Ponti[43] GIS layers were useful for finding the names and codes of each dock and bridge based on their location.

[41] Baracco
[42] GIS, *Rive*
[43] GIS, *Ponti*

The Access database from EASYDocks[44] was also utilized to note whether or not gates or their remnants were present.

The Isole[45] GIS layer provided the shape and location of each island.

The EASYDocks application provided all of the past IQP work on Docks, including pictures, locations, measurements and gate remnants.

A map was shown to us by Lucia Baracco when we first met with her, but it was never provided to us. The map idea was brought to us by Ms. Baracco, though Accessible Venice's map still remained static, which must be manually updated each time there is a change.

3.3.3. Data Collection

Some searching was done by the group to identify specific danger zones, especially to obtain pictures to identify what qualifies as a danger zone. The majority of the data collected for this project was performed in past IQPs, so the data was present in EASYDocks and our work was to compile it into one layer.

3.3.4. Creating the Maps

The first step in creating the Danger Zone Map was to link the Isole[46] layer and the EASYDocks[47] database. This link allowed our group to utilize the data regarding location and gate remnants to properly identify Danger Zones throughout Venice. Andrea Novello, from Forma Urbis, provided us with help to linking the databases and creating a 1.5 meter buffer around all of the bridges in Venice. This buffer allowed us to use the intersection tool, so that a point was created at any place where a dock was within the 1.5 meter bridge buffer (See Figure 3-7). Thus identifying our definition of Danger Zones in the city and providing an easily updatable map to provide to the public.

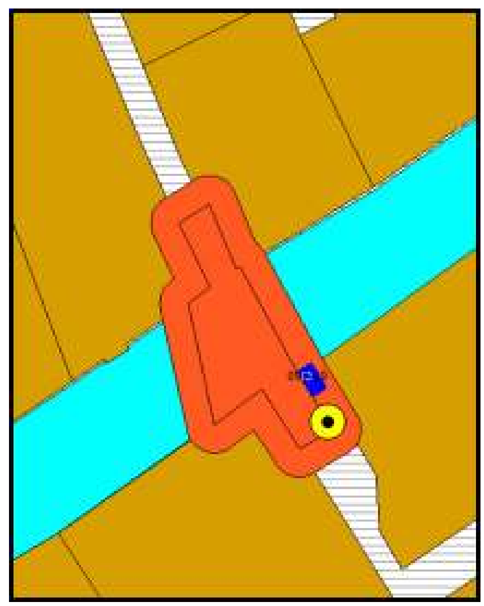

Figure 3-7: Example of the 1.5 meter buffer used around bridges to find nearby docks

Creating the Types of Docks and Usable vs. Unusable Docks maps were very similar to the Danger Zone map. The EASYDocks[48] database was again used to specify the different characteristics of the docks. Each of the different types of docks was queried and created into its own layer. Each dock on these layers was color coded with respect to the type of dock it represented and a legend was provided to distinguish between them. Similarly, the data collected in past Dock IQPs was used to distinguish usable docks from unusable docks. To determine what was usable or not, two things were considered: the type of

[44] EasyDock
[45] GIS, *Isole*
[46] ibid
[47] EasyDock
[48] ibid

dock and the number of usable steps (due to algae, high tide, etc.). Once a strict list was determined, the docks were queried based on the identified characteristics and colored by green (usable) and red (unusable).

3.4. *To design a web-based navigation tool accommodating all mobility levels*

Figure 3-8: Navigate Venice Logo

3.4.1. Determining the tool's desired capabilities

Based on our observations of the pedestrian traffic within the city, we created a list of the most beneficial features that should be included in the application. The actual application has not yet been programmed, but will eventually include the following:

Path Options

Minimize Walking Distance – determines the shortest route between two points. This option would be useful for impaired individuals that are more affected by distances than by climbing stairs. This would also be the mostly likely option used by the general public.
Minimize Number of Steps – determines the route with the least number of steps by using the fewest number of bridges and choosing the bridge with the least number of steps when one must be used. Impaired individuals, especially those with wheelchairs or wheeled accessories will most benefit from this option
Minimize Step Height – determines the route with the lowest step height. This option is designed for individuals who have difficulty lifting their legs to climb stairs.
Utilize Public Boat Transportation – this feature can be used in combination with any of the previous options. It allows the user to decide if they want to Always, Sometimes (Distances over ½ mile), or Never use public boat transportation. This option provides the primary method for impaired individuals to avoid crossing many of the bridges within the city
Utilize Tourist Routes – this feature can also be used in combination with the first three options. It allows the user to select from "Always", "No Preference", and "Never". Tourists would find it beneficial to chose "Always" in order to see as many of the sights as possible, while residents may chose "Never" in order to avoid the highly congested areas of the city.

Map Options

Scroll – allows the user to click and drag to scroll the map
Zoom In/Zoom Out – allows the user to zoom in and zoom out

Print – Creates a “printer friendly” version of the map and directions.

Input Options

Addresses can be chosen in one of three ways:

Drag and Drop – a “Start” and “End” icon can be dragged onto the map of the city. This method would be most useful to residents of the city who can easily locate their place of origin and destination on a map.

Address – An address can be entered into a text field. The program will automatically check to ensure that the address exists. This option could be used by both tourists and residents who have an address for where they would like to travel.

Drop Down Menu – a named location can be selected from a drop down list of locations sorted by type of building. Currently data is available to implement this option for both churches and palaces.

Output

Navigate Venice will output both a map showing the path of the calculated route and written directions. Directions will include additional information appropriate for the chosen options. (Examples: the number of steps for “Minimize Number of Steps” or the boat schedules when a public boat is being used)

Other Features

Updatability – Since data changes as maintenance is performed, the databases upon which the program is built must be easy to update. For instance, as pavements are raised around the city, some bridges lose their bottom step, thereby decreasing the number of steps

Acqua Alta – eventually, the program should be able to warn users in real time if acqua alta is going to flood the calculated route and will provide a secondary route that can be used to circumvent the high water.

3.4.2. Designing the web-based user interface

Figure 3-9 and Figure 3-10: These user interface mock-ups were created using Microsoft Visio to demonstrate the features Navigate Venice will eventually include

3.4.3. Preparing the necessary data sets and map layers

In order to provide the desired functionality, many databases will be required. Currently, these consist primarily of GIS Layers plus one Access Database.

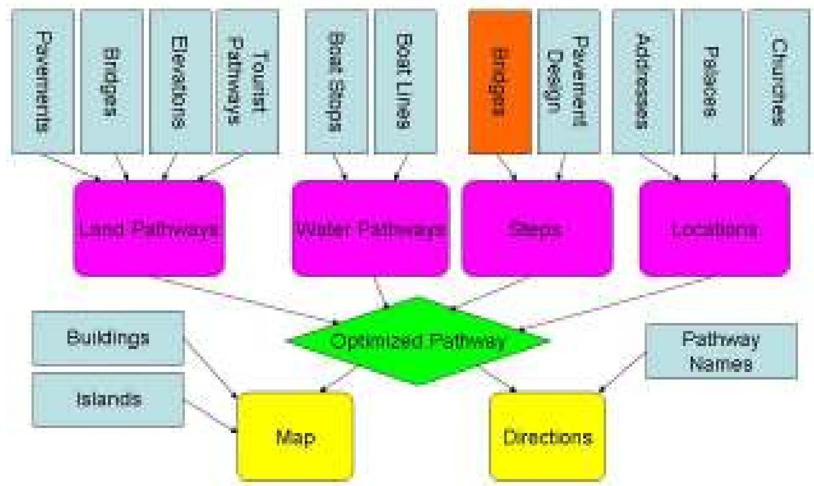

Figure 3-11: Flowchart depicting the interconnection of databases required to create Navigate Venice. Blue Boxes represent GIS map layers and the orange box represents an Access database.

GIS Layers

Pavements – all the pedestrian accessible areas of the city
Buildings
Bridges
Pathways – Showing all of the pedestrian pathways and includes the names of every square and street. For the most part, it overlays the pavements layer, but also includes a few paths across the Grand Canal which represent the traversal gondola services.
Tourist Pathways– Showing major tourist paths through the city
Boat Stops –location of the public boat stops and will eventually include detailed boat schedules.
Islands
Address– Location of every address within the city
Palaces –names and address
Churches –names and address
Pavement Designs– Shows the rough "shape" of the pavements including designs in marble and a few steps (but it's a little unclear what is a step and what is just decoration). Primarily this would be useful for estimating the number of steps on a bridge in case the bridge database (see below) does not have data on one of the bridges.
Pavement Heights –elevations for some of the pavements

Access Database

Bridges (Ponti**)** – name, number of steps, average step height

4. Results and Discussion

4.1. *Results*

4.1.1. Book Chapters

Full-length copies of the written publication chapters can be found in Appendix E.

4.1.2. Island Accessibility

It was brought to our group's attention that we could make forward progress with public awareness of varying problems and solutions in the city. We learned about the strides that organizations such as Accessible Venice[49] have made to make the city more accessible and allowing us the opportunity to make the information more available to the public. We also gained information regarding some of the problems in the city to those with vision impairments and took this data to make GIS layers.

Since the city does contain numerous accessibility solutions throughout it, such as the *servoscala* and temporary marathon ramps, our group decided to create GIS layers that incorporated the numerous solutions available. This map shows the location of the Venice Marathon ramps, the *caregòn*, *servoscala*, elevator, bridges with permanent ramps or no stairs, as well as bridges with handrails. Additionally, itineraries[50] that have been produced by Accessible Venice for the nine most popular tourist destinations were hot-linked into the layers to make the map interactive. The location of these itineraries is shown by the bold borders around the containing islands. The final result of these layers can be seen in Figure 4-3. These layers were made publishable to the internet, so that any user could use the interactive map.

The biggest problem faced with this map was not producing it but was presenting it to Lucia Baracco and her staff. Our meeting was previously intended to show her the capabilities of the advanced technology that we had, including the extensive databases, to help her with her mission to widen public awareness. It was thought by our group that we could present her with an example of how we could assist in reaching her goal. As the meeting progressed, however, it became apparent that she misunderstood the intention of this new map. The revised map was not created to take credit away from the work her organization has already accomplished, but simply to support their efforts and improve upon the effectiveness of a well thought out idea. We would like to apologize to Lucia and her staff for any misinterpretations about our intentions.

4.1.3. Incidence of Mobility Issues

After defining the various types of mobility impairments in Venice, we conducted our next stage of the project assessing the peak times of mobility impairments over bridges. The stage was a one day pedestrian traffic count at two bridges of varying traffic volume, *San Giovanni Grisostomo* and *San Cancian*, for 15 minutes on each hour for 11 hours during which we determined the following peak times:

- 09:00 to 11:00

[49] Accessible Venice
[50] *Informahandicap*

- 16:00 to 18:00

The complete results of the peak time pedestrian traffic counts of mobility impairment percentages can be seen summarized in the following figures:

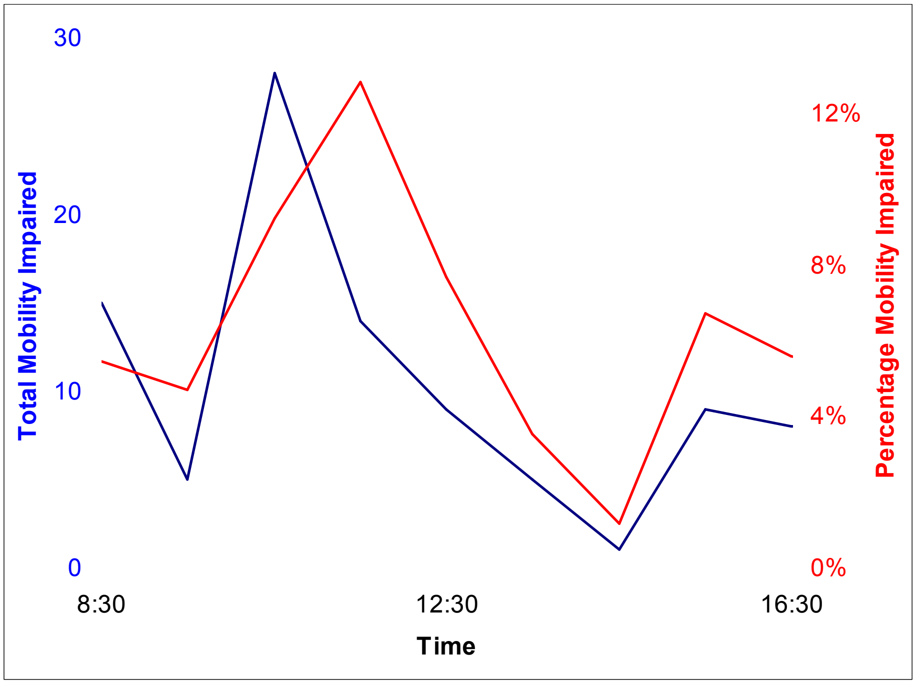

Figure 4-1: Peak time data for *Ponte San Cancian*

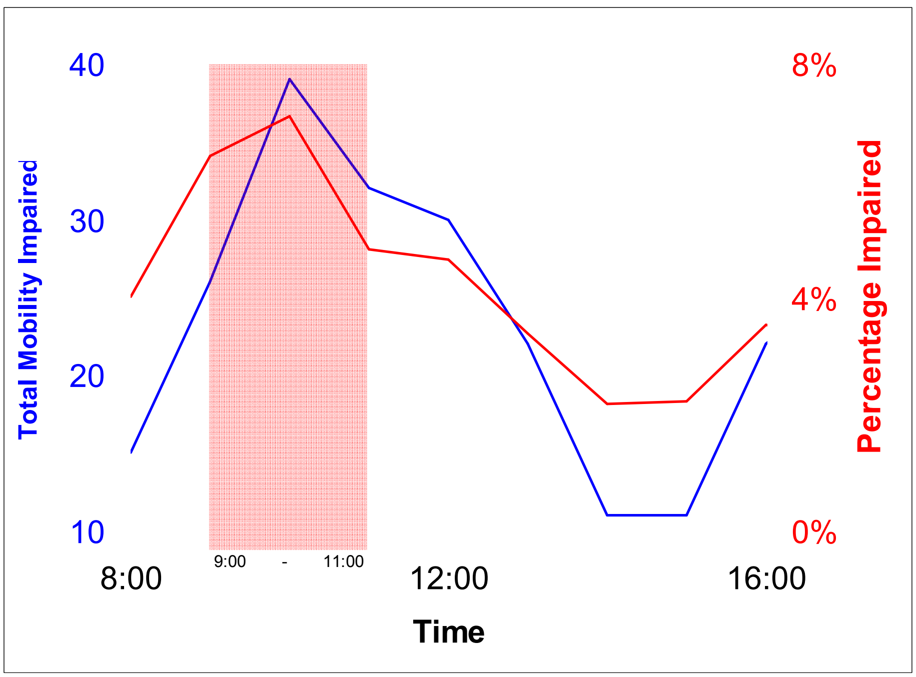

Figure 4-2: Peak time data for *Ponte San Giovanni Grisostomo*

Table 4-1: Total List of mobility impairments

Impediment	**9:00-11:00**	**16:00-18:00**	**Total**
Wheelchair	1	2	3
Stroller	21	62	83
Shopping Cart	92	65	157
Delivery Cart	55	41	96
Limp	15	15	30
Luggage	254	223	477
Walker	0	0	0
Cane	10	21	31
Crutches	0	2	2
Elderly	50	87	137
Overweight	0	14	14
Pregnant	0	2	2
Large Parcels	40	39	79
Total Pedestrians	10940	13646	22534
Total Mobility Issues	678	573	1111

As our group used those peak times for our official data collecting from all 13 public bridges on the island of *Tolentini*, we produced results broken down by those peak times (See Tables 6-1). Of the 48 hours spent gathering this data, 22,534 pedestrians were counted resulting in 1111 total pedestrians (4.9%) noted traveling with mobility issues. The pedestrian traffic counts in the morning recorded a mobility impairment of 6.2%, while pedestrian counts in the evening recorded 4.2%.

The Bridge Accessibility Field Form was created after several revisions by our team based on the 13 types of mobility impairments defined by our preliminary stage. After each revision, testing was performed to assess the success of the form during each data collection. The updated Field Form can be found in Appendix B. The field form lists the different mobility impairments with space at the bottom for any impairment not listed and for any special notes during the pedestrian counting.

4.1.4. Impact of Docks

Geographical Informational System (GIS) layers were constructed in the following areas to promote public awareness of the effects of Docks on Venetian society:

- Usable docks
- Dock types
- Danger zones

These layers were programmed with the intent that they can be accessed through use of the internet. Each layer is updatable and thus can be changed by an organization with the proper software program.

4.1.5. Web Application

The design for the web application was completed and ready for further stages of development. Data was collected to determine which important characteristics of this web application should be implemented into the interface. Our meetings conducted with *Insula S.p.A.*, Enzo Cucciniello, and Lucia Baracco[51], helped us to add the most effective options needed to make this application useful for its users. These options include alternate routes if a road/bridge is being constructed, taking advantage of the *Vaporetti* lines to limit the number of encountered bridges, adding a route to avoid bridges with high step heights. We also gave the user the advantage of following a route that will lead them to their desired destination through any of the handicap accessibility city programs, such as Accessible Venice ramps, *Servoscala*, and the *Caregòn*.

4.2. *Discussion*

4.2.1. Publication Chapters

Each chapter is an in-depth discussion based on the research completed, noting the histories and backgrounds of each section, as well as the work being completed to maintain these areas of infrastructure. Several drafts were handed in, and received with general comments to improve the quality of the content before being completed for the final publication.

4.2.2. Island Accessibility

It was brought to our group's attention that we could make forward progress with public awareness of varying problems and solutions in the city. We learned about the strides that organizations such as Accessible Venice[52] have made to make the city more accessible and allowing us the opportunity to make the information more available to the public. We also gained information regarding some of the problems in the city to those with vision impairments and took this data to make GIS layers.

Since the city does contain numerous accessibility solutions throughout it, such as the *servoscala* and temporary marathon ramps, our group decided to create GIS layers that incorporated the numerous solutions available. This map shows the location of the Venice Marathon ramps, the *caregòn*, *servoscala*, elevator, bridges with permanent ramps or no stairs, as well as bridges with handrails. Additionally, itineraries that have been produced by Accessible Venice for the nine most popular tourist destinations were hot-linked into the layers to make the map interactive. The location of these itineraries is shown by the bold borders around the containing islands. The final result of these layers can be seen in Figure 4-3. These layers were made publishable to the internet, so that any user could use the interactive map.

[51] Botazzo, Cuchinello, and Baracco
[52] Accessible Venice

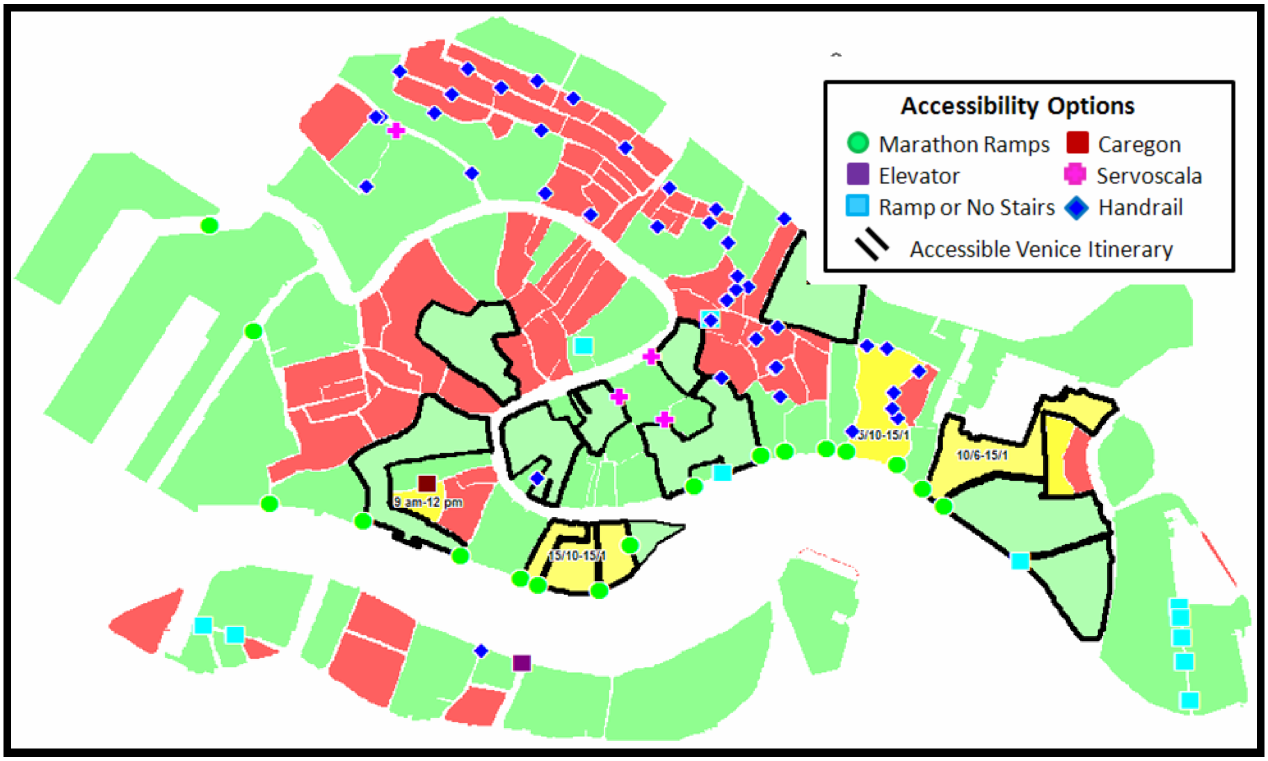

Figure 4-3 – Accessibility of Venice GIS layers

4.2.3. Incidence of Mobility Issues

Our two peak times for collecting pedestrian mobility issues revealed that although more pedestrians were crossing the bridges in the evening, there were fewer mobility impairments. In the morning peak time however, pedestrian totals were fewer, but percentage of mobility impairments increased. This analysis is re-enforced by our largest mobility issue. The most common mobility issue found, at 42.9%, was pedestrians carrying luggage. Throughout the morning hours, tourists and others with luggage make their way through the streets of Venice to get to the train or bus stations, or to get to their hotels and homes, thus carrying luggage. In the evening hours, while there may be more tourists out in Venice, they would not be necessarily carrying their luggage around.

The analysis of the mobility impairments of Venice provided clear data on the different types of impediments and the benefits that would be in store if future mobility impairment IQP's were completed in Venice. Through our discussions and analysis, we have picked the most appropriate impairments to be included on our Bridge Accessibility Field Form.

The overall percentage of people who had mobility issues proved to be an important number with regards to a previous IQP's field work. The E-Term 1998 IQP investigated the quality of bridges in three *Sestieri* and rated the condition of 157 bridges. While collecting information on these bridges, they also took pedestrian counts and calculated the number of mobility impairments crossing over the bridges. Their data revealed that approximately 4% of those crossing the bridges were those who had mobility issues. In comparing their data with the data collected during this project, it is a fact that the percentage of mobility issues increased from about 4% to 4.9%, though the 1998 project[53] logged more hours over more bridges. With further analysis of a wider range of bridges, more concrete discussion could be produced to raise awareness in the city.

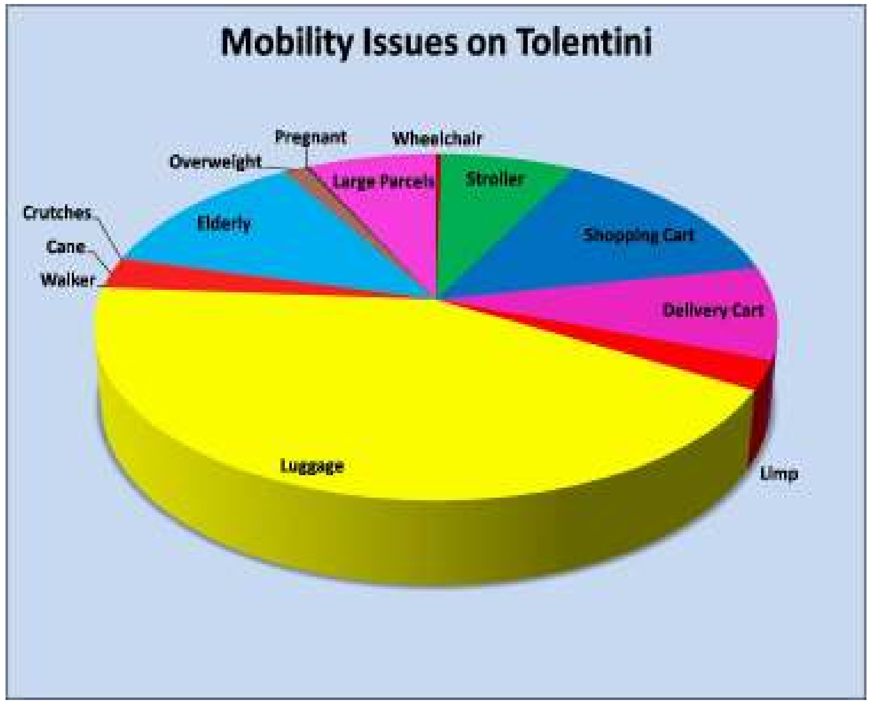

Figure 4-4 - Overall mobility issue breakdown for the island of *Tolentini*

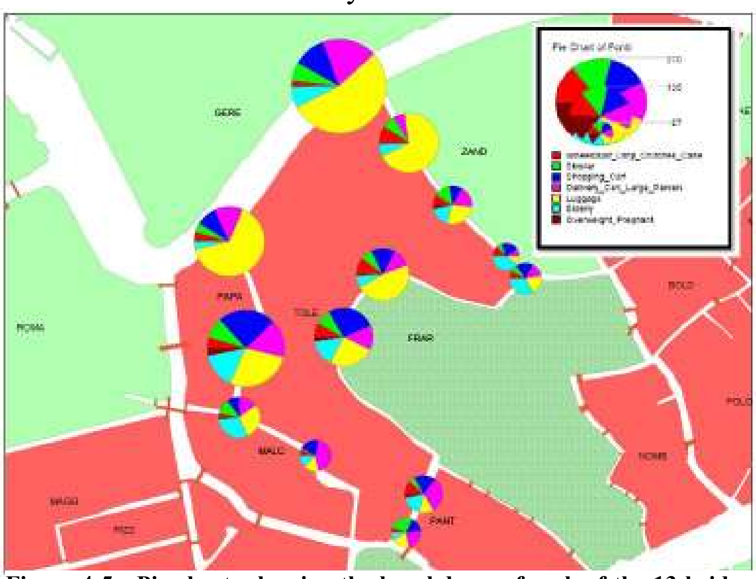

Figure 4-5 - Pie charts showing the breakdown of each of the 13 bridges data was collected at on *Tolentini*

The bridge field form went under three different revisions to help make it as effective as possible for future users to count pedestrian traffic. The 13 different mobility impairments were listed from top to bottom in order of most common impairment recorded throughout our pedestrian traffic counts. Our group added a notes section at the bottom of the most updated field form to explain any causes for skewed data, as well as any other problems or concerns. In the case of those with multiple mobility impairments, our group decided to make specifications to the tally marks to further detail our data. We decided to use the letters "R" for railing assisted, "P" for assisted by another person and "O" for overweight, to further clarify people who fell into more than one

[53] Bhan, *Analysis of Bridges*

category of mobility impairments. Though no order of priority was strictly defined, these specifications helped us to categorize each individual so that we collected as much information as possible.

4.2.4. Impact of Docks

In addition to the accessibility GIS layer that was created, 3 dock layers were also formed. Maps of both the useable and unusable docks of Venice were produced to show the severity of the problem that high tide causes to the usefulness of the docks. Additionally a layer showing the different types of docks, as broken into 8 categories, was created to show the user the variety of docks found in the city. Finally, a dock layer showing the danger zones in Venice was created. By producing a 1.5 meter buffer around all the bridges in Venice and finding where they intersect with docks, a GIS layer of the 187 danger zones was created. This layer was also created for use on the internet so that it can be made public and useful to both the tourists and residents of Venice.

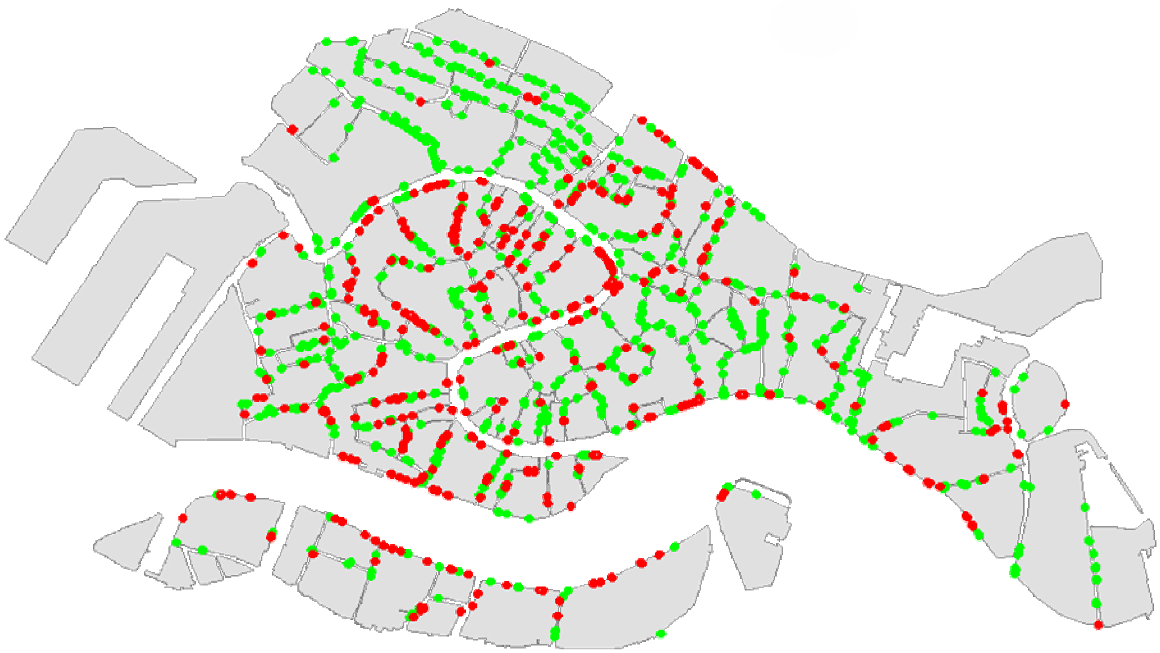

Figure 4-6: Usable (Green) and Unusable (Red) Docks

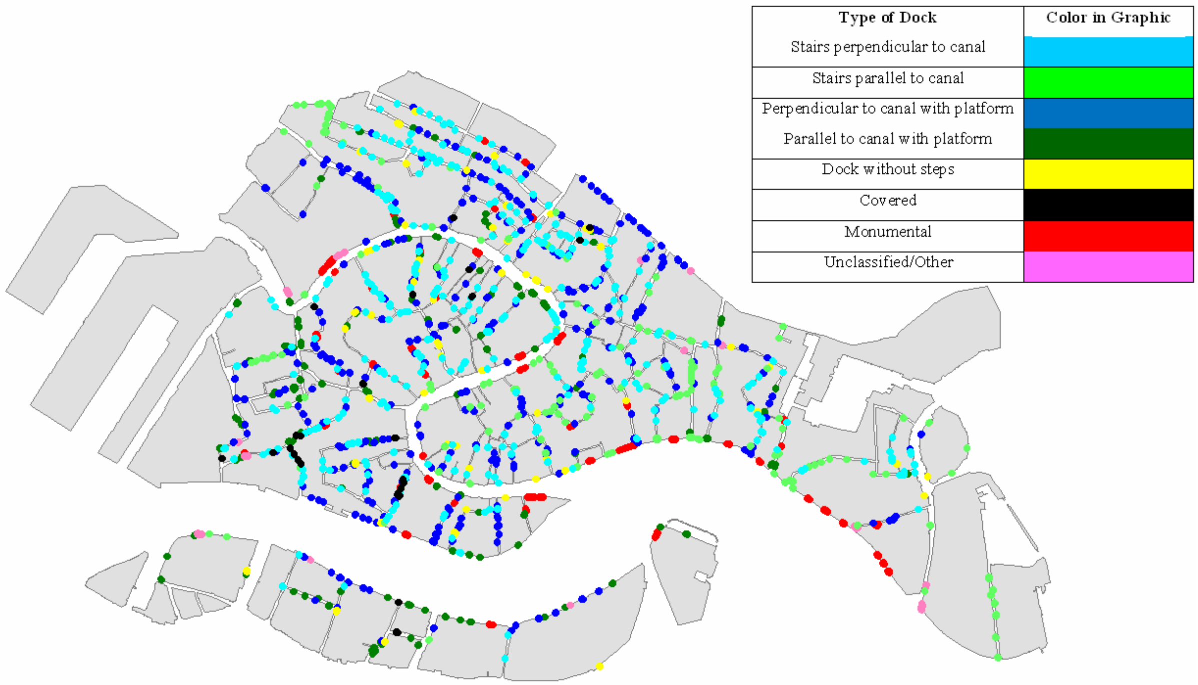

Figure 4-7: Types of Docks

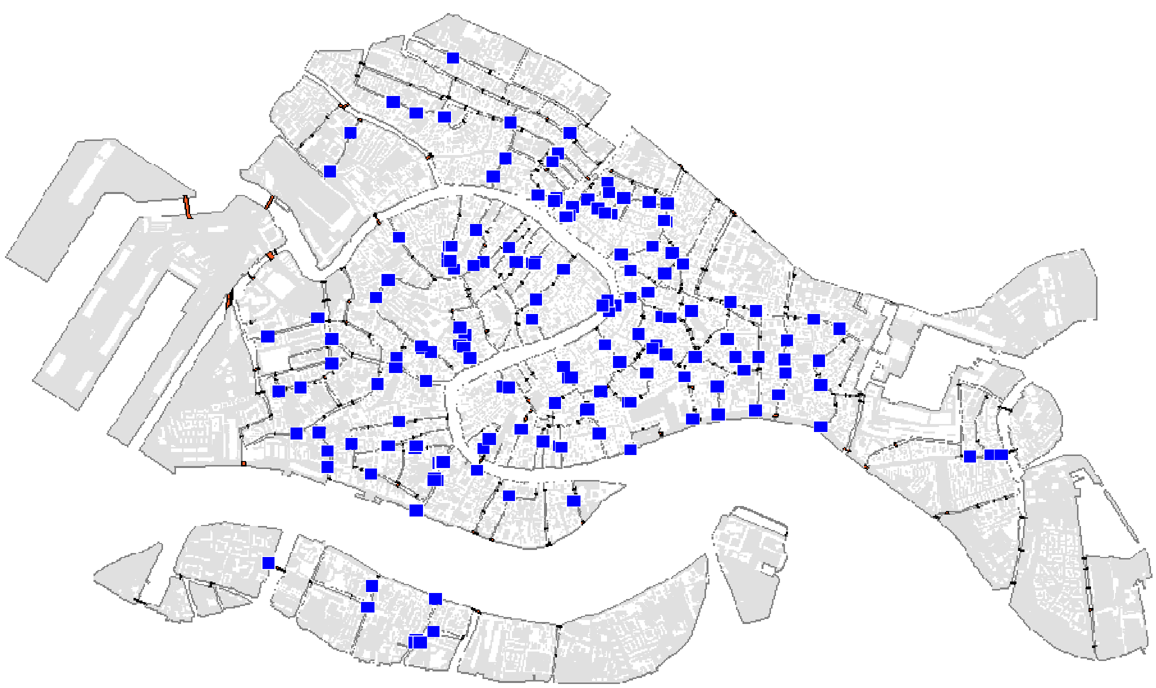

Figure 4-8 - Danger Zones

4.2.5. Web Application

The application, when opened by a user from its URL address, will open the Navigate Venice homepage as shows. The map has the option to zoom in or out and also has the ability to move around the map of Venice. The sidebar on the right gives you various options as to how you want to pick your departure point, destination point, and choice of route. There are three options to pick your destination and departure: By typing the desired addresses, by picking a selected location or by using the map to locate the area and putting a marker at the points of interested as your addresses. This benefits all users, residential and tourist. Below this information gives you the choice to decide if you want to reach the destination by way of shortest distance, least number of bridge steps and by avoiding the bridges with the highest step height. The last section of the sidebar informs the user if they would like to avoid bridges as much as possible by using the public service of a *Vaporetti* line, and if they would like to utilize tourist routes in transit.

Figure 4-9: Navigate Venice Homepage

When the user has listed their preferences, they would click the "Find Route" button to have the tool calculate the desired pathway. Figure 4-10 shows a sample route. The basic web layout is the same but the map has changed to show to the route that the user has chosen. The program took all the requirements based on the user's preferences, and developed the best route. Underneath the map are the following directions with street names to guide the user.

Figure 4-10: Navigate Venice Search Results Page

Our analysis of this program ensured us that the data collected would have to be updated on a regular basis for accuracy to make this application effective. For example, the ACTV boat service consistently changes the departure times of their *Vaporetti* lines and it is uncertain whether or not new lines would be added in the future.

During the project our group determined the necessary databases that would need to be utilized by this program. These databases include many that have been collected by the Venice Project Center and past IQP, which are readily available. We also created our own idea for a layout and design for the program, so that mock versions could be shown for presentations. Though the program was not made useable by our group, the planning and feasibility studies were completed and presented to the company Red Fish for further analysis.

5. Recommendations and Conclusions

From the data we have collected, our group would first recommend that another bridge traffic project be completed as a future IQP. This project should verify and continue the data collections that have already been made. The data needs be more complete for many of the bridges that we looked at and a better representation of how traffic flows on individual islands should be made.

Although Venice is considered by some one of the most handicap accessible cities in the world, there is still plenty of work to be done in making the city completely accessible. There is obviously a unique, historical factor to the city that needs to be left untouched, which provides special difficulties in implementing changes in the city. The city still can move forward by analyzing bridges on a case by case basis. A future IQP group can certainly provide necessary information to the city for changes to be made.

The following recommendations provide insight to allow future IQP groups to plan out and execute accurate traffic counts. The purpose of these counts should be intended to provide the City of Venice or *Insula* with information regarding possible options to make the cities bridges more accessible. By analyzing data throughout the entire city, a future group should be able to determine key locations that lack handicap accessibility and provide options and ideas to relieve these problems. It is important that a sponsor somewhere in the city is sought out to guide the group and provide necessary information and history about solutions already implemented and solutions that are currently in the works.

5.1. *Island Accessibility*

Throughout the term it became evident to our group that some of the databases from past IQPs are not fully up to date, or accurate. It has been almost ten years since most of these projects, specifically EasyBridge[54] and EasyDocks[55], have been completed and many are in need of updating. More information is attainable from *Insula*, but much of the information is no longer publically shared. Contact with *Insula* would provide more knowledge and allow advisors to determine the extent of a future project. Data from EasyBridge is incomplete and needs to be updated such as; whether handrails are present or not, the handicap accessibility of the bridge newly constructed or demolished bridges, year(s) of construction, and bridge materials.

Based on the difficulties we encountered with the public boat stop layer of the map, we recommend an alternative method which displays the same information, which will make the map more interactive be used. Instead of having geometric symbols at every island to define the different boat lines, each island that is accessible by boat should have one unifying symbol that can be hotlinked to a listing of the boat lines and their route. This suggestion would significantly reduce the congestion of the accessibility map. In addition it is recommended to contact and work in cooperation with the ACTV to possible link the actual boat stop schedules to the online map.

Lastly, it was stressed by the group that in order to produce the most effective island accessibility map, future teams would have to work on repairing the relationship with Lucia Baracco and her staff to actively communicate about future advancements.

[54] EasyBridges
[55] EasyDock

5.2. *Incidence of Mobility Issues*

The data that we collected was based on the 13 bridges on one specific island; *Tolentini*. The reason behind our data collection was to gain information regarding the flow of pedestrian traffic, as well as hard data on the number and percentage of mobility issues present in the city. As explained in our Methodology section, the data we collected was vague and for preliminary purposes. A full analysis of multiple *sestieri* or even the entire island of Venice is necessary for the city of Venice to really consider the work done. Our field work was done to provide ideas for future IQP groups and to begin to work out the many possible problems that a group may face. When collecting data, there are many different factors that must be taken into account to insure that the data is completely representative of the actual pedestrian traffic.

Another important piece of our field work was to create an effective and comprehensive Bridge Accessibility Field Form (see Appendix B). Our group worked with and tried out different field forms to test the best methods of data collection and then created a form that was most fitting for this data collection. There are certain struggles such as priority of people with multiple mobility issues and the inclusion of handrails. It is important that the group fully understands the order of priority so that consistent results are produced. From our total data collection, we determined the following order of priority based on the final percentages of each category: Luggage, Elderly, Shopping Cart, Stroller, Delivery Cart, Large Parcels, Cane/Walker, Limp, Overweight/Pregnant, Wheelchair, Crutches, Other. We recommend that this order of popularity is followed and that these following definitions are followed as well:

- Luggage – a suitcase or bag that is normally rolled along the ground, where the impediment is to stop and pick up the suitcase over the bridge, or to drag the bag up over each step.
- Elderly – any aging individual struggling to cross over the bridge who shows a clear physical impediment, commonly utilizes railings or other people for assistance or makes frequent stops while crossing the bridge.
- Shopping Cart – a bag, much like a suitcase, that is commonly utilized by Venetians for groceries.
- Stroller – any type of baby carriage that is commonly lifted over the bridge by the parents (be sure to count the child as a pedestrian crossing the bridge)
- Delivery Cart – any dolly/cart used by workers to carry heavy goods or cargo over the bridge, often 2 workers lift the dollies over bridges together (in this case, only count as 1 mobility issue)
- Large Parcels – any object carried by a pedestrian that hinders their ease of crossing the bridge and causes the pedestrian to pay careful attention to each step, commonly large boxes, boards or oversized bags/objects
- Cane/Walker – any person utilizing either of these assistive devices
- Limp – any person who shows a clear walking disability or injury
- Overweight/Pregnant – any person who is heavyset who shows a clear struggle crossing the bridge or difficulty breathing OR is childbearing with difficulty crossing the bridge

- Wheelchair – any person who utilizes this assistive device, commonly will be removed from the wheelchair to walk/be taken over the bridge
- Crutches – any person who has a temporary or permanent difficulty walking and uses this assistive device
- Other – is to be defined in the "Notes" section if a person crossing the bridge does not fit another category, for example someone with a mental disability with difficulty crossing the bridge

Even with the specific definitions it is important that the group clearly discusses these definitions and their own definitions so that clear, accurate data is provided in the end. In the cases of Elderly, Overweight and Large Parcels there is always some degree of personal opinion, which must be explained and worked out as a group.

Another piece of the Field Form that we determined was important was to use letters as specific tally marks. We used and included the letters P (assisted by person), R (assisted by railing) and O (overweight) as additional specifications to tally marks when using the field form. These specifications help to relieve the problem of people with multiple mobility impediments, such as an elderly person who uses a handrail for assistance. Rather than simply marking an elderly person as a regular tally mark, this person would be marked as an "R" in the "Elderly" row. Therefore when the data is compiled, it is clear that an elderly person was also assisted by the handrail. This is a good way to diminish multiple mobility issues, as well as provide extra information for the final data. We strongly recommend that these letters are utilized by future IQP groups to reduce confusion and provide more data and information at the end of the project on handrail usage.

To insure scientific accuracy, it is important that data is collected at various times of the day and different days throughout the week. Collecting data at multiple hours and on different days of the week will provide more encompassing results and data for the end of the project and for future recommendations. Our data collection on *Tolentini* was completely performed between the hours of 16:00-18:00, which shows obvious holes in the data received. It is suggested that data is collected throughout the entire day, taking into consideration school times, working hours, lunch hours, common shipping hours and popular tourist travelling times. Preliminary analyses of peak times should be completed before the full data collection is begun to ensure that representative data in collected for the time of year and collection areas.

Our group determined peak times in a very effective manner, but our data collection was taken in a different area than our peak time analysis. The full explanation of our peak time determination can be found in the Methodology section and a discussion of our methods can be found in the Results and Discussion section. We recommend that this method is utilized in the future because it was efficient and provided good, accurate results.

Data should also be collected under different weather conditions to analyze whether the mobility solutions already implemented by the city are safe, such as the plastic ramps and other mechanical devices. Information regarding the safety of the plastic ramps is crucial to the city when analyzing future bridge mobility solutions. If the plastic ramps, for example, are dangerous in wet, slippery conditions then the city should know not to utilize this as an accessibility option. The same is true if such devices like the *Caregòn* and *servoscala* are not as effective under certain weather conditions.

It is imperative to insure that all of the data is taken into account when performing calculations so that overall, characteristic data is presentable. In order for the City of Venice to make such changes to increase accessibility, it is key that the information provided in the argument and proposal is all encompassing and detailed. All of these recommendations, as well as insight from our contacts and sponsors, should be thought out and planned in the preparation period of the IQP.

5.3. *Impact of Docks*

EasyDocks[56] has similar setbacks as EasyBridge[57] with incomplete data and is in need of updates because of what *Insula* has repaired over the past ten years of their existence. A reanalysis of bridge and dock conditions should be completed, especially after *Insula* repairs have been completed. Forma Urbis presented a proposal to the city of Venice about completely reviewing the docks in the city that are being used versus the docks that are inaccessible from the land or from water. However the city of Venice has not made this a top priority and a follow up is necessary.

Danger zones are areas where docks come dangerously close to the first steps of bridges and cause a risk to visually impaired pedestrians. To insure the safety of these pedestrians throughout the city, a GIS layer has been made to show where all of the danger zones are located. However, the GIS layer is not completely accurate because it is not known whether or not there are presently gates that would prevent people from falling into the canals. There is minimal information about the gates in EasyDocks, which poses a problem with the program. Part of completing EasyDocks will help solve some questions about the location of gates blocking docks from being potentially dangerous. We would recommend that a group do research on which docks are actually still dangerous, and if they are, the group should propose that safety gates are implemented where applicable.

Though our group applied GIS layers and databases to bridges and docks, it is important to note that there are still existing databases in other areas of urban maintenance that GIS layers could be made for. One of the areas where further research could be performed is in handicap accessibility of public buildings. A GIS layer investigating the accessibility of public buildings throughout the city would aid numerous people with various mobility issues, especially wheelchairs. Several owners of public buildings in Venice are just now becoming aware of trying to make advancements to improve handicap accessibility, and with the help of a GIS layer, the general public would be able to know which buildings around the city were accessible to the mobility impaired. GIS layers can also be explored in the areas of utility networks and canals, with specific attention to *acqua alta*. *Insula* has begun some of the preliminary data collection for these topics, and although they have a working model, there is still room for more research to be completed[58].

[56] EasyDocks
[57] EasyBridges
[58] Botazzo

5.4. *Web Application (Web 2.0)*

Another project that our group started and began planning for was a web application, called Navigate Venice, for the mobility impaired. This application is planned to give those with special mobility impairments directions and information to get from Point A in the city to another, specified Point B. This program would be run much like Mapquest[59] or GoogleMaps[60] and would provide similar information, but more pertinent to Venice.

Navigate Venice is certainly a project opportunity for the future that could be performed by either an IQP or MQP group. We recommend that an IQP could be done by having a group obtain the necessary information for an outside company, such as Red Fish or Google. A brief meeting with Red Fish (a Santa Fe based programming company) provided us with some preliminary knowledge about the feasibility of such a project. With a group providing them with information from the bridge database, they could certainly handle the programming piece of the project. As related to an MQP, it would be a great opportunity for a Computer Science project to work with a company and provide parts of the programming themselves.

A project focused on this web application could provide the city of Venice, specifically the departments that work with accessibility, an option to publicize the program for the millions of tourists who visit each year. This web application would provide mobility impaired tourists and citizens with the information necessary to travel anywhere in the city with ease. The application would allow tourists the ability to see more of the Accessible Venice itineraries[61] that are presently available and show tourists the simplest way to move through the city by avoiding as many inaccessible bridges as possible. We recommend that the idea of this web application be further analyzed by advisors and/or sponsors that show interest to determine the feasibility of students producing the application.

Another idea our group had about additional specifications for the program includes the culmination of GIS layers that already exists within our database. The program could be expanded to the canals and lagoon of Venice and with the unusable docks GIS layer, a map could be produced showing the quickest or easiest route around the city by boat. With the addition of the unusable docks layer, a boater would be able to avoid docks that cannot be properly used during different tide levels. In addition, the program can utilize the danger zone GIS layer to find options for the visually impaired to avoid the danger zones as they make their way around the city. These options are certainly some ideas of ways to better the program, help affect more users and further incorporate existing databases.

5.5. *Interviews and Sponsorship*

Throughout our studies in Venice, we met with select people city officials and prominent members of *Insula*. The group met specifically with Lucia Baracco from the city of Venice who is in charge of the *Progetto Lettura Agevolata Informahandicap*[62] (a project to help inform the

[59] MapQuest, MapQuest Inc. 2008, www.mapquest.com (Accessed January 8, 2008).
[60] Google Maps, Google, 2008, maps.google.com (Accessed January 8, 2008).
[61] *Informahandicap*
[62] Progetto Lettura Agevolata Informahandicap, http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/341 (Accessed January 8, 2008).

city of handicap issues). Lucia was able to explain many of the city's accessibility problems, as well as solutions to us. Lucia has been in office for many of the updates including the handicap ramps and other various additions to make the city more accessible to those in need. Lucia could be an important sponsor for a project related to handicap accessibility of the city because of how much she has already done for the city. We recommend that future groups seek Lucia's insight and opinions relating to accessibility throughout the city and possibly pursue *Informahandicap* as a sponsor. However, it is important to note that the city department can be sensitive about sharing the work they have completed, which may make working with them difficult. If future students plan to meet with Lucia about a project, we suggest clearly specifying all goals and objectives beforehand.

Lorenzo Botazzo, Director of Work and Planning for *Insula S.p.A.*, was another important contact that we met with during our time in Venice. Lorenzo guided us on a tour of a bridge under maintenance by *Insula* and talked us through the process of bridge repairs where we also viewed a drained canal and learned about canal dredging. The meeting with Lorenzo provided us with a lot of information regarding the history of *Insula*, as well as information about the work *Insula* does. Since Lorenzo primarily works with "Land Work" (pavements, utilities, etc) he was unable to provide us with specific information about "Water Work." He certainly provided priceless information to us about the history and could provide a future group insight as well. Lorenzo is an excellent contact in *Insula*, specifically for Land Work, and would be able to point future groups to other *Insula* directors for information in other categories.

Enzo Cucciniello from the University of Architecture is another important person who assisted us in understanding the history of bridge maintenance in the city. Enzo had many ideas and more specifically, designs on how to make the city more accessible. One idea eventually evolved into a design that went into production and was implemented into the city: the *Caregòn*[63]. The *Caregòn* is a structure that runs alongside of a bridge as opposed to over one. The *Caregòn* is currently implemented in the *sestieri* of *Dorsoduro* and runs daily from 9AM-12PM with an attendant. We recommend that Enzo Cucciniello is utilized by future groups for his broad and deep knowledge of the history of accessibility throughout the city, as well as his progress and lobbying in future *Caregòn* installments.

Rudj Todaro is the Technical Director from *Insula* who we met with to learn more about what progress and updates *Insula* has made on the databases provided by past IQPs. We also met with Rudj to obtain and view their GIS maps and to try to gain access to their GIS portal. Rudj gave a presentation about the work *Insula* has done, including a tour of their very descriptive GIS layers. *Insula* did provide us with limited access to their GIS portals and therefore would be a great source for future IQPs in need of specific information from *Insula*.

5.6. *Preliminary Tutorials*

Many of the tools that our group often used while in Venice were computer programs such as MapInfo, EasyBridge, EasyDocks, and even Microsoft Access. Our group feels that it would have been beneficial to have had a tutorial on each of these programs during ID 2050. This

[63] Cucciniello

would allow students to spend less time learning and understanding the programs in Venice and would make students more versatile during the IQP.

The basic functions of these programs could be easily explained in simple tutorials throughout the ID 2050 program during A-term. A simple knowledge of each program would provide students with a great head start to their experience in Venice and certainly improve items of their reports and presentations, such as "killer graphics." Microsoft Access is a program that all students at WPI most likely own, yet many do not know how to use. This program is clearly very resourceful and would be an excellent program to utilize during the preparation period.

6. Conclusion

The primary goal of our team was to investigate areas within urban maintenance that could be improved by previously existing data. To preserve the quality of life for all individuals, one area of focus became the feasibility of studying the bridge usage by mobility impaired individuals in an effort to plan a future project. Once data was collected and a field form was redesigned to fit the specific needs of our group, the data was analyzed to determine if the project could be completed. A future project could be easily completed on a larger scale by expanding the amount of data we collected and spreading the studies throughout the city. A project helping the mobility impaired citizens and tourists of Venice would be able to assist the city in determining what could be done to aid pedestrians in addition to what some city departments, such as *Informahandicap*, are already working on.

As far as determining the functionality and data sources for creating Navigate Venice, our group has determined that it is possible to create such a program to help people find the easiest route for their specific needs throughout the city. The project still needs to be continued beyond our group's abilities and with a sponsoring agency to completely verify the database information and program the mockup to a working web application. Although this project has not made a large impact on the city as of now, the preliminary work we have completed will help with future ideas, such as implementing it to private boats and incorporating danger zones into the program. Hopefully, the future of this project will continue to aid pedestrians in the streets of Venice and possibly even boaters throughout the lagoon.

Overall, this project has shown, in a large way, that existing data sources can become much more versatile than their creators intend. By reusing existing data originally collected to promote urban maintenance within the city, our group found four new ways to help the handicap citizens and visitors of Venice.

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Appendicies

Appendix A: Instrament and Materials Checklist

Appendix B: Data Collection Sheets

Appendix C: Bridge Specifications

Appendix D: Publication Chapter Process

Appendix E: Publication Chapter Tables

Appendix F: Publication Chapters

Appendix G: Annotated Bibliography

Appendix A: Instrament and Materials Checklist

- ☐ Counter
- ☐ Stop Watch
- ☐ Camera
- ☐ Data Collection Sheets

Appendix B: Data Collection Sheets

Blank Field Forms (following pages)

Bridge Accessibility Field Form

Name of Bridge: ______________________________

Bridge Number: ______________________________

Location of Bridge: ______________________________

Category: ______________________________

Date: ______________________________

Time of Day: ______________________________

Total number of people exiting from the left:

Total number of people exiting from the right:

Total number of mobility impaired people:

Total number of people using ramps:

Total number of people using stairs:

Number of mobility impaired people using ramp:

Number of mobility impaired people using stairs:

Mobility Issues	
Wheelchair	
Stroller	
Cart	
Luggage	
Walking with cane	
Walking without cane	
Overweight	
Carrying large parcels	

Bridge Accessibility Field Form

Name of Bridge: ______________________________ Bridge Number: ________________

Location of Bridge: ____

Flow (Hi/Med/Lo):__________ Date: ______________ Traffic Count Time Period: __________

Mobility Issues		
	Utilized Ramp	Used Stairs
Wheelchair		
Stroller		
Cart		
Luggage		
Cane/Walker		
Assisted by another person or railing		
Limp/Difficulty Walking		
Overweight/Pregnant		
Carrying large parcels		
	Total Ramp :	Total Stairs:
Total Number of Mobility Issues:		

Totals	
Exiting – Stairs Left Left = ______________	
Exiting – Stairs Right Right =_____________	
Exiting – Ramp Left	
Exiting – Ramp Right	
Total over Bridge	

Notes/Observations:

Bridge Accessibility Field Form

Name of Bridge	
Bridge Code	
Bridge Location	
Category	
Date	
Time & Weather	
Duration of Counting	

Mobility Issues	Using Stairs	Using Ramps
Wheelchair		
Stroller		
Cart		
Luggage		
Use of Cane/Crutch		
Walking without cane		
Overweight		
Large parcels		
TOTALS		

Pedestrians	Using Stairs	Using Ramps
People Exiting from Left: ( )		
People Exiting from Right ( )		
TOTAL		

Total Pedestrians: ____________

Count Intervals	:15	:30	:45	1:00	Total Time:
Exit Left					
Exit Right					
Mobility Issues					

Notes:

____

____

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: ____________ Date: ______________ Time Period: _______________ **P = Assisted by person, R = assisted by railing**

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller								
Delivery Cart								
Luggage								
Walker								
Cane								
Crutches								
Elderly								
Overweight								
Pregnant								
Large parcels								
Total Pedestrians								

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: ______________ Date: ________________ Time Period: ________________

P = assisted by person **R = assisted by railing** **O = overweight**

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Luggage								
Elderly								
Shopping Cart								
Stroller								
Delivery Cart								
Large parcels								
Cane								
Limp								
Overweight								
Pregnant								
Wheelchair								
Crutches								
Walker								
Other								
Total Pedestrians								

Notes:

Completed Data Collections Sheets

Bridge Accessibility Field Form

Name of Bridge: Ponte de la Pietà

Bridge Number:

Location of Bridge:

Category:

Date: 30/10/07

Time of Day: 11:05

Total number of people exiting from the left: Toward St. Marks ramp 328

Total number of people exiting from the right: Away from St. Marks ramp 226

Total number of mobility impaired people:

Total number of people using ramps:

Total number of people using stairs:

Number of mobility impaired people using ramp: toward stairs 506

Number of mobility impaired people using stairs: away stairs 299

add elderly/slow moving

Mobility Issues		
Wheelchair		
Stroller	卌 1	6
Cart	卌 1	6
Luggage	卌 卌 1	11
Walking with cane	卌 卌 1	11
~~Walking without cane~~ Assisted	1111	4
Overweight	卌 11	7
Carrying large parcels	1	1
Pregnant		
mobility (limp)	卌 1111	9
walker	1	1

Bridge Accessibility Field Form

Name of Bridge: ______

Bridge Number: ______

Location of Bridge: Behind San Marco (with servo scala)

Category: ______

Date: 30/10/07

Time of Day: 12:45

Total number of people exiting from the left: away San Marco 256

Total number of people exiting from the right: toward San Marco 256

Total number of mobility impaired people: 14

Total number of people using ramps: n/a

Total number of people using stairs: all

Number of mobility impaired people using ramp: n/a

Number of mobility impaired people using stairs: all

Mobility Issues	
Wheelchair	
Stroller	II
Cart	II
Luggage	III
Walking with cane	II
Walking without cane	IIII
Overweight	I
Carrying large parcels	

- impaired railing = 2
assisted = 2

Bridge Accessibility Field Form

Name of Bridge: Ponte de la Canonica

Bridge Number:

Location of Bridge:

Category:

Date: 30/10/07

Time of Day: 12:50

Total number of people exiting from the left: from St. marks 405

Total number of people exiting from the right: to ~~away from~~ St. marks 394

Total number of mobility impaired people:

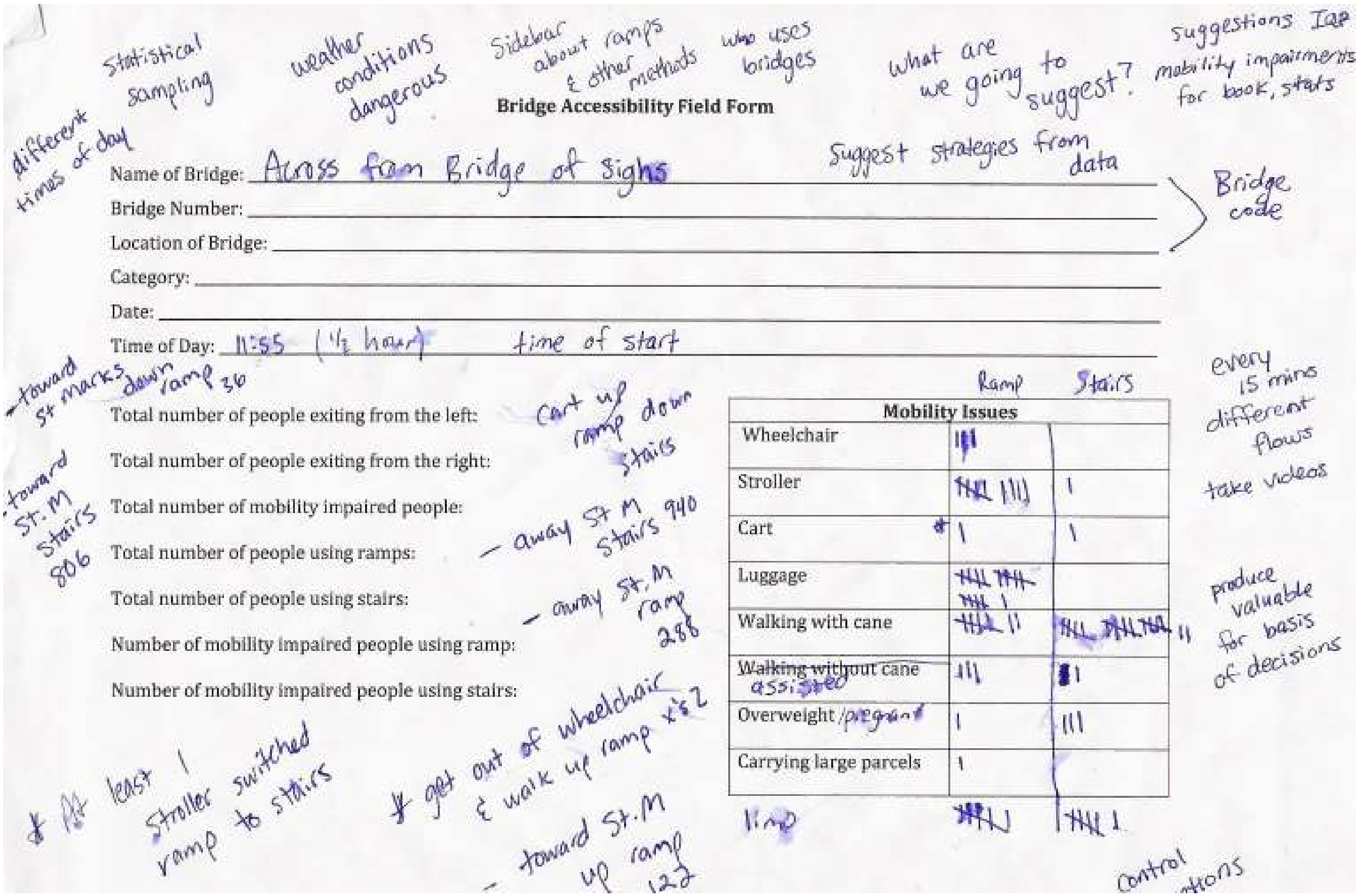
Total number of people using ramps:

Total number of people using stairs:

Number of mobility impaired people using ramp:

Number of mobility impaired people using stairs:

Mobility Issues	
Wheelchair	
Stroller	
Cart	||
Luggage	卌 卌 ||
Walking with cane	卌
~~Walking without cane~~ assisted	||
Overweight	|
Carrying large parcels	|
limp	卌 ||



Bridge Accessibility Field Form

Name of Bridge: Across from Bridge of Sighs

Bridge Number:

Location of Bridge:

Category:

Date:

Time of Day: 11:55 (1/2 hour) time of start

Total number of people exiting from the left:

Total number of people exiting from the right:

Total number of mobility impaired people:

Total number of people using ramps:

Total number of people using stairs:

Number of mobility impaired people using ramp:

Number of mobility impaired people using stairs:

Mobility Issues	Ramp	Stairs
Wheelchair	|||	
Stroller	卌 |||		
Cart				
Luggage	卌 卌 卌		
Walking with cane	卌 ||	卌 卌 卌 ||
~~Walking without cane~~ assisted	|||	||
Overweight/pregnant			|||
Carrying large parcels			
limp	卌	卌	

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: BERG Date: 16/11/07 Time Period: 9:30-11:30 **P = Assisted by person, R = assisted by railing, O = overweight**

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller					|	||		
Delivery Cart			|||				||	[illegible] |
Luggage	||	𝍸	𝍸 |	𝍸 𝍸 ||	𝍸 ||	𝍸 𝍸 𝍸	𝍸	||||
Walker								
Cane	|		|					
Crutches								
Elderly		1R	1R	RR	|			
Overweight								
Pregnant								
Large parcels		|		|		|	|	|
Total Pedestrians	190	332	603	798	940	[illegible]	1323	1477

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: PANTAL Date: 26/[illegible]/07 Time Period: 12h-18h

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller	|	||	|||	|	|		|	
Shopping Cart	|				|||		|	|
Delivery Cart							|	
Limp								
Luggage	𝍸	|||		|	|	|		
Walker								
Cane	|		P					
Crutches								
Elderly				P			|	R
Overweight								
Pregnant								
Large parcels	𝍸	|	|		|	||		|
Total Pedestrians	114	107	101	144	67	84	66	74

P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: VINANT Date: 26/11/07 Time Period: 16h - 17h /900 - 10:00

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller		II						I
Shopping Cart	I	II	I		I	II	III	I
Delivery Cart						I	I	
Limp	R	I			I			
Luggage	I		II		II	I	I	
Walker								
Cane		R						RR
Crutches								
Elderly	P	P		RR	[illegible] I	PRR		P
Overweight								RR
Pregnant				I				
Large parcels		I		III		II	~~IIII~~	III
Total Pedestrians	119	141	129	111	95	103	99	163

P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: CAPPEL 2 Date: 27/11/07 Time Period: 5:00-6:00

8:35

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller		I	I	I	II			II
Shopping Cart (S)		I		I	I	I	I ,	I
Delivery Cart		I			II	II	II (-1)	II
Limp						I		
Luggage	I	I	I	I	IIII		IIII	III
Walker								
Cane				I			RS I (-1)	I
Crutches								
Elderly			P		R R	R I	PR I	
Overweight	I							
Pregnant				I				
Large parcels				II				
Total Pedestrians	92	114	123	118	126	200	287	379

P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: CANAL 1 Date: 27/11/07 Time Period: 16:00 – 17:00

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller	|||	|	|			|	|	
Shopping Cart	|	|	|	|	||	||||	||	||
Delivery Cart		|			|	|	|	
Limp	R							
Luggage	||	|		|||	卌 卌 |	卌 卌	||||	卌 卌 |||
Walker								
Cane	| E	| E P/E		E		R		R |
Crutches								
Elderly	R	|	|		|		RR	R
Overweight			|					
Pregnant								
Large parcels	||	|				|||		|
Total Pedestrians	294	276	248	188	182	173	144	136

60 tons
P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: CRIST3 Date: 26/11/07 Time Period: 17h - 18h

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair		I						
Stroller		II						
Shopping Cart				I	II	R	II	
Delivery Cart	II						I	
Limp				O				
Luggage					I		I	I
Walker								
Cane				R				R
Crutches								
Elderly	IIR [illegible]	II	R	~~R~~ R	R I		I	
Overweight								
Pregnant								
Large parcels								
Total Pedestrians	55	~~53~~ 55	50	43	46	47	37	37

P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: LATTE Date: 26/11/07 Time Period: 16h - 17h

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair		|						
Stroller		||		|				
Shopping Cart				|	|||	|	|	
Delivery Cart	|||	|			|		|	
Limp				O				
Luggage				|	|	||	|	||
Walker								
Cane				R				
Crutches								
Elderly	||PR	||R	R	RR	|		||	
Overweight								
Pregnant								
Large parcels								
Total Pedestrians	78	~~83~~ 85	79	83	73	63	51	67

P = assisted by person **R = assisted by railing** **O = overweight**

Gambrini

Bridge Accessibility Field Form – Urban Maintenance B '07

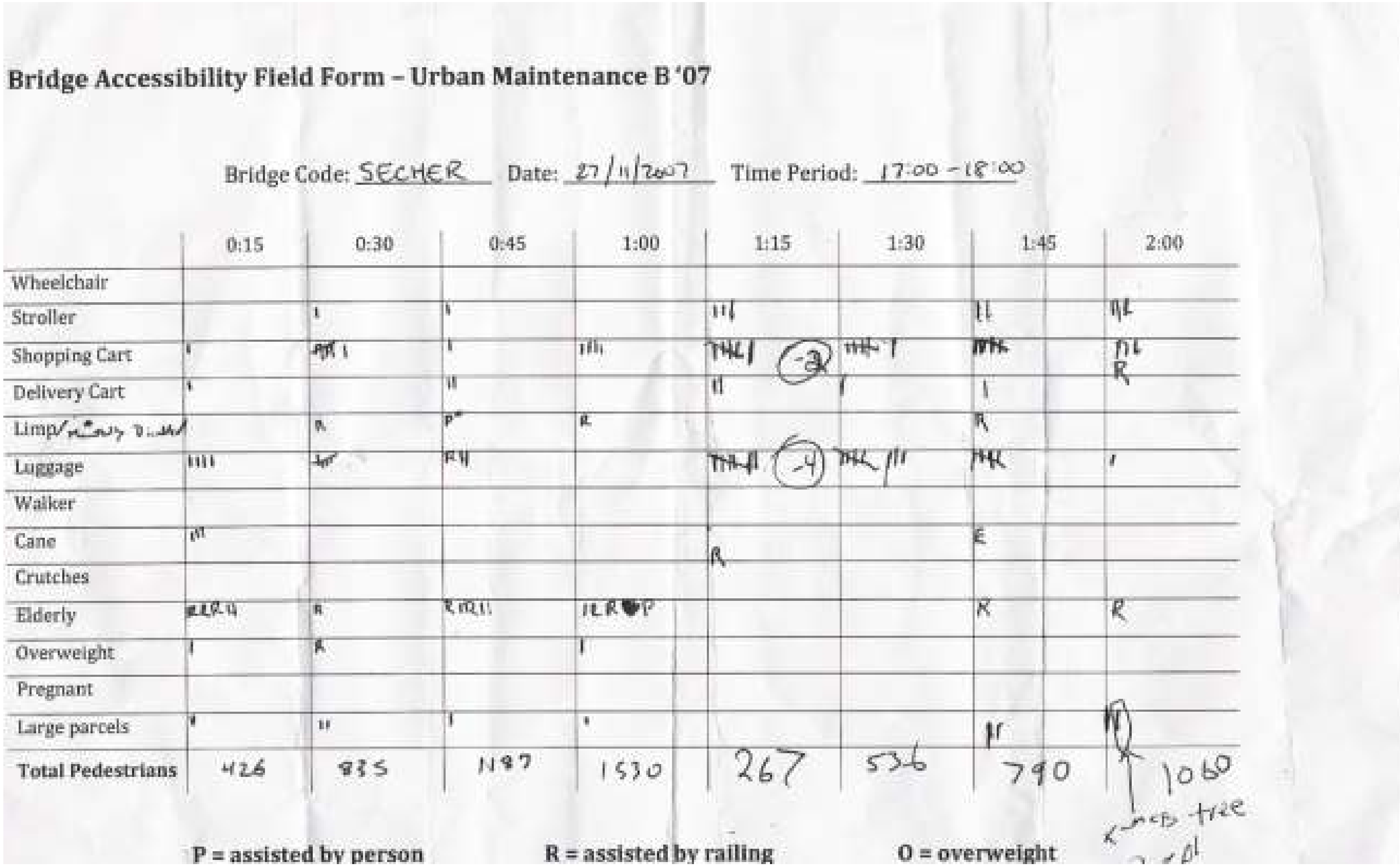
Bridge Code: BERG Date: N[illegible] 6, 20[illegible] Time Period: [illegible] **P = Assisted by person, R = assisted by railing, O = overweight**

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller	I	I	I	II		II		III
Delivery Cart		II	II	I	I			I
Luggage	IIII IIII IIII	III	IIII IIII II	IIII I	IIII IIII	IIII IIII	IIII IIII IIII IIII III	IIII I
Walker								
Cane						R		
Crutches								
Elderly	R P			R	[illegible]	R		R R
Overweight							R	
Pregnant								
Large parcels		II						
Total Pedestrians	212	225	263	216	262	302	337	286

* 1 P = person with mental disability

* [illegible]

R R



Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: SECHER Date: 27/11/2007 Time Period: 17:00 – 18:00

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller		I	I		III		II	IIII
Shopping Cart	I	~~IIII~~ I	I	III	~~IIII~~ I (-3)	~~IIII~~ I	~~IIII~~	III R
Delivery Cart	I		II		II	I	I	
Limp/[illegible]		R	P	R			R	
Luggage	IIII	~~IIII~~	R II		~~IIII~~ I (-4)	~~IIII~~ III	~~IIII~~	I
Walker								
Cane	III				R		E	
Crutches								
Elderly	RRRII	R	RRII	IIRRP			R	R
Overweight	I	R		I				
Pregnant								
Large parcels	I	II	I	I			II	[illegible]
Total Pedestrians	426	835	N87	1530	267	536	790	1060

P = assisted by person R = assisted by railing O = overweight

Bridge Accessibility Field Form – Urban Maintenance B'07

Bridge Code: TOLENT Date: 26/11/07 Time Period: 17h - 18h 7/12/07

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller		III	I	IIII	I	II	IIII	I
Shopping Cart	~~IIII~~ II	~~IIII~~ III	II	III	~~IIII~~ I	~~IIII~~ III	III	~~IIII~~ III
Delivery Cart	III O	II	O		II	~~IIII~~	II	III
Limp		I	O			R		
Luggage	~~IIII~~ II	~~IIII~~	II	IIII	~~IIII~~ III	~~IIII~~ ~~IIII~~ III	~~IIII~~ III	~~IIII~~ I
Walker					P			
Cane	R			P	RI		I	
Crutches			I					
Elderly	III RR	RRP	RPR	RRRRP	RP	RIR	PRRR	RRRR
Overweight	RCR	I	R I R					
Pregnant								
Large parcels		I	BI	II		III	I	II
Total Pedestrians	475	868 373	1289 421	775 486	432	811	1145	1077

P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: CROZE   Date: 26/11/07   Time Period: 16:00 – 17:00 / 16:00-17:00

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair							|	
Stroller	||||	||	|					
Shopping Cart	|	|	|||	||	|	||||	||	
Delivery Cart	||||	|	|||	|	|	||	|	
Limp			|		|			|
Luggage	卌 卌 卌 |	卌 卌 [illegible] |||	卌 卌 ||	卌 卌 卌 卌 卌 |	卌 |||	卌 ||||	卌 卌	卌 |||
Walker								
Cane			R 1				|	
Crutches								
Elderly	P R	P P	P		|			
Overweight								
Pregnant								
Large parcels		|			||	||	|	||
Total Pedestrians	388	812 − 388 = 424	1254 − 812 = 442	1745 − 1254 = 491	307	317	278	257

P = assisted by person   **R = assisted by railing**   **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: SCAL21 Date: 27/11/07 Time Period: 4:00-5:00 / 9:00-10:00

	0:15	0:30	0:45	1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller	||	~~||||~~	~~||||~~ |	|		|	|	|
Shopping Cart		||||	|||	||	||	~~||||~~	~~||||~~ ||	~~||||~~ |
Delivery Cart	||	||	||	||	|	|||	~~||||~~	||
Limp				R	|		|	
Luggage	~~||||~~ |||	~~||||~~ ~~||||~~ ~~||||~~ |||| R	~~||||~~ ~~||||~~ |||	~~||||~~ ~~||||~~ ||||	~~||||~~ ~~||||~~ ~~||||~~ ||	~~||||~~ ~~||||~~ |||	~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ |	~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ||
Walker								
Cane			R					
Crutches				|				
Elderly		1ROR	|||	RRR	PR	|||	P|	|
Overweight				|				
Pregnant								
Large parcels	|	||||	~~||||~~ |	|||	~~||||~~	||	|||	|||
Total Pedestrians	749	791	998	996	690	635	645	715

P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: GAFFAR Date: 27/11/2007 Time Period: 16:00 - 17:00

	4:26 0:15	4:41 0:30	4:56 0:45	5:11 1:00	1:15	1:30	1:45	2:00
Wheelchair								
Stroller	II		I			I	I	II
Shopping Cart		I	I	II	I			I
Delivery Cart	I	I			I	I	II	II
Limp					R			
Luggage					I	HHT HHT	III	III
Walker								
Cane							I	
Crutches								
Elderly	RI	RR	PR	IR	RRIR	RR	RR	RR
Overweight		R						
Pregnant								
Large parcels		I			I			
Total Pedestrians	174	344 174 170	511 344 167	166	177	389 212	133	149

P = assisted by person **R = assisted by railing** **O = overweight**

Bridge Accessibility Field Form – Urban Maintenance B '07

Bridge Code: CAMAR Date: 27/11/2007 Time Period: ~~17:00–18:00~~ 17:00-18:00 / 9-10

	17 0:15	17 0:30	17 0:45	18 1:00	9 1:15	9 1:30	9 1:45	10 2:00
Wheelchair								
Stroller	I							
Shopping Cart					I	IIII	II	I
Delivery Cart	I				II	II	II	5
Limp						I		R
Luggage	III	II				I		
Walker								
Cane								
Crutches								
Elderly	RR	R				R I		
Overweight								
Pregnant								
Large parcels	II					I		II
Total Pedestrians	79	63	52	37	68	102	75	70

P = assisted by person R = assisted by railing O = overweight

Appendix C: Bridge Specifications

Phase 1: San Marco Area

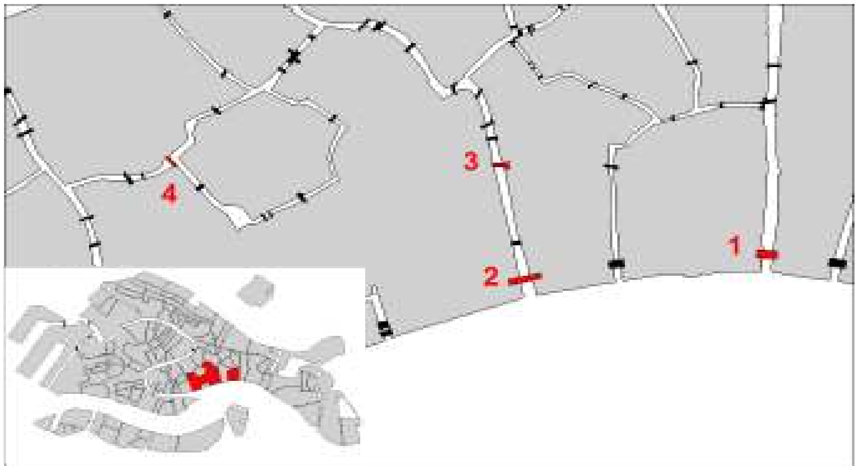


Figure 1: The four bridges used for data collection during phase one

Ponte de la Pietá

- Code: Pieta
- North Island (#94): San Zaccaria
- South Island (#95): San Lorenzo
- Total Steps: 29
- Medium Rail Width: 29 cm
- Attached Handrail: No
- Direction Start: San Zaccaria Boat Stop

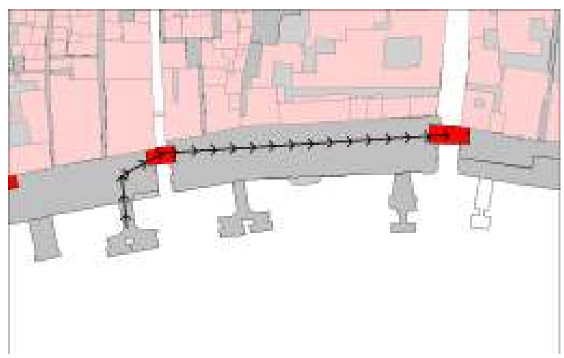


Figure 2: Directions to Ponte de la Pieta

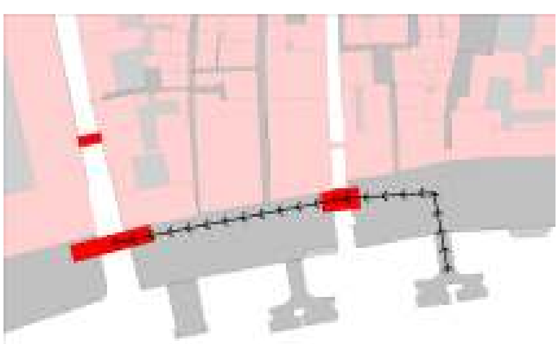


Figure 3: Directions to the Ponte de la Paglia

Ponte de la Paglia

Code: PAGLIA
North Island (#93): San Filippo e Giacomo
South Island (#92): San Marco
Total Steps: 21
Medium Rail Width: 21 cm
Attached Handrail: No
Direction Start: San Zaccaria Boat Stop

Ponte de la Canonica

Code: CANONI
North Island (#92): San Marco
South Island (#93): San Filippo e Giacomo
Total Steps: 16
Medium Rail Width: 31 cm
Attached Handrail: No
Direction Start: San Zaccaria Boat Stop

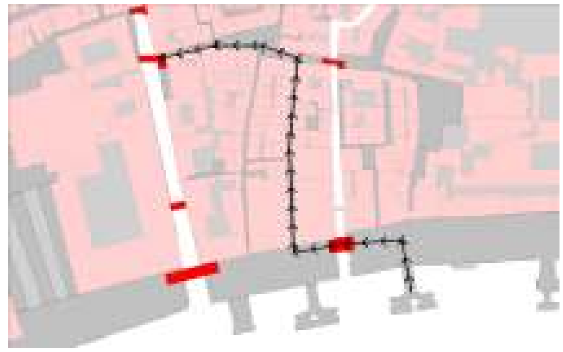


Figure 4: Directions to Ponte de la Canonica

Ponte Carlo Goldoni

Code: GOLDO
North Island (#80): San Luca
South Island (#92): San Marco
Total Steps: 28
Medium Rail Width: 4 cm
Attached Handrail: No

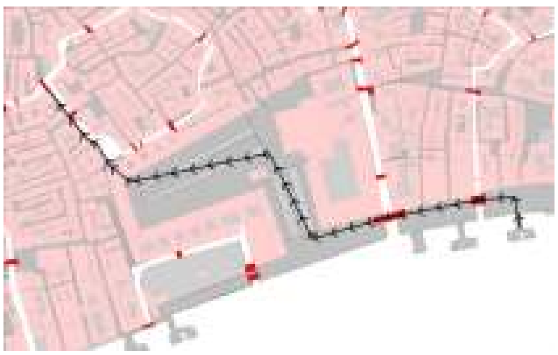


Figure5: Directions to Ponte Carlo Goldoni

Phase 2: San Cancian

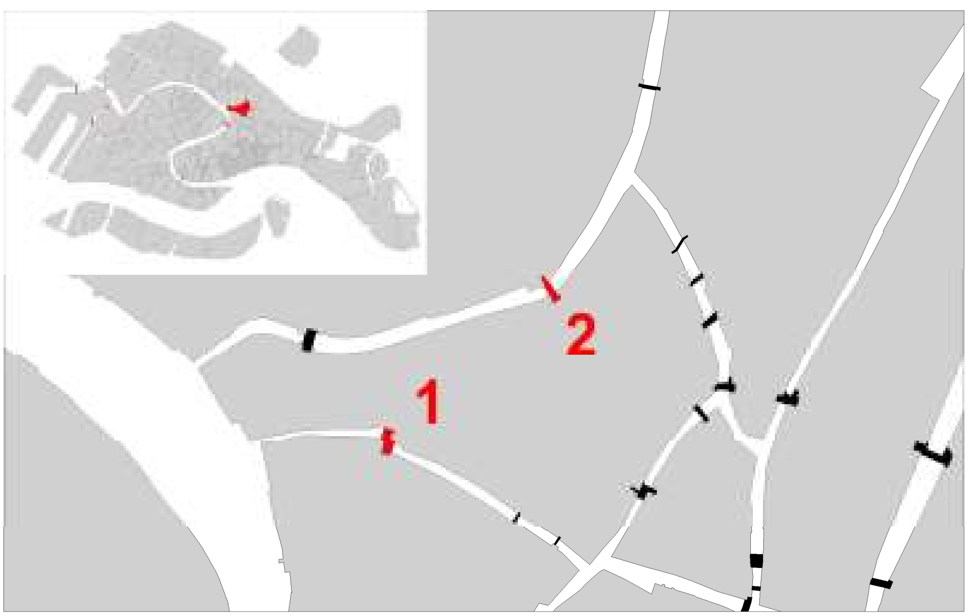


Figure 6: The two bridges used for data collection in phase two

Ponte San Giovani Grisostomo
Code: GRISOS
North Island (#69): San Cancian
South Island (#71): San Zuane Grisostomo
Medium Rail Width: N/A
Attached Handrail: No
Direction Start: VPC

Figure 7: Directions to Ponte San Giovani Gristomo

Figure 8: Directions to Ponte San Canzian

Ponte San Canzian
Code: CANZIAN
North Island (#64): San Zuane Grisostomo
South Island (#69): San Cancian
Total Steps: 26
Medium Rail Width: 4 cm
Attached Handrail: No
Direction Start: VPC

Phase 3: Tolentini

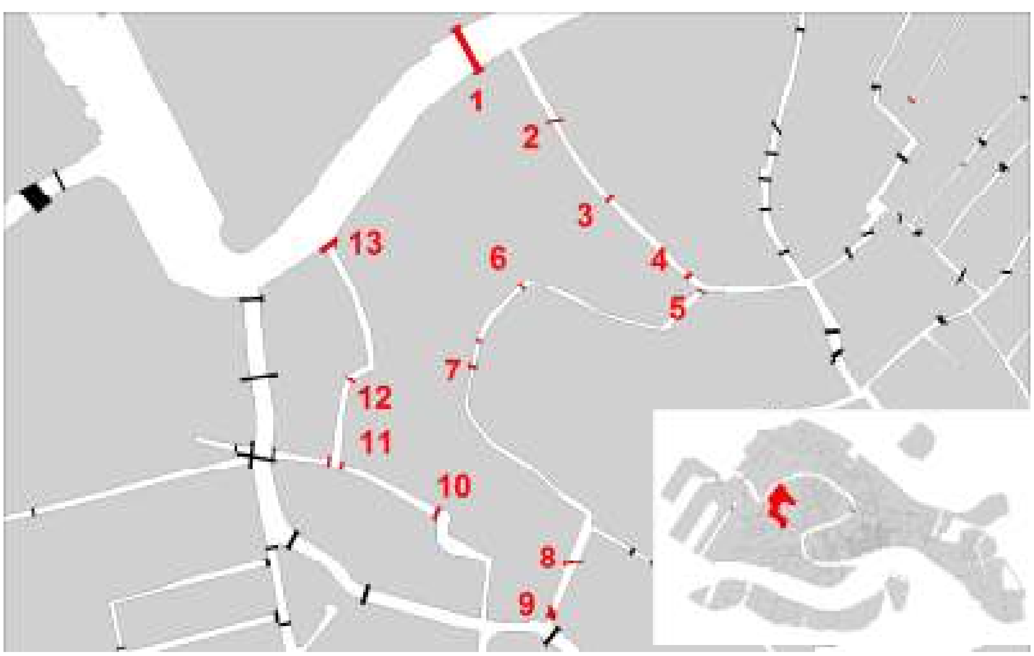


Figure 9: The thirteen bridges used for data collection in stage 3

Ponte degli Scalzi

Code: SCALZI
North Island (#20): San Geremia
South Island (#33): Tolentini
Attached Handrail: Yes
Direction Start: Ferrovia Boat Stop

Figure 11: Head on view of Ponte degli Scalzi

Figure 10: Directions to Ponte degli Scalzi

Figure 12: Side view of Ponte degli Scalzi

Ponte de la Bergama

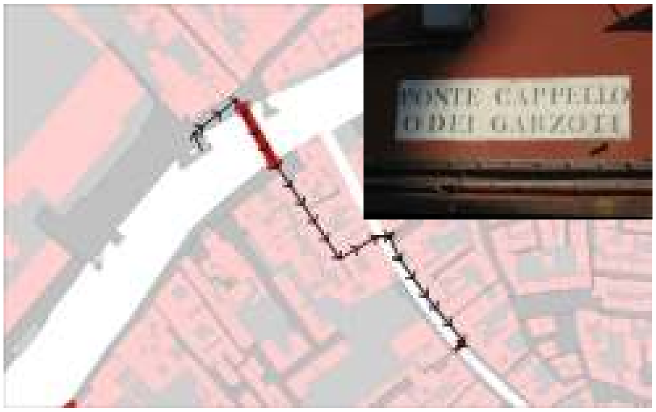
Figure 13: Directions to Ponte de la Bergama

Code: BERGAM
North Island (#21): San Zan Degolà
South Island (#33): Tolentini
Attached Handrail: No
Direction Start: Ferrovia Boat Stop


Figure 15: Side view of Ponte de la Bergama


Figure 14: Head-on view of Ponte de la Bergama

Ponte Cappello



Code: CAPPEL2
North Island (#21): San Zan Degolà
South Island (#33): Tolentini
Attached Handrail: No
Direction Start: Ferrovia Boat Stop

Figure 17: Head-on view of Ponte Cappello

Figure 16 (top): Directions to Ponte Cappello

Figure 18 (bottom): Side view of Ponte Cappello

Ponte del Cristo

Code: CRIST3
North Island (#21): San Zan Degolà
South Island (#33): Tolentini
Attached Handrail: No

Figure 19 (top): Directions to Ponte del Cristo

Figure 21 (bottom): side view of Ponte del Cristo

Figure 20: Head-on view of Ponte del Cristo

Ponte de la Latte

Figure 22: Directions to Ponte de la Latte

Code: LATTE
North Island (#33): Tolentini
South Island (#34): Frari
Attached Handrail: No
Direction Start: Ferrovia Boat Stop

Figure 23: Head on view of Ponte de la Latte

Ponte Canal

Code: CANAL1
North Island (#33): Tolentini
South Island (#34): Frari
Total Steps: 28
Medium Rail Width: 4 cm
Attached Handrail: Yes
Direction Start: San Zaccaria Boat Stop

Figure 24 (top): Directions to Ponte Canal

Figure 25 (bottom): Side view of Ponte Canal

Figure 26: Head-on view of Ponte Canal

Ponte de le Sechere

Code: SECHER
North Island (#33): Tolentini
South Island (#34): Frari
Attached Handrail: Yes
Direction Start: Ferrovia Boat Stop

Figure 27 (top): Directions to Ponte de le Sechere

Figure 28 (bottom): Side view of Ponte de le Sechere

Figure 29: Head-on view of Ponte de le Sechere

Ponte Vinante

Code: VINANT
North Island (#33): Tolentini
South Island (#41): San Pantalon
Attached Handrail: No
Direction Start: Ferrovia Boat Stop

Figure 30 (top): Directions to Ponte Vinante

Figure 31: Head-on view of Ponte Vinante

Figure 32 (bottom): Side-view of Ponte Vinante

Ponte San Pantalon

Code: PANTAL
North Island (#33): Tolentini
South Island (#41): San Pantalon
Attached Handrail: No
Direction Start: Ferrovia Boat Stop

Figure 33 (top): Directions to Ponte San Pantalon

Figure 34 (bottom): Side view of Ponte San Pantalon

Figure 35: Head-on view of Ponte San Pantalon

Ponte de Ca’Marcello

Code: CAMAR
North Island (#33): Tolentini
South Island (#40): San Pantalon
Attached Handrail: No
Direction Start: Ferrovia Boat Stop

Figure 36 (top): Directions to Ponte de Ca'Marcello

Figure 37 (bottom): Side view of Ponte de Ca'Marcello

Figure 38: Head-on view of Ponte de Ca' Marcello

Ponte del Gaffaro

Code: GAFFAR
North Island (#33): Tolentini
South Island (#40): San Pantalon
Attached Handrail: No
Direction Start: Ferrovia Boat Stop

Figure 39 (top): Directions to Ponte del Gaffaro

Figure 40: Head-on view of Ponte del Gaffaro

Figure 41 (bottom): Side view of Ponte del Gaffaro

Ponte dei Tolentini

Code: TOLENT
North Island (#37): Giardini Papadopoli
South Island (#33): Tolentini
Attached Handrail: Yes
Direction Start: San Zaccaria Boat Stop

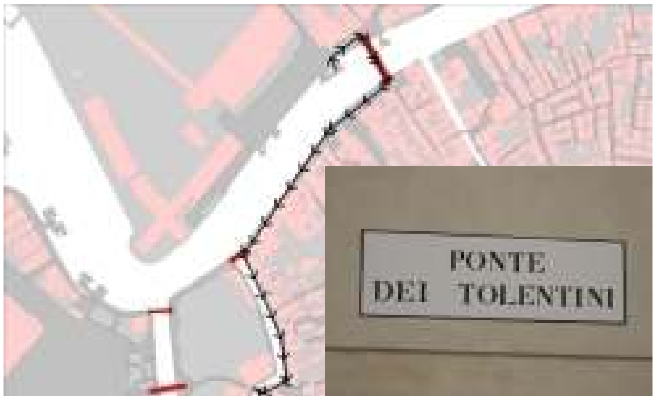
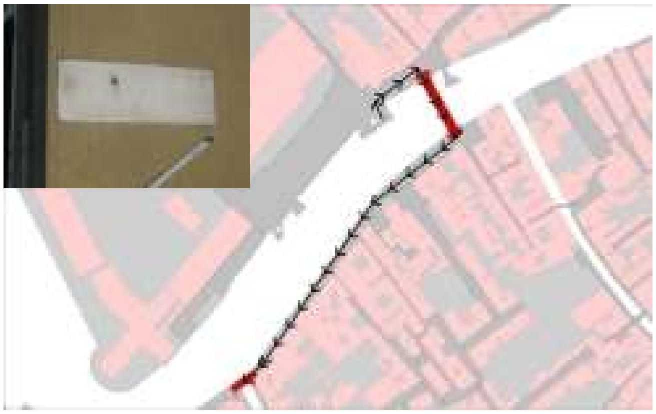


Figure 42(top): Directions to Ponte dei Tolentini

Figure 43: Head-on view of Ponte dei Tolentini

Figure 44 (bottom): Side view of Ponte dei Tolentini

Ponte de la Croze



Code: CROZE
North Island (#33): Tolentini
South Island (#37): Giardini Papadopoli
Attached Handrail: No
Direction Start: Ferrovia Boat Stop

Figure 45 (top): Directions to Ponte de la Croze

Figure 46 (bottom): Side view of Ponte de la Croze

Figure 47: Head-on view of Ponte de la Croze

Appendix D: Publication Chapter Process

Objective

Our goal was, primarily, to educate those with the desire to gain knowledge about the history of urban maintenance and the future of urban planning in the city of Venice. To this purpose, we created four educational publications that detail the impacts and progress made in the areas of canals, sewers, bridges and docks.

Methodology

Information Requirements

In order to complete this objective, information for each topic was needed in several key areas: history, usage, maintenance, and future. It is important to note that for these documents, "maintenance" referred to work performed within the previous twenty years while "future" referred to any plans already in at least the first stages of development. Much of the information about maintenance, future and some of the history could be obtained from interviews with members of Insula. Information about the usage of each system was found primarily through databases with some supplemental data from the interviews. To fully understand the complete scope of the information collected, please see the completed documents which can be found in Appendix B.

Existing Data Sources

Due to the maturity of topics relating to urban maintenance, the data required already existed within various data sources. However, many of these sources are available only in Italian: hence the need for educational publications in English.

GIS Map Layers

GIS map layers for bridges, docks, canal segments, and islands of Venice were readily available from Forma Urbis. These map layers were used to acquire statistics about each topic. Unfortunately, the layers were created before Insula began their maintenance within the city. As a result, there is a possibility that some aspects of the layers may be outdated, however, it would be impossible to know which objects need updating without physically checking each object in the layers.

A GIS layer of all the utilities within the city also existed; however, it was maintained by Insula. Despite gaining access to some of the restricted information on their website, we did not receive permission to view this layer.

EASYDocks

The EASYDocks software available in Italian from Forma Urbis provided more detailed information about each dock than was recorded in the dock GIS layer. The program was primarily used to collect data on the different types of docks within the city. Like the map layers, EASYDocks had the potential to be outdated, especially in the fields relating to wooden over-structures and the condition of each dock.

EASYBridges

Similar to EASYDocks, EASYBridges was also a software application available from Forma Urbis. When Forma Urbis turned the program over to Insula, it was not yet fully functional and, as a result, the version available to us did not have a working interface linking bridge data to maps and pictures; however the Access database could still be examined. This provided information such as the structure and materials of each bridge. Again, there was a possibility that the data was outdated. Bridges have been repaired changing their condition and as pavements are raised, some bridges lose their bottom step.

Publications

Forma Urbis maintains a large collection of publications relating to a wide variety of topics pertaining to Venice, including Urban Maintenance. A significant portion of this collection includes the project reports for the 18 years worth of IQP's that have been completed in Venice. For specific publications and projects used, please see the reference section of each chapter which can be found in Appendix F.

Interviews

When data was not readily available in written publications, the team interviewed members of Insula whom provided information that was otherwise unavailable.

Lorenzo Botazzo, Responsabile Intervento
gave information on the maintenance cycles, canal dredging, maintenance costs, sewer system, and gas system

Rudj Todaro, Technical Director, Insula S.p.A.
gave information about the computerized systems being created to help manage urban planning and showed us the various GIS layers and other databases that Insula has available for the city

Online Resources

When no other information could be found, the team was forced to use online resources. Due to the questionable reliability of these resources, they were used only as a "last resort". For a list of the online resources, please see the references section of each chapter.

Deliverables

As a result of our work in the area, we have produced four educational documents complete with pictures and sidebars. These documents can be found in the Results and Discussion.

Results

The publications produced highlight the history of urban maintenance in Venice and mention the work of previous IQP team projects involved in the investigation and progress of urban maintenance and planning.

Canals

The chapter on Canals presented a brief review of the history of the creation and development of canals. The focus was then shifted to the sources of damage to the canals, namely the canal walls. Research was put forth to list the main sources of canal wall damage and reasons behind their effects of damage. The chapter then leads into the maintenance procedures for the restoration of canal walls and the plan of Insula to continuously dredge the canals.

Docks

Our chapter on docks began with an introduction and background on the docks of Venice before a discussion the various types of docks. The next main section features the past and current problems of docks regarding maintenance. There are over 1600 docks in Venice but only a fraction of them are regularly used and this is mainly a result of damage to the docks and the design of several of the types of docks. The chapter then leads to the future of Venetian docks and the maintenance goals for them.

Utilities

This chapter highlights the way roads are constructed and repaired in Venice This chapter also reviews the history of the utility systems: Gas, Water, Electricity, and sewers. Each of these different utility system have had their share of maintenance work and the chapter mentions the process of emergency repair work, but features extensive maintenance work for pavement and sewers. The chapter ends by discussing the future for maintenance of these utility systems.

Bridges

The bridge chapter outline defines the use of bridges and history of bridges. It reveals the different types of bridges that are in Venice and provides the make-up of a typical bridge in Venice. The book chapter mentions the use of bridges for transporting utility services from one island to another. The chapter then goes on to explain the problems of bridges that affect everyone and discuss maintenance procedures for repair any possible problem. Lastly, the bridge chapter addresses the future for bridge restoration and uses in Venice.

Sidebars

The sidebars for the urban maintenance book chapters presented readers with a variety of topics that did not fit in well with the flow of each chapter, but still merited being mentioned. For the canals book chapter, sidebar topics included the Grand Canal, Acqua Alta, average minimum canal widths, Geographical Information System, and the total island of Venice proper. The bridge chapter sidebar emphasized the newest bridge of Venice by cataloging the bridges that cross over the Grand Canal, the Venetian bridge that connects the historical district with the mainland cities of Mestre and Marghera, the progress of safety for bridges, and the history of handicap accessibility involving bridges. The chapters on Docks and Sewers were of less material so most sidebars thought upon were included into the text. All chapters included sidebars referring to the work of IQP team in the fields of the chapters but not to the specific content of the maintenance of the chapter topics.

Appendix E: Publication Information Tables

Canals

Insula's formation	1997
Number of canal segments	367
Number of canals	182
Number of Tourists	20,000,000
Date motorboats were introduced to city	1950's
Earliest construction of bridges	13th century
Number of islands	125
Amount of taxi traffic	46%
Amount of cargo boat traffic	36%
Size in total area	6.3 square km/2.4 square miles
Amount of total residents	62,000
Annual revenue from tourism	$1.5 billion
Annual increase of canal traffic	2.50%
Rise in lagoon since 1897	23 cm
Speed limit in Grand Canal	7 km/hr
Initial establishment of speed limit	2001
Speed limit in inner canals	5 km/hr
Speed limit in Giudecca lagoon	20 km/hr
Percentage of energy released into canals by small cargo boats	66%
Percentage of sampled taxi's that exceed speed limit	100%
Average speed of taxi's	11.7 km/hr
Average speed of all boats	>12 km/hr
Percentage of boat's that obey speed limit	3%
Percentage of boat's that obey speed limit within 2 km/hr	13%
Percentage of unknown sediment in canals	83%
Percentage of sediment due to sewer discharge	11%
Percentage of sediment accumulated by masonry debris	6%
Annual rate of sediment accumulation	2 cm
Maintenance budget for 2006	35 million euro
Percentage of canals dredged	71%
Calculated budget of Insula's maintenance plan	1,213 million euro
Depth of metal sheet pilings	2.5 m
Average cost of vertical maintenance procedure	8000 euro
Range of average cost of traditional maintenance procedure	129 - 3264 euro
Amount of canals dredged after revised plan began	22 m

Docks

Usability of Docks:	Number:	Percent
Difficile da utilizzare	186	11.43
Difficile da utilizzare con Alta Marea	116	7.13
Difficile da utilizzare con Bassa Marea	45	2.76
Difficile da utilizzare per motivi strutturali	27	1.66
Inaccessibile via acqua	106	6.51
Inaccessibile via terra	7	0.43
Inaccessibile via terra con carretto merci	1	0.06
Inutilizzabile per mancanza pali, anelli o ganci	14	0.86
Non Rilveable	16	0.98
Usable	1110	68.18
Total:	1628	31.82
Number of Steps:		
Numero Scalini	8236	
Numero Scalini Utilizzabili	2958	
Numero Piattaforme	1131	
Percent of Usable Steps	35.92	
Types of Docks:	**Number:**	**Percent**
Gradinata monumentale	55	3.38
Non classificata	13	0.80
Parallela con piattaforma aggettante	330	20.27
Perpendicolare con piattaforma aggettante	397	24.39
Pennello sovrastante riva in pietra	5	0.31
Riva senza gradini (fondo calle o simile)	98	6.02
Scalini con asse parallelo al canale	180	11.06
Scalini con asse perpendicolare al canale	462	28.38
Scivolo	26	1.60
Varco su Parapetto	62	3.81
	1628	100.00
Monumental		3.4
Unclassified + Pannello Sovras		1.1
Parrellel to the Canal with Platform		20.3

Perpendicular to Canal with Platform		24.4
Riva senza gradini	dock without steps?	6.0
Stairs are parrallel to the canal		11.1
Stairs are perpendicular to the canal		28.4
Scivolo	slide/chute	1.6
Varco su Parapetto	Covered Dock	3.8
Type of Dock	Percentage in Lagoon	
Stairs perpendicular to canal	28.4	
Stairs parallel to canal	11.1	
Perpendicular to canal with platform	24.4	
Parallel to canal with platform	20.3	
Dock without steps?	6	
Covered?	3.8	
Monumental	3.4	
Scivolo?	1.6	
Unclassified/Other	1	
Type of Dock	**Percentage in Lagoon**	
Stairs perpendicular to canal	28.4	
Stairs parallel to canal	11.1	
Perpendicular to canal with platform	24.4	
Parallel to canal with platform	20.3	
Dock without steps?	6	
Covered?	3.8	
Monumental	3.4	
Scivolo?	1.6	
Unclassified/Other	1	

Bridges

Data Collected from EasyBridge application, December 2007

Number of Bridges	473 - Including Calatrava
Oldest Bridge	Unknown - First bridge in Rialto location - wooden 1250
Newest Bridge	Ponte Calatrava - planned opening 2008
Private Bridges	82
Crooked (Storto) Bridges	5
Limestone Bridges	2 (GRIS_P2, SCURO)
Cement Bridges	4 (MART4_P1, GCROCE, CORTEL, GALE1_P1)
Iron Bridges	14
Plaster Bridges	35
Brick base with stones Bridges	14
Wooden Bridges	48
Wood and Metal Bridges	11
Brick and Metal Bridges	1 (Private)
Brick and Istrian Marble	140
Brick, Plaster and Istrian Marble	46
Metal Bridges	27
Metal and Asphalt Bridges	1 (Ponte de la Malvasia)
Metal and Limestone Bridges	1 (Ponte dei Penini)
Metal and Cement Bridges	2
Metal and Istrian Marble Bridges	2
Metal, Brick, Asphault and Istrian Marble Bridges	1 (Ponte Vitturi)
Metal, Istrian Marble and Wood Bridges	1
Metal, Istrian Marble and Brick Bridges	4
Brick Bridges	56
Stone Bridges	2 (Ponte de Ca 'Rizzi, Ponte S. Polo)
Istrian Marble Bridges	1 (Ponte di Rialto)
0 or "Dreadful" Condition	5
1 or "Bad" Condition	27
2 or "Average" Condition	140
3 or "Good" Condition	152
4 or "Very Good" Condition	76
5 of "Excellent" Condition	14
Bridges with Decoration	73
Handicap Accessible	16
Servoscala	4 (Needs updating)
Caregon	1 (Ponte Ognissanti)

Handrail present	45 (needs updating)
Total Bridge Stairs	9440 (needs updating)
Total Stair Surface/Area	6314.79 ^2

Appendix F: Publication Chapters

Canals
Bridges
Docks
Utilities

Canals

An Introduction to the Canals of Venice

Figure 1: The view of a typical canal scene in Venice

Urban maintenance is the work that is required to preserve a city. It is a necessary measure to be taken in any large area to assure a high quality of life for its residents and visitors. Essential areas that specifically require maintenance are anything that allows a means for transportation and provides a way to get necessary utilities. For example, roads serve as a method of transportation that connects one place to another which makes all destinations within a city accessible. People drive automobiles on paved roads to transport goods, services, and people to their destinations quickly and efficiently. They also provide a means for public transportation, which is a necessity to all largely populated areas. Typical forms of public transportation include buses, subways, and automobile taxis. Like all other aspects of a large city, roads require systematic maintenance to ensure that they remain in full working condition. Another entity all cities require is the use of utilities, which are normally an underground arrangement of pipes and wires that include intricate waste removal systems. Like all other utilities, city sewer systems have modernized to adapt to the evolving technology of today's world.

Figure 2: Traffic congestion in the canals, or roads of Venice

In Venice, canals are more than just waterways between buildings; they are the roads of the city. These "roads" function similarly to ones typically found in other large cities because they perform the same tasks as traditionally paved streets. The exception in Venice is that the "roads" are actually filled with water; therefore boats must be used for transportation in place of cars and trucks. Canals serve the same function as modern sewer systems under paved roads except for, instead of flowing into a complex underground network, the sewage empties directly into the canals. Venice's current system of waste removal is not up to date with the rest of the world, meaning it requires a different kind of maintenance process to ensure it remains functional.

Figure 3: Canals must be maintained so boats can navigate through them

Since canals are highly essential to the everyday life of a Venetian, it is important to understand the significance of maintaining them. Similar to how city maintenance departments clear roads after snowfall for automobiles to safely drive on them, it is just as imperative for canals to be maintained so they remain navigable. Not only do people travel through canals to get from one place to another, but cargo boats utilize them to transport goods to different stores and shops throughout the entire island. This increases the importance of maintaining canals because if they can't be used to move merchandise then it can have a serious negative effect on the economy. Canals can also be hard to travel through because of the buildup of sediment, including the accumulation of sewage. Often the significance of canal maintenance cannot be put into perspective unless one can experience being in Venice, which allows them to appreciate how essential canals are for the city to fully function.

Canal maintenance is a very involved process which requires major organization. A routine maintenance plan for Venice has been continuously neglected in the past. After years of inattention, the city has realized the effects of canal damage caused by the lack of maintenance. To preserve their historical city, the Comune di Venezia created a company, Insula S.p.A., to facilitate the maintenance throughout Venice. Insula has organized various projects on all aspects of infrastructure, including canal maintenance. Venetians who live in the city and deal with the issues associated to canal maintenance experience the effects of damage first-hand. Since they are familiar with the maintenance work and can directly relate to it, many publications have already been written in Italian. In order to broaden the knowledge about Venetian canal maintenance it is just as important to make the same information available to outsiders, including the English speaking community.

Figure 4: The logo of Insula, the company responsible for the maintenance of Venice

In the past three decades serious measures to preserve the condition of canals has been taken. As of 2007, only ten years after they were created, Insula has completed approximately two thirds of their maintenance plan. The Integrated Canals Project is one of their large scale projects that detail the scheduled progress of canal maintenance. Their work on this project includes the dredging of canals and the restoration of canal wall linings that become damaged by excessive boat traffic. Insula's work maintaining the canals is projected to be completed in a 30 year plan.[64] There is currently no plan by Insula to repeat the maintenance cycle after The Integrated Canals Project is completed. The success of Insula's work to this point indicates their ability to perform future maintenance measures which is the next step in actively preventing serious canal damage.

[64] Insula S.p.A., www.insula.it (Accessed October 2007 – December 2007). Henceforth referred to as Insula

Roads of the Water

Formation of Canals

Canals in Venice are more unique than other canals because they were initially created when masses of islands closed in on each other to create hundreds of thin waterways that flow between the small islands. The city was planned around the natural creation of these canals. It is comprised 367 artificially improved waterway segments that channel through the entire city.[65] These segments were then broken down into 182 canals which were given names and codes by students from the earliest projects in the 1990's as part of an Interactive Qualifying Project (IQP).[66] As an early city, the canals of Venice proved vital to the survival of the city's economy. Over time the city expanded and advanced and modifications to the canals were made as they evolved artificially to meet the needs of the city.

Functions of Canals

Venice's most distinguishing characteristic is that it is built entirely on water and therefore has to use its canals as streets. This forces its residents to live a very different lifestyle than other people who live in highly traveled destinations similar to Venice. Venetians must find a way to adapt to a way of life that forces them to use the resources available. Although other cities don't have to deal with some of the problems canals create, they are so important to life in Venice that it is beneficial for them to take notice in maintaining them. To outsiders it may seem like canals are more of a problem than they are worth but the truth is that if you compare the functions of canals to the functions of roads and sewer systems in typical cities, they are identical. Besides the difference of

<u>Canal Widths</u>

When the islands of the historical district of Venice formed, the canals developed various sizes. Of the 182, the average minimum width is 7.2 meters (23.4 feet)[67]. When one factors The average width of a boat as 2.1 meters and boat parking occurring In every canal, this leave boat drivers with an average space of 3 to 5.1 meters to navigate through Venice. This leads to boat drivers having to look for alternate routes to get to their destinations, and poses a threat to public service boats such as taxis and ambulances, which rely on being time efficient. With hundreds of boats traveling through the canals each day, the small canal widths lead to several boats bumping into each other, but with the low speed limits of the canals, there are only a handful serious accidents reported each year.

Figure 5: Taxi driver finally reaches the end of a canal after struggling to maneuver his way through the canal's small width

[65] GIS Layer, *Segmenti Perímetro*, Forma Urbis. (Venice, Italy) Last Updated: October 13, 2006.

[66] GIS Layer, *Rii*, Forma Urbis. (Venice, Italy)

[67] GIS Layer, Segmenti Totale, Forma Urbis. (Venice, Italy)

being on water versus being on land canals require the same attention in terms of maintenance as both roads and sewer systems. One difference is that because it may be more difficult to perform maintenance on water as opposed to land, canals may be more expensive to maintain than paved roads or sewer systems.

Figure 6: A public transportation boat stop located on the Grand Canal

Unlike most developed cities, Venice does not have paved roads for motor vehicle transportation. Instead it is comprised of narrow streets and alleys on each *isole*, or small island, that makes the use of motor vehicles impractical. This makes Venice the only major city in the world where vehicular and pedestrian traffic never intersect. Although it lacks streets, Venice has the same characteristics of any large city in that it still needs a way provide transportation to its residents and visitors. Because there are no motor vehicles in Venice, the canals serve as the roads. Boats travel through the canals on a daily bases performing the same tasks as cars or trucks would in a typical city. The intricate network of canals that flow throughout Venice is the city's trademark and a staple of Venetian culture that attracts the attention of over 20 million tourists who visit the city every year.[68]

Figure 7: Raw sewage flowing out of piping and directly into the canal

Besides transportation, the canals also serve another major function in the city. Venice does not have a modern sewer system so canals are used as the outlet for the city's sewage. The sewer system is very basic in that the sludge from the sewers simply travels through the canals until it eventually washes out into the lagoon. It has been said that, "When you pay a gondolier to row you on the canals, he's rowing you through the sludge of Venice".[69] Although Venice was the first ancient city to develop a type of sewage disposal system, they have not modernized their technology to meet the standards of today's more recent systems. [70]

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[68] Martha Bakerejian, "Record Number of Tourists Travel to Venice, Italy," Italy Travel (2007) http://goitaly.about.com/b/2007/11/21/record-number-of-tourists-travel-to-venice-italy.htm (Accessed December 6, 2007). Henceforth referred to as Bakerejian, *Record Tourists*

[69] John Berendt, *The City of Falling Angels* (New York: The Penguin Press, 2005).

[70] Personal Communication, Fabio Carrera, Director of Venice Project Center (Venice, Italy. Henceforth referred to as Fabio Carrera

The Evolution of a City

Figure 8: A look at the Grand Canal today, the image of modern Venice

As the "roads" of the city, canals have always been used as a means of travel from one island of Venice to another. Before what is now described as modern Venice was formed, people commonly used rowboats, ferries and even wooden planks in the earliest days to cross the canals. Often when people needed to cross certain canals to get to different small islands they would pay someone who lived on the land a small fee to cross on a wooden plank. The only other option was to walk between the islands by crossing bridges which wasn't always an option. Soon enough, tradesmen started building wooden boats, which quickly became the primary mode of transportation in Venice. This provided an effective means of traveling until newer technology was invented and replaced the outdated methods. It wasn't until after WWII, in the 1950's that this newer technology was introduced to Venice and motorboats replaced rowboats to perform everyday tasks because they could provide quicker and more efficient services.[71]

As the city became more populated, walls were eventually put up on both sides of the canals to stop them from closing in on each other. This ensured that passageways wide enough for suitable water travel remained between the islands. The walls served as a foundation for building by increasing the required stability needed for construction. After these walls were added, it stabilized the land enough so that bridges that linked the small islands together could be built. As talked about in greater detail in the bridges chapter, bridges were built in Venice as early as the 13th century.[72] They continued constructing bridges over the canals until al islands were connected, now making it possible to travel across all of Venice, either by boat or foot. Before the addition of bridges nothing connected the islands, so each of them was considered their own separate community, meaning Venice was actually comprised of 125 small separate pieces.[73] These manmade changes have helped shape Venice into the unique and historic city it has evolved into today.

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[71] Stefano Ceriana, Dan Nashold, Joan Olender, and Matthew Poisson, *Monitoring and Analysis of Cargo Delivery System in Venice, Italy* (Worcester, MA: Worcester Polytechnic Institute, 1998). Henceforth referred to as Ceriana. *Delivery System*

[72] "History of Venice Rilato Bridge." (Destination 360, 2007) http://www.destination360.com/europe/italy/ponte-di-rilato.php (Accessed December 6, 2007)

[73] GIS, *Isole*

The Venetian Island – A Revealed Truth	**Geographical Information Systems**
There is controversy regarding the number of island that Venice occupies. If one were to look only at the historical district of Venice including the Guidecca, they would be looking at 125 islands[174] (refer to figure 8). Branching out from the historical district are the several islands that run at the above the historical district. These islands, which include the famous glass factories of Murano, the very colorful island of Burano, and the Lido, are not islands to be part of Venice.	Over the last 30 years, Geographical Information Systems (GIS) have become increasingly useful. They are computerized mapping programs that integrate a detailed map with data relating to certain regions. These maps can be used to display numerous of characteristics, such as specifications regarding bridges, docks, canals, islands, utilities, etc. as seen in Figure 8. GIS layers allow for the ability to publicly access information that is organized into databases. In order for a GIS system to be effective, a map of the location used must be digitized and extensive data must be collected and organized.

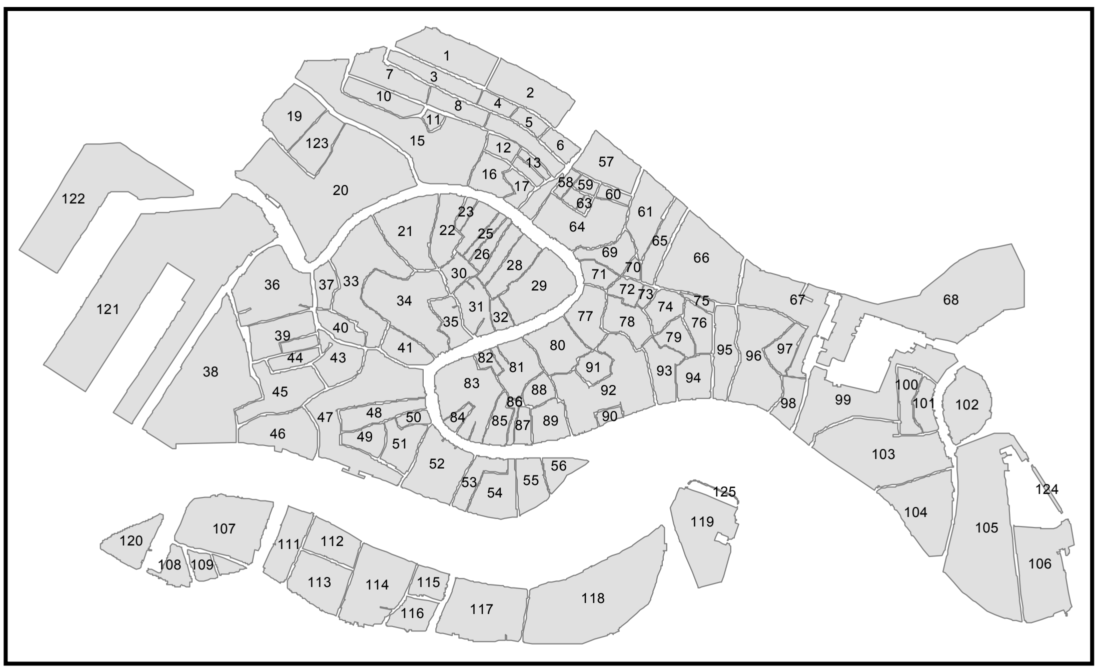

Figure 9: A GIS map layer clearly showing all 125 islands that form the city of Venice.

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[74] Ibid.

Methods of Canal Transportation

Figure 10: A traditional taxi boat traveling through a canal

When in Venice it is easy to notice that there are many different types of boats that travel through the canals. If studied more closely you can see that some boats are utilized more often than others. These boats were divided into five different classes and categorized by type including; service, sport, taxi, merchant, and gondola.[75] Although each of these boats serves different purposes they all contribute to the regular traffic flow of Venetian canals. Based on a study done in 2002 on the makeup of canal traffic in Venice, cargo boats and public taxis make up the majority of canal traffic. Being the most prominently used boats, they also contribute the most to canal wall damage, which will be discussed in further detail later in the chapter.[76] As determined during the study, taxis account for 46% of the traffic and cargo boats represent 36% of the canal traffic[77].

Figure 11: A Vaporetti, the boat used for public transportation through the Grand Canal and to the lagoon islands

A Quest for a Parking Space in Venice[78]

With all the boats that maneuver around Venice, there is a need to park all those boats. WPI Students in October 2006 investigated the use of canal parking spaces in Venice. This project gathered data about the interaction between boat traffic and parking in Venice in order to identify criteria for the allocation of permanent and temporary parking permits. They found that there were 1200 permanent canal parking spaces and 3000 temporary parking spaces. To monitor and implement these changes, an electronic parking management system was designed to assist the city in reducing the amount of time needed to process permit applications. The implementation of this system would thus benefit both the citizens and the city, and would help decrease the cost of traffic congestion. This team of students recommended that the city charge a 10 euro fee to all Venetians applying for a temporary parking space. This would help maintain the system while forcing Venetian residents to reconsider applying for temporary parking spaces continuously, and not applying for a permanent space.

[75] Moto Ondoso
[76] ibid
[77] Fabio Carrera and Caniato, Giovanni, *Venezia la Citta Dei Rii.*

[78] Gregory Bukowski, Briana Dougherty, Russell Morin, and Patrick Renaud, *Optimizing the Use of Canal Parking Space in Venice* (Worcester, MA: Worcester Polytechnic Institute, 2006). Henchforth referred to as Bukowski, *Parking*.

Although canals provide for a unique form of public transportation in Venice, their primary function is just as important as in any other populated city. Vaporetti, or motorized waterbuses, are the most commonly used form of public transportation. Like subways or public buses in other major cities, Vaporetti provide transportation to large amounts of people. It makes different boat stops along the Grand Canal and also travels to outlaying islands in the lagoon. Both Venetians and tourists regularly rely on this form of public transportation for their daily traveling needs. Unlike land based cities where people often use their own cars for transportation, it is not as easy to have immediate access to a boat in Venice. There are no driveways leading into a residence where boats can be parked like there would be outside of houses normally. This creates space problems and contributes to the lack of parking available in the canals as determined by a student research group who studied the optimization of canal parking space in 1996.[79] For this reason many residents do not even own a personal boat. Water taxis are another popular form of public transportation in Venice. Taxis are mainly utilized as an alternative to Vaporetti by tourists who are not as familiar with the city and prefer to be brought to their exact destination in a shorter amount of time. Considering it is estimated that over 20 million tourists visit the city each year, it is not surprising that taxi's are in such high demand.[80] Venetians don't regularly use taxis because the Vaporetti is a cheaper method of transportation, comparable to how a public bus or subway would be to an automobile taxi on a land based city. Because there is such a high demand for efficient public transportation in large cities, it makes the most sense that the types of boats that best support that need in Venice are the most widely used.

Assessing the Problems of Venice's Canals

The Need for a Routine Maintenance Plan

Venice is an extremely overpopulated city relative to its size in total area, 6.3 square kilometers, or 2.4 square miles in solely the historical area.[81] The amount of actual residents in Venice is has been declining over the past few years and is currently approximately 62,000. Causes of the decrease in population are suggested to be related to the historical face of the city. Based on the fact that Venice is full of original structures which date back to over 1000 years ago, proposals to restore or maintain the infrastructure have serious limitations or are often even completely rejected by the superintendant of the city. Being that a large amount of Venice's population is considered elderly, this poses problems with them being able to live and function in a city that cannot always be modified to meet their needs, which is the reason why so many of them are forced to leave the city.[82]

Over 20 million tourists visit Venice every year leading to the estimation that tourism brings in approximately $1.5 billion in revenue annually, an extremely imperative facet to Venice's economy.[83] Because Venice is heavily occupied by tourists it generates

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[79] Victor Bravo, Jose Lopez, and Zung Nguyen, *A Documentation and Analysis of Canal Boat Parking within Santa Maria Formosa Insula and Santa Maria dei Frari Insula*. (Worcester, MA: Worcester Polytechnic Institute, 1996).

[80] Bakerejian, *Record Tourists*

[81] GIS, *Isole*

[82] Comune di Venezia. http://www.comune.venezia.it. Henceforth referred to as Comune di Venezia

[83] ibid

additional job opportunities for non native Venetians. Since there aren't enough Venetians to fulfill all employment positions, more than 47,000 people commute from the mainland into Venice on a daily basis for available work.[84] On an average day the amount of nonresidents in Venice outnumbers the amount of residents two to one. Like all largely populated cities, it is crucial to provide all the people who live, work and vacation in Venice with public transportation. As the amount of actual residents in Venice continues to decrease, the amount of people coming into the outside, therefore needing public transportation increases. Every year the amount of canal traffic increases by approximately 2.5% due to the constant rise in people coming into Venice.[85] Peak visiting periods occur between the summer months of June-August, around the holiday season and throughout Carnival, a traditional Venetian event that takes place in the beginning of February. The abundance of tourists contributes to the factors that draw attention to the need for routine maintenance. Other than the aforementioned increase in of boat traffic; clogged sewer outlets, boat collisions, and biological and chemical agents also increase as more people occupy the city, all factors which significantly contribute to the causes of canal damage.

Construction of Canal Walls

Canal walls of Venice were traditionally constructed of two different materials. The lower parts of some canal walls, which are submerged in water, are made up of Istria stone. This type of stone is nonporous, which prohibits water from penetrating the surface, making corrosion almost nonexistent. Brick is generally used for construction on top of the stone. Fondamente, or sidewalk platforms, that run along the canals are made entirely of brick. Brick is a popular building material because it is readily available and inexpensive. Its major setback is that it is extremely porous, allowing it to be easily corroded by the salt water of the lagoon. Consequently, this makes brick a poor choice of material for building along the canals. Concrete is used when repairing canal walls and is installed at the very base of the walls to allow for additional reinforcement.

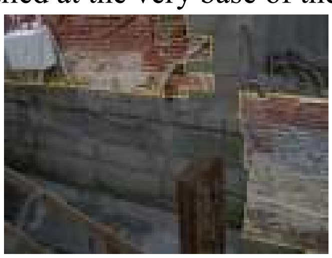

Figure 12: The yellow highlighted portions show the brick material used in construction

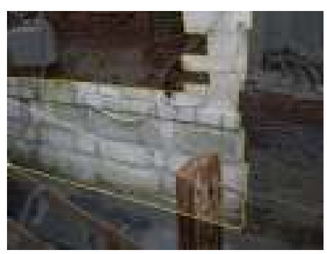

Figure 13: The yellow portion shows the next layer of construction, Istria stone

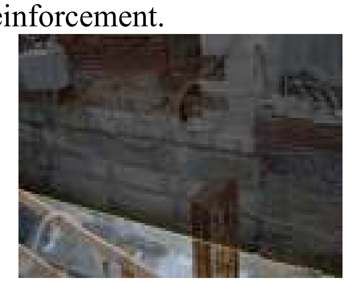

Figure 14: The bottom layer of construction, highlighted in yellow shows the concrete that is used to reinforce the wall

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84 Comune di Venezia

85 Ceriana. *Delivery System*

When the use of stone in construction of the city of Venice began, the sea level was at a much lower height than today. Due to the rising sea levels around the world, the water level in the Venetian lagoon has risen approximately 23 centimeters since 1897.[86] When the city was first built, only the Istria stone sections of the canal walls were exposed to the water. Today, since sea level has risen substantially, the extremely porous brick used in the building construction is also exposed to the salt water of the sea.

Figure 15: Damage in canals, including the restoration of docks is maintained simultaneously

Canal walls serve as the foundation for most buildings in the city so once they become damaged the buildings built on them are subjected to problems with structural instability. As the walls begin to deteriorate from the bottom of the building upward, it reduces the amount of forces it can withstand and greatly risks caving in. Residencies are not the only buildings that border the canals; local businesses and shops are also affected by the damage. Docks, which are considered part of canal walls, are similarly subjected to this same damage. Docks are built on the canal walls and either extends inward or outward depending on their design, allowing docks to be simultaneously maintained as canal walls are repaired.

The Effects of Boat Traffic & Wake Damage on Canal Walls

Traffic congestion is also damaging to canal walls because of the water turbulence caused by maneuvering. When breaking, boat drivers must put their engines in reverse to slow themselves down. Boat drivers alternate between the reverse and drive gears to remain in a constant position. This motion causes large amounts of turbulence underwater and is more evident in taxi and cargo boats.

Collisions between boats and canal walls that mainly occur because of traffic congestion also make canal walls vulnerable to erosion. Collisions most commonly take place at canal intersections and at docks. Once the holes caused by the collisions are created, then the pollution and sewage in the canal water start to corrode and decompose the mortar and brick. After a small amount of damage has been done to the wall surface, the damage will only continue and become exponentially more severe. Imperfections in the wall surface, such as missing or chipped bricks, make the canal walls more vulnerable to erosion. Sometimes a wall will appear to be almost flawless, but due to a missing brick, water has been entering and eroding behind the surface. Water currents carry away the eroded pieces which weakens the foundation. Over time the wall surface may still be intact, but the structure that lies behind the surface has been damaged and the entire wall may eventually collapse.

Figure 16: Traffic congestion created by multiple boats in the narrow canals

[86] Chiu, *Moto Ondoso*

Figure 17:Wake, which is one cause of canal wall damage is shown at the rear of the boat

Additionally, as a boat moves through a canal it creates underwater turbulence caused by the spinning of propellers, called wake. Wake is visible on the surface of the water and can be seen from the back of the boat. The intensity of the wake changes based on factors such as: the speed of a boat, the size of a boat's propeller, the power of a boat's engine, the shape of a boat's hull, the depth of the canal being traveled, and the boat's load.

The damage caused to canal walls by the wake is called Moto Ondoso. Moto Ondoso is not usually problematic in large bodies of water like oceans or lagoons because there is a lot of area for the turbulence to disperse into. This is not the case in Venetian canals where there is a limited depth and width. The energy created by boat motors reflects back up to surface of the narrow waterways, causing them to crash into the canal walls. The deterioration of the canal walls occurs when their physical conditions become altered. They then slowly erode the mortar that acts as a seal between the bricks and stones in the wall. Erosion, the most destructive force to the canal walls, occurs when water crashes against the surface of the canal wall, causing friction. When the mortar erodes, the bricks and stone become disjointed and are much more susceptible to the destructive stresses and forces of boat wakes.

One reason why wake damage is such an extreme contributing factor to canal wall deterioration is because boat speed limits are not strictly enforced. The one exception is the Grand Canal where the current 7 km/hr speed limit is more closely monitored. A boat speed limit for Venice was first established in 2001 making the maximum boat speed in the canals 5 km/hr and the Giudecca lagoon 20km/hr.[87]

Figure 18: A map of Venice which shows speed limits, orange indicates 20 km/hr, blue indicates 7 km/hr, and yellow indicates 5 km/hr limits

Based on data from the Moto Ondoso Index, a study done by students at Worcester Polytechnic Institute, which includes the energy value of each boat that passes through the canal segment each day, small cargo boats release by far the most amount of energy into the canals at 66%. This conclusion is based on the assumption that the speed limits in the canals are loosely enforced and rarely followed. These calculations are relevant to canal wall damage because if all boats were to obey the posted speed limit of 5 km/hr it was determined that taxi boats would be responsible for majority, 53% of the energy released in the canals. The data also revealed that very few boats travel within the posted speed limits. Based on testing it was noted that 100% sampled taxis exceeded current speed limit of 5 km/hr, averaging a speed of

[87] ibid

11.7 km/hr. The average speed in all boats in all canals was over 12 km/hr, which is more than 7 km/hr over the legal maximum speed. Based on the index that was created it was determined that if boats were to travel within the speed limits, there would be a drastic decrease in the heights of boat wakes and therefore much less erosive water motion. After the study it was concluded that only 3% of the total types of boats observed obey the speed limits. When the range was extended to traveling within 2 km/hr of the speed limit, still only 13% followed the speed limit. Furthermore according to their study they calculated that if speed limits were enforced, Moto Ondoso would be reduced to 1/10 of current levels.[88]

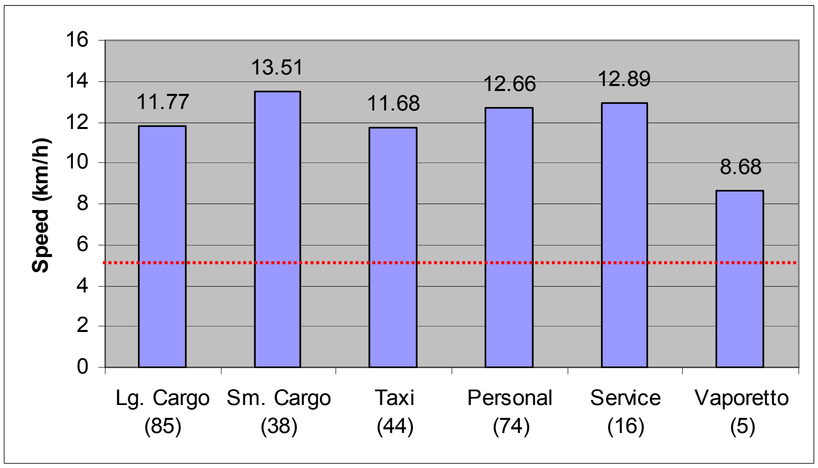

Figure 19: This chart shows the speed limit then the average speed limit divided by types of boat, as part of the Moto Ondoso Index study

Another factor that also strengthens the effects of Moto Ondoso is the different hull shapes of boats. Observations again taken during the study of the Moto Ondoso Index noted that boats with narrow, streamlined hulls produced far less wake than those with boxy, square hulls. It was concluded that regardless of boat type; boats with boxy hulls would therefore cause more damage to the canal walls than their sleek counterparts.[89]

The continuous wake impact on the canal walls has resulted in the need for constant repairs. When damaged walls go unnoticed, the result can be dangerous. Over time some walls can become damaged so severely that they develop large holes and eventually collapse. Since canal walls are essentially the foundations that support the buildings constructed on them, excessive damage can cause them to cave in to the canals they border. Once a wall has been weakened or damaged it is more susceptible to the erosive powers of the water, and is therefore destroyed at a much faster rate.

Figure 20: Example of a hole in a canal wall

[88] ibid
[89] ibid

Before motorboats were introduced into the canals of Venice, the canal walls were essentially only subjected to the forces of water as it flowed in and out of the lagoon with the tides. Canal walls were built long before motor boats were invented, and therefore were not designed to be able to withstand the force produced by boat wakes today. The amount of boat traffic that travels through the canals, as it increases, has the potential to destroy the city.

Figure 21: This is a normal sight in Venice, a motorboat traveling through the canal network

As long as Venice continues to use motorboats to travel through the canals they will always have to deal with the damage caused by Moto Ondoso. Although there will never be a solution to completely eliminate canal wall damage, measures can be taken to actively reduce its effects. One simple action could include beginning to strictly enforce speed limits in the canals. This would not entirely resolve canal wall damage but it would greatly reduce it so that such extensive measures would not have to be taken as regularly. This is also referred to as a form of preventative maintenance. As more powerful boats are being created due to advanced technology, there lays a greater risk of more damage caused to the canal walls. Even though routine maintenance can be costly, in the case of Venice where it was seriously neglected for so long, it is essential in order to return to a state where the optimal quality of life can be observed. Long-term maintenance in Venice was necessary before it became too late and the city suffered the consequences and literally fell apart.

Additional Factors That Contribute to Canal Wall Damage

Chemical materials like sulfuric acid create the pollution that weakens canal walls by expediting the disintegration of wall materials. Sulfuric acid damages stone when it interacts with the calcium carbonate, chemically changing it to calcium sulfate. In the case of the canal walls, the change in composition of the stone causes the interior structure to crumble. The source of the sulfuric acid comes from the Mestre-Marghera industrial zones where chemicals were released into the canals. These chemical plants were extremely active up until the end of the 1970's.[90]

Biological materials which live and grow naturally in the canals such as bacteria, fungi, seaweed, algae, and lichens also cause the deterioration of the canal walls. These organisms eat away at the inner supports of the canal walls as well as the stone. The humid climate of Venice exacerbates this process since the warm, moist air promotes the growth of these organisms.[91]

[90] UNESCO. http://www.unesco.org/culture/heritage/tangible/venice/html_eng/menacemon.shtml. Henceforth referred to as UNESCO

[91] UNESCO.

Venice's Sewage Removal System

Figure 22: After a canal is dredged and drained, sewer holes are able to be cleared out

Canals are a major component of the sewer system. Sewage flows from houses, into conduits located under the streets, and eventually enters the canals through outlets below the waterline where it contributes to the sediment buildup. Sewer outlets on the canal walls sometimes become blocked by silt that has built up over the years on floor of the canal. Sewage then gets backed up in the pipes behind the walls and eventually must find a different way to exit. Alternatively, the sewage is forced out through the mortar that binds the building materials, weakening the structure and making the wall more susceptible to the erosive powers of the water. Structural damage is caused by the sewer system when the silt levels get high enough to block the sewer holes in the canal walls. Since the sewage cannot flow out of the pipes and into the canal, tremendous pressure builds up in the pipes housed within the canal walls. When enough pressure has accumulated, the pipes rupture and the sewage is rerouted to other areas within the foundations of the canal walls. Finally it seeps out through the mortar, weakening the structure considerably. After the sewage starts to affect the structure causing it to crumble, the debris falls into the water and settles at the bottom of the canal.

Analysis of Structural Damage to the Canal Walls present[92]

The deterioration of the canal walls occurs when their physical and mechanical conditions become distorted. WPI groups in the early 1990's came to Venice to analyze the causes of damage to the canal walls. This study presented an analysis and quantification of the different types of damage on the canal walls of Venice. They focused their studies around the San Marco Sestiere and the boundary between this area and the San Castello Sestiere. Photometric techniques, coupled with an intricate archival system, were used to evaluate the extent of damage within the canals. Building materials, traffic levels and mud build-up were analyzed along with structural damage, in an effort to relate these causes to the existing damage. The research developed in this project provided the information necessary to evaluate the extent of damage, the causes for this damage, and the social ramifications resulting from this damage.

An alarming trend was revealed in the study of the structural damage and sewage outlets during this project. The instances of illegal sewage outlets are becoming greater every day, as are the occurrences of canal damage. From their analysis, the groups recommended that regulations be enforced more strictly in an attempt to alleviate all cases of exposed sewage outlets.

[92] Chad R Binkerd, Ralph A. Maselli II, and Scott H. Stoddard, *Analysis of Structural Damage to the Canal Walls of the Sestiere Castello di Venezia* (Worcester, MA: Worcester Polytechnic Institute, 1992).

Buildup of Sediment on Canal Floors

A combination of sewage, masonry from buildings and particles brought in by tides all contribute to the high amounts of sediment buildup found on the bottom of the canals. Based on the results of their research and testing, a study by students from Worcester Polytechnic Institute concluded that 83% of sediment in Venetian canals is unknown, 11% is due to sewer discharge and 6% accumulates from masonry debris. Sediment builds up on the floor of the canals at a rate of up to two centimeters per year. As sediment builds up, it decreases the depth of the canals, which is why they need to be dredged routinely. Because of the buildup of sediment, the water level becomes higher, which can lead to problems with bridge clearance for boats, especially during periods of high tide.[93]

The Plan to Preserve Venetian Infrastructure

The History of Canal Maintenance

Canal maintenance has been performed for much longer than most people realize, although the degree of the measures have not always been as extensive as now. There is evidence of the earliest stages of maintenance from before the fall of the Venetian Republic in 1797. Maintenance continued during the first period of Austrian rule from 1799-1805. Canals were seriously neglected during the period of the French reign. It wasn't until the Austrians returned to power in 1818 that an extensive maintenance program was set up to improve the poor state of sanitation created by the sewer system. Serious maintenance measures were again taken from 1869-1875 when Venice was annexed by the Kingdom of Italy. After this, in 1892, large scale dredging resumed. The conditions of the canals were so bad after WWI that this forced the State to perform emergency, non-routine work in the areas in need of the most immediate work. The creation of an ad hoc law in the Forties granted additional funding for maintenance and allowed large scale work to continue. Venice experienced a shortage of funding in the Seventies and Eighties which caused maintenance work to become less frequent than previous years. This seriously delayed routine maintenance and made the sanitary conditions of the canals throughout the city an alarming issue.[94]

Figure 23: A damaged canal wall in need of serious maintenance

Beginnings of a New Maintenance Plan for Venice

Over the past 30 years as damage created by the amount of boat traffic and increase of sediment accumulation has increased, it has become imperative to make more extensive and regular canal repairs in order to maintain a high quality of life within the city. One hundred percent of the money budgeted by the Venetian government for urban maintenance

[93]Alexander Borrelli, Matthew Crawford, James Horstick, and Izzettin Ozbas, Q*uantification of Sediment Sources in the City of Venice, Italy* (Worcester, MA: Worcester Polytechnic Institute, 1999).

[94] Carlo Cioffi, Vicky Dulac, José Marsano, and Robert Reguero, *Development of a Computerized Decision Support System for the Scheduled Maintenance of the Inner Canals of Venice* (Worcester, MA: Worcester Polytechnic Institute, 1997).

is handed over to an agency whose mission is to provide sufficient maintenance to the city. They are responsible for organizing and carrying out methods to control and reduce the effects of damage on all types of infrastructure, including canals. The city spends millions of Euro annually on urban maintenance, although it is not necessarily distributed equally every year. For example, in 2006 the government set aside 35 million euro to continue the scheduled canal maintenance, but the following year they were only able to budget 5 million euro. Inconsistency in the amount of money available to spend on maintenance can cause setbacks to the projected date of completion of the maintenance cycle.[95]

Venice's Leader in Operating Canal Maintenance

Over the past few decades extensive work by independent groups has been done in the area of urban maintenance in Venice. Examples of work researched by students in Venice includes extensive testing, data counts, and project proposals all related to the topic of urban maintenance. In association with companies such as Forma Urbis, all of this extensive research has been organized into databases and handed over to established agencies that have the available resources such as funding and manpower to further investigate and implement maintenance plans. Worcester Polytechnic Institute's Global Studies Project Center, with the assistance of Forma Urbis continues to explore areas related to urban maintenance in Venice to this day. They remain in close contact with many sponsors that they have collaborated with in the past including The City of Venice, UNESCO, and Insula to provide assistance collecting and organizing the data needed to complete proposed maintenance projects throughout the city.

The leading agency dedicated to fighting to maintain canals is Insula s.P.a. Insula was created by the City Council in 1997 in order to accelerate the maintenance process.[96] They have quickly become the operative branch of urban and infrastructure maintenance in Venice. Prior to Insula's creation, minimal action in maintenance preservation was taken. Insula's involvement is broken up into two different stages units, work done on land and work done on water, which includes the maintenance of canals. The primary works associated with water maintenance as it relates to canals are the dredging of silt and sludge from the bottom of canals, the readjustment and rationalization of the subsoil dredged from the canal, the static restoration of the banks and foundation of canals and the improvement of the city's hygienic and environmental conditions through the renewal of the sewer system. Another measure they are responsible for concerning water maintenance which is not directly related to canals is the raising of pavements to protect the city from *acqua alta*, or high tide as referred to in The Acqua Alta sidebar.

<u>Acqua Alta and the MOSE Project</u>

Acqua Alta, or "High Water" occurs when the waters in the canals from the high tide rise above flood levels, pouring onto the streets forcing areas of Venice to rely on elevated walkways and water boots for transportation. Acque Alta occurs on a yearly basis mainly

[95] Personal Communication, Lorenzo Botazzo. Responsible Intervento, Insula S.p.A. (Venice, Italy).
[96] Insula

during the months of November through January[97]. Venetians are informed of an Acqua Alta approaching when warning sirens are sounded. The level for an Acqua Alta to be official is 90 mm above normal high tide. The biggest factor of Acqua Alta is considered to be astronomical tidal flow of the Adriatic sea[98]. This tidal flow is strongest at the beginning and end of the full moon cycle. The winds that blow from the Balkans and the Sahara also greatly contribute to Acqua Alta[99]. Humidity and the air temperature can also play a major role with the flooding of Venice especially if it is humid and unseasonably warm. The flooding of Venice, when it does happen, Acqua Alta lasts around 1 to 2 hours depending on the severity of the tide[100]. The level of the tide does not mean that the city will be flooded by that number. For instance, when "+100 cm Acqua Alta is mentioned, that meter only represents the increase in comparison with the average sea level(the average sea level conventionally accepted is the 1897 one measured at the Punta della Salute). At this level, only a very small number of low-lying areas in the city points get flooded[101].

The worst Acqua Alta on record was on November 4, 1966, a day when tides rose 1.94 meters, nearly all of the city, inculding Piazza San Marco (St. Mark's Square). This Acqua Alta led many to believe that Venice was sinking. However, a rare event occurred during a cold November night in 2005, in what could be called the exact opposite of Acqua Alta. Temperatures that night dipped below zero and there was zero humidity. This combination led to the water levels dropping down to as low as minus 0.70 meters at low tide. The tide was so low that Venetian residents could almost walk around Venice across the exposed sand banks and marshes[102]. The lowest record height for this type of occurrence is dated back to February 14, 1934 when the waters dropped 1.21 meters below sea level.

Figure 24: **The effects of Acqua Alta on the streets of Venice**

Level of Tide	Percentage of Venice Flooded
Up to 80 cm	Normal Tide

[97] Durant Imboden's Venice for Visitors. "Acqua Alta: High Tides and Flooding in Venice." http://europeforvisitors.com/venice/articles/acqua-alta.htm. (Accessed November 29, 2007). Henceforth referred to as Durant.

[98] "Acqua Alta" & the Floods in Venice." http://tours-italy.com/venice/floods%20in%20venice.htm. (Accessed November 29, 2007). Henceforth referred to as "Floods in Venice".

[99] ibid

[100] ibid

[101] Enzo Bon, "Acqua Alta (High Tide)" http://www.comune.venezia.it/flex/cm/pages/ServeBLOB.php/L/EN/IDPagina/1066. (Accessed November 28,2007) Henceforth referred to as Bon. *Acqua Alta.*

[102] "Floods in Venice"

100 cm	4%
110 cm	12%
120 cm	35%
130 cm	70%
140 cm	90%

As the mean level of the land has lowered, the sea levels have risen. Although the city did sink about 10 cm in the 20th Century because of industrial groundwater extraction, the sinking largely stopped when artesian wells on the mainland were capped in the 1960s. Today, subsidence is estimated at 0.5 to 1 mm per year, mostly due to geological factors and compression of the land beneath the city's millions of wooden pilings.

In May 2004, In order to stop this flooding, construction of the controversial MOSE Project started. This was a project to design 79 flood barriers fixed to the lagoon bed. At normal times the barriers will be full of water and lie flat but when there is a flood warning they will be pumped full of air and raised, therefore creating a dam and saving Venice from being flooded. The project has made progress, but as the intentions are good from the city, many Venetians feel that this project is an inappropriate use of city money.

Insula's work encompasses the entire historic center of Venice as well as the inhabited areas of the islands of Murano, Burano, Pellestrina, and sections of the urban areas of the Lido. One of their main water maintenance projects is called "The Integrated Canals Project". This coordinated program of urban renewal and protection is one of their first projects, dating back to their establishment. Before they started the project each canal was classified into different priority levels based on their level of sediment, circulation of water, and importance of use and navigation. The main focus of the program is to tackle the largest and most urgent maintenance works, which include dredging the canals and restoring the walls that line them. The cycle of special maintenance determined by the Integrated Canals Project is organized and divided into two phases. The first phase is to complete the hydraulic, structural, and sanitary functionality of the canals and their walls. It is expected to be completed by 2014. The second phase was put into action in 2005 and deals with the radical restoration and upgrade of the entire sewage collection and disposal system. This stage of the project is projected to be completed by 2025. At this point 71% of canals have been dry dredged. The advancement of their scheduled plan relays on the continuity and proper disbursement of the maintenance funds by the government. In order to complete the entire project Insula has calculated a 1,213 million Euro budget.[103]

One issue that slows down the progress of Insula's work is the fact that the majority of infrastructure in Venice is considered historical because the original structures remain or have had minimal changes made to them over the years. There are limitations in Venice that prevent work from being done to change these historical structures or require special permission from the city's superintendant before any work can be considered. These restrictions create issues when repairing and restoring infrastructure, since previous occasions have shown that it is unlikely the superintendant of Venice will approve major modifications to original structures. Depending on the specific situation, maintenance

[103] Bon, *Acqua Alta*

work is sometimes even rejected by Venetians.[104] Even though Insula is working to preserve and protect the city, some of their work requires changes to be made to historical structures which are not easily accepted by many Venetians who take pride in the historical value of their city. This obstacle hinders Insula's progress because often there is a lot of behind the scenes action that must be taken care of and approved before they can begin their maintenance work.

Today, only 10 years after they were formed, Insula has made significant progress in carrying out their exhaustive maintenance plans. Insula continues to set their standards high to carry on a rapid pace of repairs for the future. This can be measured by the progress of their entire maintenance plan which was grouped into three categories based on severity; first, second, and third priority. As of now Insula has completed all the first and second priority level work. They have currently moved to the third priority level maintenance and are approximately 71% completed with the entire project.

Figure 25: A canal being dredged as part of Insula's scheduled maintenance plan

Figure 26: The same canal after Insula completed their work

Canal Maintenance Preparation

Part of Insula's work dealing with the restoration of canal wall linings and dredging of sediment buildup includes the systematic process they have created which enables maintenance to precede at a quicker rate. As part of the first stage of the process, wooden piles are driven into the bottom of the canal along the outer edge of the foundation on each side. These are used to support a kerb, or a continuous metal sheet piling that is extends approximately 2.5 meters deep.

[104] Fabio Carrera

Figure 27: The vertical technique used to dredged in The Grand Canal is also used for various locations throughout the lagoon

Figure 28: An Insula worker performing maintenance tasks in a dredged canal

Next, before the canal can be dredged the section will then go through the process of water removal by setting up barriers at the ends of the section, similar to a dam. Then, water is then pumped out of the section until workers are able to walk along the edges of the canal. Wooden planks are added along the sides of the walls and evenly placed across the bottom of the canal to allow for easy movement of the workers. Once the canal is drained and the planks are laid, the canal is ready equipment necessary for the dredging to be delivered and the workers can begin their maintenance.[105]

There are however, exceptions to the maintenance preparation routine in Venice. One of these exceptions includes areas where the widths between walls are too spread out to perform traditional maintenance tasks. For example, maintenance in the Grand Canal is more unique than the rest of the canals because of its extreme difference in depth and width. Since the depth of the Grand Canal is approximately 4 meters, there is no need to dredge the entire canal, nor is it feasible.[106] Crews can not actually block the canal because when maintenance work has to be done on the sides of the Grand Canal it would pose a threat to the city's commercial transportation. In order to prepare for the Grand Canal maintenance, a section is chosen on either side of the canal. That section is blocked off along the side of the canal. Unlike the inner canals of the city, a barrier is placed parallel to the section of the canal in need of repair and extended outward enough for maintenance crews to work. With the section blocked off, the water is drained out and the crews are ready to work, using a method that does not affect boat traffic. The average cost for this maintenance procedure is approximately €8000 / meter which is a massive difference from the normal average of €129 / meter - €3264 / meter.[107] Although, the lagoon is not a canal, maintenance to the wall of the lagoon must be performed similar to the maintenance of the Grand Canal.

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[105] Insula

[106] Richards, Genevieve. "Facts About Venice." www.travellady.com/Issues/November04/1071FastFactsAboutVenice. (Accessed November 4, 2007)

[107] Chiu, *Moto Ondoso*

The Grand Canal

Figure 29: Overhead picture of Venice, Italy highlighting the S-shape of the Grand

The Canal Grande is Venice's most famous canal. It's the longest and widest canal, measuring 3 kilometers (2 miles) in length, and a width averaging 175 feet with a peak width of 350 feet. Its' unique S-shape figure, as shown in Figure S1, starts from the lagoon, passes through the central districts of Venice and ends at the Basilica di Santa Maria della Salute. The buildings that run along the Grand Canal are masterfully decorated, which adds to the beauty of the canal. Of these buildings, there are over 100 palaces, including Ca d'Oro, Palazzi Barbaro, Ca' Rezzonico, Ca' Foscari, and Palazzo Barbarigo. There is also the famous Basilica di Santa Maria della Salute. With the train station and the bus station along the canal, the Grand Canal is the main access point for public transportation in the city. It is the only canal in Venice that is actually a river-be. Its signature characteristics make the Grand Canal an icon of Venetian beauty.

Cleaning the Canals

Canals must be dredged to guarantee the flow of water in the canals and ensure they remain navigable. There are two different techniques that can be used for dredging, wet dredging or dry dredging. The most common method used to dredge is dry dredging. During the dry dredging process the area of the canal that needs treatment is cut off from the rest of the canal by damming the area at both ends. A large steel sheet piling is driven into the bottom of the canal. A hydrodynamic vibrating head replaces the ancient wooden caissons that are filled with clay. Once the area is secure, pumps are used to drain the stretch of canal. The canal must maintain a sufficient water level to keep the pontoons afloat where the grab-bucket dredges are mounted.

Figure 30: Machinery, including the grab-bucket used to scoop out and remove sediment

Wet dredging is often used as a preliminary phase before canals are drained and tends to be more economical. This process is usually limited to the central strip of the canal so it does not disturb or damage building facings. During this technique hydraulically driven grab-bucket dredges are mounted on the bow of the barges. Once the canal has been drained, it remains dry for an average of six weeks while various maintenance work is done. In both cases of wet and dry dredging, the sediment that is dredged out is then transferred onto barges and taken away to designated treatment sites.

After Insula completes the dredging process, they are responsible for managing the removal of the subsoil. When the sludge at the bottom of the canal is removed it has to be classified by type according to Insula's predetermined standards. There are four classification levels, A-D which determines the state of the subsoil. This process is important because the different types of subsoil are relocated based on this determination. Type A subsoil contains the least amount of polluted material and Type D is classified the worst. It contains radioactive and other heavy materials which are the cause of the excessive amounts of pollution found in the silt. Type D, the most common of the four types has to be pretreated before it is brought to a special outlaying lagoon island which was created for the sole purpose of the removal of this material. Type D is so abundant because for over 20 years Margetta, the largest industrial chemical complex in Europe at the time was located in Maestre on the mainland and was releasing hazardous chemicals into the water. These hazardous materials included chemicals used in the manufacturing of items such as PVC, plastic and soda.[108]

Figure 31: Accumulation of sediment at the bottom of the canal

The Restoration of Canal Walls

Insula's method of constructing and reinforcing canal walls make the walls much more durable and resistant to erosion. This method of canal wall construction incorporates a slanted wall rather than a vertical wall, and uses more concrete than the traditional walls. Although a more modern canal wall construction would help preserve the city structurally, it would also ruin the aesthetic value of the city's appearance and therefore people are resistant to this change. They want to preserve the authenticity of the city by maintaining the original construction of the canal walls, even though this method is not as practical anymore.

Figure 32: This shows the technique used to fill mortar during the restoration of canal wall linings

After the canals are fully dredged, the first step in restoring the canal wall linings can be performed. During maintenance the mortar joints are first restored by making injections into them which reinforces the surface of the wall. Walls are resealed by a technique known as "binder sealing". During this process the missing part of the outer face is reconstructed and the body of the wall must be restored to its former compactness which allows physical continuity. The ground behind

[108] UNESCO

the walls is treated by a sealing and waterproofing process. This prevents water from resuming its deteriorating action and stops the building fabric from being undermined. Corrective action, construction, or partial rebuilding, is performed in order to compensate for any swelling that alters alignment or shifts the original geometry of the wall. As they continue their work around the city, Insula consistently monitors the conditions of the walls and foundations to ensure they are being maintained effectively.

In less than three years after the start of their newly revised schedule over 22 kilometers of canals has been dredged. The success of their actions to this point shows the potential to develop a permanent, systematic routine.

The Future of Canal Maintenance in Venice

Effectively Communicating About Maintenance Measures

Some of Insula's work is dependent on other maintenance work done by different companies involved in urban maintenance. It is important for them to be able to effectively communicate with all parties to keep them regularly informed of their maintenance activities. Insula also strives to keep the public informed of all their work.

Figure 33: Insula creates awareness about their work by posting information about their maintenance in English & Italian

They have an easily accessible, interactive website where all of their information is posted. The website, *www.insula.it* is in Italian but includes an option to allow you to automatically translate it into English. The website includes information regarding what they do, their maintenance schedule including projected completion dates, and information breaking down their financial expenditures. Other informative measures they have used include the organization of public meetings to advise the public of project updates, the time and money needed to finish them and to hear any appeals regarding their work. Insula produces and distributes informative leaflets in the area they are working in and sets up their worksites with street signs and hoardings to advise people of the constructions zones and detours. In the past they published quarterly reviews entitled *Insula Informa: Quaderni*. Today they continue to send out press releases in local newspapers to inform the public about works in progress or ones scheduled for the near future. Insula also organizes and participates in various conventions, seminars and press conferences. It has hosted local, national, and foreign television crews on its work sites and participated in radio and television transmissions in the past. Insula continues to advance communication measures by working on creating a complete record of their works with a full photographic archive and the production of cd-rom and video documentation.

Figure 34: The scene of one of the calm roads that are a part of the inner canals of Venice

The Need for Understanding Canal Maintenance
Canal maintenance an essential part of the urban maintenance system as it is related to the two primary functions canals serve; the transportation of people, goods, and services, and the removal of the city's sewage. For the maintenance of the city to be fulfilled, the City of Venice must be sure to provide a way to preserve the quality of life of everyone who occupies the city. For this reason it is extremely important to make information available to people other than the Venetians who are most familiar with the cities maintenance plan.

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Bridges

History of Bridges

Bridges serve as one of the world's most essential elements of both vehicular and pedestrian networks. Regardless of their design and makeup, these structures chiefly serve two main purposes: to keep two distinct flows of traffic separated at intersections or to grant traffic the ability to cross an otherwise impassable barrier. Venice, or the "City of Bridges,"[109] certainly utilizes the traditional purposes of bridges, but without the incorporation of cars. Due to Venice's unique water-based transportation system, all 473 bridges[110] within the city perform both of these functions simultaneously: allowing the primarily pedestrian-based land transportation system the ability not just simply to cross the canals, but also to avoid interfering with the boat traffic that utilizes the waterways below. This allows pedestrian traffic and boat traffic to serve as two completely different entities, which means they never interfere with one another; something not found anywhere else in the world. In addition to their most obvious function in the transportation infrastructure, the city's bridges also play a vital role in the utility network and serve as public art that attracts tourists from across the globe.

<u>Connecting Historical Venice and the Venetian Mainland</u>

Figure 1: bus traveling across the viaduct bridge from the mainland

It is a common misconception that Venice can only be reached by boat. There is actually a 3657 meter (12,000-ft) viaduct bridge of 222 arches over the Lagoon of Venice that connects the city with the mainland of Italy, by both vehicle and automotive. Although this bridge does not cross over a canal, its purpose is still important. This bridge not only allows materials to be delivered by train, but furthermore allows many Venetians to own cars that they can use to get to the mainland.

Bridges have served as an important piece of infrastructure throughout the history of Venice and its formation from multiple islands. Before bridges existed in Venice, the numerous islands were separate communities with their own churches, stores, and lifestyles. At one time, landowners even used planks as access from one island to the next and charged a small toll to those who wanted to cross over. It wasn't until the 13th century that bridges were actually constructed in Venice. Once the bridges began connecting the islands, the city of Venice that we now know today began to form into one community. There are now over 450 bridges in the city, with each of the 182 canals in the city having at least one bridge that crosses over it.

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109 City of Venice, "About Venice", http://www.aboutvenice.org/the-city-of-venice.html (accessed December 5, 2007). Henceforth referred to as "Venice".

110 Forma Urbis, EasyBridge Application. Venice, Italy. Henceforth referred to as EasyBridge

There is currently a fourth bridge that is being constructed over the Grand Canal; it is the first bridge added to the city in over 70 years. The newest bridge is 90 meters long and has cost over $14 million since the project was started.[111] The latest bridge has brought serious criticism from the Venetian community, but will relieve traffic in two of the most populated areas of the city. It has been a controversial project from the start; criticised as an expensive and unnecessary vanity project. As the project's timescale stretched and it went over budget, residents' grumbles grew louder. Many felt there were better areas to spend public funds on, such as housing. Some disliked the modern styling, finding it too anachronistic. Public relations hit a low point when it was revealed that there was no provision for disabled access (the council had to promise to add lifts).[112]

Venice's tourist attraction is one of the greatest across the globe. As a "city on water," Venice's bridges are certainly a main source of attention. It was in the 1950s and 1960s that the Venetian government began to reassess the ideas of urban maintenance when floods tormented the city and its canals and bridges. The floods brought a realization to the natives that bridges would need renovations and repairs to be kept up to safe and historical standards. Hundreds of millions of dollars have been spent by the Venetian government (334 million euro on urban maintenance by Insula alone[113]) and citizens to keep the bridges, and other pieces of infrastructure, intact and plans have been implemented to form a repair cycle. This cycle is based around the canal dredging schedule and is coordinated with the utility companies of Venice, so that bridges in their entirety can be maintenance all at once. The work performed on the bridges has helped keep tourism up and has kept the historical essence of Venice preserved for the world to see.

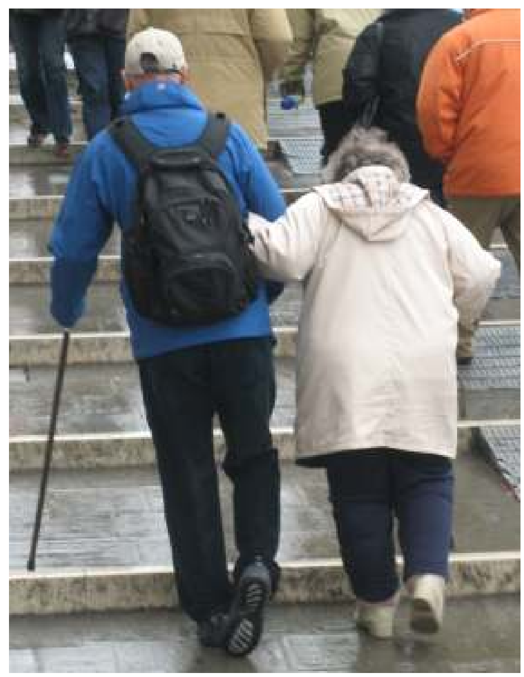


Figure 2: An elderly couple attempts to cross the bridge with the aid of an assistive device

Venetian bridges also serve a function that is unknown by most people: as a pathway and carrier for Venetian utilities. Many Venetian bridges carry pipes either underneath their pavement or on their sides. These pipes serve as connectors between islands for a number of essential items; specifically water, telephone, gas and electricity. These four utilities were added throughout the 20th century as the city began to modernize. Though many bridges in the world carry piping through them, the bridges of

[111] "Flares against 'Ponte Calatrava'," *El Mundo*, http://translate.google.com/translate?hl=en&sl=es&u=http://www.elmundo.es/papel/2007/08/09/uve/2172486.html&sa=X&oi=translate&resnum=9&ct=result&prev=/search%3Fq%3Dponte%2Bcalatrava%26hl%3Den%26sa%3DG (accessed December 5, 2007).

[112] "Ponte di Calatrava: The Fourth Bridge over the Grand Canal, Venice," Italy Heaven, (2007), http://www.italyheaven.co.uk/veneto/venice/fourth-bridge-over-grand-canal.html (accessed December 3, 2007)

[113] Insula, http://www.insula.it/ (Accessed October 2007-December 2007). Henceforth referred to as Insula.

Venice serve an especially essential purpose to the people of Venice by carrying all of the cities utilities.

Bridges can also serve as an impediment to those with mobility issues and/or impairments. Millions of people worldwide use assistive devices due to ambulatory disabilities and physical handicaps and one area of concern in the city is handicap accessibility. There are also parents with baby carriages, tourists with suitcases and delivery men with dollies who struggle to cross Venetian bridges. The world has become more and more handicap accommodating, including Venice, but the city is still working to improve handicap accessibility. Of over 450 bridges, there are only currently 7 bridges that are handicap accessible due to ramps or because they lack stairs, one bridge that has an elevator, one that contains a *Caregòn* alongside it and there are also 4 bridges that utilize a *servoscala* (a lift) for handicap individuals[114]. Although some bridges have had work done, such as the addition of handrails or small plastic ramps on each step, there are still problems present throughout the city and the city is working on improving bridges on a case by case basis.

With the help of the City of Venice, other organizations and even young, inspired college students, Venetian bridges have been utilized, maintained, analyzed and renovated to be kept up to modern standards. Through all the changes and the many years of their existence, the historic and artistic standards have been well preserved.

Types and Specifications of Venetian Bridges

The many bridges of Venice possess a mixture of designs and a variety of building materials that can be found throughout the city. The basic information concerning the classification of bridges was put together and collected by the 1998 project *The Inventory and Analysis of the Bridges and Pedestrian Traffic in Dorsoduro, San Polo, And Santa Croce Sestieri of Venice*.

Bridges are comprised of many different parts and sections, as shown below.

[114] EasyBridge.

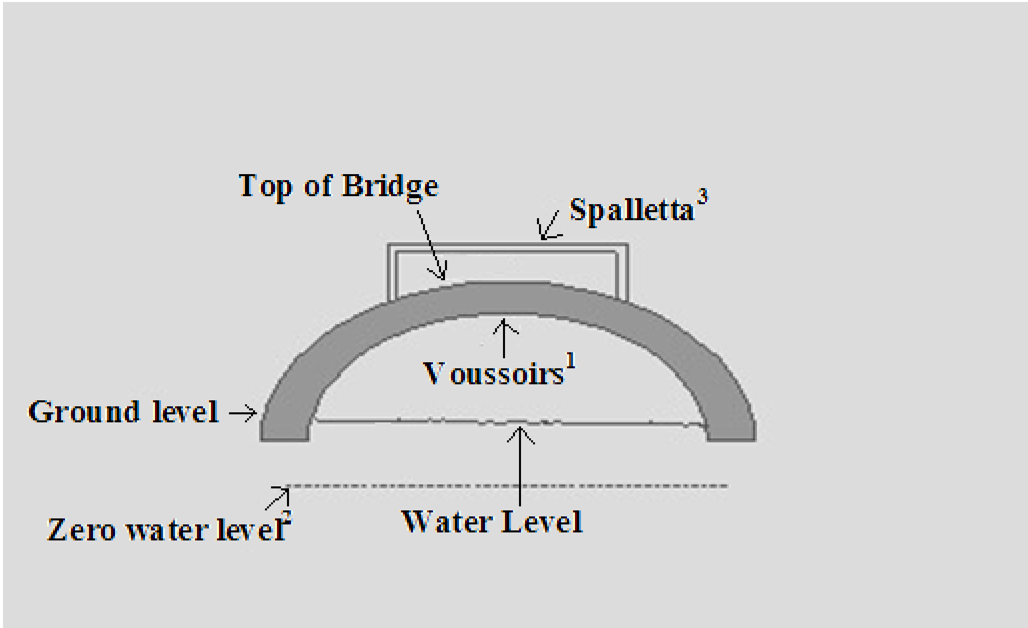
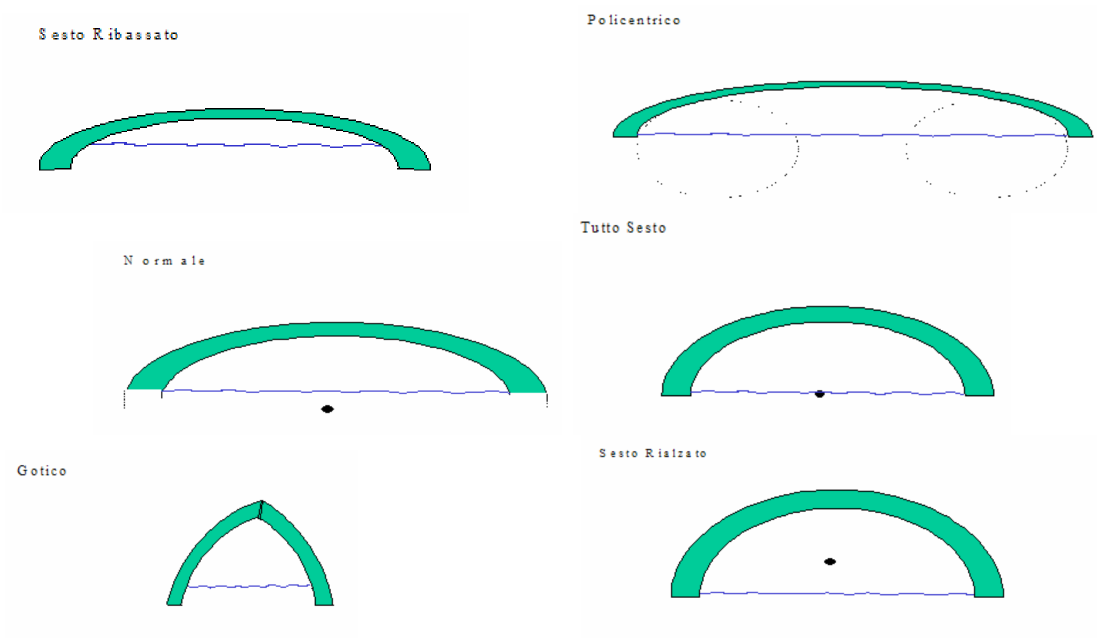


Figure 3: [1]Voussoirs- The "underbelly" of the bridge. [2]Adopted in 1897, this mark represents the average height of the tide over the course of a year in Venice. Although this level is the reference still used to this day, it is interesting to note that the current average sea level is actually 23cm. above this mark. [3]An Italian word that loosely translates to "railing" or "wall"

Three main bridge shapes are commonly encountered in Venice. The first and most prevalent of these designs is the rounded arch. This bridge shape is characterized by having the voussoirs in the shape of a rounded arc.

Figure 4- Ponte Briati, an example of an arched bridge

There are six different variations of arched bridges. These types are distinguished by slope of the steps, design of the arches and the height of the voussoirs above water. The following figures shows these arch types.



The second common bridge shape in Venice is *piatto*. Defined by its straight voussoirs, this design is easily recognized because of its uniform height over the water. Another characteristic of this design is that the steps leading up to the bridges do not traverse the water.

Figure 5- Ponte dei Guardiani, an example of a piatto bridge design

The last commonly encountered bridge in Venice is *trapezoidale*. This shape is characterized by three flat sections that make up the voussoirs in somewhat of an arch shape.

Figure 6- Ponte Molin, an example of a trapezoidale bridge

In Venice there are seven different materials which are commonly used in the construction of bridges. When building bridges, durable materials must be used so that it will not deteriorate due to weather, use or abuse. They are listed below in Italian with corresponding pictures and descriptions in English.

Muratura- Brick

Intonacato- Red or gray plaster over brick

Blocki- Block stones

Cemento- Cement

Lastre- Brick base coated with stones on the outside *Legno*- Wood

Ferro- Metal

The walkways of the bridges receive the most wear from normal use, and are generally constructed from a material that will withstand constant foot and cart traffic crossing them. The eight different materials used to construct these walkways are: cemento (cement), trachite (gray stone used regularly in the paving of Venice), asfalto (asphault), asfalto B (bicomponent of quartz), legno (wood), pietra (white stone), muratura (brick) and porfido opera incerta (flagstones). When constructing the wall and railing of a bridge, five possible materials can be used: muratura (brick), pietra (white stone), ferro (metal), ferro-pietra (metal with white stones) and legno (wood)[115].

All of these materials are used somewhere throughout the city and have proven as safe and durable bridge parts. Some materials are clearly used more commonly throughout the city due to durability and attainability. The stone bridges became more and more common throughout the city because they are strong and plentiful, which provided an easy solution for bridge makers. The wooden bridges are not so common anymore and many have been removed or replaced, such as how the Rialto was formally a wooden bridge and is now a beautiful stone structure. The materials were commonly decided on by the bridge designer, which came down to cost and personal preference in many cases, and has certainly changed since the first bridge was constructed.

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[115] Raul Bahn, Ashley Deliso, and Stephanie Hubbard, *The Inventory and Analysis of the Bridges and Pedestrian Traffic in Dorsoduro, San Polo and Santa Croce,* Worcester Polytechnic Institute: Worcester, 1998. Henceforth referred to as Bhan, *Analysis of Bridges*.

8. Bridges as Transportation

Venetian bridges are utilized for mainly three different types of transportation: pedestrian transportation, cargo transportation and utility transportation. Pedestrian traffic is obviously the most commonly used of the three and was the original reason that bridges were created in the city. Cargo transportation over bridges has developed into an enormously important aspect of Venetian lifestyle since there are no cars in the city. Only three bridges, which all connect the mainland with the islands of Stazione Marittima, Piazzale Roma, and Tronchetto on the western side of the city, allow motorized vehicles access to parking garages and bus lots. Cargo is brought in by boats and then delivered by dollies throughout the city by merchants and deliverers. The pathway of utility transportation that lies beneath the majority of bridges and pavement throughout the city is an incredibly complex system and is unknown to most tourists and even native Venetians. All forms of bridge transportation serve as an integral part to the infrastructure of the city and show the importance of fully functional bridges throughout the city.

Bridges are most commonly used as a form of transportation for pedestrians to move from one point to another. These structures serve to either avoid another form of traffic below or to pass over a natural barrier, such as water. Whether the bridge is a small, pedestrian footbridge or a massive, highway overpass, most people consider bridges as a method of transportation for humans, whether on foot, in a car or on a train. Pedestrian transport was the initial reason that bridges in Venice were originally created and this is still their main purpose today. Until defined bridges were built in Venice, the only way across the canals was either by boat or by the earliest form of bridges: wooden planks. Many landowners would place planks from one bank of an island to another island's bank as a transportation pathway, some even charging a toll for use of the plank. These planks were the first traces of bridges in Venice and were really utilized as the prime source for getting people from one island to the next.

The Bridges of the Grand Canal

As of 2007, there are currently three bridges that cross over the Grand Canal. The oldest of the bridges is the marble Ponte di Rialto. The other two bridges are the Ponte Accademia and the Ponte degli Scalzi. Construction has been under way on a fourth bridge to connect the bus and train stations since completion of that bridge is set for 2008.

Figure 7 – View of the Rialto Bridge from a Gondola

Ponte di Rialto

Famous worldwide for the arcades of boutiques that line its walkways, the Rialto Bridge is the oldest bridge spanning the Grand Canal[116]. Despite its obvious role as a major

[116] EasyBridge

tourist attraction within the city, the bridge was originally constructed to allow foot traffic the ability to cross the Grand Canal. The high arch of the bridge allows it to perform this function without interfering with the boats traveling below. The bridge has three walkways. Two walkways branch out along the outer balustrades, and the main walkway features shops where millions of tourists each year buy jewelry and glass objects of Murano. The Rialto is also a trademark for watching gondoliers make their weary way down the Grand Canal. The gondoliers add to the beauty of the scenery, occasionally gracing everyone with their Italian voices in song.

Figure 8 – The Rialto Bridge at daybreak

The history of the Rialto Bridge began in 1181 as nothing more than a series of floating pontoons. The Rialto Bridge, designed by Antonio da Ponte, was built on some 12,000 wooden pilings when the idea of a wooden bridge was implemented in 1250. This bridge only lasted until 1310 when it burned down in a revolution. The Rialto Bridge was rebuild, only to collapse twice, once in 1444, and again in 1524. Again, the Rialto would be rebuilt by 1591, but with one major change: the city decided to rebuild the bridge with stone.

Figure 9 – The Rialto Bridge would be rebuilt by 1591, but with one major change: the city of Venice decided to rebuild the bridge with stone.

The Rialto Bridge has come a long way from its creation. Many had doubted its strength after the string of collapses. One of the leading architects of Venice predicted that the rebuilt Rialto bridge would collapse again, saying that it was, “an accident waiting to happen.” The oldest bridge to cross over the Grand Canal now "stands stoic and unfazed above the water, an enigmatic symbol of the determination of a thousand architects and craftsmen."

Ponte degli Scalzi

Figure 10 – View of the Scalzi Bridge from the Train Station

The Ponte degli Scalzi, the third bridge constructed over the Grand Canal was design by Eugenuo Miozzi and completed in 1934. This bridge that means, "bridge of the barefoot" was built to replace a Austrian iron bridge. The Ponte degli Scalzi stands tall next to the Ferrovia Station (Train Station).

Ponte Accademia

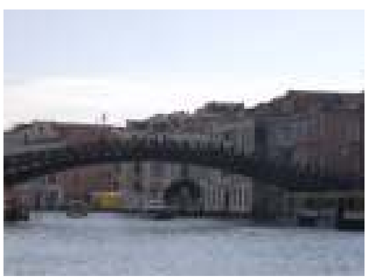

Figure 11 – The Accademia was originally constructed in 1854.

Named for the Accademia galleries in close proximity, the Ponte dell'Accademia crosses near the southern end of the canal. This bridge was originally constructed in 1854 but was talked about for centuries before. The first bridge was designed by Alfred Neville out of steel, but was taken down in the early 1930s and replaced by a wooden bridge in 1933. In 1985, that bridge was replaced with an identical bridge.

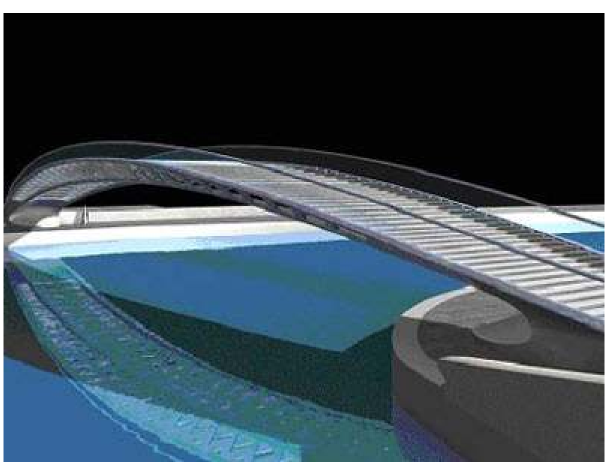

Figure 12 – Model of Ponti di Calatrava

Ponte di Calatrava

Venice's new bridge, the 473th bridge, is no doubt the most controversial of the bridges to pass over the Grand Canal. The Ponte di Calatrava's grand opening was originally scheduled for Summer 2007, but the city was unable to even lay down the foundation until August 11, 2007. The opening was pushed back to December but this target date has failed to be reached. With the grand opening now in the air, more questions have surfaced regarding this bridge and its purpose. Now with the budget reaching 14 million euro and counting (10 million euro over-budget) discussions about the bridge's safety have been growing. According to engineers that have analyzed this bridge, the Ponte di Calatrava is at a potential risk for collapse if not built to precise specifications.

Figure 13– Ponti di Calatrava under construction

The idea behind the bridge is shown by its location and architecture. The Ponte di Calatrava connects two of Venice main tourist hubs and has defining design for Venice. The bridge connects the Ferroriva Station (train station) with Piazzalle Roma (bus station) saving many Venetians and tourists time, eliminating the need to cross two extra bridges. Additionally, the new bridge shows the aim of Venice to become a model for contemporary architecture and art**.** When the designer, Santiago Calatrava, was given permission to construct this 90 meter bridge over the grand canal, the idea seemed beneficial to the city with its modernized look and use of steel, glass, and Venice's most principal raw material, Istrian marble.

Figure 14 - Pedestrian traffic on the Ponte degli Scalzi above the boat traffic of the Grand Canal

There are no official data regarding the exact date of the first bridge construction in Venice but there is information regarding the first remnants of the Rialto. It is known that the first wooden bridge in the Rialto location was built in approximately 1250, so this is a general estimation of the first bridge construction[117]. Since the first bridge appeared in Venice, 472 new bridges have been added (or construction has begun) throughout the city. The

[117] Destination 360, "History of Venice Rialto Bridge," (2007) http://www.destination360.com/europe/italy/ponte-di-rialto.php (accessed December 5, 2007)

latest bridge, set to be opened in 2008, is the first bridge to be added in to the city in over 70 years. The hundreds of bridges in Venice still serve as the main form of transportation for everyone who lives in and visits the city. Since there are no cars in the streets of Venice, the 2 main forms of transportation are by foot and boat. The unique infrastructure of the city allows these 2 modes of transportation to never come in contact with one another. Since every canal has at least one bridge cross over it, there are no intersections in which pedestrian and boat traffic interferes with one another. This is certainly an aspect of Venice, Italy that can be found nowhere else in the world.

The Progress of Safety in Venice

Safety for the Visually Impaired

In an effort to improve Venetian bridges for pedestrians, several organizations have been working hard to address the issue of accessibility and safety of bridges. For example, the City of Venice is working on plans to help those who are visually impaired cross each bridge without the risk of misjudging steps. The current problem with the steps of some bridges, specifically wooden bridges, is that those with visual impairments have a hard time distinguishing the distance between each step, as the steps seem to blend together, adding the risk of over-stepping and falling down the rest of the bridge. The city's plan, which several bridges already have, is to add a white strip at the end of each step so that anyone can identify where each step ends, which will help to avoid injuries. Some bridges such as Figure USB-X have a marble brick at the end of each step, which also aids the visually impaired. For wooden bridges where a white strip may not be possible, it is desired that a metal bracket be added at the end of each step.

Figure 15– Metal Strips are added to wooden bridges to help those visually

Safety for the Elderly

Railings were originally added on the sides of bridges to prevent the risk of falling into the canals. In addition to these protective railings, special handrails have been added to bridges on the inside of the railings contributing to the advancement in the safety of bridges. Many elderly individuals, along with those with certain mobility issues such as the use of a cane or having a leg injury, in Venice have problems climbing up the steps of the bridges especially when unassisted; this can cause major problems getting to various places in Venice. The handrails along the sides of the bridges give those who normally would struggle walking up and down the bridges the needed help.

Figure 16 – Individual using an added handrail to make his way up the bridge

Safety for Cargo Deliveries

Figure 17– Delivery cart with two wheels on the front of the cart

Transporting materials around Venice is a difficult task with all of the bridges that can be encountered reaching one's intended destination. The most common way of delivering materials is by use of a dolly or delivery cart. The addition of two extra wheels on the front of the carts makes it possible to transport the carts over bridges with more ease. Figure USB-X shows that anyone moving these carts up a bridge would have to turn around and lift the wheels over each step with all the added weight working against the mover. With the two extra small wheels added on, the mover pushes the cart until the bottom wheels touch the step and then tilts the cart down until the two smaller wheels touch the upper step, allowing the mover to pick the cart over the step with the bottom wheels easily. This also prevents the mover from having to climb up the stairs backwards and injure themselves. This concept has also been applied to a few dollies. Two extra wheels were added to each side of the dollies in a triangular shape. As the mover advances up the steps of the bridges, the wheels will rotate on each step to make lifting the dolly easier.

Figure 18- Individual transporting heavy materials on a dolly across the bridge

Figure 19– Example of a dolly with six wheels

Though bridges have caused some hardships and difficulties to merchants throughout the years, they also serve as an important part of the cargo transportation network. Like many other pieces of Venice, the city's cargo importing and exporting works in a very unique manner. All cargo is delivered in and out of the city by boat; imports are then brought into the city by deliverymen through the utilization of docks, dollies and carts. The infrastructure of the city, specifically the docks and bridges, cause the rare cargo system found in Venice. Merchants and deliverymen cannot simply drive a truck filled with cargo to one location and distribute their goods, instead they face the many obstacles that makeup Venetian infrastructure. The goods are delivered to the city by truck or boat, but then the cargo workers must individually take their deliveries by boat to the dock nearest their destination. From there they unload their packages from their boat onto a dolly or cart and head to the delivery location. On their path, there is a good chance that they have to cross bridges along the way, which of course is no easy task when moving large boxes on a dolly or cart.

The 2001 WPI project *Re-engineering the City of Venice's Cargo System for the Consorzio Prasportatori Veneziani Riuniti* was completed to assess and discuss the utilization of cargo transport throughout the city. A plan has been produced and projected for a warehouse in the city that regulates all imports. The plan will utilize the placement of docks throughout the city, in turn causing deliverymen to have to cross as few bridges as possible with each delivery. Bridges have certainly caused a problem for cargo transport into the central location of islands because dollies and carts are not traditionally designed to climb stairs. Of course through the years, dollies and carts have evolved to fit the rare city infrastructure.

The third and most unknown utilization of Venetian bridges is there use for utility transport. Almost all of the bridges in Venice are utility lines, mainly consisting of gas, water, electricity and phone lines. Upon the implementation of these four essential parts of modern living, the city of Venice decided to utilize the bridges as a means for piping to pass from one island to the next. Although there are some external telephone wires and some piping that pass underneath canal bottoms, it is very rare to find piping anywhere besides through bridges and below the pavement throughout the city. Piping under the canals would have been a possibility, but rather unrealistic. Since the canals are dredged periodically, the piping would have had to be buried deep within the sediment in the canal floors, at least below the 1.8 meter dredging line. This would have caused serious problems when utility maintenance was necessary, so passing the piping through the bridges has served as a great benefit, certainly in terms of utility management.

The bridges of Venice are clearly an important aspect of the city's traffic regulation, which in some ways even cause problems, that has caused the city to evolve around the struggles. Since the implementation of bridges in Venice over 7 centuries ago, the city and its people have overcome the challenges and developed ways to utilize the bridges to benefit the community. An important piece of infrastructure and transportation, as well as an addition to the beautiful artwork throughout the city, bridges serve a key role in the success of this ever flourishing city.

9. Bridge Repairs

One of the hardest parts of keeping a city in good condition is to keep up with proper maintenance; this takes good management and delegation to be performed properly. Especially in a tourist city, like Venice, it is sometimes difficult to find and support the necessary funding to keep the city intact at all times, so a plan of action must be taken by the city to execute all the necessities.

In Venice, this same cycle of urban maintenance exists and it just as important, if not more important, than any other city in the world. With the approximately 20 million[118] tourists who visit Venice each year, it takes a strategic plan and a massive work force to keep the city in excellent condition. Maintenance work is performed throughout the entire city on bridges, canal dredging, canal walls, docks, sewers, utilities, as well as pavement. All of these areas include important elements that affect the daily life of the thousands of citizens in the city, as well as the millions of tourists that visit each year.

Each year the different pieces of infrastructure become older and more worn due to numerous forms of damage, such as degradation from usage, weather and wake damage. The millions of tourists that visit each year certainly add to the wear and tear of the bridges, pavement and sewers throughout the city and the weather adds an aging effect to all of the external pieces of infrastructure. Moto ondoso, or wake damage, can cause serious damage to the canal walls, docks and bridge foundations, as well as the pavement that lines the cities canals.

The wear and tear of pedestrian traffic certainly takes a toll on the external portions of the bridges, especially since Venice is such a popular tourist destination. The pavements become worn with time and the railings can become loose and broken since they are used so often. Since bridges are a necessity for pedestrians to get around, they are used extremely often by citizens and tourists and become slowly worn more and more each day.

Weather adds another factor to bridge decomposition and aging as well. The bridges often become cracked with aging and the rain and various temperatures only worsen the bridge corrosion. The weather also has an effect on the handrails and can cause them to become rusty and lose their paint. This adds to the wear and tear by pedestrians to cause some serious damage, especially on the older bridges and the wooden and metal bridges.

Though moto ondoso causes mainly damage to canal walls, it also has a certain negative effect on bridges. Some bridges have abutments that lie within the canal and all bridges directly connect to the canal walls. Since moto ondoso causes so much corrosion to canal walls and can significantly weaken them, this can directly affect the bridges. With weak canal walls below the ends of the bridges, cracking often occurs, which can lead to a weak and unsafe platform that the bridge is resting on. Though no bridge collapses have occurred in recent years, it is still part of the maintenance cycle that cannot be underestimated[119].

Venetians and their government ran into serious problems when they lacked a strict maintenance plan for nearly a 30 year period. With the help of Worcester Polytechnic

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118 Martha Bakerejian, "Record Number of Tourists Travel to Venice, Italy," Italy Travel (2007) http://goitaly.about.com/b/2007/11/21/record-number-of-tourists-travel-to-venice-italy.htm (December 5, 2007)

119 David Chiu, Anand Jagganath, and Emily Nodine. *The Moto Ondoso Index: Assessing the Effects of Boat Traffic in the Canals of Venice.* Worcester Polytechnic Institute: Worcester, 2002.

vi "Venice"

Institute (WPI) students and other local organizations, such as Insula, the 1990s served as an important decade of data collection. It wasn't until 1997 when local groups, such as Insula, were formed to help develop a plan and take action for repairs and renovations of bridges. A 1998 project completed by WPI students provided a full analysis of 157 bridges in Venice was completed and documented in a database. This analysis included documenting and evaluating various physical dimensions and observations on the conditions of each bridge, as well as collecting data on the flow of pedestrian traffic and cargo deliveries over selected bridges[120].

Insula S.p.A. is a semi-private corporation, 52% of which is owned by the Venice Municipality. The remaining 48% ownership is equally distributed between Aspiv, Ismes, Italgas, and Telecom Italia. These companies are responsible for supplying water, electricity, gas, and telecommunication lines, respectively, to the city of Venice. Established in 1997, Insula's primary purpose is to maintain the canals of Venice, by coordinating the efforts between the respective companies that comprise Insula. Their goal focuses on speeding up the process of dredging canals, restoring the banks and ancient sewer systems, and taking proactive measures to protect the canals and bridges from water erosion[121]. In 2006, the service contract between Insula and the City of Venice was extended. In 2007 when the private partners sold their shares to Vesta spa (now Veritas spa) Insula became an entirely public company, reinforcing its role as the operative arm of the City of Venice in the process of implementing urban maintenance projects and infrastructures[122].

Now, Insula has taken over the majority of maintenance work on Venetian bridges and have spent countless hours planning and repairing the most damaged bridges. The first actions were taken by Insula in 1998 after WPI students completed their 1998 bridge project. The students had begun obtaining physical data on the bridges across the city and Insula took the information that the project team had worked on and created a comprehensive catalog, which contains the measurements collected, as well as photographs of each bridge, and a map of the location. Appropriate thematic maps and graphs detailing the accessibility, conditions, and traffic flow of bridges were constructed using the data. The information benefitted Insula in various ways by providing information that aided them in the process of restoring bridges, allowing them to plan appropriate detours for pedestrians while renovations are taking place, and helping with the issues of handicapped accessibility[123].

Most of the bridge maintenance work is performed around the canal dredging schedule, since it was canal problems that initially caught the cities attention. Insula has implemented a long term plan for bridge repairs and have also handled the everyday and emergency renovations necessary. Canals were divided into different classifications in terms of damage and makeup of the sediment and have been dredged in order of most damaged to least damaged. During the dredging, the canal is shut down and water

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[120] Bhan, *Analysis of Bridges*.
[121] *Ibid*.
[122] Insula.
[123] Bhan, *Analysis of Bridges.*

barriers are put up to dry the canal. Since this provides a unique advantage and access to the entire canal and its surroundings, maintenance work is performed on the canal walls, docks, bridges, sewers and pavements all at once. The majority of repaired canals are shut down for approximately a six month period and in that period all other surroundings are to be repaired as well. It is important that all the bridges are kept to top physical standards for safety reasons, as well as the importance of keeping the historical aspect of the city intact. Insula has repaired bridges in many different aspects including work on the pavement, the abutments, railings and piping. Work is completed in emergency situations as well, but only when necessary. For example, emergency repairs on bridges would be performed if the bridge has become a safety hazard due to a broken railing. This could cause serious injury to a pedestrian and also increases the chances of an individual falling into the canal or off of the bridge.

The majority of the bridge work that is completed during the canal dredging is along the bridges foundation and abutments. Since the canal is dry, workers gain access to the underside of the bridge, as well as where the bridge meets the pavement of the streets. It is here where cracking and sinking occurs and workers are able to restore the pavement and foundation that has been damaged since the last bridge repair, or even since the creation of the bridge. Since most bridge repairs are coordinated with canal repairs, many damaged bridges are not immediately repaired. To resolve this problem, Insula began repairs on damaged bridges that absolutely needed the restorations.

The pavement and stairs of Venetian bridges serve as another important piece of bridge maintenance. While bridges are being repaired, Insula contacts the utility companies to coordinate any work that may need to be performed on the pipelines that run through the particular bridge that is being renovated. Serious cracking does occur on the bridges pavement, which usually causes the companies to restore either parts or the entire face of the bridge. When this occurs, it is a prime opportunity for the utility companies to work on the pipes while the bridge face is opened up. This takes a lot of coordination because the companies work to keep the bridge shutdown for as short of a time period as possible.

Figure 20 - A bridge under repair showing the exposed utilities

Not only are repairs performed to keep the city to the safest standards possible, but to keep the historical and artistic aspects of the infrastructure intact as well. Venice is a well known tourist city for not only its unique infrastructure, but the public artwork that the infrastructure creates, as well as the art included on the bridges. The bridges, docks and canals certainly create a special artistic atmosphere that cannot be found anywhere else in the world. Millions of tourists visit the city to witness the beauty that is presents, but many do not understand the endless work that is performed to manage the city. For the small amount of public artwork restoration that is done, it is commonly preserved by nonprofit organizations and other companies throughout the city and is maintained on a separate repair cycle.

There are also 83 private bridges[124] located throughout the city, meaning that the bridge connects directly to a home or business. These private entities, though sometimes still repaired on Insula's schedule during canal dredging, often have to be funded by the private owners.

10. Future of Bridges

In 1998, Insula created a 25 year plan for canal dredging, which directly effected bridge maintenance. After 8 years, they decided that they would need 23 years to completely finish the dredging, so a 31 year plan (starting in 1998) was implemented and is set to be completed in 2029. During this time, every bridge should be repaired along with all of the canal dredging and/or emergency repairs. Once the plan finishes, it is expected that a new cycle will probably begin again and be more efficient from the data and knowledge obtained from the first cycle.

Figure 21 - One of the temporary ramps added annually for the Venice Marathon by Accessible Venice

Along with the plans for bridge repairs, there is the endless fight to make the bridges more handicap accessible. Accessible Venice and the Plan to Eliminate Architectural Barriers (PEBA) are two programs that are working to raise awareness of mobility issues in the city and to better the city for those with mobility and vision impairments. They are the force behind the Venice Marathon ramps remaining up from October-January, the Biennale of Contemporary Art accessibility ramp, as well as numerous additions to help those with vision problems. The city has worked to put grooved strips that run across the pavement perpendicular to some bridges so that blind

[124] EasyBridge.

and low sighted individuals can feel where bridges cross the canals. Accessible Venice has also produced brochures that include specific paths around Venice's top tourist locations for handicapped individuals, brochures on the *servoscala* that include the keys to operate the machines, information about boat shuttle services, as well as information in brail for the blind and others with vision problems.

Another area of the work in this category includes the plan to eliminate danger zones throughout Venice. A danger zones is defined as an area where a bridge and dock are located next to each other, but there is no gate blocking the dock. This poses a problem because a blind or low sighted individual could walk directly into a canal since the dock is not marked or blocked. Another example of a danger zone is a street that ends with only a dock and no gate, again causing a problem to people with vision problems. The cities work will help to implement gates throughout the city, many attached to bridges, which will block docks and eliminate the problems that are now present.

Making Accessibility in Venice a Reality

There are many people in Venice and worldwide that are affected by mobility issues. For those that can not walk or who are limited by mobility, there have been several projects implemented to insure that they can still travel around Venice. Some of these projects have been successful, while some have been met with several problems.

Servoscala

Figure 22 – The Servoscala system

The *Servoscala* system was designed to transport handicapped individuals across a bridge. Figure USB-X shows that the *Servoscala* serves as a lift that the handicapped individual would sit on and then would be transported to the top of the bridge. Then they would cross over the top of the bridge and take the *Servoscala* back down the other direction. This project was met with reservation as currently, the four *Servoscala* systems (FormaUrbis n.d.) are all out of service in Venice. Getting the *Servoscala* system started proved also to be a problem as a key was necessary and no one who where to retrieve them. Accessible Venice additionally created tourist itinerates that had the key to the *Servoscala* attached for use alleviating the problem.

Figure 23 – One of the Servoscala systems that is out of order

Caregòn

Figure 24 – The Caregòn can be called a "high chair" since it runs on tracks across the canal floor and alongside the bridge

In an attempt to eliminate the need for individuals with mobility issues to cross over bridge, a project was put forth to use mechanics to transport those individuals beside the bridge. A team, led by Enzo Cucciniello, designed and implemented the *Caregòn* project in the city of Venice. The *Caregòn* serves as a "high chair" that runs alongside a bridge on tracks that run across the canal floor. The mobility impaired individual stands on the *Caregòn* platform while traffic is halted by the only two traffic lights in Venice, and travels across the canal, much like a train on its tracks. This idea has been implemented once in Venice, next to Ponte Ognissanti and serves as an alternative to physically travelling over the bridge. Like the *Servoscala*, the *Caregòn* has run into problems such as vandalism and lack of usage, but does have an attendant for a small time daily who runs the machine for the mobility impaired.

Figure 25 – The *Caregòn faces the problem of vandalism since it is only in use from 9am to 12pm.*

Figure 26 – The elevator, which is located in Giudecca, is another advancement towards making Venice more accessible

Elevator

One bridge, Ponte Longo, in Venice became handicap accessible with the addition of an elevator. This system works much like the *Servoscala* by transporting the mobility impaired individual to the top of the bridge. First, the elevator raises the person from the ground level to the top of the bridge then, the person crosses the top of the bridge and takes the elevator back down the other side. There are many people working to better the city for the mobility impaired and it is evident that bridges will have to be analyzed and modified on a case by case basis.

Figure 27 – The elevator raises the person from the ground level to the top of the bridge

The city also has other plans for the future of handicap accessibility throughout Venice. Some of these plans include the implementation of another mechanical *Caregòn*, which allows people in wheelchairs, as well as with other mobility issues, to cross a canal without having to use a bridge. This solution along with ramps and elevators are certain examples of possible accessibility throughout the city. Since each bridge and island is unique in its own way, the city will have to treat each bridge with a case-by-case solution to better Venice's accessibility one bridge at a time.

The future of bridge maintenance can be explained as an endless cycle of renovations. There will always be repairs necessary, as well as options to make the city and its bridges more accessible to the millions of different people who visit each year. There will always be unique solutions and new ideas for how to upkeep the bridges and make them accessible, yet preserve the historical and artistic elements that they bring to the city. It is evident that by working with groups, such as Accessible Venice and Insula, future projects done by WPI students and other students from across the world can be completed to help better the city of Venice. There is plenty of data collection and compilation that could be done to help support the fight for a completely accessible city. Local groups, like those mentioned throughout this chapter, are constantly working to better the city one ramp, elevator or *servoscala* at a time. They also remain open to new suggestions and support the work of others to help benefit their city. Though no one solution is readily available, with the hard work and diligence of these groups, the City of Venice, as well as future students, work will continuously be performed to better Venice, one bridge at a time.

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Docks

Docks are a crucial part of global infrastructure for many cities with booming economies and extensive trade power. Throughout the years, ordinary docks have been used mainly for the transportation of cargo into and out of a city, and for the transportation of people. In most cities, after immense amounts of cargo are unloaded off a boat, they are then loaded onto a truck and delivered to their specific locations. Docks make it easy for boaters to transport goods, access the water, and complete shipments, increasing their quality of life in many cities.

Venice is a unique city when it comes to transporting goods because the "roads" are actually small waterways, or canals, where boats travel, similar to how cars drive on roads. When compared to traditional docks, the docks in Venice are diverse because of their complex infrastructure and configuration with canal walls. Traditional docks are built mostly of stone and brick, which is quite different than the conventional floating wooden docks in other parts of the world. The traditional dock in Figure is different from typical docks because it does not move with the tides and boats have to adjust as the height of the water changes. Different types of docks are located in different positions of the city depending on which docks work best for the area, and which docks are easiest to use.

Figure 1: A traditional dock with steps parallel to the canal

In the city, there are approximately 1600 docks[125], so it's difficult to imagine that they would all work perfectly. Docks are often impractical because as the tides change, it makes maneuvers difficult for a majority of the workers, which is one of the main problems. Delivery men often have trouble using certain types of docks in the city because steps may be covered with algae or inaccessible from the canals.

Information has been collected on docks and it has been determined that 32%[126] cannot be used because of their configuration to the canals. Based on the amount of space boats take up while being docked on the side of canals, workers and certain citizens would rather see the wasted space being better utilized for overnight parking or completely removing the dock. Venetians have already solved some of these problems by reassessing the unusable dock space for parking; however, attention is still needed in many parts of the city because problems still remain.

[125] Forma Urbis. EasyDocks Application. Venice, Italy
[126] ibid.

Although there are problems with the dock system, the general public has found ways to work around the issues. In certain locations of the city, citizens are more interested in preserving the beauty of historical docks than they are with making every dock useable. As Venice continues to grow, the amount of shipments and docks needed also grows dramatically, therefore, the city must decide if it is more important to have more useable docks, or conserve the beauty. After all, docks are crucial to the survival of the city because they are the medium through which everything is brought into the city.

Figure 2: Dock which is being partially blocked by parked boat

History

Docks are essential to the shipping and receiving of goods to all areas of the city. In a city built on waterways, it is crucial that shipments move through the waters seamlessly, and having a good infrastructure of docks is necessary for transportation. Docks are helpful to shipments because there are so many throughout the city and on the individual islands. The issue with having a large amount of docks on many different islands is that based on the fact that not all docks can be easily used, it may be difficult for a boater to find a good dock if they are not familiar with the area. Although there are many docks on each island, all of them might not be useful for the boaters because of the size and configuration of the dock in the canal.

From a transportation point of view, the upkeep of docks also affects people because the docks are used to accomplish many daily tasks. In some cases, citizens use their own personal boats to move around the city day to day and get tasks done when they need to, but this doesn't work out very well for the whole city. About 32 % of docks cannot be used because of the different problems that occur within the canals including tides, and sometimes traffic. The docks which cannot be used take up space that could be used for boat parking (Figure), either overnight or during the day. The state of docks also affects tourists, and commuters who are attempting to get into the city during the day. Docks have also made it difficult for mobility impaired people to get around, such as elderly, injured, or people with disabilities, depending on which dock they choose to use. It is important for people trying to commute into the city that docks are easy to use, as well as for tourists, who want to see the entire city in the short time they are here.

As far as the scheduled maintenance and upkeep of docks is concerned, docks are actually part of the canal walls so they are conveniently preserved and maintained in the same way as the rest of the canal walls. In the past years, the process of preserving docks as well as the continuation of maintenance has been the responsibility of Insula. With many of the docks, Insula repairs the parts of the stairs that are damaged or not working properly. Insula also makes suggestions to dock owners of what measures could be taken to help preserve their docks and suggest structures that could be placed on or over some of the less useful docks, hopefully making them functional again.[127] For example, when Insula dredges a canal, they inform dock owners that while the canal is empty, it would be the opportune time to maintain their dock. If they choose not to maintain the dock while Insula is working, then dock owners would have to attempt to fix it while there is water in the canal, which is nearly impossible, or pay to have the canal emptied again.

Figure 3- Dock with lower steps covered in algae

Problems

Although there are over 1600 docks, problems with docks have continued to occur because of their structure, configuration, tides, and their position of the canals. Throughout the day, the low and high tides cause a portion docks to become inaccessible to boats which creates the most basic problem with the dock system. The tides affect the ability to dock as well as the size of a boat, which can create a back up of traffic through the canals, or block them all together. Docks also pose a safety problem with "Danger Zones" when they are adjacent to bridges without a gate blocking the street.

Figure 4- Worker unloading cargo to sidewalk, ignoring dock

At high tide in the lagoon, the stairs of many docks are underwater and there less space on the dock for boats to pull up to. The high tide makes shipping and receiving of products difficult because there is usually a large amount of space required for the bigger boats. On the contrary, when low tide occurs, the stairs that were originally underwater during a higher or regular tide are uncovered so there is more space for people to use, but

[127] Personal Communication, Lorenzo Batazzo, Insula S.p.A. Venice, Italy. Henceforth referred to as Batazzo

unfortunately, this proposes two more problems. One of the problems is that all of the stairs that were underwater for some portion of time are covered with green algae which make the stairs dangerously slippery (Figure). This causes a problem for people moving to and from the docks for transportation, and with cargo delivery. When cargo is brought to the area, the dock cannot be used because the delivery person cannot stand on the docks. Deliveries are usually required to use the sidewalk (Figure) to unload all of their cargo to insure their safety and keep their products from accidentally falling into the canals.

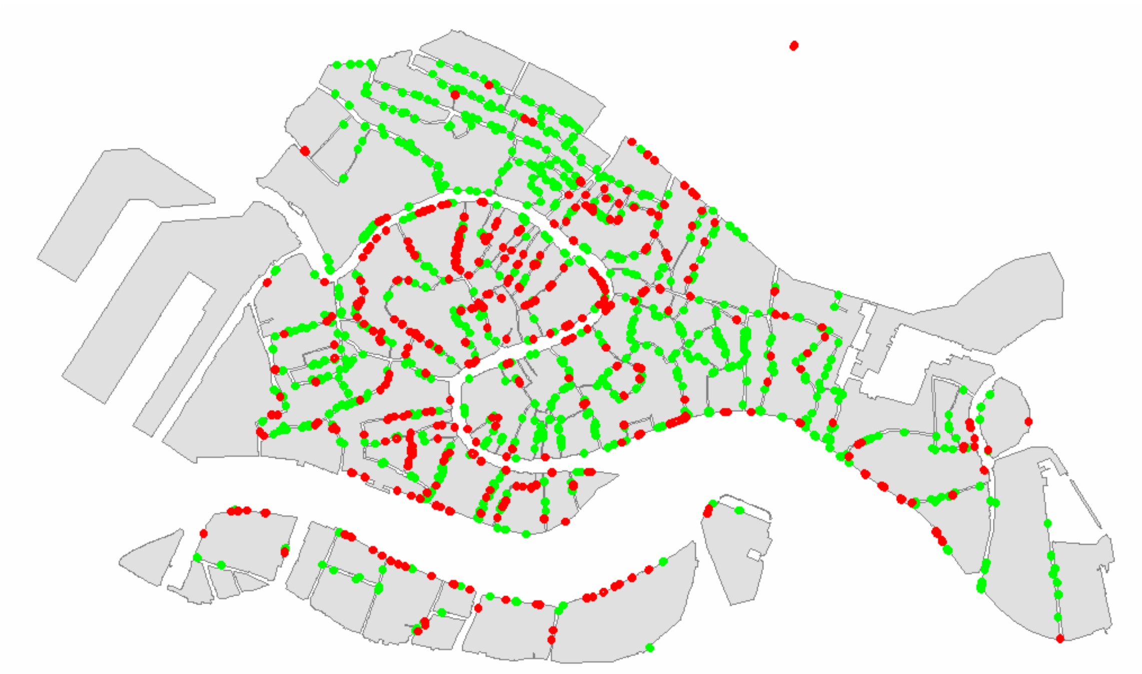

Figure 5- GIS Layer representing useable docks in Venice

Boats may have a difficult time utilizing the docks because of the height difference between the top of the boat where cargo is stored, and the level of the sidewalk. When the tide is very low, the street sometimes lies far above the boats, forcing the workers to lift boxes over their heads to get them onto the sidewalks, creating more work for them. This process makes it more difficult for workers to use the docks and areas around them in specific situations. In some extreme cases, low tides would prohibit shipments to be made to certain parts of an island because the docks are completely inaccessible to workers. Depending on the type of dock previously referenced, workers may be able to walk up the stairs of the dock. As is the case in Figure though, most of these steps are covered with water, which means that during low tide they would be covered with algae, making them useless.

Over 32% of docks are unused in the city because they are inaccessible from the water or from the sidewalk. Figure shows the breakdown of usable and unusable docks on the island and the locations of the docks using a Geographic Information System map layer where green represents useable docks and red represents unusable docks. There are specific docks located throughout the structure of canals that there are specific instances when docks are ignored all together. Again, referring to Figure where a worker is shown a ignoring the dock all together and instead using the sidewalk next to the dock to make shipments to store owners. Ignoring the actual steps of the docks seems to be the preferred way near docks such as this to deliver shipments to the stores because of the inaccessibility of a percentage of docks. Often, boats will block the opening of a dock with their boat and use the sidewalk to unload cargo, instead of using the dock.

Traffic issues could also be caused by docks because if a boat stops to unload cargo for a long period of time, the boats can create a traffic backup in the canal. The boat may even be large enough that the canal would be impassable, and boats would actually have to back out of the canal, causing a major traffic jam. Boats are often docked and unloading cargo while other boats have to wait behind them for them to finish.

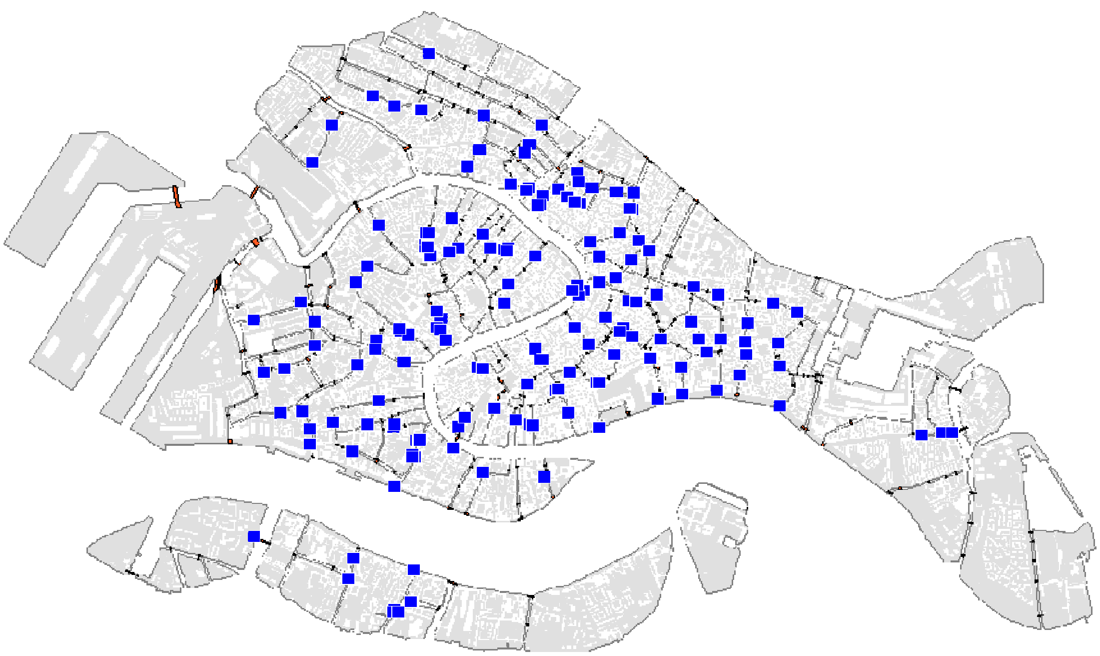

Figure 6: GIS Layer representing the "Danger Zones" of Venice

Danger zones are a safety hazard that is becoming important to the city as maintenance continues. A danger zone occurs when a dock is directly adjacent to a bridge (Figure) and is deemed dangerous when there is no gate blocking pedestrians from the dock. This is a problem for vision impaired people because any person using a walking stick to maneuver around the city is unaware of which side of the path the dock is on, and which side the bridge is on. This could unfortunately cause a pedestrian to become injured, or fall into a canal. However, there are some instances in which a gate placed between the path and the steps of the dock, making it safer for pedestrians.[128] Danger Zones are becoming the most prevalent problem with docks and although there are many problems in the city when it comes to docks, Venetians do a good job with working past them.

[128] Personal Communication, Lucia Baracco, City of Venice. Venice, Italy.

Types of Docks

Different types of docks are spread around the whole city and all have names that describe their configuration to the canal, but none of them have names that are common knowledge to people. Table 10-1 and Figure 10-14 show the different types of docks[130], and the total number of each kind of dock throughout the city. The docks can be found in various locations around the city and are shown in Table 1 (above) and Figure . The different types have varied amounts of usability depending on how accessible they are for boaters and their accessibility to workers on the surrounding sidewalks. Docks differ by whether they have stairs that are parallel or perpendicular to the canals, if there are platforms, and if they are placed in the sidewalk or project out into the canals.

Type of Dock[129]	#	Color
Stairs perpendicular to canal	462	
Stairs parallel to canal	180	
Perpendicular to canal with platform	397	
Parallel to canal with platform	330	
Dock without steps	98	
Covered	62	
Monumental	55	
Unclassified/Other	44	

Table 1 (above) and Figure 7(below)- Representation of the 9 different types of docks. Note: lagoon not shown so figure only represents 1321 docks.

The most abundant type of dock is the dock in which stairs are configured perpendicular to the canal; however, it is not the most useful type in the lagoon. Although there over 450 docks of this specific type, they are difficult to use during high and low tide. There

[129] Translated from EasyDocks by Daniela Pavan., Forma Urbis. Venice, Italy.

[130] Carlo Cioffi, Vicky Dulac, Marsano Jose, and Robert Reguero. *Development of a Copmuterized Decision Support System for the Scheduled Maintenance of the Inner Canals of Venice.* WPI; Worcester, MA, 1997.

are numerous stairs that remain underwater during high tide, making it impracticable for boats to get close enough to the shore to actually tie up to the dock. Once the water moves to a lower tide, plenty of steps are uncovered, but they are unfortunately now covered with algae, still making it difficult to maneuver. In this design, larger boats with a great deal of cargo cannot dock because of the difficulty presented by not being close to the sidewalk once docked. Very often, boats ignore these types of docks overall even though they are plentiful throughout the city and they are often considered the least useful type of dock design in the system.

One of the most useful types of docks has stairs which are directly parallel to the canals (Figure). It has become the most useful because people are able to utilize them even when considering the problem docks have with algae and the changing of tides through the city. As noted before, only 32% of total steps on docks are actually useable, however, during low tides, all of the steps would be accessible to boats, depending on how dangerous the steps are due to algae. The parallel docks are flexible because boats can adjust their position by moving back and forth according to how high the water is on the stairs and based on the amount of space they need.

Figure 8- A versatile dock with stairs parallel to the canal

Figure 9: Monumental dock with large platform covered in

Similar, the parallel and perpendicular docks can also have platforms (Figure or Figure), and although they are classified differently, the two types of perpendicular docks and two types of parallel docks are very similar to each other. The only main difference is that there would be a platform located somewhere along the steps that move out of the canal onto the sidewalk. The platform can sometimes come in handy when unloading cargo; however, as shown in Figure, if it is covered with algae, it only makes that part of the dock useless. For the docks that have stairs perpendicular to the canal with a platform, the platform very often keeps the boat even further from the sidewalk and is unused because of the difficulty imposed by the useless platform.

Throughout the city, there are not many monumental docks (Figure); however, they are still important and hold specific historical value because of their beauty and history. Even though the docks are not easy to use for docking purposes, the city has forbidden any permanent or temporary changes on all off the monumental docks. There is no interest in adding any over structure to the docks or removing them from the city all together. Monumental docks may not be used daily for common purposes, but they are still appreciated because of their unique beauty and specific locations.

The public boat system throughout the city, known as the Vaporetti, has a type of dock all to itself. Unlike other docks in the city, the Vaporetti system of docks works great for the purpose it has intended. All docks for the Vaporetti are handicapped accessible, easy to use, and well maintained. Another positive feature about the Vaopretti is that the entire schedule is mapped out and accessible to the public, so customers always know what time the boats will show up, and how long it will take them to get to their stop. These docks have been working so well, that it almost makes other docks seem completley pointless from a transportation point of view. The docks that the Vaporetti use to move around are a unique type of dock because they actually float up and down with the water unlike the traditional docks that have been previously explained. The floating dock is convenient for the Vaporetto because commuters and tourists do not have to awkwardly move to get onto the boats, which keeps the boat system moving quickly and efficiently. These types of docks seem to work the best for every aspect, if only they had enough space in more canals to use these types of docks.

Other Uses & Efforts for Improvements

Many times, there are docks that are not used for docking boats to receive shipments for public or private transportation. Throughout the day and especially during the night, some of the docks that are considered useless based on their ineffectiveness and are commonly ignored and used for parking. The docks that have been temporarily used for parking spaces cannot be used for docking because of their inaccessibility to the sidewalks, their configuration in the canals, or their shape and size. The city has determined that using them as parking spaces is a better solution that saves space in the canals and money. Improvements to current canals include adding on over-structures to docks that are usually difficult to use. As shown in Figure 10-17, the over-structures protrude out into the canals rather than into the sidewalk like other docks. The over-structures make docks usable and are convenient for workers because there is usually far less algae on the wooden dock. In addition to being safer, the over-structures are usually position so that the normal high tide does cause the dock to flood. One of the downsides however, is that it affects the boat traffic passing in the area because it protrudes into the canal.

Figure 10- Wooden over-structure to help increase the usefulness of a dock

When it comes to making any dock useful, most workers have become relatively creative by adding whatever temporary structure they can. In some extreme cases, such as in Figure , a board has been placed across the top of the dock and a boat in order for a maintenance worker to move a wheelbarrow. This has become popular with maintenance workers and delivery men as shipments are becoming more frequent.

Maintenance of Docks

Over-structures such as in Figure 11 have been implemented, which has helped make some of the docks easier to use. The over-structures are usually made of wood and cover some of the steps of the dock that may be covered with algae or may have broken pieces. This helps workers because there is more space on the docks for them to unload cargo and it is easier to dock boats on a wooden structure.

Figure 11- Temporary structure to enable workers to use a useless dock

With a well working docking system, and the reorganization of shipping products around the city, life in Venice should become less stressful and easier to navigate. As Insula moves through the city making these repairs, the important docks on each island are being repaired. In some cases, these docks now have useful over-structures and large portions of the algae have been covered over so the docks are less slippery.

As Insula repairs the canals, bridges, and continues their dredging schedule, they also repair the docks in the city as needed. Many of the docks have been repaired by them and even some of the over-structures for the docks have been added onto the docks. Insula has plans for continuing maintenance in Venice; however, after the scheduled canal maintenance is complete there are no further plans laid out yet for the city.[131]

What's Next?

Fortunately, the docking system has been improved recently, and the city is continuing to make improvements to many of the docks. Although docks have been worked on throughout the past years, there are still issues with docks that need to be resolved. The majority of problems have been assessed through the city, and the city is currently in the position to keep most docks the way they are to preserve the beauty of the city. Insula is presently doing maintenance to the docks and keeping them in good working order. In the immediate future, Insula plans to continue the maintenance on docks as they are found in disrepair, but for the most part, the city of Venice seems pleased on the order of the dock system.

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Forma Urbis. EasyDocks Application. Venice, Italy

[131] Botazzo.

Utilities

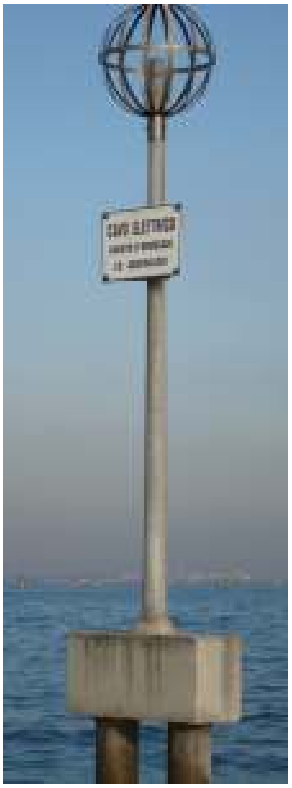


Figure 1: To install utilities within the city, many of the resources had to first be brought to the island by means of submerged pipes crossing the lagoon. These pipes are marked by poles such as the one above to indicated the potential danger for nearby boats

Although famous world wide as one of the most romantic places on earth, it is important to remember that Venice remains a fully functioning city. While the picturesque bridges and canals do serve an important purpose in the transportation network, it is the virtually unknown network of public utilities that truly keep Venice alive. Buried within the layer of sand and clay beneath the paving stones of the streets and bridges lies a complex network of pipes and wires which support the transportation of resources vital for modern living.

Like all other modern cities, new utilities were installed within Venice as they became available in order to replace old and outdated systems. Currently, the mostly widely used utilities within the city are natural gas, water, electricity, and sewer which allow for heating, cooking, indoor plumbing, lighting, electronic appliances and many other modern conveniences. Additionally, telephone and data lines and a new fire fighting network can be found.

Also similar to all other cities, Venice's utility network requires constant preventative maintenance and emergency repairs. What makes this process unique is the large percentage of the city protected by federal and local law as historical regions. In these areas, painstaking efforts must be made in order to leave the city looking exactly the way it did before construction began. Any changes that do get made to the appearance of the city must first be approved by one of the two custodians of the city, called the *Superintendenzia*, by means of a long application process oftentimes ending in disappointment for the applicants. As a result of these laws, new construction only occurs when it is essential to the survival of the city, making it difficult for new utilities, such as an upgraded sewer system, to be implemented.

Figure 2: A section of the various utilities exposed for maintenance work. The new fire fighting network is still being installed within the city. Implementation began after the old fire fighting methods were

Streets

The belief that the Venetian canals completely surround every building is a common misconception held by those who have not seen the city. In fact, only a small percent of the buildings have one or more sides abutting a canal. The reality is that the city is composed of many large islands, some housing hundreds of buildings. As a result, the city does, in fact, have a complex network of streets and alleyways. These pathways serve as the core of the pedestrian transportation system and many different types can be found though out Venice.

Figure 3: *Fondamente*, which run parallel to canals, are the type of street most associated with Venice. Many believe that the every building in the city is surrounded by water with only the *fondamente* allowing for pedestrian transportation.

Figure 4: In actuality, many of the streets of Venice are actually *calle*, such as the one shown above. These are the streets found on the interior of the islands. Many of the major paths through the city follow *calle* and other land locked routes.

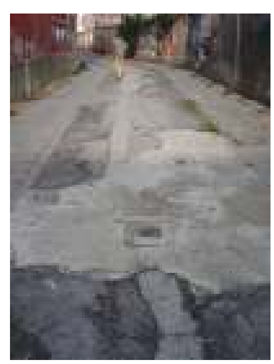
Figure 5: Among several other minor types of streets, the *sotoportegi* is one of the most interesting. Since land on islands is so valuable, several buildings were constructed over existing pathways resulting in tunnels called *sotoportegi*

In addition to the various types of streets, there are also several different types of building materials used to construct those walkways.

stone block

cobble stone

brick



asphalt

Gas

In the 1840's Venice installed its first gas network for the purpose of public lighting. This system carried a gas produced from coke to lanterns throughout the city. This altars which were originally installed in areas where the light from the altar's candles would illuminate important walkways. A century later, the system was converted to the methane that is still used toady and was expanded to allow citizens the option of paying to bring gas directly into their homes. This upgraded system made Venice one of the first cities in the world with publicly available natural gas.

Figure 6: Public alters were originally placed at important intersections and locations within the city so that candles placed on them would illuminate the area

As houses began to convert, gas began to replace wood and oil as a means for cooking and heating; however, not everyone was willing to change. During the flood of 1966, oil tanks throughout the city spilled into the water damaging buildings and canals. This resulted in the Venetian government imposing a mandatory conversion to gas throughout the 1970's and 1980's. Today 178 kilometers of piping, controlled by Vesta, Enel, and Eni S.p.A., supply gas to over fifty-five thousand inhabitants of the city.[132]

Water

Note: This section currently contains insufficient amounts of information. Further interviews and better translations of existing materials are required before this section can be considered for publication.

Originally, Venice relied on sand-filtered well water. These wells were maintained by several different guilds. One guild was responsible for creating the wells while others specialized in cleaning them while yet another guild would carry water in from the mainland during times of drought. Unfortunately, many of the wells became contaminated with disease and industrial pollutions. Seeing the inevitable failure of the well system, Venice constructed an aquifer to carry fresh mountain spring water into the city.

Figure 7: With the addition of the new water system, public fountains were installed throughout the city.

[132] Personal communication, Lorenzo Botazo, Project Supervisor, Insula S.p.A.

Electricity

Note: There is currently no information available for this section. Further interviews and better translations of existing materials are required before this section can be written.

Sewer

The Venetian sewer system is like no other in the world. Unlike other medieval cities where chamber pots were emptied out the windows creating an unsightly and unsanitary mess on the streets, Venice's canals provided an easy method for disposing of household waste and having it wash out to sea with the tides. Even for the landlocked houses, only a short length of pipe was needed for quick disposal. As a result, Venice developed the first sewer system to be implemented in the world. The city's unique gravity driven system called the *fognature* consists of three parts and relies heavily on the tides[133].

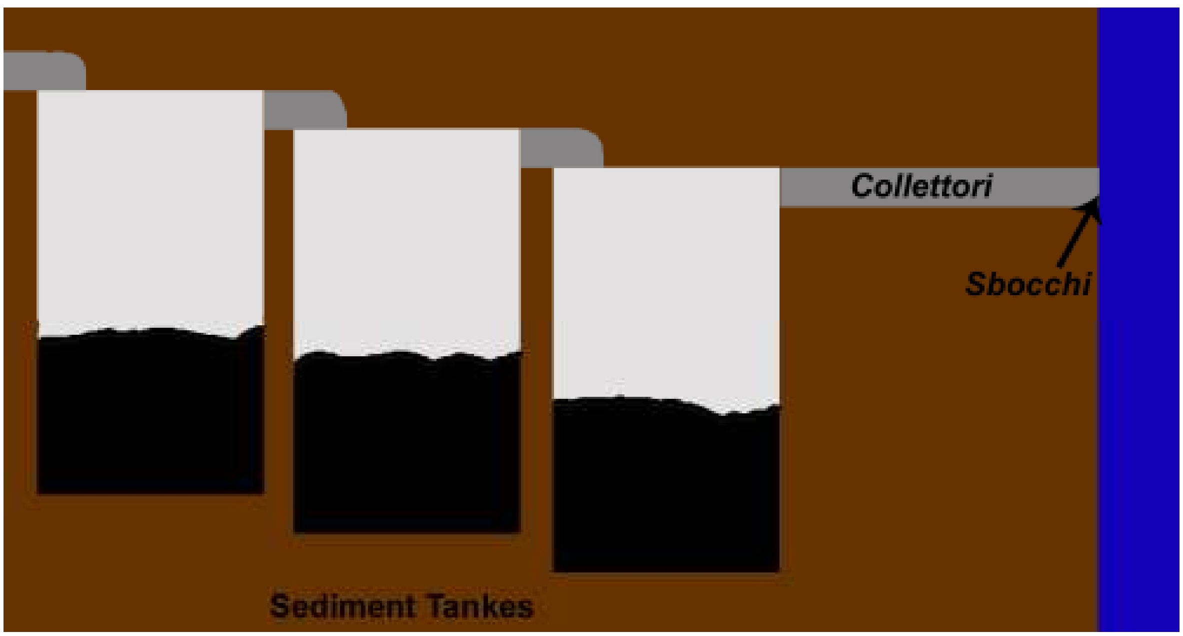


Figure 8: The fognature, Venice's sewer system, consists of three parts. First, one or more sedimentation tanks collect solid waste while decanting off liquid waste. The liquid waste then flows into the collettori, which are channels buried beneath the streets.

Similar to modern in-ground systems found on buildings in rural areas, the first part of the system is the sedimentation tanks. These tanks are built into the foundations of the houses and collect the black and grey water from sinks, toilets, showers, and other devices. The solids then settle to the bottom of the tank while the liquid is decanted off the top. More complex systems can consist of several sedimentation tanks in series to

[133] Felices, Martin, Lauren Goodfellow, Jay Johnston, and Sonali Maheshwary. *A Preliminary Feasibility Study of a HIFLO Vacuum Sewage System within the city of Venice, Italy.* Worcester Polytechnic Institute: Worcester, MA, 1997. Henceforth referred to as Felices, *HIFLO System*.

Figure 9: One of the sewage collection boats used to remove solids from sediment tanks

Figure 10: A portion of the *collettori* exposed for maintenance work. Underground, multiple *collettori* merge into one major channel that ultimately caries the waste to the canal.

further separate the solids. Also similar to modern in-ground systems, the tanks occasionally fill with solids and must be emptied.

From the sediment tanks, sewage flows through the *collettori* which underground channels made of brick. The channels are inclined to induce the flow of liquid in the appropriate direction. The *collettori* from each house usually flows into a major *collettori* which then transports the waste towards the perimeter of the island.

Figure 11: Usually hidden beneath the surface of the water, *sbocchi* can be seen when canals are drained for maintenance. The *sbocchi* allow sewage to flow from the *collettori* into the canals.

On the perimeter of the islands, *sbocchi*—sewer outlets—interface the *collettori* with the canals, depositing the sewage directly into the water. The *sbocchi* were originally located 1.8 meters below the zero sea level in order to ensure that they would remain below the lowest low tide level. During more recent repairs, the *sbocchi* were rebuilt higher than the originals at 1.3 meters and, most recently, at 0.8 meters. However, since the zero sea levels are also rising, the outlets are still located below the low tide mark. Once the sewage is discharged into the canals, the system is dependant on the tides to carry the material from the city out to sea. Overall, it is estimated that 12% of the sediment that accumulates in the canals results from sewage disposal[134].

[134] Borrelli, Alexander P., Matthew J. Crawfod, James W. HOrstick, and Izzettin Halil Ozbas. *Quantification of Sediment Sources in the City of Venice, Italy.* Worcester Polytechnic Institute: Worcester, MA, 1999. Henceforth referred to as Borrelli, *Sediment*.

Repair Work

Figure 12: Pallets of paving stones being stored while work is performed on the near by fondamente.

Like systems in all other cities, the Venetian utilities require constant maintenance which can come in one of two forms: preventative maintenance or emergency repairs.

During the current round of preventative maintenance, the city is performing two tasks. The first is called "rationalizing" the network. Because each utility was added separately as new technology became available, the pipes and wires were installed one on top of the other with no attention to organization. To "rationalize" the system, the pipes are being rerouted to form a more organized network. In the process, old pipes and fittings are also replaced and all the elements of the networks are being catalogued in Global Information System map layers.

Figure 13: Section of Fondamente Nouve in the process of being raised

The second task performed in some areas after rationalizing the network is to raise the pavements that cover the utilities. This process is necessary to prevent flooding in areas where the previous pavement height was below the standard high tide mark. When pavements are reinstalled, extra base material is used beneath them to raise them above this mark when possible. In some locations, the actual height increase is limited by the height of doors along the street.

For emergency repairs, the city uses a call in service named MIMUV. With this service, residents can call to report damaged or malfunctioning pieces of infrastructure within the city. An inspector is then sent to verify the report and can then order repair work to be done. MIMUV keeps track of all progress made on each report through out the repair process.

Future

While the majority of the streets and utilities within Venice are in good condition, the sewer system has become outdated and inadequate. The current sewer system presents both a health hazard and a physical threat to the city.

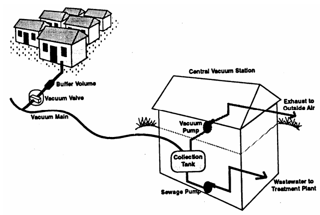
By directly depositing sewage into the canals, the sewer system contaminates the water with bacteria such as salmonella that are hazardous to humans[135]. While this was more sanitary than the other methods of disposal in its early days, health standards have since increased and Venice has fallen behind the rest of the world. In an attempt to modernize the sewage system, the city has recently required that all hotels, restaurants, and other businesses with facilities install mini treatment facilities which process the sewage before it is deposited into the canal. Additionally over 100 other mini treatment stations have been installed throughout the city. These devices intercept sewage flowing in the *collettori* and process it before it is discharged into the water. However, despite these efforts, a large percentage of residential systems still connect directly to the canals.

In addition to the health hazards, this system can also be destructive to the city. Despite the sediment tanks, some solids inevitably escape containment and are deposited in the canal. In addition to crumbling masonry, trash, and particles carried in by the tides, the solids collect on the bottom of the canals forming layers of sediment. During periods such as from the 1960's until the 1990's when no maintenance was performed on the canals, the level of the sediment increased until it began to block the *sbocchi*. When this occurred, pressure built up within the *collettori* until the structural integrity of the mortar holding the bricks together was compromised. The pressurized sewage was then able to escape by finding new pathways through the fractured mortar into the canals. The weakened mortar became incapable of holding the stones together and large holes around the *sbocchi* began to develop throughout the city. During the ongoing repairs, sediment is removed and damaged sewers and canals walls are repaired, but nothing is been done to fix the core of the problem.

In 1999, a student research team concluded that approximately 12% of the yearly sediment results from the direct disposal of sewage into the canals. Additionally, crumbling masonry contributes 6% of the sediment while the remaining 82% comes from unknown sources which could include debries carried into the city by the tides. These team was also the first to correlate localized canal wall damage to blocked sewer outlets[136].

[135] CS Clark, "Potential and Actual Biological Related Health Risks of Wastewater Industry Employment." *Water Pollution Control Federation Journal* 59.n12 (1987): 999-1008.

[136] Borrelli, *Sediment*



In 1998, a team of researchers investigated the potential for installing a HIFLO vacuum sewage system within the city. This special type of vacuum sewage system is specifically designed to handle the high volumes of sewage that are produced in high density areas of cities. The team determined three different methods of installing the system each with different benefits and drawbacks. These proposals are currently among the options being considered by the Venetian government for upgrading the city's sewer system[137].

Without continuous, costly maintenance , this system will once again fall into disrepair and begin destroying the city. Even with maintenance, the canals are polluted with biological waste that not only results in an unpleasant odor, but also has the potential of transmitting diseases. Currently, the only known way to remedy the issues related to the *fognature* is to replace it with a more modern system. Since the city is so close to sea level, leaching fields are impractical so a collection facility is required. Unfortunately, the limited elevation differences between the houses and the collection facility eliminate the possibility of a conventional gravity driven system. Instead a vacuum sewage system, which uses pressure differences to pull the sewage through pipes, would be required. At the time of this writing, Venetian officials are pursuing several different methods of implementing this type of system within the various districts of the city; however, limited funding and reluctance to modify the historic sections of the city have greatly slowed the process. The installation of the gas, water, and electric utility networks within the city have proven that the city is not unwilling to add modern amenities: hopefully, it will just be a matter of time before the problems with the sewer system are remedied.

[137] Felices, *HIFLO System.*

References

Borrelli, Alexander P., Matthew J. Crawfod, James W. HOrstick, and Izzettin Halil Ozbas. *Quantification of Sediment Sources in the City of Venice, Italy.* Worcester Polytechnic Institute: Worcester, MA, 1999. Henceforth referred to as Borrelli, *Sediment*.

Clark, CS. "Potential and Actual Biological Related Health Risks of Wastewater Industry Employment." *Water Pollution Control Federation Journal* 59.n12 (1987): 999-1008.

Felices, Martin, Lauren Goodfellow, Jay Johnston, and Sonali Maheshwary. *A Preliminary Feasibility Study of a HIFLO Vacuum Sewage System within the city of Venice, Italy.* Worcester Polytechnic Institute: Worcester, MA, 1997. Henceforth referred to as Felices, *HIFLO System*.

Appendix G: Annotated Bibliography

Babic, Kristopher T. and Grant G. Leeds, Stylianos Sidiroglou, Michael Borek. ***Analysis of Sewer Holes and Canal Wall Damage in Venice, Italy***, Worcester Polytechnic Institute, 1998.

This project, sponsored by UNESCO, is an analysis of the canal wall damage and sewer holes of the Sestiere of Castello in Venice, Italy. A database of previously catalogued data was checked for accuracy and for increases in damage size. Any unrecorded holes or damages were also catalogued at this time. From the information we obtained in the field, an in depth analysis was performed revealing correlations between various factors present in the canals and canal wall damage. For example: sediment buildup Vs traffic. The amount of sewage output into each canal was also calculated and from this information the canals with highest concentrations of sewage could be determined. Recommendations were made to provide possible solutions to the problems of sewage disposal and canal wall damage.

Baker, Brian A. and Russell H. Beavis, Beth A. Newton. ***A Geographical Information System for Venice, Italy***, Worcester Polytechnic Institute, 1992.

The C'92 IQP, A Geographical Information System for Venice, Italy, continued and expanded the work began by the E'91 IQP, Venetian Cartography, to create a detailed, computerized map of Venice. The final GIS will utilize menus to access databases and display information ranging from scientific to cultural in nature. We completed much of the detailed map and outlined the necessary steps to link the map with the databases. We developed a computer-aided data entry process (CADE) and additional programs that future groups studying Venice will use to record and display their information.

Binkerd, Chad R. and Ralph A. Maselli II, Scott H. Stoddard. ***Analysis of Structural Damage to the Canal Walls of the Sestiere Castello di Venezia***, Worcester Polytechnic Institute, 1992.

This project catalogs, quantifies, and evaluates the sewage outlets and structural damage found along the canal walls in the sestiere Castello di Venezia. Utilizing photo documentation and an intricate archival system, the information collected can be easily accessed for use in facilitating the restoration of the canal walls. Also, social aspects are addressed in the creation of a program for Venetian school children aimed at educating them about their canals.

Borrelli, Alexander P. and Matthew J. Crawford, James W. Horstick, Izzettin Halil Ozbas.
Quantification of Sediment Sources in the City of Venice, Italy, Worcester Polytechnic Institute, 1999.

The overall goal for this project was to contribute to the organization of an efficient dredging schedule for the canal system in Venice, Italy. More specifically, we collaborated in the validation of a sediment model designed to predict the flow and accumulation of sediment in the canals. Location and status of sewer outlets and wall damage in the sestiere of Cannaregio were documented and the previously unresearched topic of the contribution of masonry debris to sediment was investigated.

Bravo, Victor and Jose Lopez, Zung Nguyen. ***A Documentation and Analysis of Canal Boat Parking within Santa Maria Insula and Santa Maria dei Frari Insula***, Worcester Polytechnic Institute, 1996.

This project contains an emphasis on the improvement and organization of parking spaces within and around the insula of Santa Maria Formosa and the insula of Santa Maria dei Frari in times of scarcity due to canal closures. In correlation with COSES and the City of Venice, organizational tools consisting of databases and maps are created. The integration of existing data with the production of canal boat parking solutions will seek to maintain original, uninterrupted traffic flow patterns. The challenge inherent in this project is that a solution is rarely simultaneously optimal with respect to all the different criteria to be considered. The final solution is therefore dependent on the organizational tools developed; thereafter improving and organizing the parking spaces within the canals after dredging and maintenance. The organization and the management systems of canal boat parking and canal traffic are then used for municipal purposes in Venice.

Cahill, Amy and Gregory Masterson, Carlos A. Zapata. ***Le Sponde dei Canali di Castello, Venezia**,* Worcester Polytechnic Institute, 1994.

Working as official partners of UNESCO, this project homogenizes and integrates all existing data on sewer holes and structural damage to the canal walls in the Sestiere Castello di Venezia. A comprehensive report about the insula Santa Maria Formosa was created using photodocumentation and innovtive software. All the information collected can be accessed for use in the city's restoration program. A maintenance program was developed in an attempt to avoid the reoccurence of the critical conditions in the Sestiere di Castello. New hyppotheses on the causes of sediment build up and sewage outlet blockage are also explored in this study.

Carvajal, Hernando and Manrico Federico, Carlos Gonzalez, Tim Johnson, Jeff Levesque. *A* ***Study of Tide Flows, Mud Buildup, Boat Traffic, and Structural Damage on the Cannaregio Canal Subsystem***, Worcester Polytechnic Institute, 1991.

This report, prepared in collaboration with the Cento Previsioni e Segnalazioni Maree and the Istituto per lo Studio Dinamica Grandi Masse (ISDGM) of the Italian National Research Council, presents the results of a hygienic and dynamic study of the Cannaregio canal subsystem of Venice, Italy. The study analyzes the tide flow, mud buildup, boat traffic, and structural damage on five primary canals, fourteen secondary canals, and four major surrounding bodies of water.

Cioffi, Carlo and Vicky Dulac, Jose Marsano, Robert Reguero. ***Development of a Computerized Decision Support System for the Scheduled Maintenance of the Inner Canals of Venice***, Worcester Polytechnic Institute, 1997.

This project provided the Comune di Venezia with a preliminary decision support system (DSS) for planning canal maintenance. The project first regularized previously collected data and established fields and processes for further collections of canal characteristics (dimensions, traffic flows, hydrodynamics, hygiene) as well as docks, bridges, and parking spaces. Then the project created a menu driven DSS providing access to all the data for decision makers. The project concluded with recommendations to the technical team that will implement the actual DSS.

Cupples, Timothy and Garret Trombi, George Willwerth. ***Analysis of Structural Damage to the Canal Walls of Venice, Italy***, Worcester Polytechnic Institute, 1992.

This study presents an analysis and quantification of the different types of damage on the canal walls of Venice. The project area involved is the San Marco Sestiere and the boundary between this area and the San Castello Sestiere. Photometric techniques, coupled with an intricate archival system, were used to evaluate the extent of damage within the canals. Building materials, traffic levels and mud build-up were analyzed along with structural damage, in an effort to relate these causes to the existing damage. The research developed in this project will provide the information necessary to evaluate the extent of damage, the causes for this damage, and the social ramifications resulting from this damage.

Cutonilli, John and John A. Roy, John B. Thornton. ***A Geographical Information System for the Canals of Venice***, Worcester Polytechnic Institute, 1992.

The D'92 IQP Geographical Information System (GIS) for the canals of Venice, continued and expanded the work began by the E'91 Venetian Cartography and C'92 GIS for Venice, Italy projects. The final GIS will contain a detailed computerized map of Venice, with the ability to access databases and to display information of scuentific and cultural nature. This project added various sections to the computerized map, including canal information about the San Marco sestiere, such as tidal/velocity, traffic, damage/sewage, bridge and other info. Additionally, our group created separate menus to browse through scientific data in MapInfo or D-Base to allow a complete look at all known data concerning the canal system of Venice.

Deliso, Ashley and Rahul Bahn, Stephanie Hubbard. ***The Inventory and Analysis of the Bridges and Pedestrian Traffic in Dorsoduro, San Polo, and Santa Croce Sestieri of Venice***, Worcester Polytechnic Institute, 1998.

The purpose of this project was to analyze the bridges of Venice in the sestieri of Dorsoduro, Santa Croce and San Polo. This analysis included documenting and evaluating various physical dimensions and observations on the conditions of each bridge, as well as collecting data on the flow of pedestrian traffic and cargo deliveries over selected bridges. From this we created a comprehensive catalog, which contains the measurements collected, as well as photographs of each bridge, and a map of the location. Appropriate thematic maps and graphs detailing the accessibility, conditions, and traffic flow of bridges were constructed using the data we collected. It is expected that the data collected for this project will benefit Insula S.p.A. in various ways, including, but not limited to, providing information that will aid them in the process of restoring bridges, allowing them to plan appropriate detours for pedestrians while renovations are taking place, and helping with the issues of handicapped accessibility.

Doherty, Kevin and Joseph Maraia, Carlos Parodi, Flavia Souto. ***A Documentation and Analysis of the Traffic, Cargo Deliveries, and Docks within the Insulae of Santa Maria Formosa and Frari****,* Worcester Polytechnic Institute, 1995.

This project provides the city of Venice with an in depth study of the present traffic flows, delivery patterns and docking facilities of the canals surounding the islands of Santa Maria Formosa and Frari. It forcasts the impact on traffic, deliveries and docking, of the closure of segments of these canal systems. Data was gathered, analyzed, and methods developed, to provide alternative traffic and delivery routes during the canal's closures.

Felices, Diego and Carlos Moreno, Alexander Munoz, Brian J. Smith. ***A Documentation and Analysis of the Docks, Cargo Deliveries, and Boat Traffic within the Santa Maria Zobenigo Insula***, Worcester Polytechnic Institute, 1994.

The objective of this project is to document and analyze the usage of docks, cargo deliveries, and boat traffic in the insula of Santa Maria Zobenigo, in order to aid the City of Venice in preparing for the closings of the canals in this area during reconstruction. The closings of the canals has to be done in a way that will minimize the disturbance of the lives of the people in the area. This report provides the City of Venice and future IQP groups important data and analysis on docks, cargo and traffic, as well as useful methods on how to conduct similar studies.

Felices, Martin and Lauren Goodfellow, Jay Johnston, Sonali Maheshwary. ***A Preliminary Feasibility Study of the Implementation of a HIFLO Vacuum Sewerage System within the City of Venice***, Worcester Polytechnic Institute, 1997.

This study, sponsored by Alan Hassett, president of the Oak Hill Company, analyzes the feasibility of the implementation of a HIFLO vacuum sewerage system in Venice. In depth valve and piping schematics were made for the islands of Santa Maria Formosa and Santa Marta. From these schematics, thorough cost estimates were projected. A form of implementation was recommended to the city. This is a preliminary feasibility study that may lead to the implementation of a vacuum sewerage system in Venice.

Jagganath, Anand and David Chiu, Emily Nodine. ***The Moto Ondoso Index: Assessing the Effects of Boat Traffic in the Canals of Venice***, Worcester Polytechnic Institute, 2002.

This project, sponsored by the Consorzio Trasportatori Riuniti Veneziani, and Pax in Aqua, located in Venice, Italy created an index for ranking the energy level of each canal segment in the Venetian canal system. Boat traffic in the canals produces wake that erodes and destroys the walls of the canals, causing structural problems to the city. Wake heights of different boat types were measured, and the energy released by these wakes was calculated. The index was then created by assessing canal traffic patterns combined with the amount of energy released by different boat types when traveling at different speeds with different payloads. Additionally, this project suggested new traffic regulations that would reduce the total amount of energy in the canal system, and analyzed how probable traffic pattern scenarios would affect energy levels.

Kirkos, Greg A. and Marc Nicolazzo, Glen V. Zoladz. ***Structural Damage on the Canal Walls of Venice, Italy***, Worcester Polytechnic Institute, 1992.

This study offers an evaluation and quantification of the structural damage on the canal walls of Venice, with particular attention to the San Polo, Santa Croce, and Dorsoduro Sestieres, to illustrate how much of the Venetian infrastructure is literally falling to pieces. Photometric techniques long with a detailed archival system was used to quantify both the extent of and distribution of this damage, with efforts made to correlate such damage to boat traffic and the deteriorating effects of boat wakes. Highly damaged canal walls were explained by analyzing the traffic level within the canal, the nature of the building material of the canal walls, and the extent of mud buildup on the canal floor.

www.comune.venezia.it

This website provided general facts and figures about Venice. It included information about tourism which we found useful. The website was also provided information on measures the city has taken to make Venice more accessible. It included links to the itineraries they produced to create awareness of their work. These are made available to tourists with impairments who wish to learn more about the measures they can utilize throughout the city. Although it was in Italian it provided helpful information during our research.

www.insula.it

Insula's website is extremely advanced in the sense that it provides a lot of information on their work. It is organized by the different types of maintenance measures they perform. There are also list of their maintenance schedules with dates of completion, anticipated dates of completion, and financial figures of their work. This website was extremely helpful because it allowed an option to translate the entire website in English.