VENICE BELLS AND BELL TOWERS
A Striking Source of Knowledge

AN INTERACTIVE QUALIFYING PROJECT
WORCESTER POLYTECHNIC INSTITUTE

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Abstract

The project compiled, updated and blended into a single database all previous information collected by the Venice Project Center on the bells and bell towers of Venice, Italy in the years between 1992 and 2004. The project team visited a few previously inaccessible bell towers and captured improved quality video and sound recordings of bells and bell towers in the city. Finally, the project proposed templates and specific pages linked to the city's 109 bell towers and numerous bells for the specialized online encyclopedia: Venipedia.org, modeled after Wikipedia. The project also contributed information to the UNESCO Venice Public Art mobile application, a demo of which can be found at www.preservenice.org. An interactive website was created as part of this project to show the ringing times of the bell towers of Venice using a Google Maps image, as well as to provide a tool that allows users to play the sounds of the bells that were recorded using improved sound recording equipment. The website is available at bells.veniceprojectcenter.org.

Acknowledgments

First, and foremost, we would like to thank our advisors professors Fabio Carrera and John Zeugner, who have given us guidance on our project for the past two months. Professor Carrera, being a resident of Venice himself, has been one of our primary sources of information for our work on bells and bell towers. He has also supported us in the difficult task of gaining access to bell towers by speaking on our behalves. Both Professor Carrera and Professor Zeugner have taken the time to accompany us to bell towers and assist us with data collection. They have also been thorough in editing our report as well as spending countless hours preparing us for presenting our results. Our project would not have gone so smoothly without both of them.

We would also like to thank Paolo Tocchi and Massimo Rigo for letting us spend numerous hours collecting data at the towers they oversee and providing us with extensive history and info on the towers and bells. Paolo helped to us to chalk bells, take measurements, and read inscriptions at the three towers, San Giobbe, San Aponal, and Torcello, where he was working to renovate. He was also a great resource on information about the tower structures and the restorations that he was working on. Massimo also played an active part in our data collection, helping us to collect amazing sound recordings of each bell in San Giorgio. In fact, he stood at the bottom of the tower playing each one three times at thirty second intervals while we tried to figure out which one was ringing. He also provided us with helpful information on his restorations of the tower. Without these two people, we wouldn't have been able to collect any data.

We would also like to thank Kyle Miller, Ben Lichtner, Neil Pomerleau, and Wesley Ripley who have advised us on all things technical, whether it has been on bells.veniceprojectcenter.org, the PreserVenice app, or Venipedia. Kyle and Ben have played critical roles in preparing Venipedia and helping us to create our Venipedia pages. Neil and Wesley have also been great resources of information and for bouncing question off of. In addition, UNESCO has played a big role in listening to our

presentations and giving us advice on our projects. They also sponsor the PreserVenice app that we contributed to.

For Venipedia, we have worked closely with two other project groups, the churches team and the Venipedia team. We appreciate their collaboration and helping us to make our templates look fantastic.

We greatly appreciate our peers for keeping an ear out for when the towers ring and giving us their ringing times.

Lastly, we thank Professor Frederick Bianchi for providing us with excellent sound recording equipment.

Executive Summary

Material culture is an important part of the past; it is a physical representation of history that tells the story of how a specific society once lived and what they valued. The same can be said of one of the world's oldest and most beautiful cities, Venice, which is bursting with culture and art. Venetian bells are part of the city's material culture as well as a form of public art because anyone strolling through the streets of Venice can hear them, and most likely will hear them. In the past, bells have signaled worship, celebration, danger, and war. They have also served as a way to tell time and navigate the winding streets and canals of Venice. For many people, these uses are still relevant. However, due to the technology of the current era most people have replaced bells as a time-keeping mechanism with digital watches, computers, and phones. And, those that oversee the towers have become uninvolved as almost all bells in the city of Venice ring automatically. Therefore, bells and bell towers tend to be neglected and become vulnerable to guano, grease drippings, corrosion, cracks and structural stresses. Our project intends to renew people's interest in the towers, so there may be more initiative to preserve these artifacts.

Figure 1 Bells covered in Pigeon droppings in Santa Fosca.

Figure 2 A map of the all the bell towers visited by our project (green) and previous projects (black)

There are over 98 bell towers throughout Venice and its lagoon. Since 1992, the Venice project center has visited and documented information on 43 of the towers. The fields of data collected include general information and history, exterior bell tower data, interior bell tower data, and all data relating to bells. We took quantitative as well as qualitative data. However, unlike past projects, when taking data, we prioritized bells first. Our team visited 5 bell towers this term: San Giorgio, San Aponal, Torcello, San Giobbe, and San Marco, and we

collected data on 24 bells.

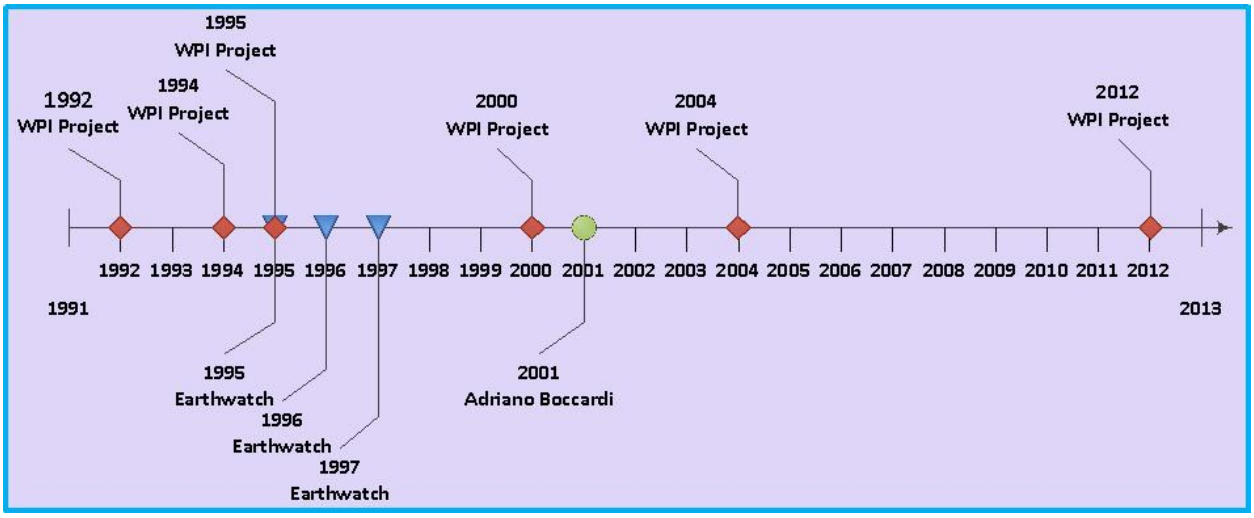

Figure 3 Timeline of all the past projects completed on bells and bell towers

Our three main objectives, over the course of the term, were to organize all the existing information, update our data, and distribute that information to the public. We accomplished the first objective by taking all the data, which was originally organized in a Microsoft Access database, and putting it into one single Microsoft Excel spreadsheet. This made it easier for us to transfer information so it could be used for other applications, and it also made our information better organized so that it was easier to view than the previous format.

We were also able to update our data as we visited towers. Video, audio, and photos were collected for each of the towers and all of their bells. The equipment used for these collections was up-to-date, and the quality of data was improved overall from the past projects. This was integral to our third objective because much of the media we collected would be used for our Venipedia pages and our website. In addition, the audio could be analyzed to obtain the musical note and frequency of the bell at its strike note. Also updated was the field data we had on all the bells and bell towers of Venice.

We completed our last goal of disseminating the information gathered from our project and previous projects in a few ways: Venipedia, a website, and a mobile application. We made three types of pages for both bells and bell towers. For instance, the bell pages consisted of a typical page, giving general information on bells; an aggregate page, giving statistics on only the bells of Venice; and individual pages, which catalog each bell in Venice. The bell towers have similar pages following these guidelines. The UNESCO PreserVenice Public Art application also provides similar information on each bell and bell tower in Venice. The user can navigate to the bell tower from a map, and then to each of the tower's bells. By clicking on the icons on the map, the user can learn more about Venice's bells and bell towers from our data. Our final deliverable was a website that offers interactive learning tools. The homepage brings the user to a Google Map that shows all the bell towers in the city. When bells ring in real time those bell towers flash green on the map. Another section of the website allows users to play and hear the

bells of three towers that we collected sound recordings from. The interactive tools on the website do not encompass all of our data, but they offer a more interactive experience.

Figure 4 Image taken from the website of the interactive bell map

Included in our aggregate Venipedia pages are statistics as well as graphs on both bells and bell towers. For bells, we analyzed the frequency of the strike notes, the size, the ringing method, and the condition based on rust, discoloration, and cleanliness. We also took a look at the number of bells per tower, the number of bell towers in each sestiere, and the height of the towers. While in Venice we were only able to visit five bell towers, which is not nearly enough to draw conclusions for every tower in the city. However, since the first project team in 1992, the Venice Project Center has collected at least some data on 43 of the over 98 bell towers in Venice. While each tower does not have a complete set of data, we could still look at the fields that we had information for.

There are still 55 towers left to be visited by the Venice project center. We believe that future studies on the bells and bell towers of Venice will find our data useful and our user applications helpful in their endeavors. Over the past seven weeks, we have worked to increase our knowledge of bells and bell towers and share it with the public. We have immersed ourselves in the project by brainstorming ideas to achieve our mission; organizing, collecting, and analyzing our data; preparing Venipedia pages; and designing our website. Bells are not only important to us, but they are also critical to the history and culture of Venice. By achieving the objectives described above, we hope to preserve the bells as a part of material culture by reconnecting the public with the bells of Venice.

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1 Introduction

Bells are one of the few simple objects that have withstood the test of time and have held an important position in cultures across the world. In the past, bells have signaled worship, celebration, danger, and war. They have also served as a way to tell time and navigate the winding streets and canals of Venice. Because they have served such crucial purposes, it is essential for bells to be heard over great distances. With bells positioned high up in bell towers, entire communities can hear them ringing. Unfortunately the development of new methods of communication has stripped these aging devices of many of their important functions. Because their purpose in society is not as significant as it once was, bell towers have been neglected and ignored resulting in the damage of precious artwork on the bells inside. Bells are a physical representation of history and culture that, if not preserved properly, will become irrelevant to society.[1]

Figure 5 An example of a pristine bell from the 2004 WPI project

Like bells found in other cities, the bells of Venice have lost purpose in society, and thus their ability to captivate an audience. The increasing neglect of bell towers has left many bells in bad shape, some bell towers in a state of disrepair, and in extreme circumstances, some towers near collapse. Even bell ringing, once an art form in itself, has been largely replaced by automated systems reducing what little human interaction the bells received in recent history. Left alone to combat the harsh elements of Venice, the bells will continue to degrade; and, if left unchecked, the damage to these pieces of art and history could be more than dollars and cents. When Venice was inducted as a cultural heritage site, the United Nations Educational, Scientific and Cultural Organization (UNESCO) endorsed the conservation of Venetian culture, which the organization believes to be an "irreplaceable source of life and inspiration."[2] Therefore, with the guidance of UNESCO's ideals we are charged with the difficult task of creating a context for people to care about the bells once more.

Indifference is the major issue preventing the bells of Venice from being appreciated. The majority of bell towers are inaccessible to the public which severely limits any direct contact with Venetians and tourists. The bells are not intimately incorporated in a person's daily life, making it difficult to encourage people to care about these isolated structures. The World Heritage Convention recognized the importance of creating a personal investment in tangible culture in order to preserve the local heritage.[3] Although the preservation of bells and bell towers has not been a priority for UNESCO, their goals and the

[1] Alfred Gatty, "The Bell: It's Origin, History, and Uses", 2.

[2] whc.unesco.org.

[3] Saleh Lamei, "Insights into Current Conservation Practices".

goals of the Venice Project Center in preserving culture and educating the public have been similar.

To address these issues, various studies were conducted from 1992 to 2004 by the Venice Project Center to preserve data about the bells and bell towers of Venice. The Project Center began studying bells in 1992 when the first project produced and tested a methodology for the collection of data on a small sample of bell towers. In 1994 and 1995, two WPI projects were able to improve upon the methodology, test it on a sample of towers and some bells, and design a database for all collected information. In 1995, 1996, and 1997, Earthwatch volunteers were recruited to use the methodology of the previous two projects to collect data and record videos. Bells were revisited in 2004, when a group further developed the Microsoft Access database, studied the structural elements of the towers, and updated past data with information on both towers and bells. Most of the past work on this topic has had to do with bell towers, not bells. Also, due to changing technology, the videos captured by Earthwatch volunteers and the 2004 project are often incorrectly labeled and poor quality by present standards. No project has yet to study all standing towers or bells in Venice; we are missing information of 55 towers. Most importantly, data from these projects are neither up-to-date nor located in a publicly accessible database.

The goal of this project is to prevent the bells from losing significance as a part of Venice's material culture by eliminating the knowledge gap. Building upon the efforts of previous Venice bell teams, we standardized the data by visiting and documenting bells and bell towers that had not been recently surveyed and updating information when existing data was outdated. Once all data were compiled, it was organized and inserted into the Venice-dedicated online encyclopedia, Venipdia. This contribution gave the city of Venice a digital form of all its history and current data on bells and bell towers.

2 Background

Material Culture is the set of objects that define the social identity of a society. In the case of Venice, bells and bell towers have become a part of this culture because they are so abundant and because they have held such an important place in society in the past. Both are considered irreplaceable pieces of art and history for the city of Venice. For bells it is in their function, inscriptions, engravings, and sound. For towers it is in their architecture that characterizes the landscape of Venice. To preserve bells and bell towers, people must not only physically restore them, but document the information in a way that is accessible for anyone. Appreciation precedes action; therefore if people understand the importance of bells to material culture and know of their condition, they will be more willing to make an effort to preserve them.

2.1 Bell Towers

Bell towers may often look very similar to the casual observer, but when one looks closely at the minute details, he or she may find that the differences are numerous depending on the part of the tower being studied and the time it was built.

2.1.1 The Anatomy of a Bell Tower

There are four main components to the structure of a bell tower: base, shaft, belfry, and spire. Each of these contributes to the overall style and integrity of the tower.

The main purpose of the base is to maintain the structural integrity of the tower. The walls at the base of the tower are often thicker than those at the top. Non-porous materials are used so that it is resistant to salt water from flooding and heavy enough to withstand the pressure from the weight of the tower.

The shaft is the part that contributes to the height of the tower and contains stairs, ramps, and landings that lead to the belfry. It is usually constructed of brick and mortar, which varied in strength based on the year that it was constructed. Brick makers improved over time upon the method for making bricks so that bricks could withstand a greater amount of pressure. In addition, to provide the tower with greater flexibility and support, some towers were built using metal rods.

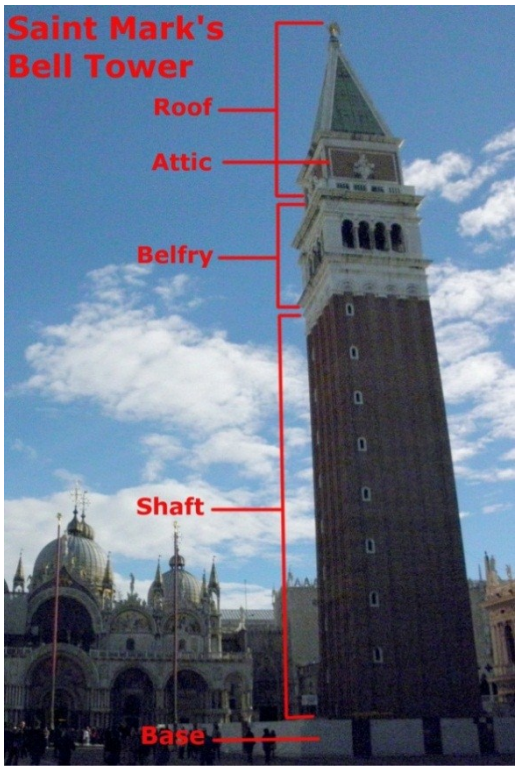

Figure 6 Diagram of the parts of a bell tower

The belfry, located above the shaft, contains the bells and usually some type of landing. The exterior of the belfry is generally the most ornate part of the tower, built using brick and other types of stone or clay. Typically, there are windows or arched openings that let light through and occasionally netting to keep pigeons from entering. The bells are hung from the top of the belfry with wood, although some newer towers use metal. It has been

found, however, that the vibration of the bell through the metal to the walls results in dynamic stress, further increasing deterioration.

Above the belfry there may be an attic, which provides additional storage or access to the top of the tower for maintenance. There may also be a balustrade, or a balcony with a railing that runs around the outside of the attic. This is usually accessible from the attic, so that one may enjoy a more expansive view and have additional access to the roof. To get to the attic, there is either a ladder or stairway.

The spire varies depending on the tower, but it can have many shapes: conical, pyramidal, bulbous, and others. There also may be a lightning rod or weathervane at the top of the tower.

2.1.2 Bell Tower Styles

Venice bell towers, along with the bells they hold, have been a constant part of daily life for citizens for over a thousand years. Essentially, each tower displays the same set of basic features: a tall square base, usually attached to a church, an opening for the bells, and a spire or dome on the top. Depending on the time of construction, bell towers differ in features such as type of opening, type of roof, material, and decoration. Because of age and deterioration, many of these towers require restoration usually having to do with weak foundations.[4] When towers were restored, the new parts often reflected the time period in which it was restored and not the period in which it was built. Therefore, towers frequently feature multiple styles of architecture.

Styles that were close in time period may share some of the same features. For instance, Baroque and Renaissance towers often have marble columns to separate openings in the belfry. In addition, earlier towers, such as towers from the Romanesque era, were very simplistic, showing little to no artistic design. Later towers, like those from the Baroque period, became more detailed.

Overall, bell towers contribute a great deal to the ambiance of the city. They add a new dimension to the landscape of Venice. Just as the New York skyline is seen as an iconic image throughout the world, the bell towers of Venice bring a vertical dimension to an otherwise flat city.

2.1.3 Deterioration of Bell Towers

Catastrophic events such as earthquakes and flooding do not frequently cause any major damage, but there have been cases, not specifically in Venice, where this has occurred.

Seismic activity is but one danger the bell towers of Venice must face. Earthquakes have rocked many towers to the ground through the centuries (See Figure 4), with one of the most recent incidents happening in 1902 when the bell tower in the Piazza San Marco collapsed.[5] When originally built, these monuments were intended to support the vertical force of gravity rather than horizontal shifting forces from earthquakes.[6] Furthermore, clay

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[4] Knopf, Venice, 1993, 84.

[5] Jeff Cotton, "San Marco".

[6] Angelo D'Ambrisi, "Seismic assessment of a historical masonry tower with nonlinear static and dynamic analyses tuned on ambient vibration tests".

soil at the foundation of the towers causes a large amount of weight to be displaced over a small area, leading to instability.[7] As a result, some bell towers in Venice have struggled to remain standing.

Figure 7 Tower of Finale Emilia after earthquake

The damaging effects of flooding in Venice were brought to international attention on November 4, 1966 when the water level rose 1.9m above standard water level.[8] This flood caused innumerable costs of damage to the cultural heritage of Venice, harming both art and architecture. Since then, flooding has become more noticeable each year than in previous years. In the past century the water level has risen by about 12 cm which is believed to be caused by global climate change and the resulting increase in sea level.[9] Flooding is presumed to worsen with increasing subsidence of land. The number of instances of flooding is projected to increase 20 to 250 times by the end of the 21st century.[10]

The effect of water levels on historical monuments is significant. It affects the foundation by eroding away supports and softening the soil with sediment deposits. In addition, many basements in Venice consist of water-resistant stone: however, the rest of the building is vulnerable to rising water levels. The brick exposed to flooding is weak against the intrusion of water as it enters through its porous surface and creates crystallization of salt.[11] This chemical reaction causes damage to the façade of the building in the form of weathering and deterioration, as well as causing the weakening of the building's structural integrity.

Damage due to flooding is a major issue affecting Venice because it leads to deterioration of material culture. This deterioration is an issue recognized in Venice and globally by UNESCO and other organizations. Thus, their efforts to explore ways of preservation began.

2.2 Bells

Bells exist all over the world. From China to Europe to America, some bells stand high in stately towers so that their ringing can be heard from the widest possible radius. Before modern times, these bells had more purpose than pure musical entertainment. They were signals of danger, disaster, and alarm. With improvements in technology and communication, bells are not of the importance they once were, but most people fail to realize that they are a portal to our past. Many bell towers of today were built in medieval

[7] G. Russo., "Experimental Analysis of the "Saint Andrea" Masonry Bell Tower in Venice. A New Method for the Determination of 'Tower Global Young's Modulus E'".
[8] Albert J. Ammerman, "Saving Venice".
[9] Laura Carbognin, "Global Change and Relative Sea Level Rise at Venice: What Impact in Term of Flooding."
[10] Laura Carbognin, "Global Change and Relative Sea Level Rise at Venice: What Impact in Term of Flooding."
[11] Michael Freemantle. "Safeguarding Venice."

times, and were manufactured using a specific set of techniques and materials. The bells of the past were carefully planned out and constructed, without even the most minute detail cast aside. From the precisely tuned pitch, to the carvings on the body, bells were designed by a dedicated artist.

2.2.1 History of Bells

The beginning of bells dates back to 132 A.D. in China.[12] The idea came from a Chinese philosopher by the name of Chang Heng. He invented the first known earthquake detector.[13] The structure operated with an internal pendulum mechanism that would swing due to the earth's tremors. This pendulum would then hit a ball out of one of the structures' eight openings, not only alerting of an earthquake, but of its direction.[14] The philosophy of this mechanism was later adapted so that the pendulum would hit an instrument to produce a sound. And, this idea progressed to become what we know as bells today.

Bells then migrated to Europe where they were modified, becoming greatly popular in the medieval time period.[15] Churches in Europe adopted bells, putting them up in steeples to signal churchgoers when to attend mass or when to pray.[16] In modern times, churches still ring their bells for the same reasons.

2.2.2 The Anatomy of a Bell

All church bells have similar features. There is the crown, from which the vibrations mostly come and the shoulder, which is the curvature at the top of the bell. The part that induces the sound, in most cases, is the clapper, or the long pendulum that hangs from the top of the inside of the bell. When swung it hits the strike point, or soundbow, of the bell. Figure 2 below labels the parts discussed.

[12] Richard Babyak, "Reinventing the Bell Tower", 2005, 5.
[13] Ibid.
[14] Ibid.
[15] Ibid, 22.
[16] Ibid, 22.

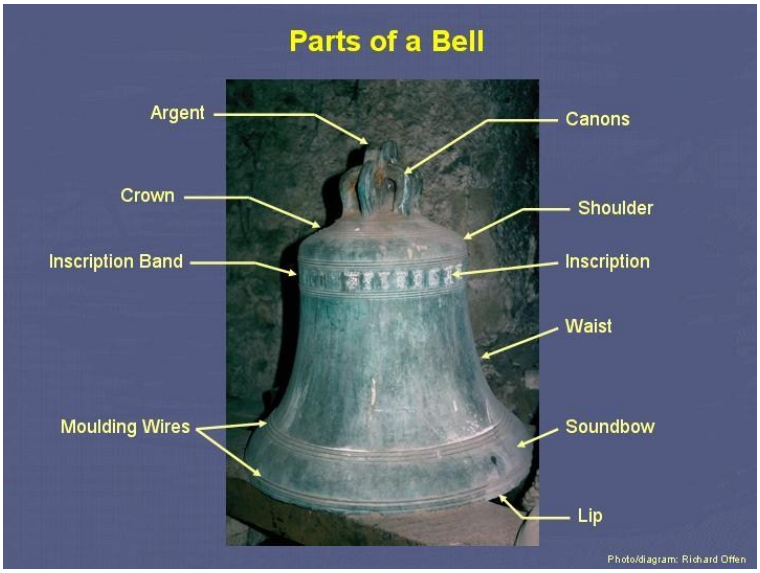

Figure 8 Parts of a Bell

2.2.3 Bell Casting

The casting of bells is a delicate and precise process. The style of a particular bell depends upon the foundry in which it was made, along with the materials that compose it and the period of its creation. Bells have typically been made using the same process for over six centuries.[17] A popular method of bell casting is to use sand-casting.[18] In medieval times, when many bells were being produced, molds were made from clay as a template for the bells. A bell mold had a center mold and an outer mold. Molten bronze was poured between the two and then allowed to cool to take the shape of a bell.[19] Back in the middle ages, sometimes wooden templates were also used. Through the use of these templates, the distinctive shapes of the bells were formed.

The most common material for bells is bronze, an alloy of copper and tin.[20] Very rarely bells were cast in steel and cast iron.[21] This shift in bell materials occurred mainly during times of war, when alloys such as bronze were in short supply since copper was needed in the manufacturing of some weapons.[22] Around 1857 A.D. a combination of iron and carbon, also known as steel, became a material for bell-making. Not soon after it had begun being used, it was discarded since the compound was deemed unsuitable for a material of bells, as sound quality was poor, and its lifespan was relatively brief.

2.2.4 Bell Decoration

Most European bells are similar in their decorations. They usually include an inscription about where or when they were made or an engraving of a religious figure. Rev. Geo. S Tyack's book, *A Book about Bells,* thoroughly explains English bells, but can also be applied to Venetian bells. The author describes how bell makers were known for their bells

[17] www.verdin.com, 2012.
[18] Ibid, 22.
[19] Ibid, 23.
[20] Ibid, 23.
[21] Strafford, Newell, Audy, Audy, 23.
[22] Ibid, 25.

by the designs they used to distinguish themselves. For instance, Oldfield, an English maker from the seventeenth century, used a classic foliage design as a border around the shoulder and lip, while Purdue instead molded a grape vine design. Another trend founders have implemented was to design a trademark with a symbol or initials instead of writing out the full name of the founder[23].

Historical figures are another common form of art found on bells. These include effigies of saints, angels, or royal leaders. In addition, one may find the shield of the patron who invested in the tower or church. However, the most frequently used decor were inscriptions which offer information of whom the bell was dedicated to, who the maker or donor was, when it was cast, and other supplemental information.[24] These are typically in Latin, although some may be in the native Italian. There have also been some cases, in England, in which an inscription on a bell has defamed another founder. Also, when change-ringing was first introduced, bells had inscriptions that would refer to the order in which they were rung.[25] And, others may have a verse or couplet, on something historical, religious, or something specifically pertaining to the bell. When ancient bells were cast, the moldings and decor on them were treated as a form of art. The inscriptions, figures, and design on each bell were well thought out by the founder and were intended to be a reflection of the founder's work.

2.2.5 Bell Frame Designs

Two bell frame types are primarily used to suspend bells, the H frame and the A frame. The H frame (See Figure 9) occurs when the bell is suspended on a "cross bar made of heavy H castings" usually composed of a durable metal material such as cast iron.[26] The metal material resists twisting and provides a secure base for the bell.[27] The popularity of this type of design resides in its "greater convenience and construction."[28]

Figure 9 Example of H frame (San Felice)

[23] Tyack, "*A Book about Bells",* 1898, 63.
[24] Ibid, 70.
[25] Ibid, 77.

[26] Heywood, Arthur Percival, e.t al, "*Bell Towers and Bell Hanging, An Appeal to Architects*", 43.
[27] Ibid, 43.
[28] Ibid, 44.

The second frame design is the A frame (See Figure 10) which, as the name suggests, is a frame in the shape of an A which supports the bell. This type of frame is, physically, more sound than the H type because it manages to distribute the weight properly and as a result relieves most of the stresses seen by the H type.[29]

Figure 10 Example of A frame (Santa Maria di Nazateth Scalzi)

2.2.6 Bell Ringing

Bells don't have one uniform way of being rung. In fact, the number of ways of ringing bells is almost as diverse as bells themselves. Asian bells, which are never suspended, are usually struck from the outside with a wooden mallet or a horizontal wooden beam in order to produce a sound.[30] Western bells, commonly found in churches, are categorized by three types of swinging systems; English, Spanish, and Central European.[31] However, they all have the common trait of being struck by a piece of metal otherwise known as the clapper.[32]

The English system, utilized in Britain, Ireland, USA, Canada, Australia, New Zealand, Southern Africa, and Northern Italy is characterized by its 360° motion where the bells freely make full circles.[33] The Spanish system is common in Spain, Southern France, USA, and in some Latin American countries and consists of bells mounted in a window with a counterweight causing the bells to rotate in the same direction.[34] Finally the Central European type, found in Central Europe, USA, Canada, Italy and in some Latin American Countries, commonly attaches counterweights to the tops of the bells which only allow them to swing a total of 160°.[35]

Spanish Bell System	English Bell System	Central European System

[29] Ibid, 44.
[30] *Encyclopedia Britannica*, s.v. "Bell.".
[31] Ivorra, Salvador, e.t al "*Dynamic Forces Produced by Swinging Bells*", 47.
[32] *Encyclopedia Britannica*, s.v. "Bell.".
[33] Ivorra, Salvador, e.t al "*Dynamic Forces Produced by Swinging Bells*", 47.
[34] Ibid, 48.
[35] Ibid, 48.

Table 1 Illustrations of different Bell systems

Swinging bell types can be further divided into four ways. The first way "clocking," occurs when a rope attached directly to the clapper is pulled against the bell to strike it.[36] The second, known as "chiming" or "tolling," involves an external hammer which is either controlled by hand or by machine.[37] "Tooling," the third way for a bell to swing has a rope attached to the bell directly and the bell itself is swung.[38] This can be extremely difficult, near impossible, considering bells can weigh as much as several tons. The final method is "ringing" during which the bell is swung from side to side typically on a wheel.[39] This type is the common method used in the previously discussed swinging systems.

The "ringing" method can be accomplished in two ways; a "flying" clapper and a "falling" clapper. A "flying" clapper begins with a bell attached to the pivot point of what is known as a "headstock" or "yoke," generally composed of either wood or steel.[40] A pulley system is attached to the yoke from which a rope is fed and pulled to rock the bell which causes the clapper to swing freely or "fly" (English system) and strike against the bell.[41] A "falling" clapper involves a counterweight (Spanish system) attached to the yoke "allowing the bell to pivot with a high center of gravity".[42] The clapper initially hangs at the pivot point and "falls" onto the walls of the bell with changing directions.[43]

While most of the previously discussed information suggests manual ringing of the bells, a popular trend has developed in which the bells are governed by an automated system. A common type of automated system involves a motor with cables leading up to either side of the bell wheel.[44] The motor is activated when the bell reaches the peak of its swing by

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[36] Strafford, Newell, Audy, Audy, 26.
[37] Ibid, 26.
[38] Ibid, 26.
[39] Ibid, 26.
[40] Ball, Dr. Steven, "*The Defense of Bells*", 20.
[41] Ibid, 20.
[42] Ibid, 21.
[43] Ibid, 21.
[44] Ibid, 24.

spinning the cables in the opposite direction which, in turn, reverses the bell's direction.[45] A drawback for this system was it couldn't monitor the state of the bell in case its swinging became erratic which was later remedied by a group that outfitted the motor with a computer which would halt the bell in case of malfunction.[46] Another automated ringing system involves a mechanized striker which can be installed either on the outside of the bell (often used for swinging or stationary bells) or on the inside (only used for stationary bells).[47]

2.2.7 Deterioration of Bells

Although modern technology has reduced the need to ring the bells manually, it has resulted in people being removed from the process of maintaining those bells. Most of the bells in Venice, being made of bronze, suffer from a cyclic degrading process known as Bronze Disease. The disease refers to a chemical process in which the copper in bronze reacts with elements and moisture in the atmosphere, creating what is known as a patina, in this case, a film signifying corrosion.[48] Patina on bronze is composed of two layers. The first is a thin dark brown layer consisting of copper oxide which conforms to the surface of the object.[49] The second layer, best known for its characteristic greenish color, consists of copper sulfides and chlorides.[50] Patina formation is affected by several factors including temperature, relative humidity, duration and intensity of rain, mist, dew, sun radiation, direction and intensity of wind, and atmospheric pollution by sea salinity.[51] Bell towers provide perfect conditions for Bronze Disease to propagate by leaving bells exposed to environmental conditions such as humidity, high winds, rain, and moisture.

The process of Bronze Disease is facilitated by moisture and dry air. Initially the copper in the bronze reacts with the salt and sulfates in the air to create copper chloride and copper oxide. The oxide is relatively harmless; however, the chloride causes damage.[52] The copper chloride reacts with moisture to create hydrochloric acid which reacts with unaffected bronze to create more copper chloride thus continuing the cycle.[53] Eventually equilibrium is reached where there is no more bronze on the surface to cause a reaction.[54] Oddly enough the corrosive green patina layer acts as a thick buffer from future deterioration.[55] However the thick green coating has the ability to transform the object by corroding the surface and possibly removing valuable artwork from its face.[56, 57] Many of the bells have intricate images exuding from their surfaces making corrosion a significant problem.

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[45] Ibid, 24.
[46] Ibid, 25.
[47] Americlock, Inc., "*Church Bell Ringing & Bell Strikers*" 1990-2012, http://www.usbellco.com/bell-strikers.
[48] Scott, David A., "Bronze Disease: A Review of some Chemical Problems and Role of Relative Humidity", 193-206.
[49] Hedberg, Yolanda, "Protective Green Patinas on Copper in Outdoor Constructions", 956-959.
[50] Ibid.
[51] De Oliveira, F, "Study of Patina Formation on Bronze Specimens", 761-770.
[52] Hamilton, Donny L., "Methods of Conserving Archaeological Material from Underwater Sites", 74.
[53] Ibid.
[54] De Oliveira, 761-770.
[55] Hedberg, 956-959.
[56] Fitzgerald, K.P., "The Chemistry of Copper Patination".

2.3 Venetian Bell and Bell Tower Studies

A great majority of the data presented in our project comes from the past projects completed by WPI students from the Venice Project Center, the work of the Earth Watch volunteers led by Fabio Carrera, and research by art historian Adriano Boccardi. These projects focused on the collecting of data for all bells and bell towers in Venice, and the data collected ranged from the physical appearance of the towers and bells, to ratings on condition, and to media, including video and photo. The projects also made recommendations on how to revive the significance of bells and bell towers so there might be more interest in preserving them.

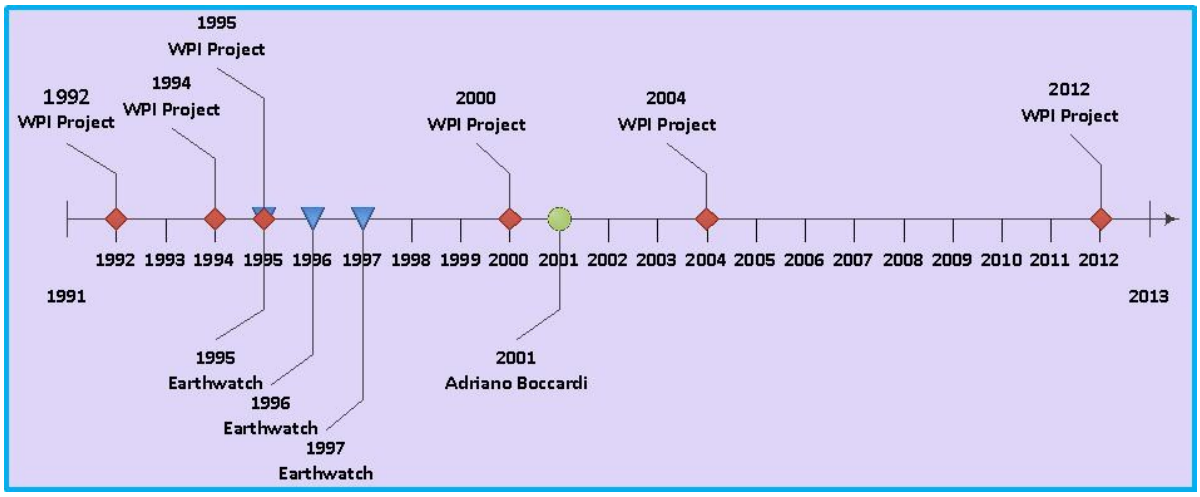

Figure 11 Timeline of past research on Venice Bells and Bell Towers

The first project done by the Venice project Center on Venice bell towers was in 1992, and it collected general information as well as interior and exterior information. They were only able to test their methodology on 3 bell towers (Figure 12).

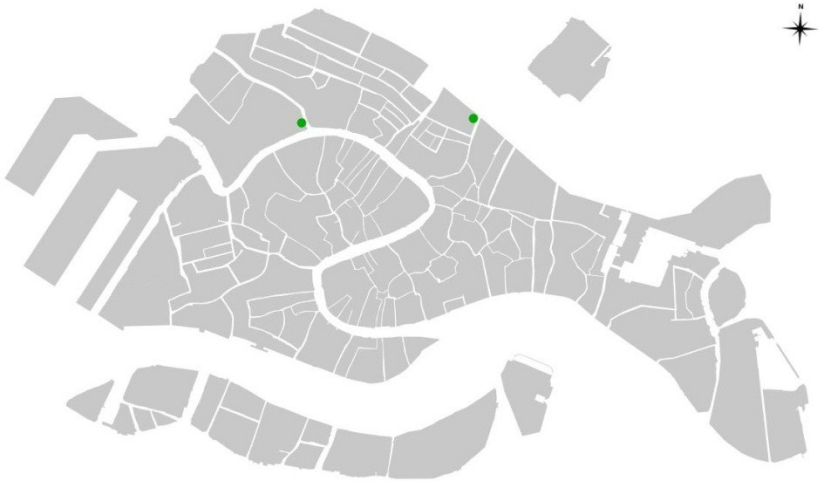

Figure 12 Map of towers visited by the 1992 WPI Project (not including towers in the lagoon)

[57] Scott, 193-206.

However, the methodology for collecting data was not refined until the 1994 Project, entitled A Method for the Evaluation of Venetian Bells and Bell Towers, by Morillo and Rosas. The main concern of this project was to establish a methodology for the set of data to be collected at each tower, including what is recorded and how it is measured. This project reviewed literature on the structural and aesthetic elements of bell towers to come up with the fields that would need to be included in their data. With these in mind they laid out the procedure for how groups should record data and tested this procedure on a sample population of 2 bell towers for interior data and an additional 8 for exterior information (Figure 13). From their data, they reviewed each bell tower to decide the urgency for restoration and prioritized its need by a visual assessment. Their data consisted of general, exterior, and interior information.

Figure 13 Map of towers visited by the 1994 WPI Project (not including towers in the lagoon)

The next year, another project, Computerized Catalog of Venetian Bells and Bell Towers by Carlson, Prince, and Roosa, worked to catalog the bells and also organize the data into a Microsoft Access database. To store the information collected, the group designed the database for future groups to use as well as MapInfo layers to display the towers they had visited. The main focus of the WPI project was to improve the research methodology, which was used later by Earth Watch volunteers. They made some drastic changes to the procedure set by the group before, collecting general information, exterior and interior bell tower data, and technical bell data. They tested it on a sample of three bell towers. They also collected external data for nineteen towers (Figure 14).

Figure 14 Map of towers visited by the 1995 WPI Project (not including towers in the lagoon)

In 1995, 1996, and 1997, Earth Watch volunteers, led by Fabio Carrera, used the guidelines of the two projects before to collect data and input it into the database. The EarthWatch volunteers are responsible for collecting the majority of the data found in the Microsoft Access database as that was their only task at hand. The first team of EarthWatch volunteers collected data at five bell towers (Figure 15).

Figure 15 Map of towers visited by the 1995 EarthWatch volunteers (not including towers in the lagoon)

The 1996 EarthWatch volunteers collected data on 17 towers (Figure 16).

Figure 16 Map of towers visited by the 1996 EarthWatch volunteers (not including towers in the lagoon)

And, the 1997 team collected data on 15 towers (Figure 17).

Figure 17 Map of towers visited by the 1997 EarthWatch volunteers (not including towers in the lagoon)

Bell towers were not revisited by the Venice Project Center until 2000, when the project Cellular Bell Towers proposed using them as cell phone towers, giving them a new function altogether. The main focus of this WPI project was to explore ways of reviving the significance of bell towers by brainstorming alternative uses. Their goal was to analyze whether their idea was realistic or not by visiting the towers and taking external measurements. After visiting 54 towers, taking external data, the group determined that this was a feasible idea because they were so tall and distant from the public. However, the idea met resistance with the clergy owners of the towers and was never executed.

The work of Adriano Boccardi, in 2001 contributed a great deal to the information in the Project Center's database. Boccardi, an art historian interested in the work of the WPI projects, developed his own methodology for observing each tower and more specifically the bells. He was concerned with the inscriptions and decorations on the bells and transcribing them with accuracy. He found that the inscriptions and artwork would often provide more information about the bell or church. Therefore, his data only included general information

on the church and tower and data on the bells. He collected data on bells in 11 towers (Figure 18).

Figure 18 Map of towers visited by Adriano Boccardi in 2001 (not including towers in the lagoon)

The most recent and up-to date project was Preservation of Venetian Bell Towers, produced in 2004 by the group of WPI students consisting Marion, Milkin, Mill, and Vitone. This project dealt with organizing the data from past projects and assessing the structural integrity of the towers as well as filling in information gaps from previous projects. The main concern of the WPI project was to continue collecting data on 9 towers (Figure 19) as well as analyze the structural integrity of the towers to determine which ones needed to be renovated. In addition, they updated the methodology used by the previous groups of WPI students and EarthWatch volunteers. Their goal was to create a comprehensive source of information including general information on the church and tower, interior and exterior bell tower data, and data on all the bells.

Figure 19 Map of towers visited by the 2004 WPI Project (not including towers in the lagoon)

Over the course of our project, we visited 5 bell towers (Figure 20) as described in Section 3.2.

Figure 20 Map of towers visited by our project in 2012 (not including towers in the lagoon)

Therefore from 1992 to 2012, disregarding towers that were revisited, the Venice Project Center database includes data from 43 towers and 108 bells (Figure 21).

Figure 21 Towers visited by all past projects (not including towers in the lagoon)

Although, there are 55 towers left to be visited and there is no data on how many bells that would be.

These projects all intend for bell towers to be put to better use so there may be more concern for their maintenance in the future. More recently, the towers have been put into the hands of the city, for their meteorological use in signaling high tides. However, these sirens are not associated with the bells. While there may be interest in preserving the towers, there may not be as much interest in preserving the bells.

3 Methodology

The goal of this project is to help preserve the material culture of bells and bell towers in the city of Venice by gaining knowledge on their historical significance and by creating an extensive source of information that will reconnect modern Venice with its past. This study includes pertinent information to the history, size, sound, and aesthetics of these bells and bell towers. Video and sound recording was limited to whether permission was granted to gain access to bell towers. Because of the seven week time constraint, we gathered as much

bell data and recordings from as many bells and towers as possible while in Venice. In order to accomplish our goal, we achieved the following objectives:

1. Systematically arranging bell and bell tower data
2. Collecting bell and bell tower data
3. Distributing collected data to the public

3.1 Systematically Arranging Bell and Bell Tower Data

Our first task, organizing existing data, was partially completed while we were still on the Worcester Polytechnic Institute (WPI) campus.

3.1.1 Organizing Information

The projects we focused on were conducted by Earthwatch volunteers in 1995, 1996, and 1997 and WPI Venice project teams in 1994, 1995, and 2004. The 2004 project was our main source of data, as it catalogued dates, architects, history, physical features, structural integrity, and other statistics of the bells and bell towers that they researched. Although the 2004 team only visited nine bell towers, their database provides information collected from all of the projects. A full list of measured quantities can be found in Appendix D. Most of the information the team collected is stored in a Microsoft Access database (see Figure 22), in which links to information were broken and inaccessible.

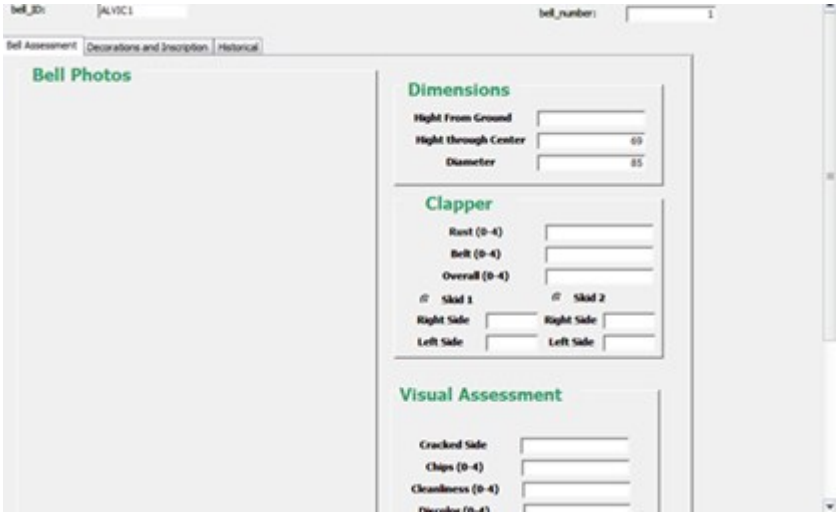

Figure 22 "Bell Master" page from 2004 Database

Our group learned to get around the broken links by going into the individual database pages and exporting the information into an excel spreadsheet. The information from the 2004 database was cross referenced by another access database created by Adriano Boccardi who compiled detailed information on bells specifically. This was so we could manually take the raw information and use it for our purposes. We explored different options to export the information in the form of a CSV file to save time.

In addition to organizing the written data, we developed a system for classifying videos filmed by past projects. There are approximately one hundred videos that come from

the work of the Earthwatch volunteers and the 2004 project. When we initially began familiarizing ourselves with the videos, we found that many are not up to current standards. The images were grainy and lacking color, and background noise was affecting the sound quality.

Figure 23 Chiesa di S. Geremia e Lucia Q1 video

To determine the quality of a video we implemented a rating system to include on the digital tag of the video. The system ranges from Q1 to Q3: Q1 being completely unusable and Q3 is a video or potential audio which would be a good addition to our project. Figure 6 provides an example of an unstable video (Q1 rating). The Q2 rating means that this video would only be used if access to the tower pertaining to it was not granted. This would be the case where we could not replace it with a better video of our own and would have to use the Q2 video that was available to us. In addition to rating the quality of the videos, we reorganized them by the church that they were taken in. The 2004 project devised a system in which each church has its own code, and for consistency we organized these videos according to their system. Before, all the videos were organized by year but now they are organized by the specific church code. The newly sorted videos were then organized into folders named with the corresponding church code, and each video was renamed to include our quality rating.

Once in Venice, we explored Venipedia for information from past projects. We also obtained any missing information at the Venice Project Center. We proceeded to consolidate all the information, written, video, and pictures, into folders arranged by church code. This information created a strong base for the rest of our project.

3.1.2 Master Spreadsheet

To ensure that all of the data from past projects and from our project would be appropriately preserved, we created a Master Spreadsheet in Microsoft Excel containing a complete record of our information. We began by manually excavating all of the information in the 2004 Venice team's Microsoft Access database and organized it into this Master Spreadsheet. The 2004 project had made great strides with the information; however, much of the information from the past had been overlooked or broken links had made some of the information unsalvageable. Two access databases created by the 1995 Earthwatch project had information that needed to be included into the spreadsheet. More information needed to

be included from the work of Adrianno Boccardi who had written a thesis about more than twenty bell towers and their associated churches and bells. Adrianno also organized some of his condition information into and Access database which needed to be combed through to include into the excel spreadsheet.

The Master Spreadsheet is broken up into separate sub-spreadsheets labeled "Bell Tower Exterior", "Bell Tower Interior", "Bell Tower Extraneous Info.", and "Bell Info." Bell Tower Exterior and Interior contain information about the bell tower inside and out. The Extraneous information sheet contains background knowledge and history about the bell tower as well as other information that does not necessarily fit into the other sheets. Bell information contains all information pertaining to the bells of the tower. Each of these spreadsheets has many fields for each piece of data that was collected.

The collection of data into this Master Spreadsheet represents the fields from our data collection forms, and each of the different sub-spreadsheets represents one of the four types of data that our forms could be broken-up into.

Without this Master Spreadsheet, it would be difficult for others to have access to the abundance of information which groups of bell and bell tower researchers have accumulated over the years. With this, our team has delivered a vast amount of knowledge that can be easily manipulated to one's needs of accessing this data for an assortment of uses.

3.2 Collecting Bell and Bell Tower Data

Integrating new information about bells and their towers was decided to be our primary focus. With this aim in mind, we used a table created by the project completed in 2004 which listed each church in Venice and when it was visited in the past to choose which bells to visit. Examining the table, we determined approximately fifty bell towers which had never been visited by past projects for whatever reason. This list was sent to Professor Carrera who attempted to gain access to these bell towers.

While we were prepared for the situation in which all of the bell towers we listed were not accessible, we were able to gain access to five towers: San Aponal, San Giobbe, San Giorgio Maggiore, San Marco, and Santa Maria Assunta di Torcello. After we had mapped out where these bell towers are located in the map below, we created a plan to visit them

based on accessibility and weather conditions.

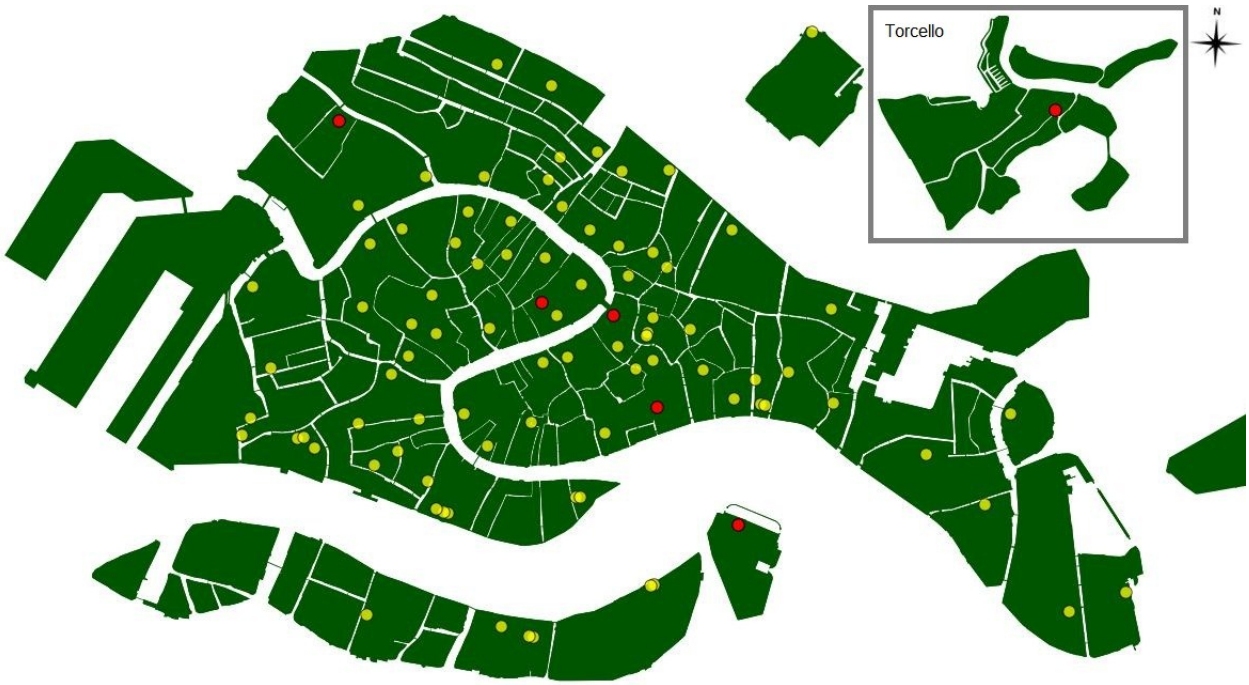

Figure 24 Map of bell towers in Venice

We started at San Giorgio Maggiore, since we knew that was open to the public and we could always revisit it if need be. We also went a second time, with Massimo, who restored the tower in 2004. This visit gave us many data that would not have been possible to collect otherwise. The tower is visitor friendly, meaning the stairs have been blocked off and now only an elevator is available to take visitors to the top. The bells are also hung extremely high in the belfry, too far for us to record any detailed observations. Massimo was integral to this visit as he allowed us to study the stairs leading to the top. He also played each of the bells from the digital wall unit from the bottom of the tower so we could record the ringing of each individual bell. Next was San Aponal, Torcello and San Giobbe, which we received access to from Paolo, who was working on major projects to restore these towers. San Aponal had not yet been visited by the Venice Project Center so we made some major contributions to the information for this tower. Our last bell tower visit was to San Marco, which was very similar to San Giorgio in that the stairs were not accessible and the bells were hung high. Although, we were unable to collect all the information the forms ask for, we did collect whatever information was possible for us.

3.2.1 Forms for Data Collection

Looking through past projects, we came across forms which had been used and modified over the years to encompass a vast amount of data about the bells and the bell towers of Venice. The major types of information collected fell into four categories, general information, exterior information of the bell tower, internal information of the bell tower, and

information about the bells. General information encompassed background information about the bells and bell tower which could not be measured or quantified such as history or types of ringing mechanisms of the bells. External bell tower data included measurements such as the dimensions of bricks of the Tower. Exterior data also included observations of the tower's condition which were given a rating based on what was observed. The rating system was developed by previous projects where the attribute in question was given a rating between zero and four (See the 2004 Venice Project *Preserving Venetian Bell Towers* Guide for a detailed explanation of the process). Zero meant there were no negative effects while a four meant the attribute was numerous or enormous. In other words zero was considered as a reflection of positive conditions while four was a reflection of negative conditions. Interior tower information includes similar types of data as exterior information such as measurements of the landing and rating the conditions of the landing. Finally bell data included dimension measurements of the bells, observations of conditions of the bells and the bell frame, and transcribing the inscriptions and decorations on the bells.

Reading through the forms we compiled a list of all of the pertinent information they had collected which we wanted to focus on during the course of our project and added several fields of our own about information we wanted to collect. The full list can be seen in Table below:

Bell Data	Previous Projects	Our Project
Bell Height	X	X
Height from ground	X	X
Diameter	X	X
Date cast	X	X
Founder	X	X
Inscriptions	X	X
Location of inscriptions	X	X
Location in Venice	X	X
Restoration efforts	X	X
Art on bells (and location)	X	X
Type of Ringing	X	X
Time of bell ringing	X	X
Striking Note		X
Resounding pitches		X
Church (affiliation)	X	X
Bell Material	X	X
Style of architecture	X	X
Owner/Affiliated Persons	X	X
Damage/Cracks	X	X
Condition of the Bell / Tower	X	X
History	X	X
Outside of Tower (clock/art)	X	X
Arrangement/Number of bells	X	X
Years monitored	X	X

Skid marks from clapper	X	X
Arches/Windows in Tower	X	X
Tower Danger	X	X
Audio		X
Video	X	
High-Definition Video		X
Photographs	X	X

Table 2 List of data collected by past projects compared to data we wish to obtain

In order to make the most of our visit, we found it most advantageous to divide the many tasks that needed to be completed once inside the tower. Also, having one person perform the same tasks every time provides consistent data throughout the towers. One individual was responsible for chalking and taking pictures of the inscriptions and decorations on each bell as well as taking pictures of all sides of each bell. In addition, the student filled out the General Bells and Frame Data Sheet (See Appendix D). Another student was in charge of taking pictures of other bell towers as well as the exterior of the tower. Due to the student's familiarity with the sound recording equipment, she recorded the sounds of the bells. The student also completed the Technical Bells Data Sheet and helped with measurements. Another individual was most familiar with the video recording equipment so was responsible for taking video of the bells ringing and of the view from the tower. He was also responsible for the three Internal Bell Tower Data Sheets. The fourth student was responsible for taking the bearing of the front wall. She also counted the steps between each landing, took bell measurements, and filled out the Bells Inscriptions and Decorations Data Sheet. Whichever team member finished first was then responsible for the External Bell Tower Data Sheet. This person varied depending on how long each task took in a particular tower.

After identifying what data was missing from past projects about each of the bell towers, we set out to remedy this knowledge gap. Many of the towers remained inaccessible despite our best efforts to gain access to them. However, we were able to collect data on many of the bells and bell towers during our time in Venice. The two most critical tools used in updating the data were the Tascam audio recorder and the GoPro video recorder which both used high definition audio and video recordings. Over the course of our project, we acquired from our data collection and past projects 55 audio recordings, 56 video recordings, as well as 1,231 photos.

3.2.2 Video Capture

To capture video from the top of the tower, we used a GoPro video camera, which recorded in 1080p high-definition video. We began with the camera pointing north and panned clockwise until reaching north again. This gave us a 360° view from the top of the towers we visited. We also used the camera to pan around each of the bells so we would have a unique view of the bell from every angle. If there happened to be a scheduled ringing of the bells while we were in the tower, we were able to film the bell or bells that were ringing automatically, either by wheel or hammer. Afterwards, we were able to edit some of these videos by simply using windows movie maker to cut out any unnecessary images or sounds that happened to be captured.

3.2.3 Audio Capture

While in Venice, we used a DR-40 Linear PCM Recorder[58] to capture audio of each of the bells ringing. This gave us the sound of all of the bells ringing in their usual pattern. We then used a program called Audacity to analyze the signal and identify the note that each bell tolls at. We did this by zooming in to the moment in the audio when the bell is first struck and then highlighting that part in Audacity. Then, we analyzed the plot spectrum of the highlighted section and retrieved the frequency at the highest peak in the spectrum. Using this frequency, we looked up the musical note that it correlated to. In several cases, we were unable to record the sound of individual bells and instead recorded the sound of multiple bells in the tower ringing. Using the Audacity software, we were sometimes able to cut the audio track so that only the sound of one bell would be captured. Another, positive aspect of the software is the noise removal tool, which can be very helpful in removing wind, voices, or any other background noise from the sound clip.

3.2.4 Photography

Much of our project involved taking pictures of each aspect of the bells and bell towers. In addition it was also important to update existing pictures from previous projects. We decided that the use of the 1080p GoPro camera in addition to the use of an HD sixteen mega-pixel Canon camera were the best options to complete the job.

The GoPro being a wide-angle lens was perfect for tight spaces such as the belfry where it was difficult to take one picture which would capture the whole area. It shows a lot more of the belfry simultaneously with the bells to give the viewer a better idea of what it is like inside.

Figure 25 San Giobbe Belfry 2012 with Canon

[58] Tascam, "Handheld 4-Track Recorder: Giving You Flexibility Needed to Record Anywhere."

Figure 26 San Giobbe Belfry 2012 with GoPro

The GoPro was also ideal for panoramic shots of the view of the city from the bell tower. The wide lens was able to capture more of the horizon than a regular lens camera so one can view more of the city.

Figure 27 View from San Geremia

Figure 28 View from San Marco (GoPro) 2012

Ideally we wanted to take new photographs of bells and bell towers; however, this was not always feasible so instead we focused on updating the old photos. We looked through the old data including photos which helped us determine which photos were missing and needed to be taken and which photos were unclear and needed to be updated. While the GoPro worked extremely well with the previous examples, unfortunately one downside to the GoPro is its inability to zoom. This made it necessary for a secondary camera which had a decent zoom and autofocus for the bells that were located high above our heads, such as the example shown below with a bell located in San Marco.

Figure 29 San Marco Bell 1

Figure 30 San Marco Bell 1 2012 (Canon)

Over the course of our project we took many photographs, videos, and audio recordings. However, all these types of media are useless to other interested parties unless they are shared.

3.3 Distributing Collected Data to the Public

One of the major goals we have accomplished in completing this project was to begin to make all the data on bells and bell towers in Venice that both our project and previous projects have collected available to the public. No group before us has been able to do this. We have three outlets for users to view our data: Venipedia, the Venice Bells Website, and the UNESCO Venice Public Art mobile application (app). We contributed to Venipedia, the wiki resource supported by the Venice Project Center, by making three different types of pages to give the user a comprehensive understanding of the bells of Venice. Also, we created a website specifically for our project that provides additional information as well as interactive maps, sounds of bells, and access to our project files. Our data was also added to the UNESCO Venice Public Art app to increase the accessibility of information on bells and bell towers.

3.3.1 Venipedia

Once we had organized all of the data on bells and bell towers, we created Venipedia pages (Appendix B) to make that information accessible to the public. Links to other pages within the Venipedia site will have been incorporated appropriately on each page. These pages serve the ultimate purpose of organizing all of our data in a public and logical way.

With the guidance of the Venipedia team we developed several types of wikipages for bells and bell towers: Bell Towers (aggregate), Bells (aggregate), Bell Tower (typical), Bell (typical), Bell Ringing (Typical) and individual pages for both the bell towers and the bells. In designing these pages, we asked ourselves the question: what information would a Venipedia user be looking for?

The aggregate pages for Bells and Bell Towers give an overview and statistical analyses of all of the bells and bell towers in Venice. They also include links to all of the individual pages discussed below.

The typical pages contain general information that refers to all of the bells and bell towers in Venice, as well as how a typical bell is rung. We based most of the information in the bell and bell tower pages on the former page in Venipedia and drew heavily from the background chapter of this report. These typical pages link to the aggregate pages discussed above.

The Bell Ringing page was created using information from our background section. Originally, this was intended to be a sub-section on the Bell page. However, it is information that needs to be accessed from multiple locations, and we have a lot of information on that subject, so we decided to create a separate page for it. This page links to both the typical and aggregate pages for Bells.The aggregate and typical pages, as well as the bell ringing page were all created manually, meaning we wrote them ourselves and edited pages directly from Venipedia

The individual pages cover, as suggested by their title, information about specific individual bells and bell towers. We used the various field forms in order to design the layouts of the pages. The Bell Tower pages are a combination of the Tower Interior and Tower Exterior forms, while the Bell pages take their data from the series of Bell Data forms. Much of the general church information that was collected was not included on our pages and was instead incorporated into the individual Church pages. The individual pages link to their respective typical and aggregate pages. Both types of individual pages are created automatically from our data sets by creating CSV (comma-separated value) files, and uploading them to a City Knowledge console. We incorporated all of the data that past teams have collected into these pages. Unfortunately, not all of the data sets are complete, so some individual pages contain little to no information beyond the name.

3.3.2 Bells.VeniceProjectCenter.org

A main component of our project was to create a website. We used the domain, bells.veniceprojectcenter.org, for the development of this site. We wanted to provide users with easy access to all of the collected information for this project, but we also wanted to display some of our data about the bells and bell towers of Venice in a fun and interactive way.

To build this site we began by using HTML (Hyper-Text Mark-Up Language), a mark-up language widely used for the coding of websites, and CSS (Cascading Style-Sheets), a style-sheet language, used for designing the look and formatting of the site built with the HTML. The majority of the coding was done in the text and source-code editor Notepad++. A basic theme and page-structure was developed with the HTML and CSS.

We wanted to be able to show users the times that different bells were ringing, so we determined that the homepage of our website would have a map of Venice that had icons for the bell towers throughout the city. We needed a way to represent when the bell towers went off, so we decided that the bell icons for the ringing towers would flash, indicating bells ringing.

To build the main map, we used the Google Maps API (Application Programming Interface) in our code. We used the scripting language JavaScript to work with the Google Maps API and to customize the map to represent our data in the way we preferred. With the Google Maps API, one can create Google Map Marker Objects to represent different data points on the Google Map. We made a data point on the map for each bell tower so those towers would appear where they actually exist in the city of Venice.

In the JavaScript, we created all of the Google Map Marker Objects for each of the Venetian bell towers. We stored these Marker Objects in an array of objects called "markers", and set up each individual marker to have four main attributes. The first attribute was called "marker" which stores the information for creating a specific Google Maps-type Marker, including the latitude and longitude of the marker, which we obtained from our bell tower data, as well as the icon for this data point, which is simply a .PNG image given a size and a center in relation to Google Maps. The next attribute for the Marker Object was called "time" and was set-up to be an array of specific time objects. A time object could be created for each piece of data on time of ringing and stored in this time array.

Each time object has attributes for day, representing the day of the week, hour, and minute. The "day" attribute simply represents a day of the week Sunday-Monday represented by the numbers 0-6 (for example, 0 would represent Sunday). The "hour" attribute represents an hour 0-23 on the 24 hour clock, with 0 being midnight, 1 being 1:00 AM and so on. And the "minute" attribute is just as intuitive, where each minute 0-60 represents its corresponding minute on a regular clock. If the bell tower for that marker did not have any documented ringing times, then the time array was left empty.

The third attribute was named "hourly", and existed mainly to make it easier to store bell ringing frequency data on each tower. By using a key of 0 meaning that the tower does not ring on the hour, 1 meaning that the tower rings on the hour and on the half-hour, and 2 meaning that the tower rings just on the hour, many ringing times could be stored for the various towers without having to input every hour for every day of the week for all the different bell towers into the "time" array. The fourth and final attribute was simply "name" for storing the codice name of the tower so that it would be easy to find in the code and edit. The name attribute may be able to be used later for other purposes, but was useful to at least store for the time being.

With all of these Google Map Marker Objects stored, we could then write various functions in the JavaScript code to access their different attributes, and create a system where bells would light-up and chime based on the information that we had stored. By referencing the "time" and "hourly" attributes, we programmed in the code that if either of those fields matched up with the local Venice time (obtained from the browser's internal clock, and then calculated by doing simple arithmetic to determine the user's time zone difference from Venice) the tower's

icon would change to a green bell icon on a set interval to give the appearance of "flashing." We embedded a sound file in the code that changes the icon as well, so that a bell sound would play as the bells were ringing. We programmed a checkbox into the code so that this option could be turned off, if the user did not want to listen to the bell chiming.

We wanted users to be able to see the times when different bells lit up without having to wait for the actual ringing times. For this reason, we decided to implement sliders for the day of the week and the time of day so that users could control when they saw the bells ring, and discover the ringing times of various bells. To do this, we used JQuery, a JavaScript Library, which already had the tools for building functional sliders. We set the sliders to our specifications. We programmed the time slider to move in steps of fifteen-minute-increments, so that users would not have to scroll through every minute of the day to navigate to the time of their choice. If time data objects fell within these fifteen-minute intervals, we lit them up as well, so that all data would be represented.

Figure 31 Generic bell used for bell playing page on bells.veniceprojectcenter.org

We wished to provide users of our website with even more interactive information on the bells of Venice. And, we wanted some way to let users experience the sounds of all the different bells from the towers we visited so that they could play the bell sounds themselves and visualize how the bells of each tower related to one another.

To do this, we made a section within the website for playing the sounds of the bells of the towers that we collected sound data on. By using the sounds that we recorded from our visits to these towers, we paired those with our bell icon image, which was changed in size to represent the pitch of the bell whose sound it was paired with. To accomplish this, we wrote up some HTML code that contained all of the instances of the bell images for each bell. Then we set the "width" and "height" attributes of these images to give the bells their various sizes. In another JavaScript file, we wrote a simple function to embed a sound-file in the page when the bell icon was clicked by using the onClick() event. This function was designed to take in a sound file, so that the unique .mp3 audio file for each bell could be used. All that had to be done for this was to call our JavaScript function in the onClick() event in the HTML for each bell, and to pass the bell's particular audio file to this function.

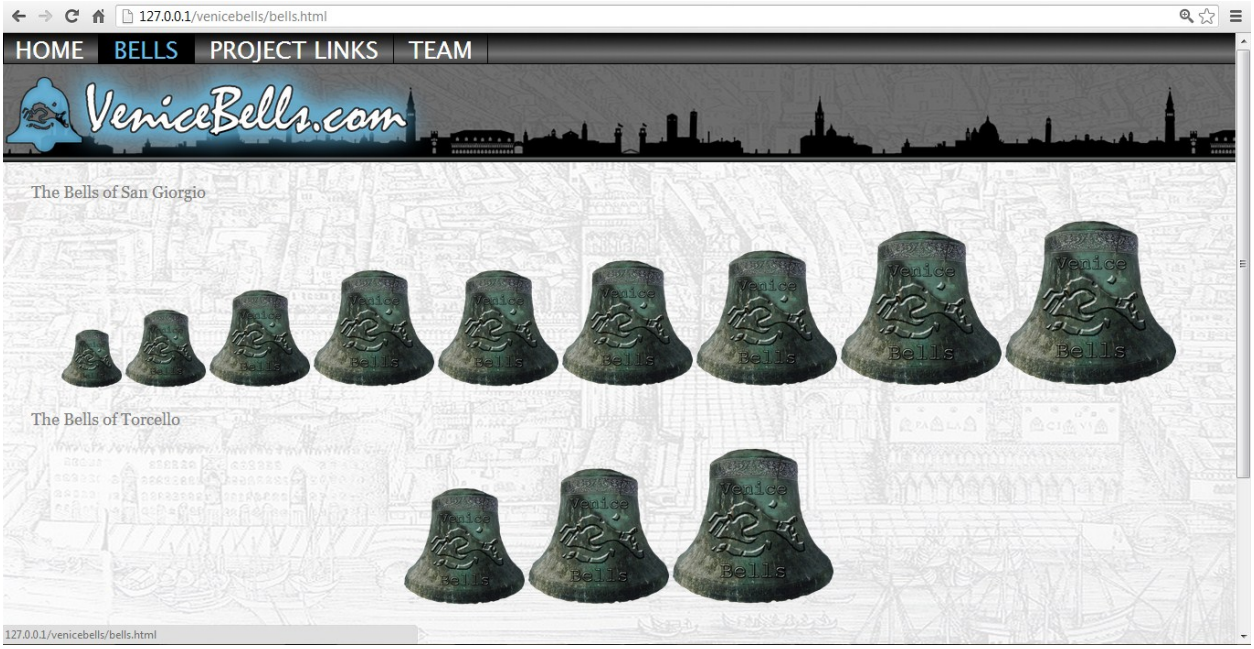

Figure 32 Bells playing page on bells.veniceprojectcenter.org

We also made it so that users of our site could go to the Project Links tab of the website to download our report, presentation, and master excel-spreadsheet of data. The Project Links tab contains links to our Venipedia pages, and our Google Sites website for our project as well. This was done using simple HTML coding, and by using anchor tags (<a>) to direct users to either URLs or files that we had uploaded to our server.

Once our website at VeniceBells.org was completed, we re-uploaded the entire site to bells.veniceprojectcenter.org so that it would be another subdomain of the overall Venice Project Center's site. With our code also available here, we made it so other teams would be able to edit and access it in the future.

3.3.3 PreserVenice Venice Public Art App

To distribute the information that we had collected and organized throughout the duration of our time in Venice, we wanted to make our data available through the UNESCO Public Art Application, which provides information on art such as coats of arms, wellheads, confraternity symbols, street altars, sculptures, and fountains. This application is available at preservenice.org and can also be downloaded to an Android smartphone. One benefit of having our data available via a mobile application is that it will be a portable source of information that will provide its users with an engaging way

Figure 33 Image of the Venice Public Art application displayed on an iPhone

to learn about Venetian bells and bell towers, as well as other artifacts.

The purpose of the application is to allow users to view the different works of public art throughout the city of Venice. Overlaid on a Google Maps image are different icons representing different types of art. By clicking on these icons, one can read more about the information on these pieces of art, as well as see where their locations are in the city of Venice.

We wanted to add bells and bell towers along with these by creating our own bell tower and bell icons and contributing those to the application as well. Because this app was already designed, we found we could easily add data using a CSV file from our spreadsheet. Because it is a mobile application, we needed to make a smaller CSV file with less information. We designed a mockup version for both a bell and bell tower page to see how it would look in the app as well as determine what information we needed. Like Venipedia, we could then upload our file to City Knowledge and automatically create the pages that would be added to the map for bells and bell towers.

4 Bell Towers of Venice

While in Venice we were only able to visit five bell towers, which isn't nearly enough to make assumptions about all of the towers. However, since the first project team in 1992, the Venice Project Center has collected at least some data on 43 of the 98 bell towers in Venice. While each tower does not have a complete set of data we can still look at the fields that we have information for.

4.1 Sestiere

Castello is the sestiere with the most bell towers at 18, while Burano, with only one tower, has the least. Technically speaking, there are several islands that have no bell tower at all, but of the islands that have bell towers, Burano has the least. Below is a graph showing the percentage of bell towers in each sestiere.

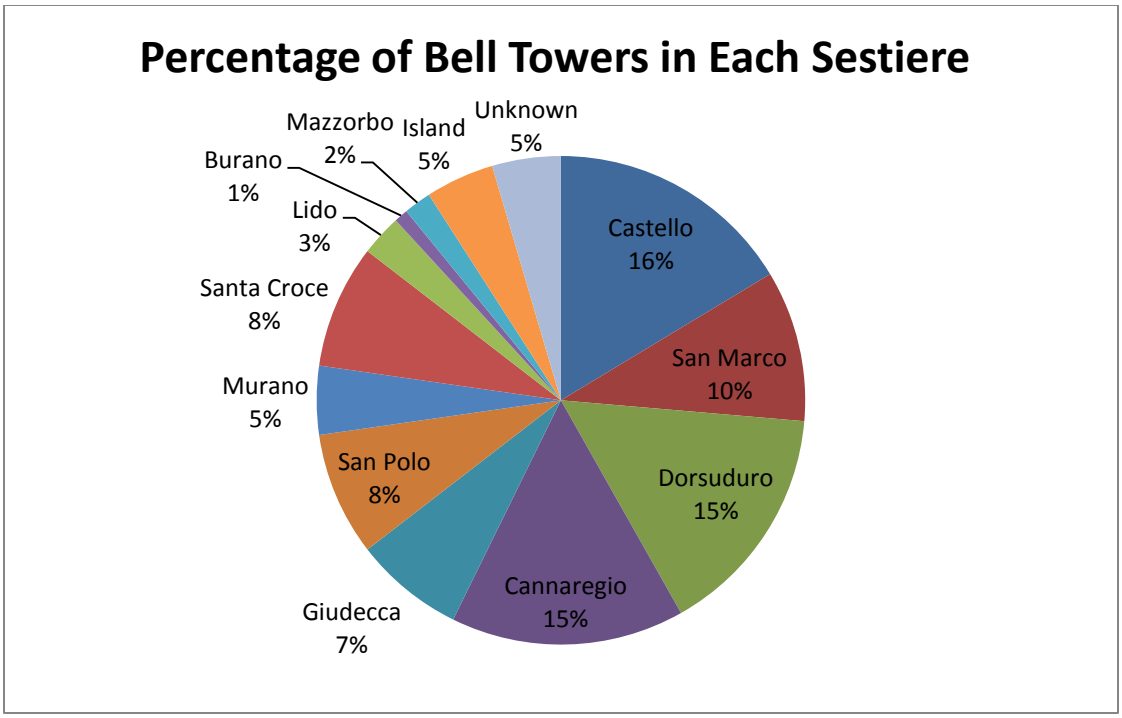

Figure 34 Pie chart comparing percentage of bell towers in each sestiere

As would be expected, the highest number of bell towers can be found on the main islands of Venice, particularly in Castello, Cannaregio, and Dorsuduro. The sestiere of Giudecca and Murano have almost as many bell towers as the main island districts of San Polo and Santa Croce. As is expected, the outlying islands have the lowest number of bell towers. Presumably the areas with a higher concentration of churches are in the areas with a higher population density.

4.2 Height

The shortest tower, Santa Eufemia, is only 10m tall. The tallest tower is San Marco, at a whopping 98m in height. Below is a graph of the various tower heights.

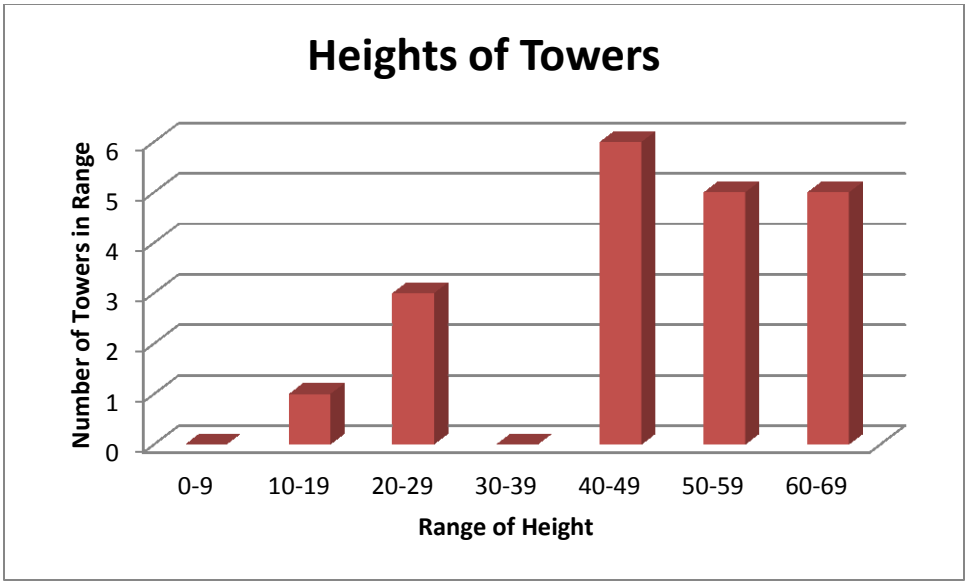

Figure 35 Graph displaying number of bell towers with similar heights

The majority of towers are between 40 and 70 meters tall. For a bell tower this makes sense because the ultimate goal is to be able to hear the bells from some distance away. Between 0 and 40 meters the sound would get obstructed by surrounding buildings and wouldn't travel very far. However, go too high and the sound has farther to travel and will dissipate considerably before reaching the ground. There are also a significant number of towers between 20 and 30m tall. Most of these are older towers, suggesting that they were built as high as possible for that time period.

4.3 Bells per Tower

The tower of San Giorgio di Maggiore has 9 bells, the most in the city. With only two bells, Santa Maria di Nazateth Scalzi has the least. Once again, there are towers with no bells, but those are not included in the count. A graph with the number of bells in each tower is below.

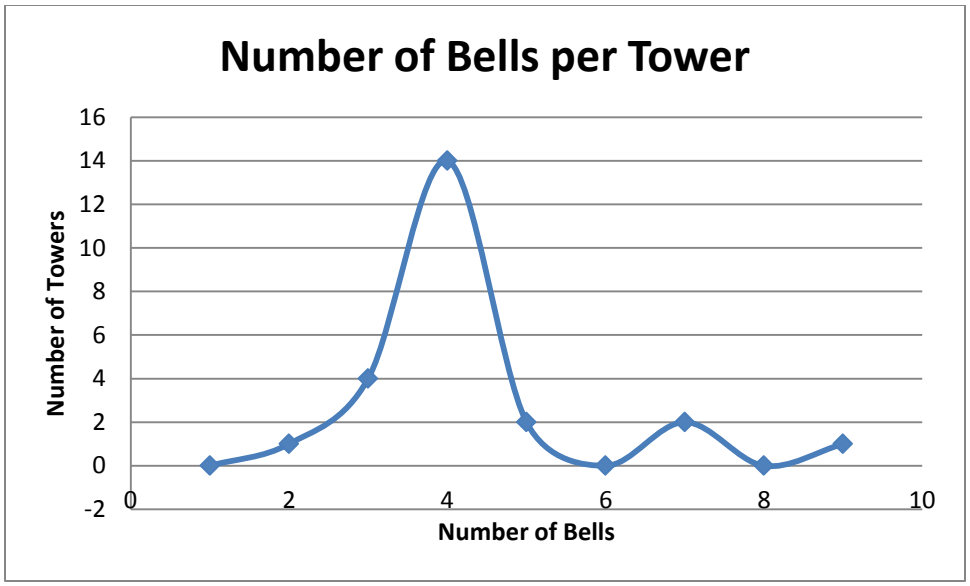

Figure 36 Graph showing number of bells in every tower

Interestingly enough, the number of bells per tower forms an approximate bell curve peaking at 4. The reason for that is most likely musical. Three notes create a chord. In most cases, changing only one note in the chord can produce an entirely different sound. While three bells can produce one chord, having four means the tower can ring four different chords by changing which bell is silent. Another possibility is the size and shape of the belfry. Many of the towers have square belfries. Bell hangings are large and cumbersome, so having more than one per side may not be possible in some cases.

4.4 Bell Tower Venipedia Pages

After we compiled all of our data on the bell towers of Venice we created a number of Venipedia pages to display this information. As discussed in Section 3.3.1, there were aggregate, typical, and individual Bell Tower pages.

The aggregate Bell Towers page (Appendix B-1) gives an overview of all of the bell towers in Venice and was created manually. It contains information about the total number of towers, their location, how many are in each sestiere, the heights of various towers, and the number of bells in each tower.

The typical Bell Tower page (Appendix B-2) was created manually and contains information about a typical Venetian bell tower. It describes the different aspects of tower structure such as Base, Shaft, Belfry, and Roof, the different architectural styles of the towers, and issues affecting bell tower maintenance. An interactive Google Map is also included, showing the location of the bell towers in Venice.

The 109 individual bell tower pages (Appendix B-3) are each about a specific bell tower. Key information for each page includes: age, architecture type, dimensions, accessibility to the public, video of the view at the top of the tower, location on a map of Venice, owner or persons

in charge (either of bell tower or of the church), and pictures of the bell tower. It also contains links to both the church it is affiliated with and to all of the bells contained within the tower.

4.5 Bell Tower Map on Bells.VeniceProjectCenter.org

A main component of our project was to create a website under the URL bells.veniceprojectcenter.org. One goal of this website was to provide users with easy access to all of the collected information for this project, but it was also created to display some of our data about the bell towers of Venice in a fun and interactive way.

The website features an interactive map of Venice, created using the Google-Maps API with icons for all of our documented bell towers. This map allows users to visually experience the ringing times of the Venetian bell towers. While bells are ringing in real time they are also highlighted on a map. We have 109 different data points of bell tower locations on the map within the website.

Figure 37 Interactive time map displayed on the bells.veniceprojectcenter.org homepage

Based on the data that we have collected and organized, these bell icons light up and flash green when the bells are ringing. This was determined by checking the time on the clock, and comparing it to the times that the bells rang from our data. If the two were the same, the bells blink green at that time for a duration of five minutes. We found in our data that many of the clocks in the towers were slightly skewed, so if a bell happened to ring at 9:04 a.m., we rounded the time to 9:00 a.m. A bell sound will also go off each time the bells light up to represent the sound of bells ringing, however this can be turned off by unclicking the checkbox at the bottom of the page labeled "Bells On."

There is also the option to navigate to specific days of the week and specific times to see which bells will be ringing. To do this, there are time and day sliders so that the user can scroll to a specific day and time to see which bells ring and where they ring. When the user selects a time and day where bells are ringing, the bell icons for those towers are highlighted in blue.

The code for the website is easily expandable and modifiable, so that future teams can input data into the map and make the site an even more extensive source of knowledge about bell towers.

4.6 Bell Tower Pages on the PreserVenice App

By clicking on the bell icons, placed in their actual locations on the Google Map, users will be able to see all of our known data about those bell towers through the UNESCO Public Art Application. Once the user navigates to the particular bell tower he or she is looking for, all of the information on the tower as well as links to its bells will be available on the page.

Because of the format of the application, the information displayed is less than what is on our Venipedia pages. It includes both the sestiere and the church affiliation so the user can find it easily. It also displays some general information on the page such as height, date of construction, architect, material and number of bells in the tower. If there is a field without information, it displays "n/a". There are two sections for links at the bottom of the page: links to the tower's bells and a link to Venipedia. Each of the bells is numbered according to the Venipedia numbering system, consistent with our data. In addition, the link to Venipedia will bring the user to the Venipedia page specific to the tower.

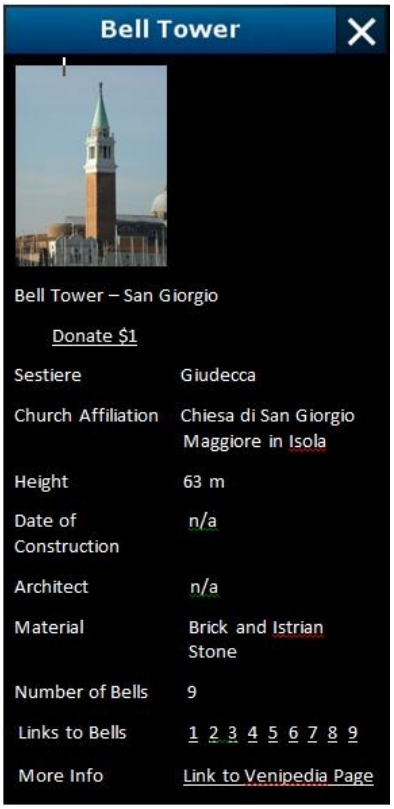

Figure 38 Mockup of bell tower page for the PreserVenice Public Art App

5 Bells of Venice

The conclusions made from data collected by us and previous research tell us about the conditions of the bells, what aspects they have in common, and important facts such as age, number, and size. By examining the data collected thus far, we can better generalize the information on the all bells in Venice and look for trends or similarities that they may have in common. This will provide us with a better idea of strategies used for deciding what and how many bells are required and may also help us predict when restoration is needed.

5.1 Bell Sizes

Venice has 203 bells spread throughout the city. The largest bell documented is bell 2 of Sant' Elena with a diameter of 152 cm, and the smallest bell documented is bell 4 of San Nicolò dei Mendicoli with a diameter of 21 cm.

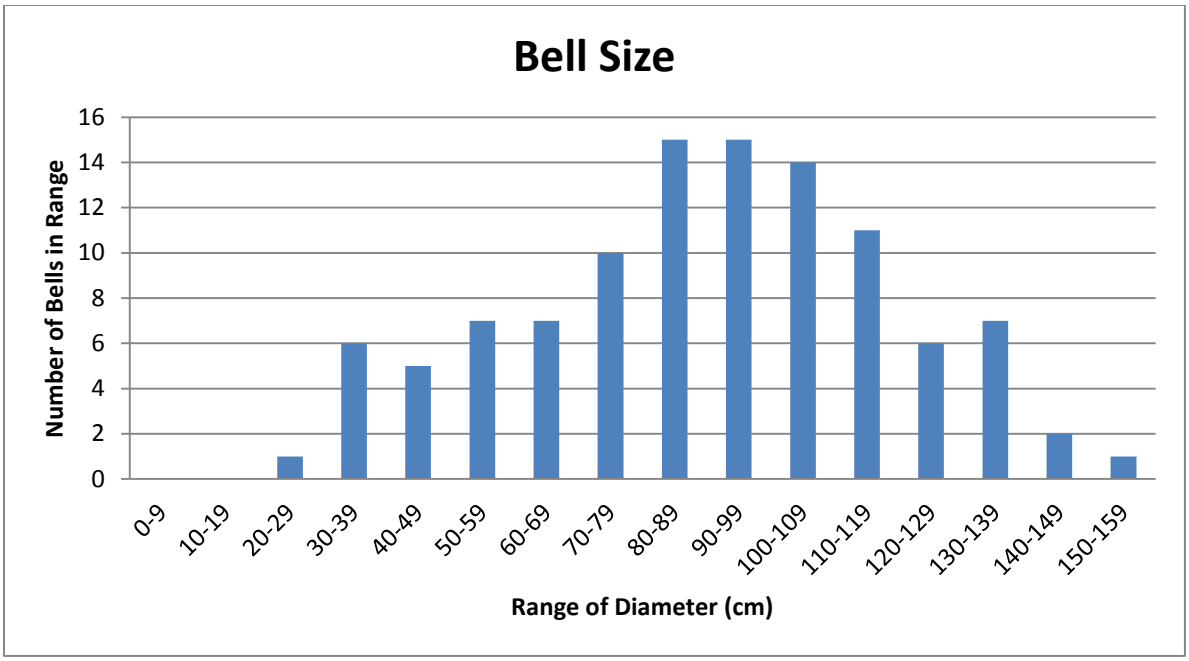

Figure 39 Graph showing the number of bells which have a diameter in each range

From the graph above, it can be determined that the most frequent size for the diameter of a bell is from 80 to 99 cm.. Ironically, the shape of the graph resembles a bell curve. The average ratio of diameter to internal bell height is 1.22 cm with a standard deviation of .106 cm. Therefore, the size of the bells may vary, but the shape is similar for all bells in the city.

5.2 Ringing Methods

The ringing method is the same for most bells in the city of Venice. Hammer and wheel are the primary types of ringing. However, wheel is most common, as 87% of the bells in Venice are rung by wheel. The second most common, are bells rung by both wheel and hammer, which is 12%. The graph below gives an idea of the popularity of these ringing mechanisms for the bells of Venice:

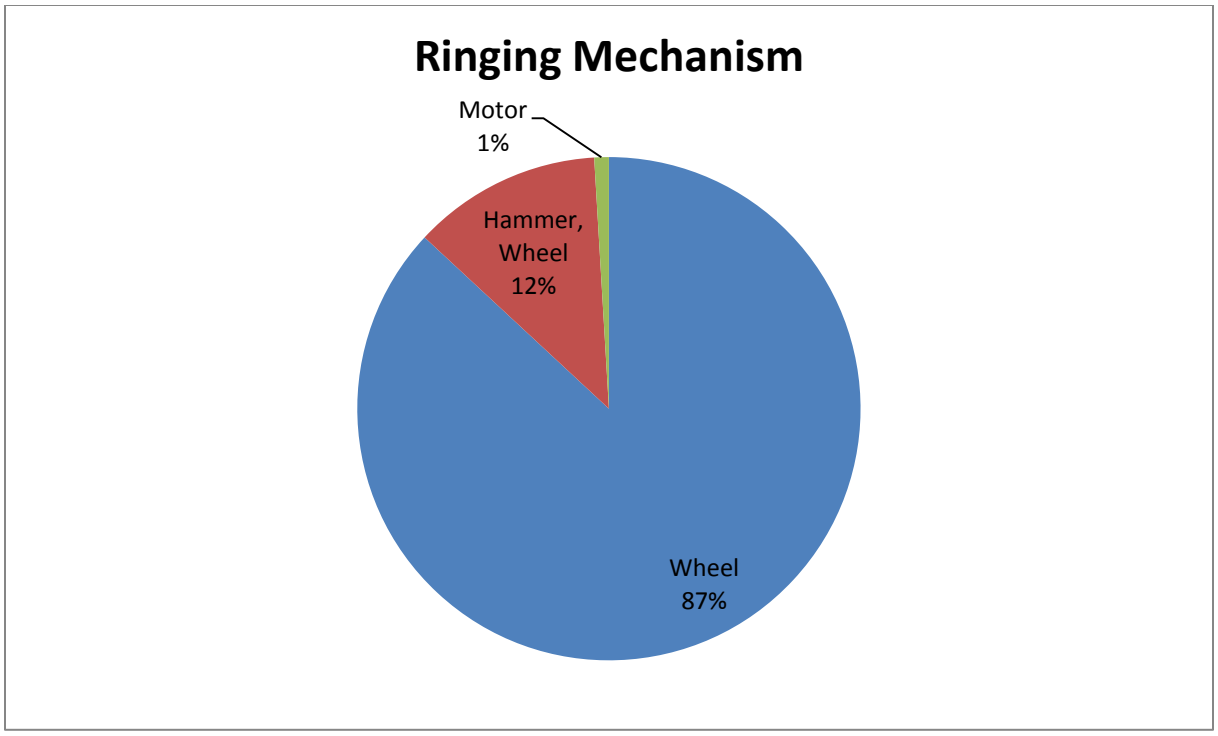

Figure 40 Pie chart displaying percentage of bells rung by each method

5.3 Bell Condition

Because we believe bells to be an integral part of the material culture of Venice, it's important to track the conditions of bells so it is possible to determine when and how much renovation is needed. As discussed before, the materials that they are made from, although durable, are still vulnerable to chipping and cracking, discoloration, and rust. Our team and past teams have rated these criteria on a scale of 0 to 4: 0 meaning there is no need for restoration and 4 meaning that restoration is urgent.

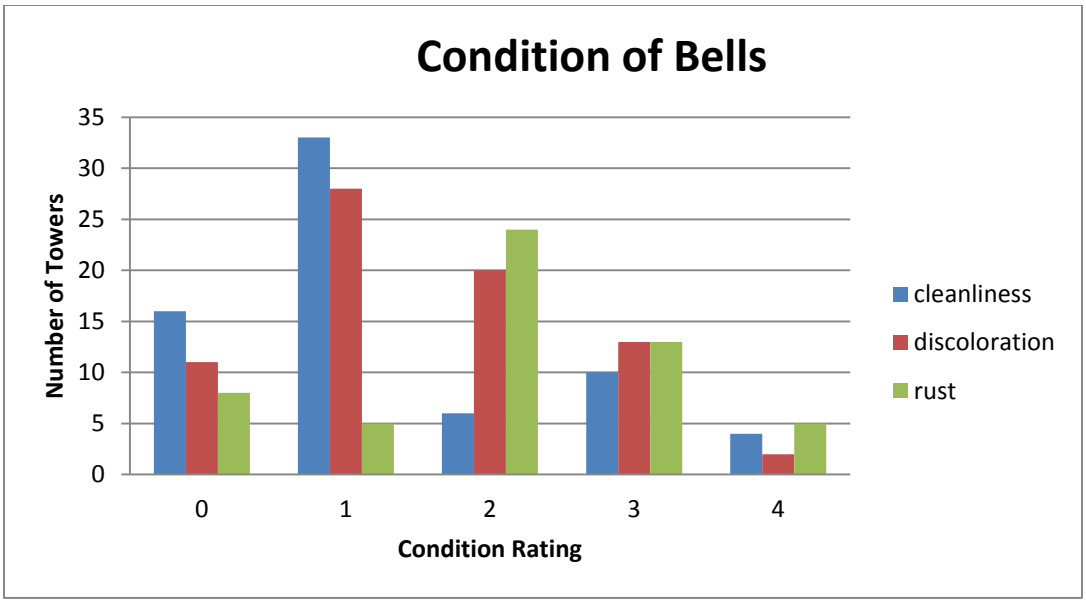

Figure 41 Graph comparing number of bells with certain conditional rating for cleanliness, discoloration, and rust

The majority of the bells measured thus far have had a conditional rating of 1 for both cleanliness and discoloration. This means that there is some, but not a problematic amount. Rust had a slightly higher common rating of 2 which still is not very problematic. The ones that need restoration should have rating of 4 for each category. Luckily, there are 5 or less bells for each of the categories that had ratings of a 4. There seems to be little correlation between the three categories. Where there seems to be a great number of bells with a certain rating for one category, there may only be a few rated the same for a different category. Perhaps, when considering a bell for restoration, one may only have to confront one problem. However, from our data we found some bells with a rating of 4 in all categories, such as those in the bell tower of San Silvestro. Future groups may want to revisit the tower to determine if restoration is needed.

5.4 Bell Venipedia Pages

There are several Venipedia pages containing information relevant to bells. There are aggregate, typical, and individual Bell pages, as discussed in Section 3.3.1.

The Bell aggregate page (Appendix B-4) was created manually and contains an overview of all of the bells in Venice. This page includes statistical information such as how many there are, how big they are, how they are rung, and what condition they are in.

The next page is the typical Bell page (Appendix B-5). This page was also created manually and includes information regarding a typical bell in Venice. Information on this page includes: a discussion on the different materials and methods used for casting the bells, the variations in types of frames bells are hung from, the anatomy of a typical bell, an overview of common bell decorations, and a section on bell degradation and maintenance. As with the Bell Tower page, an interactive map showing the bells' locations in Venice has been included.

The Bell Ringing page (Appendix B-6) discusses the swinging systems and types used in Venice, with external links to other systems and types. It also introduces the concept of automated ringing, since the majority of the bells today are not rung manually.

Using the City Knowledge console, we were able to automatically generate 214 individual bell pages (Appendix B-7). For the individual bell pages pertinent data includes: the pitch of the bell, the material used to cast the bell, pictures of the bell, documentation of artwork or inscriptions on the bell, whether it is manual or mechanical ringing, the time of day it rings, video and audio of the bell ringing, and a link to the bell tower it is associated with.

5.5 Bell Playing Component of Bells.VeniceProjectCenter.org

Another feature of our website is a section for playing the sounds of the bells from San Giorgio, Torcello, and San Giobbe. By using the sounds that we recorded from our visits to these towers, we paired those with our bell icon image, which was changed in size to represent the pitch of the bell whose sound it was paired with. With our site, users can listen to the sounds of the nine bells of San Giorgio, the three bells of Torcello, and the four bells of San Giobbe. Not only does this allow users to get to experience the actual sounds of different Venetian bells, but they can see how the bells of individual towers relate to one another. This part of the site provides a visual way to see the bells of these three towers in relation to the sounds that they play. For an image of the page on the website, see Appendix C-2.

5.6 Bell Pages on PreserVenice App

After navigating to the bell tower page from the bell icon on the UNESCO app there is a link to each of the bells that can be found in that particular bell tower. Basic information such as the dimensions of the bell, ringing method, and the ringing frequency are available on the page. If the user wishes to know more about the particular bell then all they need to do is go to the link provided to the bell's specific Venipedia page.

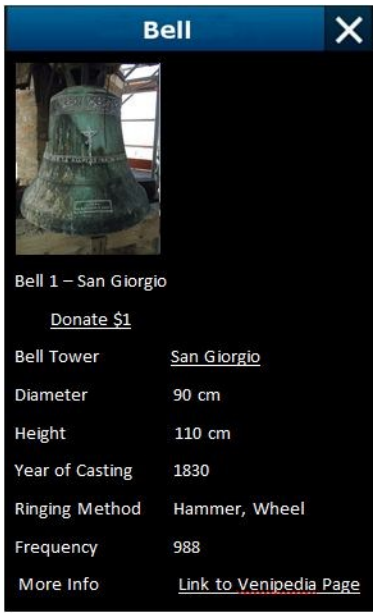

Figure 42 Mockup of bell page for PreserVenice Public Art App

6 Conclusions/Recommendations

There are still 55 towers left to be visited by the Venice project center. However, we believe that future studies on the bells and bell towers of Venice will find our data and user applications helpful in their endeavors. Over the past seven weeks, we have worked to increase our knowledge of bells and bell towers and share it with the public. We have immersed ourselves into the project by brainstorming ideas to achieve our mission; organizing, collecting, and analyzing our data; preparing Venipedia pages; and designing our website. Bells are not only important to us, but are also critical to the history and culture of Venice. By achieving the

objectives described above, we hope to preserve the bells as a part of material culture by reconnecting the public with the bells of Venice.

Some of our major accomplishments were preparing the data, media, and Venipedia pages for future students to use and improve upon. Time constraints, however, restricted the amount we could achieve. From our work in Venice, we came up with a few suggestions along the way for potential deliverables that future project center groups might find helpful.

6.1 Getting Access to Towers and Planning Data Collection

Gaining access to towers over the course of our project proved to be very difficult, as church officials, as well as others in charge of the bell towers are worried about the liability and the safety of allowing students into the towers. We hope that our work this term will prove to those granting access that WPI students are both professional and dedicated to the study of the bells of Venice. However, future groups should plan on visiting only three to six towers while in Venice.

We believe that there is still a great deal of work to be done even without access to the towers. There is external data missing for at least 57 towers. Groups should consider taking trips to these towers and collecting what they can even without interior access. Another contribution students can make without having access to the towers is cataloguing when the bells ring. This can be difficult because in most cases, not even the priests always know when the bells are rung. Some ways this can be done are by word of mouth or by going to towers on the hour or half hour, when it is most likely that its bells will be ringing. This is something that we began to do this term but could not finish. Whatever information is gathered on this subject in the future can be added to our interactive map of the bell ringing times, as discussed earlier in 4.3.2, found at bells.veniceprojectcenter.org. Once the additional data of bell ringing times is collected, all that is needed is for the times to be put into the JavaScript file named “map2.js” where the data-points of the towers are stored.

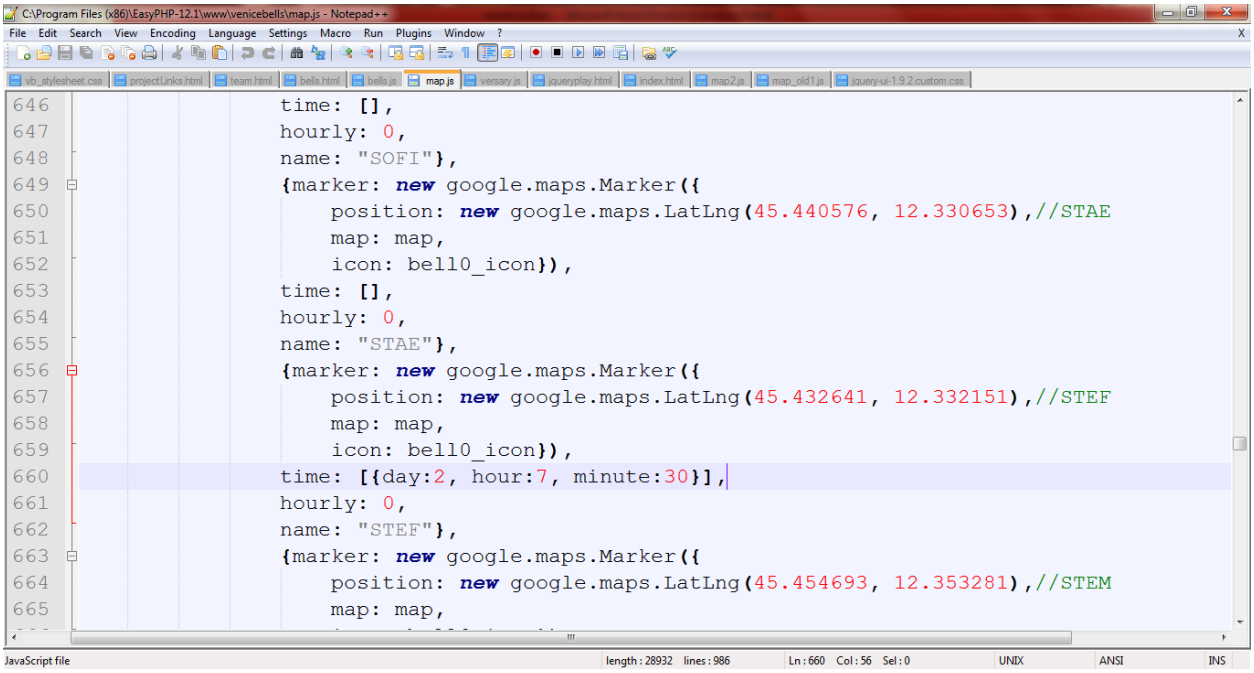

Figure 43 Image of the JavaScript file "map2.js"

Each bell tower is a Google Maps Marker Object, and has an attribute for ringing times called “time”. Time keeps an array that is composed of specific time-objects. These objects have attributes for “day”, “hour”, and “minute”, respectively. By following the format from the figure above, it is easy to input the ringing-time data for the appropriate tower. The “day” attribute simply represents a day of the week Sunday-Monday represented by the numbers 0-6 (for example, 0 would represent Sunday). The “hour” attribute represents an hour 0-23 on the 24 hour clock, with 0 being midnight, 1 being 1:00 AM and so on. And the “minute” attribute is just as intuitive, where each minute 0-60 represents its corresponding minute on a regular clock.

Future groups can edit this code on bells.veniceprojectcenter.org, where our contributions on this topic will be save for all future groups to add to and expand upon.

6.2 Altering Data Collection Forms

When visiting the towers, we collected data using the forms from past projects. However, it became clear that a few of these forms were no longer necessary. For instance, one of the forms had to do with describing each photo taken and labeling it with which roll of film it was taken on. Graphics and audio from each instrument were stored on their own respective SD cards so there was no need to keep track rolls of film. For pictures taken of each bell, there was a preceding photo in which we showed the bell number with our fingers. If it was necessary to also catalog the side it was taken on, we started from the front side and then took consecutive pictures in a clockwise direction, so we knew which side each picture was taken from. There was an additional form for collecting photos and videos which had a large box with each side labeled

front, left, right, back. We also neglected to use this sheet because we did not find it to be very intuitive or easily understandable.

As for future groups collecting data in the towers, we would recommend altering the forms based on the data already available from previous projects. There has already been quite a lot of information collected. If the group is only revisiting a bell tower, they may want to use a second type of form that is shorter and only tries to fill in gaps where there is no information, or where information is not as accurate. This would prevent the group from performing redundant work and give them more time to update the media on the tower with photo, video, and audio recordings.

6.3 Adding to the Mobile Application

One deliverable for our project was to add all of the bell and bell tower data to the Venice Public Art application sponsored by UNESCO. One possibility for future groups to explore would be adding specific functions to the application for the bells and bell towers. Then, the app could be a source of information as well as a tool for collecting information. There could be a function for users to help with data collection, whether it is taking pictures and videos, or recording the ringing of the bells. These would make a great addition to the website which could hold a gallery of the pictures and media taken of or at different bell towers. Another possible function for the application could be a Shazam-like feature that would tell you what bell or bell tower is ringing. However, because the bells sound so similar, it might be better for the app to determine which bell tower is ringing by using location and the radius of sound of the bells. This data could also help determine what day and time certain bells or bell towers ring throughout the city.

6.4 Making a Fundraising Plan

People have stopped caring about the bells in Venice because they cannot physically climb up to the top and see all of the bells and the views of Venice. A future goal would be to help the churches associated with these bells obtain more funding for the maintenance of their bell towers. It would be interesting to determine whether it is economically beneficial for the churches if people were allowed access to the bell towers. Future groups may also want to determine whether churches could potentially renovate their bell towers using the income gained by giving access to the public. The information collected by our project and the projects before us could be put to use by the churches and the people visiting the towers.

To accomplish this goal, we would recommend contacting the people who oversee the bell towers at San Marco and San Giorgio Maggiore. From there, you may be able to obtain information concerning the costs incurred to renovate and the operating costs to run the tower as well as income from visitors. One of the potential downfalls of opening another tower could be location. If a church is off the beaten path, not many people will visit. Another negative may be that churches do not want all these tourists to visit or that they would need to have someone to guide tours up to the towers. However, one of the biggest concerns of the churches that we know of is that the towers are not safe. For some towers, climbing up the stairs is dangerous and for

others, the belfries are not sanitary. The church may have to invest in repairing the towers to remove these safety concerns before allowing people to go up into them.

To accomplish the task of giving people access to the towers, we would recommend proposing to the priests of several churches a plan to provide access for a fee to those who want to go and see the bells up close. From this fee the churches may then save money for renovations from the crowds of tourists who visit Venice each year as well as from history and art enthusiasts who would have never had the chance to see the Venetian church bells until now.

6.5 Analyzing the Bell Recordings

An integral part of our project was introducing the use of the Tascam recorder in our data to provide high quality sounds of the bells. After taking these recordings, we determined the musical note of the bell when it is first struck. However, once there is enough data, it would be interesting to find any trends in the musicality of the bells. For instance, one could analyze if there are common chords that the bells may make when played together because most towers have three to four bells.

It may also be useful to determine the radius in which the bells can be heard, which can be determined mathematically. However, one should also account for sound reverberating off of buildings. This may help with creating a function for the Venice Public Art mobile application that would allow someone to determine what tower they are hearing bells ringing from. This could be accomplished by analyzing their current position in relation to the location of the tower.

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Appendix A: Where to Find Our Data

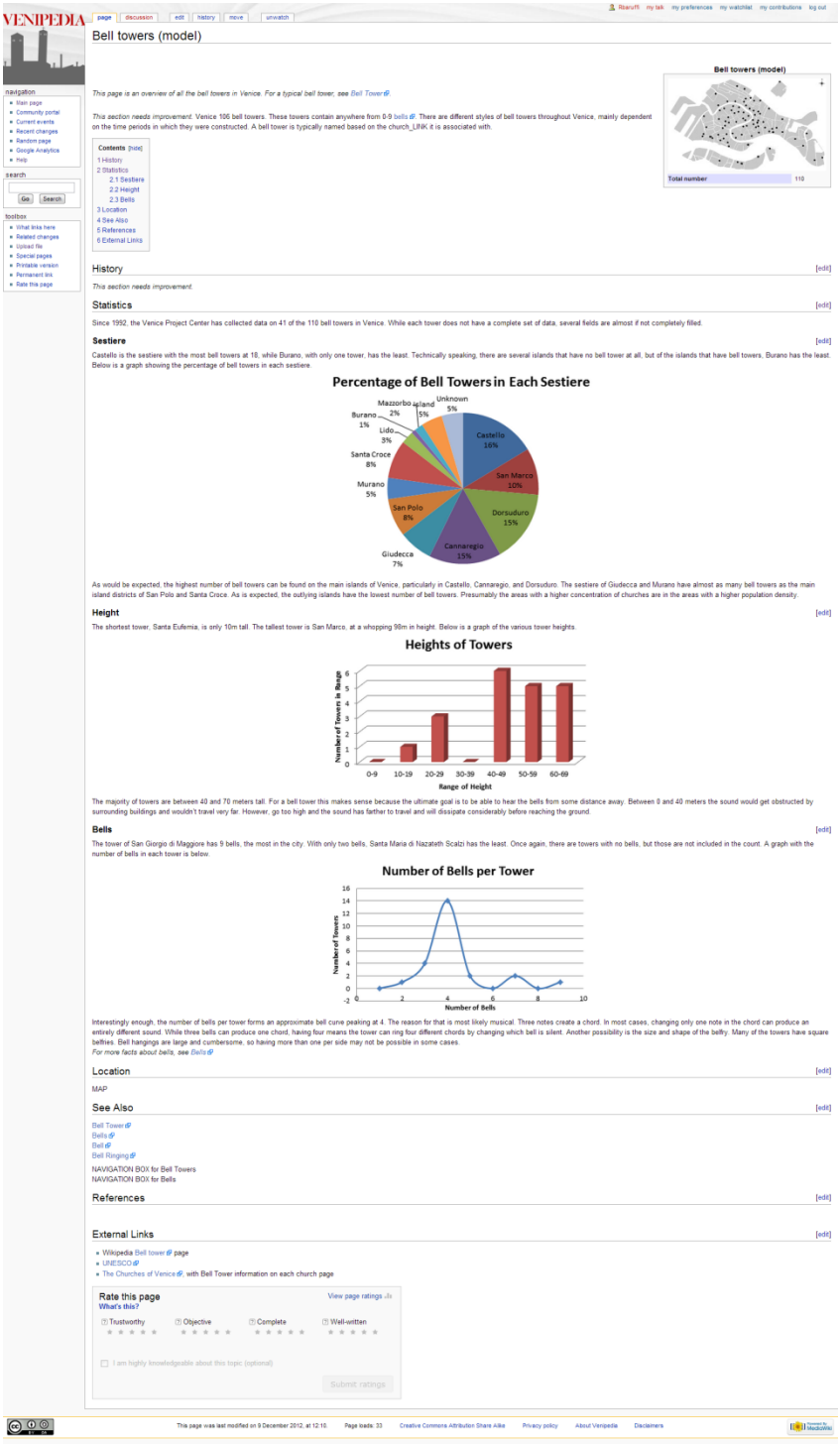
In Worcester: Loaded onto a CD in the office of Professor Fabio Carrera

In Venice: Printouts and loaded onto a CD stored in the Venice Project Center

Online: bells.veniceprojectcenter.com/projectLinks.html

Appendix B: Venipedia Pages

B-1: Bell Towers page



VENIPEDIA

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Bell towers (model)

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search
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Bell towers (model)

Total number 110

This page is an overview of all the bell towers in Venice. For a typical bell tower, see Bell Tower.

This section needs improvement. Venice 106 bell towers. These towers contain anywhere from 0-9 bells. There are different styles of bell towers throughout Venice, mainly dependent on the time periods in which they were constructed. A bell tower is typically named based on the church_LINK it is associated with.

Contents [hide]
1 History
2 Statistics
2.1 Sestiere
2.2 Height
2.3 Bells
3 Location
4 See Also
5 References
6 External Links

History [edit]

This section needs improvement.

Statistics [edit]

Since 1952, the Venice Project Center has collected data on 41 of the 110 bell towers in Venice. While each tower does not have a complete set of data, several fields are almost if not completely filled.

Sestiere [edit]

Castello is the sestiere with the most bell towers at 18, while Burano, with only one tower, has the least. Technically speaking, there are several islands that have no bell tower at all, but of the islands that have bell towers, Burano has the least. Below is a graph showing the percentage of bell towers in each sestiere.

Percentage of Bell Towers in Each Sestiere

As would be expected, the highest number of bell towers can be found on the main islands of Venice, particularly in Castello, Cannaregio, and Dorsuduro. The sestiere of Giudecca and Murano have almost as many bell towers as the main island districts of San Polo and Santa Croce. As is expected, the outlying islands have the lowest number of bell towers. Presumably the areas with a higher concentration of churches are in the areas with a higher population density.

Height [edit]

The shortest tower, Santa Eufemia, is only 10m tall. The tallest tower is San Marco, at a whopping 98m in height. Below is a graph of the various tower heights.

Heights of Towers

The majority of towers are between 40 and 70 meters tall. For a bell tower this makes sense because the ultimate goal is to be able to hear the bells from some distance away. Between 0 and 40 meters the sound would get obstructed by surrounding buildings and wouldn't travel very far. However, go too high and the sound has farther to travel and will dissipate considerably before reaching the ground.

Bells [edit]

The tower of San Giorgio di Maggiore has 9 bells, the most in the city. With only two bells, Santa Maria di Nazareth Scalzi has the least. Once again, there are towers with no bells, but those are not included in the count. A graph with the number of bells in each tower is below.

Number of Bells per Tower

Interestingly enough, the number of bells per tower forms an approximate bell curve peaking at 4. The reason for that is most likely musical. Three notes create a chord. In most cases, changing only one note in the chord can produce an entirely different sound. While three bells can produce one chord, having four means the tower can ring four different chords by changing which bell is silent. Another possibility is the size and shape of the belfry. Many of the towers have square belfries. Bell hangings are large and cumbersome, so having more than one per side may not be possible in some cases.

For more facts about bells, see Bells

Location [edit]

MAP

See Also [edit]

Bell Tower
Bells
Bell
Bell Ringing

NAVIGATION BOX for Bell Towers
NAVIGATION BOX for Bells

References [edit]

External Links [edit]

- Wikipedia Bell tower page
- UNESCO
- The Churches of Venice, with Bell Tower information on each church page

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B-2: Bell Tower page

VENIPEDIA

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Bell Tower

This article contains information about a typical Venetian bell tower. For an overview of all the bell towers, see Bell Towers.

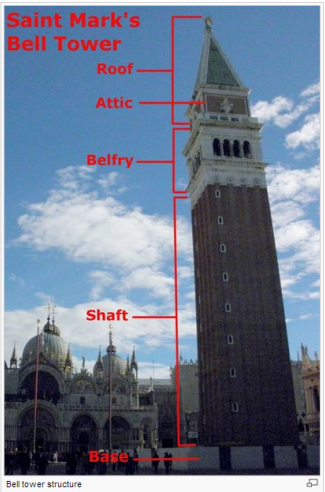
This section needs improvement.

A Venetian bell tower, known in Italian as *campanile*, is used to house many bells. A bell tower is typically named based on the church_LINK it is associated with.

Contents [hide]

Bell Tower Structure [edit]

There are four main components to the structure of a bell tower: base, shaft, belfry, and spire. Each of these contributes to the overall style and integrity of the tower.



Bell tower structure

Base [edit]

The main purpose of the base is to maintain the structural integrity of the tower. The walls at the base of the tower are often thicker than those at the top. Non-porous materials are used so that it is resistant to salt water from flooding and heavy enough to withstand the pressure from the weight of the tower.

Shaft [edit]

The shaft is the part that contributes to the height of the tower and contains stairs, ramps, and landings that lead to the belfry. It is usually constructed of brick and mortar, which varied in strength based on the year that it was constructed. Brick makers improved upon the method for making bricks so that bricks could withstand a greater amount of pressure. In addition, to provide the tower with greater flexibility and support, some towers were built using metal rods.

Belfry [edit]

The belfry, located above the shaft, contains the bells and usually some type of landing. On the exterior, it is generally the most ornate part of the tower, built using brick and other types of stone or clay. Typically, there are windows or arched openings that let light through and occasionally netting to keep pigeons from entering. The bells are hung from the top of the belfry with wood, although some newer towers use metal. It has been found, however, that the vibration of the bell through the metal to the walls increases deterioration.

Roof [edit]

Above the belfry there may be an attic which provides additional storage or access to the top of the tower for maintenance. There may also be a balustrade, or a balcony with a railing that runs around the outside of the attic. This is usually accessible from the attic, so that one may enjoy a more expansive view and have additional access to the roof. To get to the attic, there is either a ladder or stairway.

The spire varies depending on the tower, but it can have many shapes: conical, pyramidal, bulbous, and others. There also may be a lightning rod or weather vane at the top of the tower.

Architectural Style [edit]

Like most buildings, there are many different styles of tower architecture. Over the centuries many of the towers have seen numerous renovations resulting in overlapping styles, causing the original style to be virtually indistinguishable. Their eclectic nature reflects the city's history and the diverse ideas that evolved in Venice. Overall, bell towers contribute a great deal to the ambiance of the city.

For more information on architectural styles, see external_LINK.

Bell Tower Maintenance [edit]


Earthquake destruction

This section needs improvement

Catastrophic events such as earthquakes and flooding do not frequently cause any major damage, but deterioration is possible if the bell towers are not maintained properly. Although modern technology has reduced the need to ring the bells manually, it has resulted in people being removed from the process of maintaining those bells and their towers.

Location [edit]

MAP

See Also [edit]

Bell Towers
Bells
Bell
Bell Ringing
Church_LINK

NAVIGATION_BOX for bells
NAVIGATION_BOX for bell towers

References [edit]

External Links [edit]

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B-3: Bell Tower – San Geremia

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Bell Tower - San Geremia

The bell tower of San Geremia is located in the city district (sestiere) of Cannaregio and is part of the San_Geremia_church_LINK. It was constructed in 1147 by Doge Sebastiano Ziani, after the church was already built. In 1355, the tower was reconstructed to be taller, and in 1848, it was renovated after a fire caused by Austrian shelling. The tower follows the Romanesque and Gothic styles of tower construction. It is considered to be in fairly good condition. The front of the bell tower, which is aligned with the front of the church, has a compass bearing of 43°, meaning left side has a bearing 133°, the back a bearing of 223°, and the right a bearing of 313°. When referencing details of the tower, these names for each of the sides will be used. The tower overlooks the Campo San Geremia and it is located next to the church along the Cannaregio canal, but it is not accessible to the public.

Contents [hide]
1 Foundation
2 Shaft
3 Belfry
4 Roof
5 View from the Bell Tower
6 Location
7 Bells
8 See Also
9 References
10 External Links


San Geremia bell tower

Foundation [edit]

The dimensions of the foundation are 4.3x4.5 meters and the material of the base is brick. There is a door on the left side of the tower which is not accessible from the street, but only the church. The height of the door is 172 cm and the width is 84 cm. IMAGE (The door to the tower)

Shaft [edit]

The shaft is constructed with brick and Istrian stone, there is no exterior clock on any facade, and there are 3 lessene. It is considered to be in the Romanesque style. There are wooden stairs leading up to the belfry of the tower, with landings periodically. It can be generally described as about 10 stories high. Windows are double arched. There is rose-like design for a support beam on a Roman archway featured on the back side.


Belfry [edit]

The belfry is constructed of brick and Istrian stone. There are 2 arches for windows on each side of the tower. Above the belfry, there is an octagonal drum, which includes an attic and a balustrade made of Istrian stone. The architecture of the belfry is classified as Gothic.


Roof [edit]

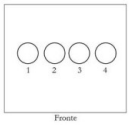
The roof is metal and includes a weathervane, finial, and lightning rod.

View from the Bell Tower [edit]

Location [edit]

Bells [edit]

San Geremia contains four bells arranged in a straight line that are supported by an iron frame that is in good condition. The bells were originally rung manually, but renovations in 1984 removed a broken bell and converted all of them to an automatic ringing system. The broken bell is now located inside the church. The diagram below show the placement of the bells within the tower. For more information on each of the bells, see Bell 1, Bell 2, Bell 3, and Bell 4.



Fronte

See Also [edit]

Bell 1
Bell 2
Bell 3
Bell 4
Church - San Geremia

NAVIGATION BOX for bell towers
NAVIGATION BOX for bells

References [edit]

External Links [edit]

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B-4: Bells Page

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Bells (Model)

This page is an overview of all the bells in Venice. For a typical bell, see Bell.

This section needs improvement.
Venice has 203 bells spread throughout the city.

Contents [hide]
1 History
2 Statistics
2.1 Bell Sizes
2.2 Ringing Methods
2.3 Bell Condition
3 See Also
4 References
5 External Links

History [edit]

The beginning of bells dates back to 132 A.D. in China.The idea came from a Chinese philosopher by the name of Chang Heng, who invented the first known earthquake detector.

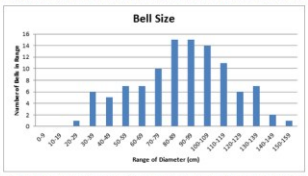
For more information about bell history, see external_LINK.

Statistics [edit]

Venice has 203 bells that have been documented, spread throughout the city. The conclusions made from data collected tell us about the conditions of the bells, what aspects they have in common, and general info such as age, number, and size. By examining the trends for the conditional ratings of bells, it is possible to determine the urgency for renovation. We can also see if this has any relation to the founder or the date of casting of the bells.

Bell Sizes [edit]

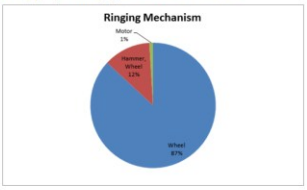
The largest bell documented is bell 2 of Sant' Elena with a diameter of 152 cm, and the smallest bell documented is bell 4 of San Nicolò dei Mendicoli with a diameter of 21 cm.



From the graph above, it can be determined that the most frequent size for the diameter of a bell is from 80 to 99 cm. Ironically, the shape of the graph resembles a bell curve. The average ratio of diameter to internal bell height is 1.22 cm with a standard deviation of .196 cm. Therefore, the size of the bells may vary, but the shape is similar for all bells in the city.

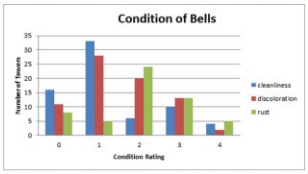
Ringing Methods [edit]

The ringing method is the same for most bells in the city of Venice. Hammer and wheel are the primary types of ringing. However, wheel is most common, as 87% of the bells in Venice are rung by wheel. The second most common, are bells rung by both wheel and hammer, which is 12%. The graph below gives an idea of the popularity of these ringing mechanisms for the bells of Venice.



Bell Condition [edit]

Because bells are an integral part of the material culture of Venice, it's important to track the conditions of bells so it is possible to determine when and how much renovation is needed. As discussed in Bell, the materials that they are made from, although durable, are still vulnerable to chipping and cracking, discoloration, and rust. These criteria have been rated on a scale of 0 to 4. 0 meaning there is no need for restoration and 4 meaning that restoration is urgent.



The majority of the bells measured thus far have had a conditional rating of 1 for both cleanliness and discoloration. This means that there is some, but not a problematic amount. Rust had a slightly higher common rating of 2 which still is not very problematic. The ones that need restoration should have rating of 4 for each category. Luckily, there are 5 or less bells for each of the categories that had ratings of a 4. There seems to be little correlation between the three categories. Where there seems to be a great number of bells with a certain rating for one category, there may only be a few rated the same for a different category. Perhaps, when considering a bell for restoration, one may only have to confront one problem. However, from our data we found some bells with a rating of 4 in all categories, such as those in the bell tower of San Silvestro.

See Also [edit]

Bell
Bell Ringing
Bell Tower
Bell Towers

NAVIGATION BOX for bells
NAVIGATION BOX for bell towers

References [edit]

External Links [edit]

- Wikipedia Bell page
- UK Central Council of Church Bell Ringers
- Verdin Bells & Clocks
- AmenClock Inc., Church Bell Ringing & Bell Strikers

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B-5: Bell Page

VENIPEDIA page discussion edit history move unwatch

Bell

This page is a description of a typical Venetian bell. For an overview of all the bells in Venice, see Bells.

This section needs improvement. A Venetian bell, known in Italian as *campana*, has had many different uses. Before modern times, bells had more purpose than pure musical entertainment. They were signals of danger, disaster, and alarm. Many bells of today were built in medieval times, and were manufactured using a specific set of techniques and materials.

Contents [hide]
1 Bell Construction
1.1 Material of Bells
1.2 Bell Casting and Founding
1.3 Bell Frame Design
1.4 Anatomy of a Bell
1.5 Bell Decoration
2 Bronze Corrosion
3 See Also
4 References
5 External Links

Bell Construction [edit]

This section needs improvement to organization based on team discussion on 14 November 2012 The casting of bells is a delicate and precise process. The style of a particular bell depends upon the foundry in which it was made, along with the materials that compose it and the period of its creation.

Material of Bells [edit]

The most common material for bells is bronze, an alloy of copper and tin. Very rarely bells were cast in steel and cast iron. This shift in bell materials occurred mainly during times of war, when alloys such as bronze were in short supply since copper was needed in the manufacturing of some weapons. Around 1857 A.D. a combination of iron and carbon, also known as steel, became a material for bell-making. Not soon after it had begun being used it was discarded since the compound was deemed unsuitable for a material of bells.

Bell Casting and Founding [edit]

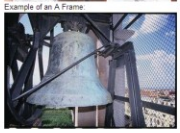
Bells have typically been made using the same process for over six centuries. A popular method of bell casting is to use sand-casting. In medieval times, when many bells were being produced, molds were made from clay to make a template for the bells. A bell mold had a center mold and an outer mold, where molten bronze was poured between the two and then allowed to cool to take the shape of a bell. Back in the middle ages, sometimes wooden templates were also used. Through the use of these templates the distinctive shape of the bells was formed.
For more information about bell founding, see external_LINK.

Bell Frame Design [edit]

Two bell frame types are primarily used to suspend bells, the H frame and the A frame. The H frame occurs when the bell is suspended on a cross bar made of heavy H castings usually composed of a durable metal material such as cast iron. The metal material resists twisting and provides a secure base for the bell. The popularity of this type of design resides in its greater convenience and construction.

Example of an H Frame:

Example of an A Frame:



Anatomy of a Bell [edit]

All church bells have similar features. There is the crown, in which the vibrations mostly come from and the shoulder, which is the curvature at the top. The part that induces the sound, in most cases, is the clapper which is the long piece that hangs from the top of the inside of the bell. When rung it hits the strike point, or soundbow, of the bell.
For more information on bell ringing, see Bell.

Bell Decoration [edit]

When ancient bells were cast, the moldings and decor on them were treated as a form of art. The inscriptions, figures, and design on each bell were well thought out by the founder and were intended to be a reflection of the founders work.

Most European bells are similar in their decorations, which usually include an inscription about where or when they were made or an engraving of a religious figure. Another trend founders have implemented was to design a trademark with a symbol or initials instead of writing out the full name of the founder.

Historical figures are a common form of art found on bells. These include effigies of saints, angels, or royal leaders. In addition, one may find the shield of the patron who invested in the tower or church. However, the most frequently used decor were inscriptions which offer information of whom the bell was dedicated to, who the maker or donor was, when it was cast, and other supplemental information. These are typically in Latin, although some may be in the native Italian.

IMAGES with examples

Bronze Corrosion [edit]

Most of the bells in Venice, being made of bronze, suffer from a cyclic degrading process known as Bronze disease. The disease refers to a chemical process in which the copper in bronze reacts with elements and moisture in the atmosphere creating a film signifying corrosion. Bell towers provide perfect conditions for bronze disease to propagate by leaving bells exposed to environmental conditions such as humidity, high winds, rain, and moisture. The thick green coating has the ability to transform the object by corroding the surface and possibly removing valuable artwork from its face. Many of the bells have intricate images exuding from their surfaces making corrosion a significant problem.
For more information on bronze corrosion, see external_LINK.

See Also [edit]

Bells
Bell Ringing
Bell Tower
Bell Towers

NAVIGATION_BOX for Bells
NAVIGATION_BOX for Bell Towers

References [edit]

External Links [edit]

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B-6: Bell Ringing

VENIPEDIA

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navigation
- Main page
- Community portal
- Current events
- Recent changes
- Random page
- Google Analytics
- Help

search
Go Search

toolbox
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
- Permanent link
- Rate this page

Bell Ringing

This article discusses the various ways bells are rung. For an overview of all the bells in Venice, see Bells. For a typical bell, see Bell.

This section needs improvement. Bells don't have one uniform way of being rung. In fact, the number of ways of ringing bells is almost as diverse as bells themselves.

Contents [hide]

Swinging Systems [edit]

There are two main types of swinging systems; one for western bells and one for Asian bells.

Western Bells [edit]

Western bells, commonly found in churches, are categorized by three types of swinging systems; English, Central European, and Spanish. However, they all have the common trait of being struck by a piece of metal otherwise known as the clapper. Only the English and Central European systems are used in Italy.

Western Bell Systems

English System	Central European System	Spanish System
		

English System [edit]

The English system is characterized by its 360° motion where the bells freely make full circles. This system is utilized in Northern Italy as well as Britain, Ireland, USA, Canada, Australia, New Zealand, and Southern Africa.

Central European System [edit]

The Central European system commonly attaches counterweights to the tops of the bells which only allow them to swing a total of 160°. This system is found throughout Italy, as well as in Central Europe, USA, Canada, and in some Latin American Countries.

Spanish System [edit]

For more information, see external_LINK.

Asian Bells [edit]

Asian bells, which are never suspended, are usually struck with a wooden mallet or a horizontal wooden beam in order to produce a sound.
For more information, see external_LINK.

Types of Swinging [edit]

Swinging bell types can be further divided into four ways they are swung: clocking, chiming, tooling, and ringing.

Clocking [edit]

Clocking occurs when a rope attached directly to the clapper is pulled against the bell to strike it.

Chiming [edit]

Chiming, also known as tolling, involves an external hammer which is either controlled by hand or by machine.

Tooling [edit]

Tooling has a rope attached to the bell directly and the bell itself is swung. This can be extremely difficult, near impossible, considering bells can weigh as much as several tons.

Ringing [edit]

During ringing, the bell is swung from side to side, typically on a wheel. This type is the common method used in the western swinging systems. Either a flying or a falling clapper is used with the ringing system.

Flying Clapper [edit]

A flying clapper begins with a bell attached to the pivot point of what is known as a head-stock or yoke, generally composed of either wood or steel. A pulley system is attached to the yoke from which a rope is fed and pulled to rock the bell which causes the clapper to swing freely or "fly" and strike against the bell. This clapper is used with the English and Central European systems.

Falling Clapper [edit]

A falling clapper involves a counterweight attached to the yoke allowing the bell to pivot with a high center of gravity. The clapper initially hangs at the pivot point and falls onto the walls of the bell with changing directions. This clapper is used with the Spanish system.

Automated Ringing [edit]

While many of the previous sections suggest manual ringing of the bells, a popular trend has developed in which the bells are governed by an automated system.

Motorized Ringing [edit]

A common type of automated system involves a motor with cables leading up to either side of the bell wheel. The motor is activated when the bell reaches the peak of its swing by spinning the cables in the opposite direction which, in turn, reverses the bell's direction. A drawback for this system was that it couldn't monitor the state of the bell in case its swinging became erratic. This problem was later remedied by outfitting the motor with a computer which would halt the bell in case of malfunction.

Mechanical Striker [edit]

Another automated ringing system involves a mechanized striker which can be installed either on the outside of the bell (often used for swinging or stationary bells) or on the inside (only used for stationary bells).

See Also [edit]

Bells
Bell
Bell Tower
Bell Towers

References [edit]

External Links [edit]

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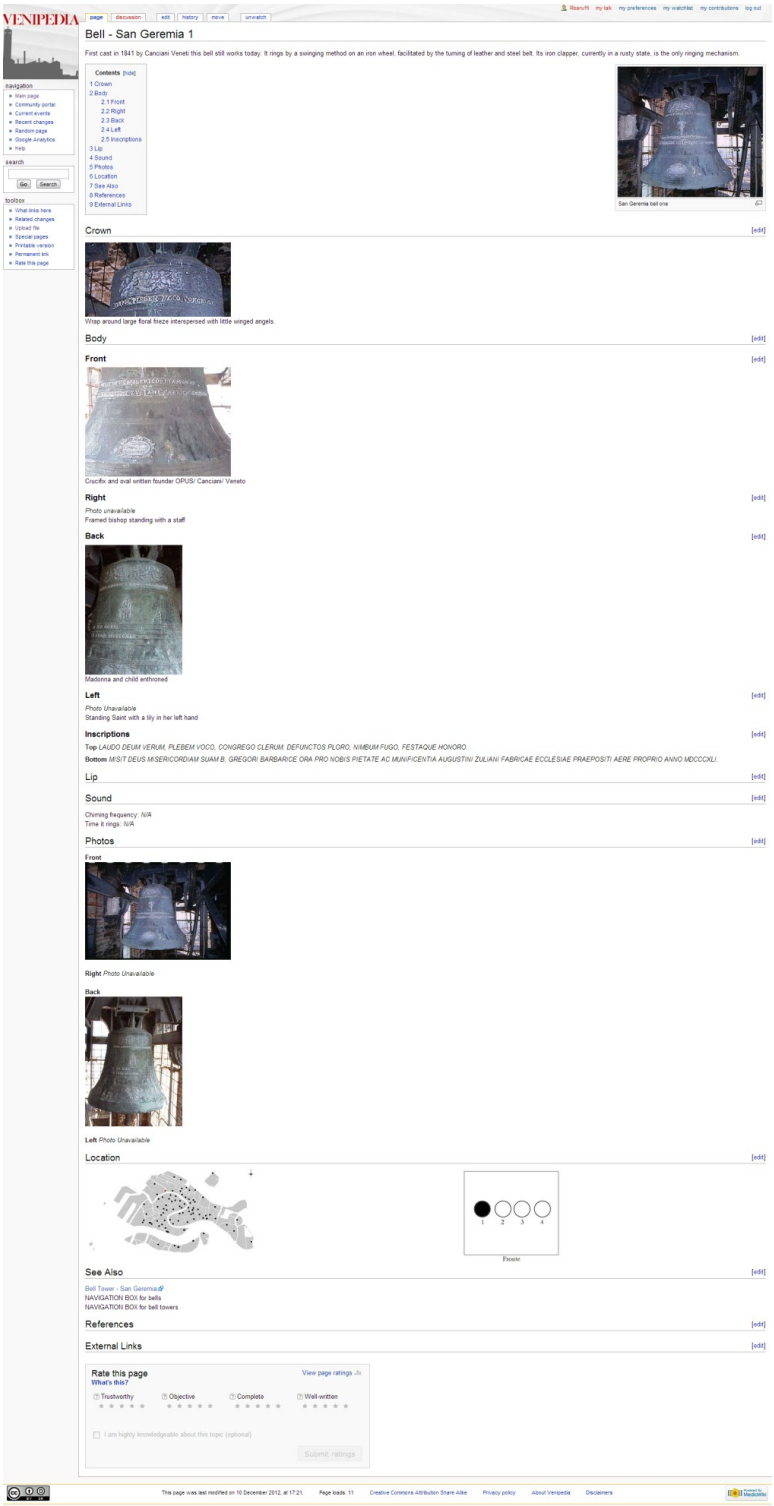
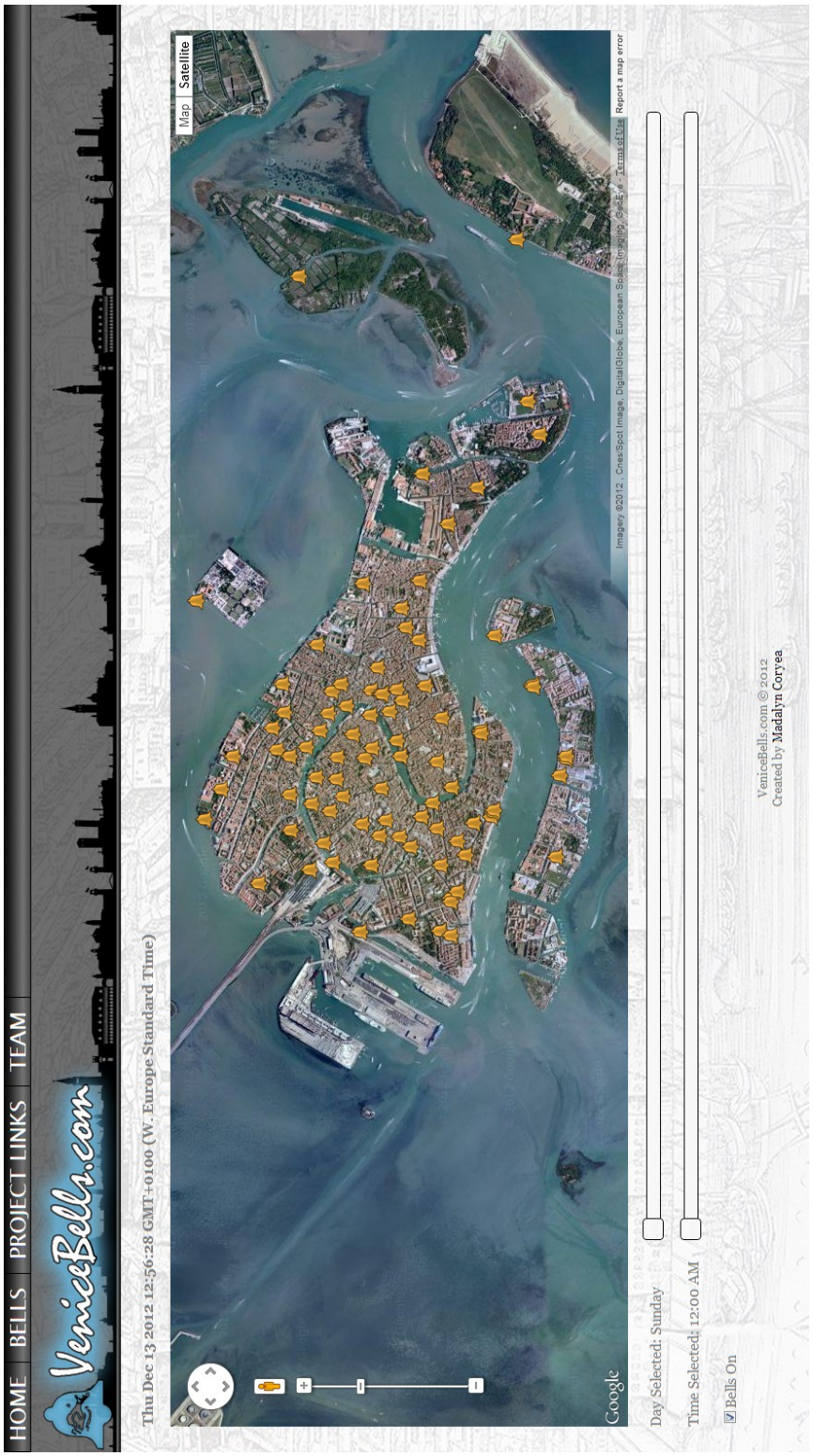
B-7: Bell – San Geremia1

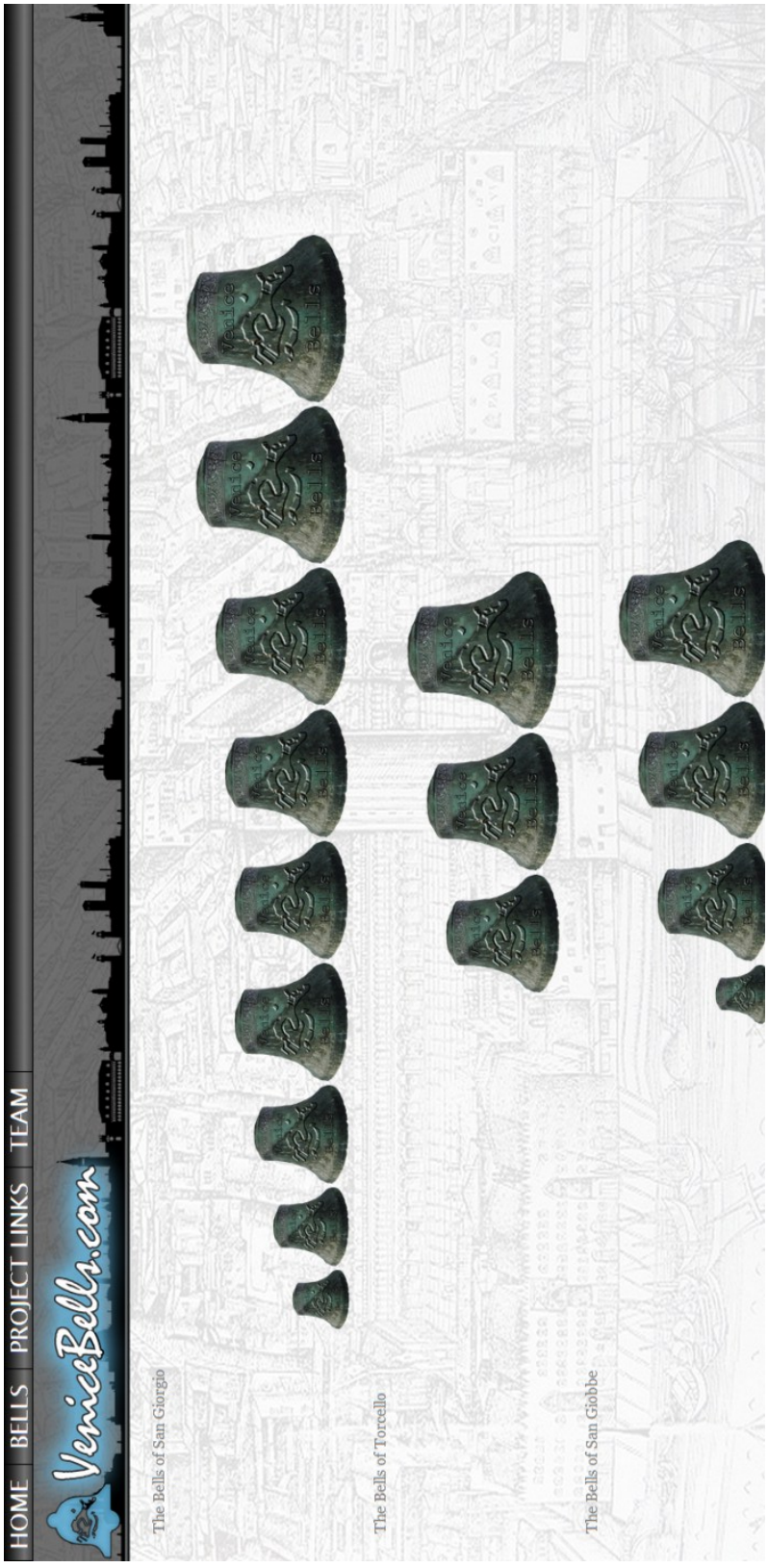


Appendix C: Bells.VeniceProjectCenter.org

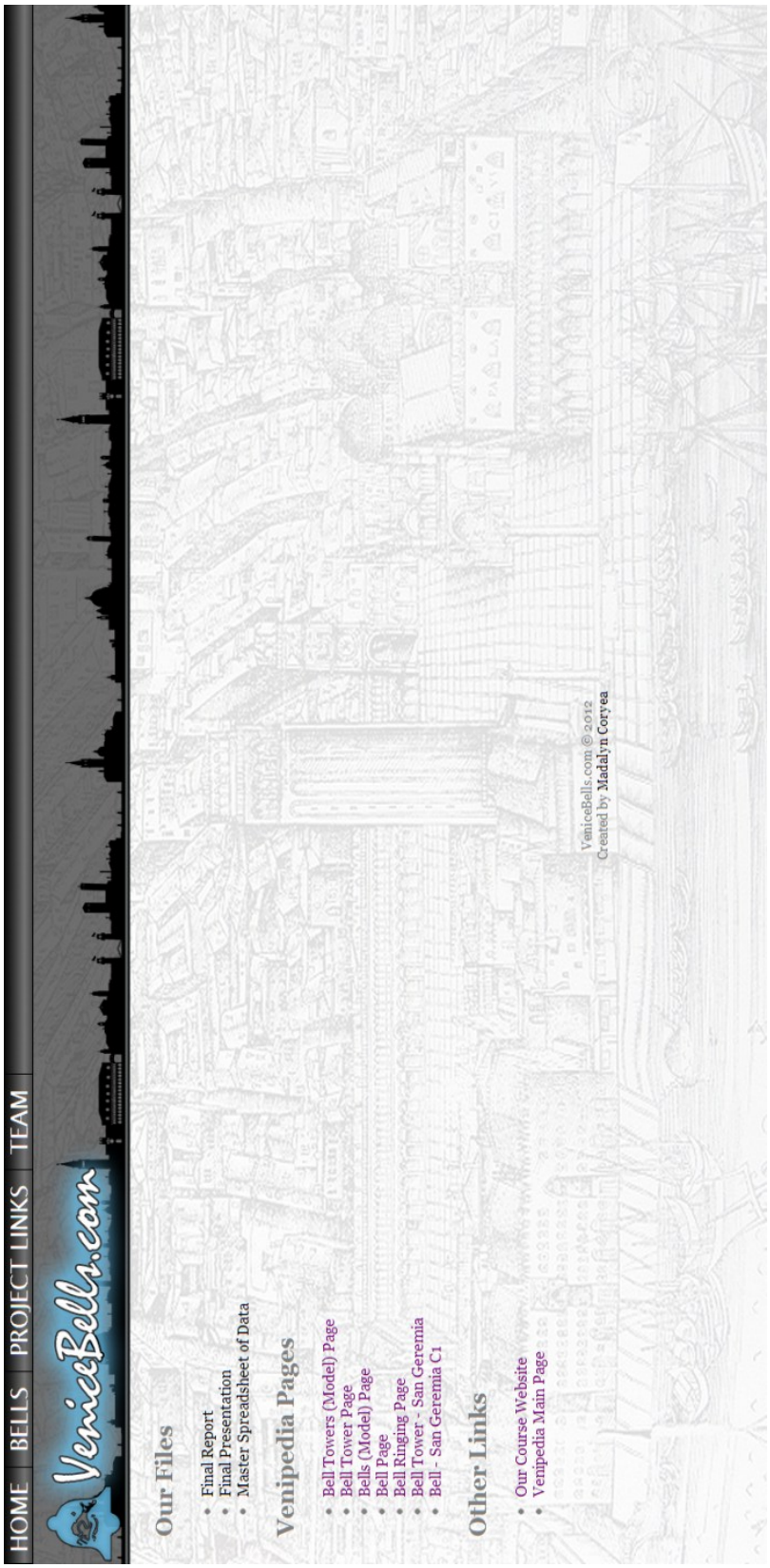
C-1: Bell Tower Map on Home Page



C-2: Bell Playing Component on Bells Page



C-3: Project Links Page



C-4: Team Page


HOME
BELLS
PROJECT LINKS
TEAM
VeniceBells.com
The Team
This is the website for the Venice Bells IQP.
This website offers a one of a kind source of knowledge on both the bells and the bell towers of Venice. The goal of our project is to help preserve the material culture of bells and bell towers in the city of Venice by gaining knowledge on their historical significance and by creating an extensive source of information that will reconnect modern Venice with its past.
As a product of the 2012 Worcester Polytechnic Interactive Qualifying Project team, this website aims to provide the public with a free source of information collected by the Venice Project Center, led by Fabio Carrera and run by the students of Worcester Polytechnic Institute. Our objectives, for the eight weeks we have had here in Venice, are to:
Organize bell data from past Venice projects
Update old information on the bells and bell towers in Venice
Distribute collected bell data to the public
Fredrick Baruffi Robotics Engineering Class of 2014
Danielle Spector Mathematics Class of 2014
Janelle Boucher Mechanical Engineering Class of 2014
Madalyn Coryea Computer Science Class of 2014

Appendix D: Field Forms

The following set of forms was created by the 2004 Bells IQP group. This set is meant to also be used as a stand-alone guide that should be printed out on its own and carried by any group to any bell tower that they are visually monitoring.

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

CAMPANILE

di

_____

External Recorded by:	_____	**on date**	_____
Front	_____	**on date**	_____
Back	_____	**on date**	_____
Left	_____	**on date**	_____
Right	_____	**on date**	_____
Internal Recorded by:	_____	**on date:**	_____
	_____		_____
	_____		_____
Bells Recorded by:	_____	**on date:**	_____
	_____		_____
	_____		_____
Photos by:	_____	**on date:**	_____
	_____		_____
Video/Sound by:	_____	**on date:**	_____
Data Entry by:	_____	**on date:**	_____
	_____		_____
	_____		_____

Completed on Date: _____

C - 1 💻☐

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

QUESTIONARIO per i PARROCI

Nome dell' intervistato: _____
Titolo: _____
Nome della Chiesa: _____
Numero di telefono: _____

Numero Campane: _____
Metodo usato per suonare le campane:

- ☐ Manuale
- ☐ Automatico
  - ☐ A martello
  - ☐ A distesa
- ☐ Motivo campane non suonate
  - ☐ meccanico
  - ☐ sicurezza
  - ☐ altro: _____

Ore suonate:

- ☐ Ogni ora — Quali campane: _____
- ☐ Ogni mezz'ora — Quali campane: _____
- ☐ Altro: _____ — Quali campane: _____

LU	MA	ME	G	VE	SAB	DOM
_____					_____	_____
_____					_____	_____
_____					_____	_____

Data costruzione campanile: _____
Architetto: _____

Storia del campanile (per esempio, data ricostruzione o restauro, ecc.): _____
_____
_____
_____

Possiamo accedere al campanile per un sopralluogo?: Si / No
Se no, perché? _____
Esistono informazioni sulle campane _____ o il campanile _____?
Esiste un archivio della chiesa? _____
Vi si può accedere? Sì/No Se sì, come? _____
Come possiamo ottenere informazioni scritte? _____
_____
_____
_____
_____
Quali sono le opere d'arte, statue o sepolcri più importanti nella chiesa?
_____
_____
_____
_____
_____
Note: _____
_____
_____

C - 2

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

EXTERNAL BELL TOWER DATA SHEET

Background Information

Church Name: _____ Pastor's Name: _____

Church hours: _____ Phone #: _____

Sestiere: _____ (or Location)

Orientation and Inclination

Orientation of sides: (F= Front of church)

Inclination: 0 (none) 1 (slight) 2 (serious)

Direction of inclination: none unclear F R B L

_____° B

_____° L R _____°

_____° F

Potential Fall Zone

Zone Contents:

☐ school ☐ church

☐ campo ☐ residential area

☐ shopping district

Public Visibility:

☐ on the Grand Canal ☐ none

☐ along a canal ☐ by a shopping street

☐ near tourist spot: _____

Architectural/Artistic Information on bell tower

Architect: _____ Date of construction: _____

Style: _____

Artistic Decorations: Good Avg. Poor

# of Inscriptions: _____ Legibility: 0 1 2 3 4 description: _____

# of Art pieces: _____ Avg. condition: 0 1 2 3 4 description: _____

Significant History: _____

_____

Other Information

Access to tower

☐ through church

☐ from street

☐ other: _____

Access to sides

Front: ☐ Right: ☐ Back: ☐ Left: ☐

Tower Doors

Front: ☐ Right: ☐ Back: ☐ Left: ☐

Public access to tower possible?: ☐

Steeple

Cross: ☐ Balustrade: ☐

Lightning rod: ☐ (Grounded wire?: yes / no / unclear)

Weathervane: ☐ Describe:

Finial: ☐ Describe: _____

Type: _____

Clock: ☐

On what side?: _____ Working?: yes / no

Accuracy: +/– _____ minutes

Notes:

_____

_____

_____

_____

C - 3

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

EXTERNAL DATA SHEET (continued)

Technical Data

Key (measurements are in cm)

Material	*Presence*	*Where*	*Ratings*
M = metal	N/A = non-applicable	N = north	0 = excellent / none
I = istria	Y = yes	E = east	1 = good / few / small
B = brick	N = no	S = south	2 = average
S = stone		W = west	3 = poor / several / large
W = wood			4 = bad / countless / enormous
O = other			

	FOUNDATION				SHAFT				BELFRY				ROOF			
	F	R	B	L	F	R	B	L	F	R	B	L	F	R	B	L
Material																
Height estimated (%)																
Side Length																
Visibility (%):																
From Distance (m)																
Connected With:																
Length Attached (%)																
Building Blocks:																
Length																
Height																
Depth at Corner																
Restoration (Y/N)																
# of Ties / Bands																
# of Brick Colors																
Damaged Areas (0-4)																
Cracks / Holes (0-4)																
Plants/ Veg (0-4)																
Number of Lessene																
Number of Arches																
Roll #, Photo #																

Only perform the following measurements if internal access to the tower is not possible.

# of Windows:																
# Blocked																
# Barred																
# w/ Wire Mesh																

Notes: _____

C - 4

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

INTERNAL BELLTOWER DATA SHEET

Internal Artistic Decorations

# of Inscriptions: _____ Average legibility: 0 1 2 3 4

# of Other Artworks: _____ Average conservation: 0 1 2 3 4

Location(s): _____

Transcription/Description(s):_____

_____

_____

_____

_____

General Data

Door height: _____cm width: _____cm What landing is the clock mechanism on? _____

Technical Data by Landing/Floor

Floor Number	GROUND Floor				1st Landing				2				3				4			
	F	R	B	L	F	R	B	L	F	R	B	L	F	R	B	L	F	R	B	L
Wall: Material																				
Landing Length(F to B)																				
Width (L to R)																				
Height																				
Landing: Material																				
Sturdiness (0-4)																				
Cleanliness (0-4)																				
Brick: Length																				
Height																				
Depth																				
Plumb Line Length																				
Plumb Bob Distance																				
Num. of Windows:																				
Mesh/Bar (0-2)																				
Length																				
Height																				
Depth																				
Restoration (Y/N)																				
# of Ties/Bands:																				
# NOT Connected																				
Cracks / Holes (0-4)																				
Damaged Stone (0-4)																				
Bowing (0-4)																				
Stairs/Ramp: Order																				
Material																				
# Steps to Next Landing																				
# of Bad Steps																				
Railing Condition (0-4)																				
Natural Lighting (0-4)																				
Artificial Lighting (0-4)																				
Cleanliness (0-4)																				
Sturdiness (0-4)																				
Roll # . Photo #																				

C - 5

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

INTERNAL DATA SHEET (continued)

Floor Number																			
	F	R	B	L	F	R	B	L	F	R	B	L	F	R	B	L	F	R	B	L
Wall: Material																			
Landing Length(F to B)																			
Width (L to R)																			
Height																			
Landing: Material																			
Sturdiness (0-4)																			
Cleanliness (0-4)																			
Brick: Length																			
Height																			
Depth																			
Plumb Line Length																			
Plumb Bob Distance																			
Num. of Windows:																			
Mesh/Bar (0-2)																			
Length																			
Height																			
Depth																			
Restoration (0-4)																			
# of Ties/Bands:																			
# NOT Connected																			
Cracks / Holes (0-4)																			
Damaged Stone (0-4)																			
Bowing (0-4)																			
Stairs/Ramp: Order																			
Material																			
# Steps to Next Landing																			
# of Bad Steps																			
Railing Condition (0-4)																			
Natural Lighting (0-4)																			
Artificial Lighting (0-4)																			
Cleanliness (0-4)																			
Sturdiness (0-4)																			
Roll # . Photo #																			

Notes:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

C - 6

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

INTERNAL DATA SHEET (continued)

Floor Number													BELFRY				ATTIC			
	F	R	B	L	F	R	B	L	F	R	B	L	F	R	B	L	F	R	B	L
Wall: Material																				
Landing Length(F to B)																				
Width (L to R)																				
Height																				
Landing: Material																				
Sturdiness (0-4)																				
Cleanliness (0-4)																				
Brick: Length																				
Height																				
Depth																				
Plumb Line Length																				
Plumb Bob Distance																				
Num. of Windows:																				
Mesh/Bar (0-2)																				
Length																				
Height																				
Depth																				
Restoration (0-4)																				
# of Ties/Bands:																				
# NOT Connected																				
Cracks / Holes (0-4)																				
Damaged Stone (0-4)																				
Bowing (0-4)																				
Stairs/Ramp: Order																				
Material																				
# Steps to Next Landing																				
# of Bad Steps																				
Railing Condition (0-4)																				
Natural Lighting (0-4)																				
Artifical Lighting (0-4)																				
Cleanliness (0-4)																				
Sturdiness (0-4)																				
Roll # . Photo #																				

Belfry/Dome

Condition of Inside of Roof: 0 1 2 3 4

Drain Holes: Front: 0 1 2 3 4 Right: 0 1 2 3 4 Back: 0 1 2 3 4 Left: 0 1 2 3 4

Lesena Wall Thickness: _____ cm Railing around Steeple? ☐ Railing Cond.: 0 1 2 3 4

Attic Condition 0 1 2 3 4 N. Attic Windows: _____ (N. without nets: _____)

Notes:

_____

_____

_____

_____

C - 7

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

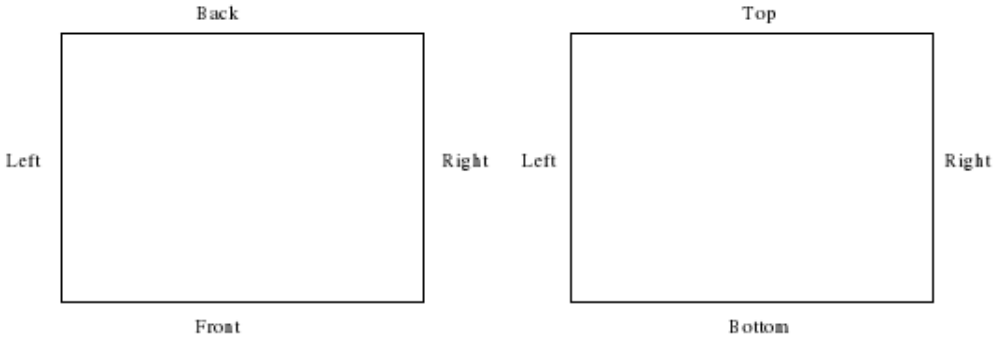
GENERAL BELLS and FRAME DATA SHEET

Bells

Total number of bells: _____

Diagram of Bells

Top View **Side View** (from Side _____)

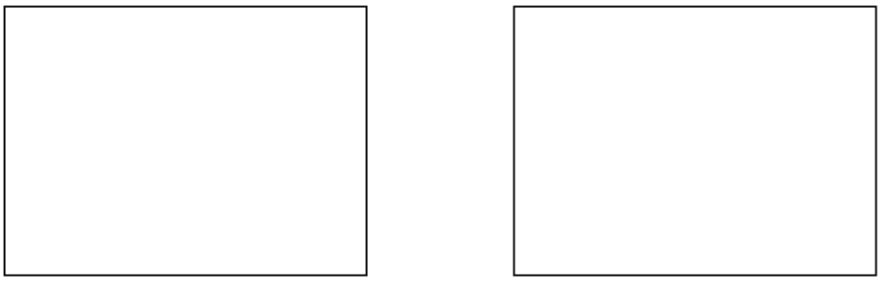


Bell Frame

Shape: A H other: _____		Material: wood metal other: _____	
Restored?:	Y / N	Missing Screws/Bolts:	Y / N
Rust:	0 1 2 3 4	Warping:	0 1 2 3 4
Cracks:	0 1 2 3 4	Dents:	0 1 2 3 4
Cleanliness:	0 1 2 3 4	Overall Condition:	0 1 2 3 4

Diagram of Bell Frame

Top View **Side View** (from Side _____)



Note:

C - 8

Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

TECHNICAL BELLS DATA SHEET

Bell and Clapper Information

Key (measurements are in cm)

Presence
N/A = non-applicable
Y = yes
N = no

How Rung
H = Hammer
W = Wheel

Ratings
0 = excellent / none
1 = good / few / small
2 = average
3 = poor / several / large
4 = bad / countless / enormous

Chiming Frequency
O = other
H = hourly
1/2 = every 1/2 hour
1/4 = every 1/4 hour
N = never

Bell	1	2	3	4	5	6
First Casting						
Second Casting						
Foundry						
Foundry Location						
Height through Center						
Height from Ground						
Diameter of Mouth						
Working? (Y/N)						
How Rung (H, W)						
Swing Direction						
Side Hammer Hits						
Ringing Schedule						
Side Cracked						
Chips (0-4)						
Cleanliness (0-4)						
Discoloration (0-4)						
Decorations (0-4)						
Inscriptions (0-4)						
Overall Condition (0-4)						
Clapper? (Y/N)						
Rust (0-4)						
Belt (0-4)						
Safety Cable? (Y/N)						
Overall Condition						
Skidmark 1: Side						
Right Skid (cm)						
Left Skid (cm)						
Skidmark 2: Side						
Right Skid (cm)						
Left Skid (cm)						
Photos						
Front Side Photo						
Right Side Photo						
Back Side Photo						
Left Side Photo						
Front Engravings						
Right Engravings						
Back Engravings						
Left Engravings						
Inside Photo						

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Bell Tower Code: _____ Sheet number: _____ of _____

Bell Tower Code: _____ Sheet number: _____ of _____

Date: _____ Time: _____ Recorder(s): _____

BELLS INSCRIPTIONS & DECORATIONS

Bell Number: _____ Sound/Video Frames: _____ to _____

	FRONT	RIGHT	BACK	LEFT
Crown				
Body				
Lip				
Photo N.				

Notes:

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Bell Tower Code: _____ Sheet number: _____ of _____