AUDIO GUIDE DEVELOPMENT & VISITOR RESEARCH AT THE BRUNEL MUSEUM

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Audio Guide Development and Visitor Research at the Brunel Museum

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Abstract

Audio guides are increasingly used to enhance museum interpretation and accessibility. The goal of this project was to create a prototype audio guide, develop a visitor tracking and heat mapping tool, and collect visitor data to support the Brunel Museum's Reinvented Project. We visited local museums and interviewed staff to determine current practices in the design of audio guides. We tracked and observed visitors at the Brunel Museum using our visitor tracking tool and identified potential exhibit improvements. We recommend the museum use the tracking tool for future visitor evaluations and expand on our prototype audio guide by transferring it to Bloomberg Connects, adding QR code signage, and including translations for commonly spoken languages.

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- Robert Keirle - Former Collections Access Coordinator

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Executive Summary

Museums are crucial to the preservation of history and culture. They disseminate knowledge to visitors through interpretations of exhibits using text panels, guided tours, and increasingly through technical means. One of the most popular of these techniques is recorded audio guides; they are meant to supplement or replace text descriptions for museum exhibits and provide additional depth to the learning experience. The Brunel Museum, located in Rotherhithe in the London borough of Southwark, preserves and shares the history of the Brunel family and the Thames Tunnel they built. The museum will be closing in October 2025 to undergo extensive renovations as part of their Reinvented Project. One part of this project is to add an audio guide to the exhibit spaces.

In conjunction with the Brunel Museum Reinvented Project, our goal was to create a prototype audio guide, develop a visitor tracking and heat mapping program, and collect visitor data to support future museum organization decisions. We achieved this goal by:

1. Assessing how audio guides are developed and implemented in nearby museums and heritage sites;
2. Creating and testing a visitor tracking system for museum staff and summarize findings in a heat map and other graphics;
3. Developing a prototype audio guide in the current Engine House, currently undergoing initial trials with visitors; and,
4. Presenting our research findings and recommendations to staff and volunteers and sharing our resources for visitor tracking and audio guide development.

First, we conducted extensive research on audio guides at museums in and around London, identifying strengths and weaknesses while comparing delivery platforms. For our second objective, we employed visitor tracking and observation techniques in the Engine House exhibit area, generating heat maps and path maps to understand visitor behavior. Finally, we developed a prototype audio guide and webpage, incorporating design specifications and qualitative data to enhance engagement. Our findings from visitor research indicated varying levels of engagement with different exhibits, with insights gleaned from a trial run of the audio guide. Comparative analysis of audio guides across museums highlighted best practices and challenges, offering valuable insights for the development of our prototype.

During our museum visits, we discovered the most common platforms for museum audio guides in London are Bloomberg Connects, Smartify, Guide ID, and Acoustiguide. We recommend the Brunel Museum move forward with Bloomberg Connects. It is the most cost-effective option that still includes features that would benefit the Brunel Museum. Its implementation is supported through Art UK, with whom the museum already has a relationship. This partnership will provide ample tech support through both Art UK and Bloomberg Connects to relieve staff from maintaining the software. It also offers professional guidance in the development of content for the guide, as well as increased exposure through the Bloomberg Connects community.

With the completion of 14 weeks of research, the development and implementation of an audio guide as well as visitor research at the Brunel Museum, we have compiled the following series of conclusions and recommendations and provided the museum with three main deliverables. The deliverables include a visitor tracking tool, four prototype audio guide stops and a presentation to volunteers and staff summarizing our key findings. Both the visitor tracking tool and audio guide stops underwent testing and iterative refinement during this process.

The predominant trend we observed through visitor tracking indicates that interactive and interpretive exhibits attracted the most interest among visitors. We recommend that the Brunel Museum move forward with its current exhibit improvement plans for the Reinvented Project which feature the addition of numerous interactive exhibits and updates to text panels. Once the new exhibit layout is finalized, we recommend the staff continue using our visitor tracking tool with new floor maps.

Although we recommend the adoption of the Bloomberg Connects platform, we encourage the museum to continue implementing our prototype audio guide through their website until the museum closes in October for renovations. Once the museum is closed, existing audio content and new sections should be added to Bloomberg Connects, in addition to information from the museum's existing collections page. Regarding the design of the audio guide, we recommend the museum continue to have staff and volunteer narrators, use music and soundscapes to engage listeners, and use common language to increase comprehension. We also recommend audio guide signage and a non-linear format similar to that used in the prototype audio guide. Including QR codes on the audio guide signage would allow visitors to use the guide to learn more about any exhibit the visitor finds interesting. In this way, the guide is

non-sequential and allows visitors to choose what they listen to based on their individual interests.

Authorship

Section	Author	Primary Editor	Editor(s)
Introduction	CQ	-	BA, NC, SU
Literature Review - Museum Definitions	CQ	NC	CQ
Literature Review - Visitor Research & Data Collection	NC	CQ	BA, SU
Literature Review - Audio Guide Design & Development	BA	SU	NC, CQ
Literature Review - The Brunel Museum	SU	BA	NC, CQ
Methods - Introduction	NC	CQ	BA, SU
Methods - Evaluating Audio Guides	SU	-	BA, NC, CQ
Methods - Evaluating Visitor Engagement	CQ	NC	BA, SU
Methods - Audio Guide for the Brunel Museum	SU	CQ	NC
Methods - Recommendations & Future Improvements	NC	SU	-
Findings - Visitor Research & Data Collection	SU	BA	NC, CQ
Findings - Audio Guides at Other Museums	SU	-	BA, NC, SU
Findings - Evaluation of Audio Guide Platforms	BA	-	NC, CQ, SU
Findings - Evaluation of the Hayra Audio Guide Script and Guided Tours at the Brunel Museum	NC	CQ	BA, SU
Findings - Our Audio Guide	SU	NC	BA, CQ
Conclusions & Recommendations	CQ	NC	SU, BA

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Introduction

Museums are crucial to the preservation of history and culture. They disseminate knowledge to visitors through interpretations of exhibits using text panels, guided tours, and increasingly through technical means. One of the most popular of these techniques is recorded audio guides; they are meant to supplement or replace text descriptions for museum exhibits and provide additional depth to the learning experience. The Stedelijk Museum of Amsterdam introduced the first audio guide to the public in 1952 (Straughan 2019). Since then, audio guides have evolved with the use of new technologies for user interfaces (e.g., apps and personal phones) and location-aware delivery (e.g., via scanning QR codes and automatically with Bluetooth beacons). Audio guides have become a favored method to improve museum accessibility for those who have trouble reading text panels, as well as for those who want additional information on specific topics.

Located in the London Borough of Southwark, the Brunel Museum has yet to implement an audio guide but is interested in developing one as part of the Brunel Museum Reinvented Project. The Reinvented Project is sponsored by the National Lottery Heritage Fund and includes adding a new visitor center, renovating the Engine House, creating new interpretations for all exhibits, and opening space for more artifacts from their off-site collections. With new interpretive approaches and interactive exhibits, the project aims to expand the museum audience to more non-technical visitors and local families.

In conjunction with the Brunel Museum Reinvented Project, our goal was to create a prototype audio guide, develop a visitor tracking and heat mapping program, and collect visitor data to support future planning and decision making at the museum in the future. We achieved this goal by:

1. Assessing how audio guides are developed and implemented in nearby museums and heritage sites;
2. Creating and testing a visitor tracking system for museum staff and summarize findings in a heat map and other graphics;
3. Developing a prototype audio guide in the current Engine House, currently undergoing initial trials with visitors; and,
4. Presenting our research findings and recommendations to staff and volunteers and sharing our resources for visitor tracking and audio guide development.

Through evaluations, observations, and testing of museum audio guides, we gained insight into best practices and how visitors interact with and respond to audio guides. These methods guided our understanding of long-term success strategies, the development of our audio guide, and future recommendations to the Brunel Museum. We identified and recorded audio for several test stops within the Engine House to incorporate into our guide interface. To collect data on how visitors experience the museum, we created a visitor tracking platform to better understand museum engagement through heat mapping and graphical analysis. Ultimately, we delivered our software to the Brunel Museum along with a tutorial and our visitor data, as well as summarized our findings and presented our recommendations to the Brunel Museum staff and volunteers.

Literature Review

Introduction

In this chapter, we will be covering four main topics: (1) the definitions and missions of museums, (2) the changing approaches to education and engagement in museums, (3) the design and development of audio guides, and (4) an introduction to the Brunel Museum and our project.

Museum Definitions

According to the Encyclopedia Britannica, a museum is an "institution dedicated to preserving and interpreting the primary tangible evidence of humankind and the environment" (Lewis 2024). Despite this clean and concise definition, others have proposed significantly different definitions of what constitutes a museum over the years. The first definition adopted by the International Community of Museums (ICOM) in 1946 was exceptionally general and included public collections of anything from art to animals, which resulted in zoos being included but libraries being excluded (François 2019). Most recently at a conference in Prague in 2022, the ICOM adopted a new definition that won over 92% of the vote among attendees and is now the most widely accepted definition of what is a museum. It states that "a museum is a not-for-profit, permanent institution in the service of society that researches, collects, conserves, interprets and exhibits tangible and intangible heritage. Open to the public, accessible, and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment, reflection, and knowledge sharing" (Museum Definition 2023).

In short, museums are often seen as having three primary roles: maintaining collections, conducting research, and educating visitors. Museums achieve their educational role through exhibits, programs, and events. The way museums present and interpret exhibits has changed dramatically since the early 20th century in response to the findings from visitor studies, which we will discuss in the next section.

Visitor Research & Data Collection

Visitor research began with the tracking studies of Melton (1935) but was not widely used in museums until the 1980s and 1990s (Yalowitz & Bronnenkant 2009). Yalowitz & Bronnenkant (2009) gives credit to Stephen Bitgood for conducting groundbreaking research in visitor tracking, as well as developing many of the techniques that are still used in studies today. Bitgood observed how visitors circulate through museums and concluded that visitor knowledge and personal interests combined with exhibit factors, such as architecture and organization, influenced the paths of visitors (Bitgood 2006). Tracking studies were used primarily to evaluate exhibits and galleries before or after their installation to best suit visitor interests and expectations. Researchers such as Beverly Serrell (1998) developed several metrics, including attractiveness, holding power, and dwell times, to measure the impact of exhibits and different interpretation styles on visitor engagement. Without easy ways to measure learning in museums, researchers assumed that longer dwell times signified greater engagement, and therefore greater learning (Borun et al. 1998).

Other visitor studies examined best practices for engaging visitors in museum exhibitions, including individuals with different learning styles. For example, Jones (2015, p.540) noted that Falk and Dierking (2013), in their article The Museum Experience Revisited, stress "the need to view the museum experience in a holistic way, understanding that the museum visitor is not an 'empty vessel, waiting to be filled with our wisdom' (7) but bring their own knowledge, understanding, needs, expectations and motivations into the museum with them." Visitor studies revealed that there are different learning styles, as per Gardner's notion of multiple intelligence and different learning outcomes specified by Hooper-Greenhill's (2003) taxonomy (knowledge, skills, attitudes, enjoyment, behavior). Thus, people learn different things based on their lived experience, learning styles, and interest in the material. Hawkey (2004, p. 15) distills this research to distinguish among four types of learning styles shown in Figure 1 below as accommodator, assimilator, converger, and diverger.

	Learning style					
Component			Accommodator	Assimilator	Converger	Diverger
	Concrete experience:		✓			✓
	Observation and reflection			✓		✓
	Concept formation / generalisation			✓	✓	
	Testing concepts in new situations		✓		✓	
	In museum exhibitions... (Serrell 1996)	Prefer...	imaginative trial and error	interpretation that provides facts and sequential ideas	to try out theories	interpretation that encour ages social interaction
		Look for...	hidden meaning	intellectual comprehension	solutions to problems	personal meaning

Figure 1: Hawkey's four types of learning styles (Hawkey 2004).

Additional experts have developed different types of taxonomies along similar lines. For example, Falk (2016, p. 360) distinguishes between five types of visitors, namely explorers, facilitators, professionals and hobbyists, experience seekers, and rechargers. Similarly, Kuflik et al. (2012) distinguish between ant, fish, butterfly, and grasshopper visitor types. Market researchers have adopted and developed these kinds of taxonomies and promoted an area of research called 'audience segmentation'. In the UK, museums often engage consultants, such as Morris, Hargreaves, and Macintyre or the Audience Agency, to conduct audience segmentation studies. The resulting data are used to inform how museums design exhibits, programs, events, and audio guides as well as how they conduct their marketing efforts. Specifically, audio guides and other forms of digital interpretation provide an opportunity for museums to tailor the experience to meet the needs of different types of visitors.

In light of the results from this visitor research, museums have recognized the limitations of traditional didactic or instructional approaches and have moved towards more interactive and engaging models (Weber 2022). Jeffrey-Clay (1998) stresses the need for museums to connect new knowledge to prior experiences and stimulate personal interest, promoting inclusivity and engagement. Hawkey acknowledges George Hein's theories, focusing on the differing views of knowledge and learning in museums. As museums have shifted from acting as repositories of

artifacts and knowledge to being a dynamic learning environment, the constructivist theory has played a critical role. The constructivist theory differentiates between knowledge and learning, leading to four general views, two of which are didactic and constructivist. The didactic view emphasizes that knowledge is independent of lived experience and learning is passive and incremental, while the constructivist view states that both knowledge and learning are constructed from ideas and experiences, as visualized in Figure 2 (Hawkey 2004, p.16). To develop a more inclusive environment, museums have shifted to encourage hands-on, constructivist, learning experiences to stimulate personal interest (Jeffery-Clay 1998).

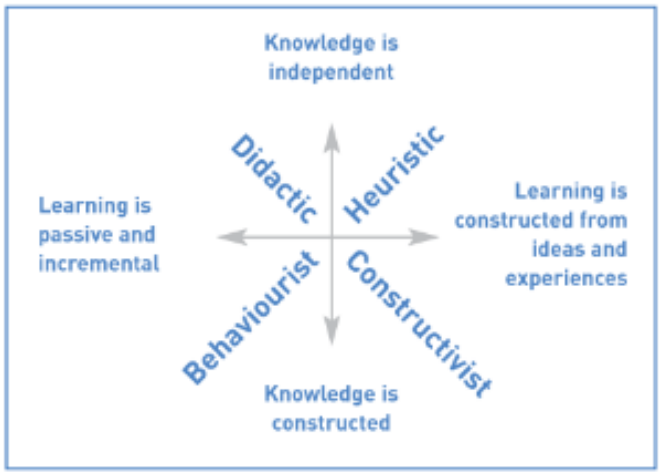

Figure 2: Model of Knowledge and Learning according to Hein (Hawkey 2004, p.16).

One way this has been implemented is by embracing new technologies that help to align museums with Hein's beliefs in interaction and interpretation. In this way, modern museums have been bridging the digital divide, especially due to the COVID-19 pandemic, through the use of virtual guides and exhibits (Weber 2022). In Hawkey's words, "museums are a heterogeneous set of institutions whose original twin functions of scholarship and education, once inseparable, but subsequently divorced, are being reunited by digital technologies" (Hawkey 2004 p.2). In addition to the learning styles in Figure 1, Hawkey also developed a taxonomy for the learning opportunities presented by digital technologies in museums (Figure 3) which includes onsite interpretive audio that can be tied to specific locations or be carried by the visitor (Hawkey 2004). Although some of the terminology Hawkey uses in his taxonomy is 20 years old, the general classification still holds.

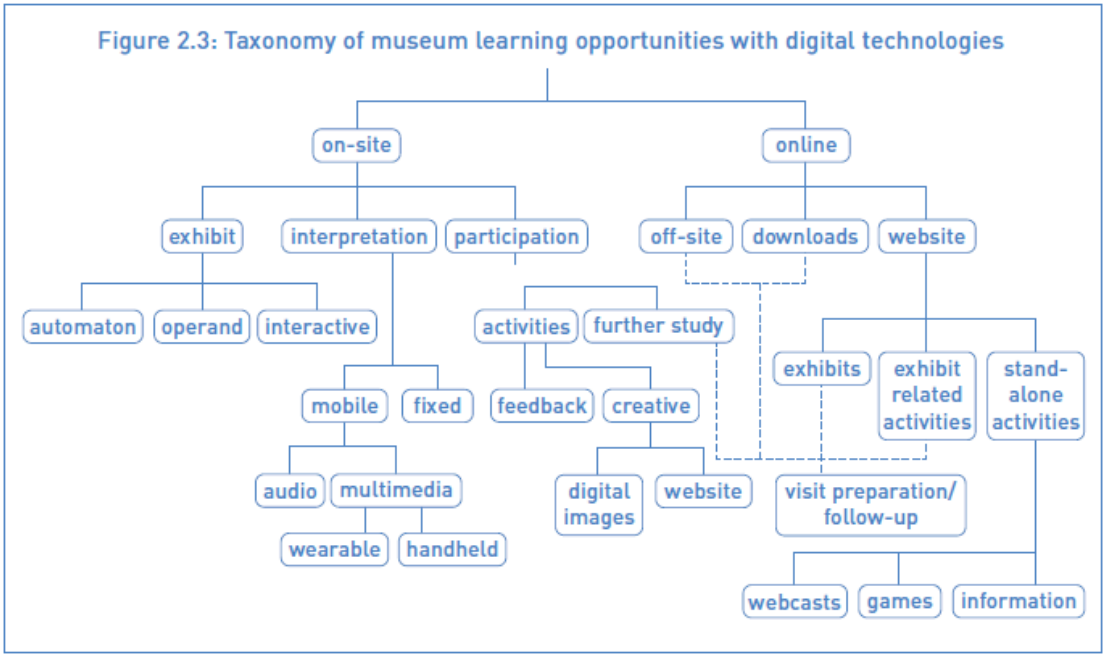

Figure 3: Hawkey's taxonomy of the learning opportunities available to museums through digital technologies (Hawkey 2004).

Audio guides are typically received well by visitors and increase the time spent at a given location. They also effectively communicate the desired information and do not seem to hinder social interactions between visitors (Novey and Hall 2007). In the next section, we will discuss how audio guides are designed and developed.

Audio guide Design & Development

The design and development of audio guides is an interdisciplinary and collaborative process with key contributions from museum directors and staff, experts on the content of the guide, sound designers, and user experience designers. For the initial design and development, we will consider the goals of the museum, its audience, and its exhibit layout to shape the initial form of the audio guide. Additionally, the user experience will vary significantly depending on the design factors such as the mode of delivery, be it on personal devices or provided ones with or without individual headphones.

Commonly, the design and development of museum audio guides begins with an investigation into the audience of the museum, which then informs discussions on content and delivery method (Mallchok 2017). With an understanding of the museum audience, audio guide designers can create audio experiences that effectively cater to the museum's visitor population.

When considering the potential audience for an audio guide, visitor research is critical to understanding the languages spoken, ages, abilities, and interests of visitors. In the design and development of an audio guide, museums often use their audience data to focus their efforts on specific audience demographics. For example, some museums prioritize offering audio guides in many languages, while other museums attract more families and prioritize offering guides in family-friendly formats and creating content suitable for young audiences. Many audio guide delivery systems such as Bloomberg Connects and Smartify can allow participants to select from a range of guides, however, for museums with limited resources, creating multiple versions of a guide may prove resource-intensive. Understanding the interests of museum visitors allows audio guide designers to create content better catered to their audience and decide on relevant guide stops.

Other important design factors are the style and objectives of the narration. For example, audio guides can be designed to provide wayfinding instructions, basic audio descriptions of artifacts (especially for the visually impaired), and more detailed, in-depth audio interpretations (Çapar & Atçi 2023). The narration also has two main styles; In the context of audio guides, *audio descriptions* are considered a characterization of something physical, an objective description without analysis. In contrast, *audio interpretations* provide some description while mainly focusing on analysis by including historical context and highlighting elements that speak to larger themes, thus building a narrative around an exhibit that further enhances the visitor's

understanding. For example, at The Metropolitan Museum of Art in New York, many visitors choose to listen to the audio guide due to the added value of the audio interpretations from experts (Tung 2015). Audio descriptions can still have great benefits as an accessibility strategy for the blind and partially blind, although many visually impaired visitors prefer audio interpretations as well (Eardley 2022).

When designing an audio guide, many museums immerse their audience in soundscapes that provide social, historical, and geographical context (Dedousis 2021). In this way, some audio guides serve as more than just a mere content delivery mechanism, and instead, as an immersive part of the exhibit experience. Soundscapes are defined as a set of background sounds that emulates an environment, and are frequently used in theatrical productions to set the scene for an audience. Background sounds may be present throughout the guide, or tailored to provide appropriate context at particular audio guide stops. Additionally, relevant music can be used as part of soundscapes to help set the scene and engage visitors. When a soundscape is successful, the sounds help visitors' imaginations construct a mental image or sense of their imaginary environment, allowing them to feel more immersed in the guide and story.

Audio guides can be designed as one experience or several shorter specialized segments. Some museums find that a singular, "one size fits all" audio guide experience is well-suited to their audience, while others find that differentiated guides are a better fit (Mannion 2015). One guide is a resource-efficient method to ensure all visitors can hear a complete narrative of the museum's story. However, this strategy lacks personalization opportunities and some visitors may not be interested in all topics covered in the guide, leading them to stop listening. Increasingly, museums are focusing on a specialized approach with several guides, each with a unique focus, such as an engineering guide, local culture guide or children's guide. These narrower options allow visitors to customize their experience and listen to what interests them most. However, these guides require the development of additional content and even different styles of delivery which is more resource intensive for museums.

Audio guides can also have the ability to serve multiple purposes, such as being helpful wayfinding aids and adding new content or analysis to exhibits. In 2018, the study *Flow, Staging, Wayfinding, Personalization: Evaluating User Experience with Mobile Museum Narratives* examined the merits of providing a multimedia companion website on tablets within exhibits at the Acropolis in Athens (Roussou 2018). They created a prototype multimedia experience,

tracked visitor interactions, administered surveys, and sought open-ended feedback. Broadly, visitors greatly enjoyed viewing exhibits in a new way and felt the interactive story plot and narration helped engage them. The researchers noted that when implemented successfully, storytelling can "…communicate value, cultivate experiences with emotional resonance, encourage empathy, trigger visitor's attention and meaning-making" (Roussou 2018). The researchers' prototype included way-finding in the physical space and found that some visitors appreciated the non-linear path and directions of the guide experience, while others were indifferent. Guide personalization was also tested by first surveying visitors with a standardized visitor assessment then offering each visitor one of several guide experiences, which varied in duration and exhibit recommendations. Researchers concluded that the most important element of personalization was the length of each guide stop and thus, the length of the overall guide. Many visitors noted that they liked choices throughout the experience to hear more about a topic by playing optional guide stop extensions. Researchers noted that some participants opted to listen to every available subpart, while others opted for a brief guide and did not engage in optional content. Lastly, those who visited the museum alone considered the multimedia experience to be a companion during their visit and allowed them to further connect with the exhibit content. However, the prototype experience was purely individual, and those visiting as a group were isolated into their individual experiences. The researchers suggested that future designers should consider offering activities that promote social interaction and collaboration, such as encouraging all members of a group to participate in completing a challenge or offering each member of the group a unique story. The aforementioned insights and additional recommendations are summarized in Appendix A.

When selecting the delivery method for an audio guide, personal devices are often favored for ease of use and low cost to museums as well as the variety of distribution methods in the form of apps that are available on the personal devices (Mallchok 2017; Roussou 2018). Hosting the guide on a museum website and providing links via QR codes can be a low-cost, easy-to-implement solution since the QR code can be printed and requires no costly maintenance. NFC (Near-field communication) can be used similarly to QR codes, but requires newer personal devices and visitors must be in close physical proximity to interact with the NFC tag. For well-resourced museums, Bluetooth beacons provide an integrated, location-aware delivery solution where the guide can auto-advance based on visitor movement. However, this

approach is initially costly and may require ongoing maintenance. In terms of accessibility, Bluetooth beacons are ideal since they require minimal user interaction to advance the guide. For many, QR codes can be difficult to scan, especially for those with mobility or sight challenges, so it can be helpful to offer an alternate mode of delivery even if QR codes are posted.

Previously, the Brunel Museum commissioned Hayra, a small startup focused on museum audio guides, to develop an audio guide. The museum staff were able to provide us with the script (Appendix B) and best practices created by Hayra in collaboration with the museum, however, all prototypes and other documentation were no longer available since the project was discontinued. Museum staff expressed interest in utilizing the available resources as a starting place for future audio guide development.

The Brunel Museum

The Brunel Museum opened in 2006 with the mission "[t]o preserve and share widely the ground-breaking stories of the Thames Tunnel project and the outstanding achievements of the Brunel family and their relevance to our lives today. We inspire communities through exploration, learning, and performance" (*The Brunel Museum*, n.d.). The museum is located in Rotherhithe, a neighborhood in south-east London within the London Borough of Southwark, and works to actively engage people from the local community, the greater London community, the UK, and abroad. The Brunel Museum offers a wide range of exhibits that appeal to visitors of various interests and backgrounds, attracting people who are interested in architecture, the history of the Thames, engineering in general and the engineers, Marc Isambard Brunel and Isambard Kingdom Brunel, in particular. The museum also attracts school groups since the exhibits can be related to several parts of the curriculum, including mathematics and science.

The museum comprises the 19th-century Engine House, Tunnel Shaft, rooftop garden, and piazza. Originally housing the steam pumps used to extract water during tunnel construction, the Engine House is now used as the primary exhibit space as shown in Appendix C. The Tunnel Shaft was the original tunnel entrance and can be seen from the outside as a round white building, shown in Appendix D; the interior is pictured in Appendix E. A concrete floor has been installed at the base of the shaft to seal it off from the tunnels below that are still used as train tunnels by the London Overground. Additionally a strong roof was added to the previously open-air shaft during WWII to prevent bombs from being able to reach the railway below (*The Brunel Museum*, n.d.). Today, the museum continues to uphold its mission to educate people about the Thames Tunnel through hosting community outreach programs and other events.

The museum recently received funding from the National Lottery Heritage Fund to begin its "reinvented" project to expand the museum's reach, preserve the historic buildings, and house its collection of Marc Brunel's watercolor paintings. (*The Brunel Museum,* n.d.). The general plan is for the museum to build an entirely new visitor center to house their ticketing desk and store and to rebuild the interior of the Engine House to create a space that is both able to house more of their collections and be more accessible.

As part of the Brunel Museum Reinvented Project, we have been asked to complete visitor research and data collection in the Engine House, where the majority of their exhibits are

currently located. By observing what parts of the exhibit visitors spend the most time at, as well as the path that the visitors take through the exhibit space, we will be able to give the museum staff important data that could advise the future layout of the Engine House. An overview of the proposed redesign of the museum, including the Engine House, is shown in Appendix F.

Another aspect of our project is the creation of an audio guide prototype within the Engine House space. The goal of this project is not to produce a complete audio guide; rather it is to create a functional prototype as well as detailed recommendations for future audio guide development for the museum staff. These recommendations will include topics such as what technology they should use, what the user interface could look like, and what content would most lend itself to an audio guide format.

Methods

Introduction

Our project goal was to create a prototype audio guide, develop a visitor tracking and heat mapping system, and collect visitor data to support future museum decisions related to the Brunel Museum Reinvented Project. To achieve this goal, we:

1. Assessed how audio guides are developed and implemented in nearby museums and heritage sites;
2. Created and tested a visitor tracking system for museum staff and summarized findings in a heat map and other graphics.
3. Developed a prototype audio guide in the current Engine House and began a trial with visitors; and,
4. Presented our research findings and recommendations to staff and volunteers and shared our resources for visitor tracking and audio guide development.

Our project goal, supporting objectives, and associated tasks are illustrated in Figure 4 below.

We learned about the Brunel Museum through background research, site visits and observations, interviews, and visitor tracking. To understand local best practices in audio guide design and development, we visited and held interviews with staff at other local museums. Through evaluations, observations, and testing of museum audio guides, we gained insight into current audio guides and how visitors interact with this technology. Learning about the museum and its peers helped us understand long-term success strategies, develop our prototype audio guide, and provide future recommendations for the Brunel Museum.

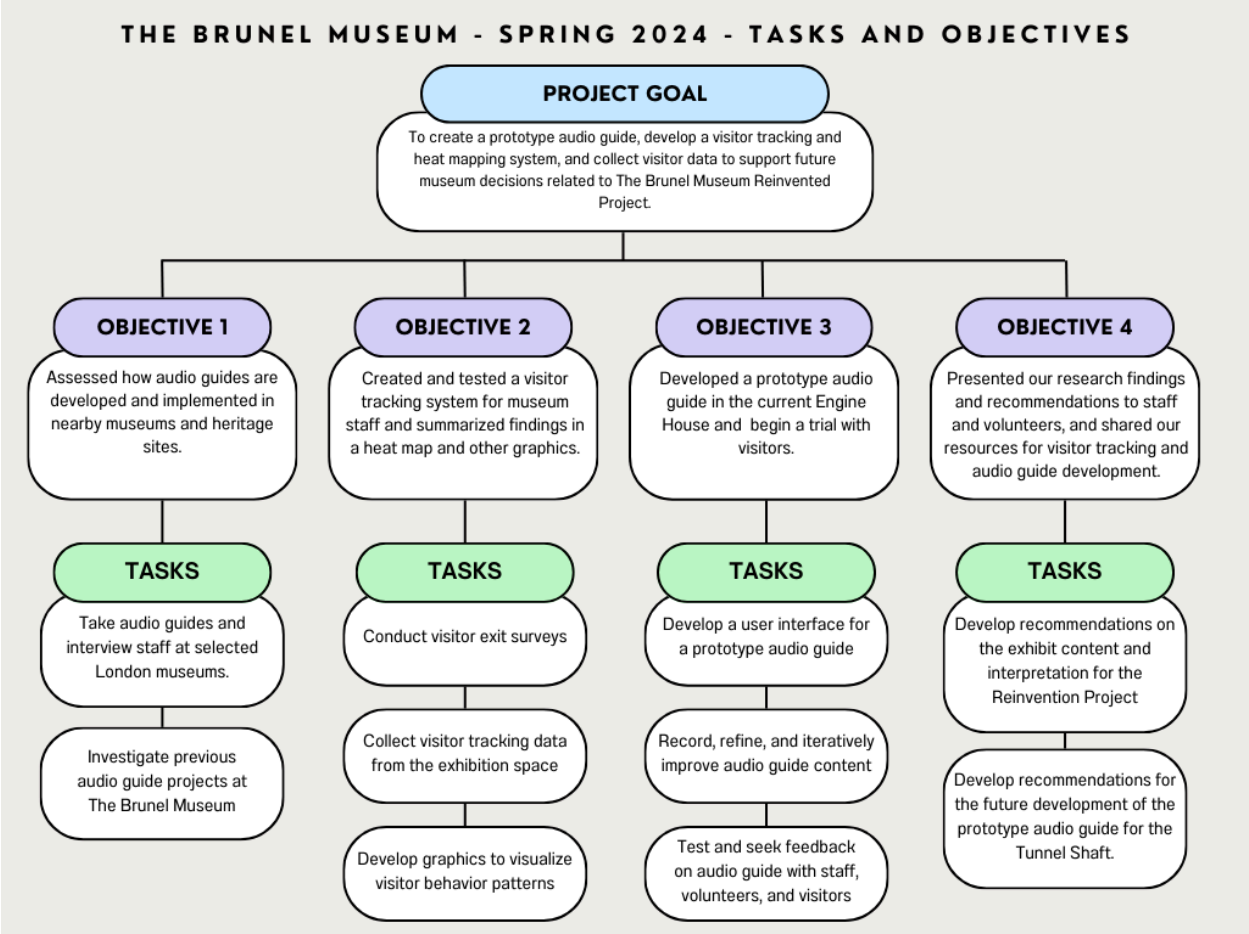

Figure 4: Summary of the project goal, supporting objectives, and related tasks.

I. Evaluating Audio Guides

We evaluated how audio guides are developed and implemented in local museums and heritage sites by testing them ourselves and interviewing staff at selected London museums. We also reviewed the audio guide prototype previously developed for the Brunel Museum.

A. Audio Guides at Other London Museums

To understand current practices in museums, we reviewed audio guides at a sample of London museums. After consulting with our sponsor, we connected with staff members involved in the design and development of audio guides at several museums, including The National Gallery, The National Portrait Gallery, the Churchill War Rooms, the Bank of England Museum, the HMS Belfast, the Tower of London, Tower Bridge, The Chiswick House and Gardens, The Freud Museum, and the Roman Baths.

We chose a variety of museums that were diverse in their size, resources, and content focus. Although we created an audio guide for a smaller museum, evaluating audio guides in large, well-resourced museums provided insight into current and best practices and common visitor experiences. On the other hand, learning about audio guides at small museums was beneficial in demonstrating budget-friendly audio guide development and delivery options. Additionally, we reviewed audio guides at museums focused on a range of content areas to seek creative ideas to make our guide engaging and relevant. For example, cultural museums may commonly present guides in one style, while children's museums or science museums may take a more creative and interactive approach. As we visited each museum, we asked staff members to recommend other museums with audio guides that might be valuable to review, and used those suggestions to broaden our research.

We developed an observation sheet (Appendix G) to guide our assessment of each audio guide. We assessed aspects of each guide, such as timing, navigation, audio elements, access and delivery methods, and content. We additionally noted features of the guide, such as cost (if any), type of audio delivery technology (e.g., phone, headsets, etc.), and narrative style. After testing our sheet at several museums, we reviewed and refined our observation criteria based on our experiences.

After our initial visits, we identified staff who were involved with the development of the audio guide at each museum and asked them to participate in informal interviews. Using questions created from the topics found in Appendix H, we held semi-structured interviews and focused on gathering insights relevant to the creation of an audio guide at the Brunel Museum.

We conducted these interviews in person when possible, or by video conference when necessary. In these interviews, we specifically asked about the formats the museums had found to be successful, be that physical devices, a mobile app, or a website, and their audio guide development process. We also gathered qualitative data on how the audio guides have been received by visitors, as well as any relevant feedback the museums have collected. We used the preamble in Appendix H to explain the nature of the research and solicit consent to quote participants anonymously or by name. The preamble also explains the rights of the interviewee to stop the interview and to review our materials before publication.

B. Hayra Draft Audio Guide for the Brunel Museum

The Brunel Museum commissioned a small company called Hayra to develop an audio guide script in mid-2022. Hayra developed a script but did not finalize or test the audio guide and interface with an audience. We reviewed the script, attached in Appendix B, focusing primarily on the tone that was used to present different topics and pieces of information. For example, is it more an audio description of the exhibits or an audio interpretation? Did they plan to use voice actors playing characters? The guide provided helpful insight into how the story and content of the museum could be presented in audio form.

II. Evaluating Visitor Engagement

Our second project objective was to evaluate how visitors engage with the Brunel Museum exhibits. We collected visitor data to inform the redesign of the exhibit layout and artifacts as part of the Reinvented Project.

A. Engine House

In the Engine House, we used a combination of visitor tracking, observation, and exit surveys. Using a customized spreadsheet with a built-in timer, we recorded how much time visitors spent at particular exhibits and discreetly noted movement patterns as visitors made their way through the museum. We also captured the order in which they visited each display within the exhibition area. While engaged in this task, we also recorded any key interactions between visitors and the objects as well as with each other.

We administered exit surveys to as many visitors as possible on multiple days (Fri-Mon) to acquire a representative sample. Our exit survey can be found in Appendix I. It Includes multiple questions from the Brunel Museum's existing survey for continuity. After we implemented this survey, it became clear that taking qualitative observations within the exhibit space would be more beneficial to the goals of our project than the survey. Because of this, we stopped implementing the exit survey and started gathering qualitative data.

Before beginning visitor tracking and data collection, we consulted with and received approval from relevant museum staff. They helped us identify where to station ourselves within the museum for unobtrusive visitor observation. When there was an overabundance of visitors and we were unable to track them all, we used random sampling to determine who to track.

Additionally, we created and posted signage at the discretion of museum staff to indicate who we were and what we were doing within the museum. We also had a member of the group near the till to show visitors that visitor data collection was occurring. Throughout the project, we remained in constant communication with museum staff, sought renewed approval as our plans evolved, and complied with all relevant GDPR guidelines.

B. Tunnel Shaft

Although our project did not involve the Tunnel Shaft, we shadowed several guided tours led by different volunteers and noted how information was communicated and received. We found that going on the tours provided insight into the narrative style the museum prefers to use when presenting information to visitors.

III. Audio Guide for the Brunel Museum

We developed a prototype audio guide and webpage that provides additional information about specific artifacts within the Engine House exhibit space. We focused on four main tasks. First, we took our findings from Objectives I and II and developed a set of design specifications. Second, we created a user interface (UI) for the prototype guide. Third, we recorded and edited the audio guide content. Finally, we implemented the prototype guide in the museum and developed resources to enable staff to monitor and track visitor engagement with the prototype audio guide in the future.

A. Design specifications

From our research and interviews with staff and volunteers at the Brunel Museum and other London museums we created design specifications to steer the development of our prototype audio guide and to include in our recommendations for a revised audio guide. Our design specifications include delivery technology (mobile app versus web interface, signage/numbers, QR codes, etc.), guide length (for individual sections and total length), narrative style, and potential expansion opportunities[1].

There are several technology options for delivering audio guides, including mobile apps and websites on phones or tablets, as well as physical devices (e.g., handheld devices with headsets) provided by the museum. In addition to these options, different wayfinding technologies are used within audio guides, such as digital maps with stop annotations, QR codes and Bluetooth beacons. These affect the way that visitors travel between exhibits.

B. Develop Audio Guide Content

We initially reached out to Jack Hayes, the Collections Access Coordinator at the Brunel Museum, to see which staff members and volunteers might be interested in sharing their insights on specific portions of the exhibits as well as what objects the museum wanted to have highlighted in an audio guide. Dr. Hayes wrote an initial script for three of the four stops and read it over together with us and the narrator for each stop to make sure it had the correct tone. For the tunnel shield stop, we developed the audio guide script ourselves and

[1] The ability to add additional guide stops in the future.

solicited feedback from staff and volunteers before proceeding to recording. In initial drafting and development, we referenced the audio guide script written by Hayra, the tour guide scripts provided by the museum, recordings of guided tours by volunteers, and books/media about the Thames Tunnel. Once the first draft of the script was complete, we went to the exhibit area and read the script aloud to determine if any parts needed to be changed before recording. Before recording, we created sample recordings to ensure all equipment was working as expected and the recording space was reasonable for spoken word recording. We then scheduled a time to record with each participant and worked with them accordingly.

C. Recording

We borrowed recording equipment and received training from the WPI Global Labs for a handheld audio recorder and a wireless Lavalier microphone kit. We used this equipment to record audio guide content with museum staff and volunteers as well as for soundscape components (London Overground noises, street sounds, et cetera). Once the recordings were complete, we listened to and edited the recordings as a group before presenting the audio to museum staff.

D. Test and Refine Audio Guide

During the creation of our audio guide, we worked closely with museum staff and volunteers, gathering feedback as we went. Before recording each stop, we had a meeting with the person narrating to alter the script as needed. After the fact we reviewed each recording with staff and volunteers for final approval. This process allowed us to collect feedback and iterate the guide in a fast-paced manner to accomplish all project goals before our time in London came to an end.

After incorporating feedback into the first two stops of the prototype guide, we released them to museum visitors. The guide was implemented using QR codes at each location, which visitors could then scan to hear more about objects they were interested in. These two stops along with two more implemented after the first weekend of testing were left up to remain available until the Brunel Museum closes to start their Reinvented Project. We also provided staff with a way to track visitor usage of the guide so that they can determine

whether they would like an audio guide to be implemented permanently after the Reinvented Project is complete.

IV. Recommendations and Future Improvements

For our final objective, we developed recommendations concerning guide content and exhibit interpretation for the Reinvented Project in the Engine House. These recommendations were based on the findings from our visitor tracking and observations. We also recommended how the Brunel Museum should proceed with the future development of the prototype audio guide in the Engine House. Ultimately, aside from a final report and presentation, our primary deliverables were the prototype audio guide and the visitor tracking tools.

Findings

This chapter covers our findings from our research into audio guide development and visitor tracking. This includes discussions of visitor tracking and observations, an evaluation of audio guides at other museums, an evaluation of audio guide platforms, an evaluation of the Hayra audio guide script and guided tours at the Brunel Museum, and a discussion of our audio guide. Additionally, the audio guide design specifications and content development process is examined in detail.

Visitor Tracking and Observations

A large component of our project entailed conducting visitor tracking and observation in the Engine House. We discussed with museum staff, including the Collections Access Coordinator and the Community Curator, what tracking and observation data would be most useful for the Reinvented Project. We determined that data on exhibit attractive power (i.e., the percentage of visitors stopping at each exhibit), dwell times (i.e., the average time visitors spent at each exhibit), and the pathways visitors followed through the museum would be most pertinent. Additionally, we gathered qualitative data about how visitors interacted with each other and the museum to get a more well-rounded view of the exhibit space.

Figures 5 and 6 display data about the attractive power of each exhibit. Figure 5 shows the percentage of visitors who went to each stop in a heat map format using the floor map template in Appendix J (Figures 7 and 8 use the same template). Figure 6 shows the number of visitors who stopped at each exhibit once, more than once, or not all. From these visuals, we can see that the two most popular stops were the Tunnel Construction model and the 2nd section of Wall Panels which included *The Tunnel & The Men Who Built It*, *The Tunnel's Dangers & Disasters*, *The Tunnel as a Tourist Attraction*, and *The Tunnel & It's Uses*. Figure 6 shows that both of those stops had relatively high numbers of repeat visitors, that is, visitors who went back to the stops one or more times after their initial visit. These results may reflect that the panels have substantial amounts of text. Additionally, the Info Panels and Peepshow stops had the next highest numbers of visits and return visits. Both figures show a relative lack of visitor engagement with the Floor Map, Floor Diagram, Push Button, Banquet Painting and Watercolour. For the first three of these, the lack of interaction was likely due to lack of

awareness. The floor map and diagram are the only exhibit elements on the floor while the rest of the exhibits are on the walls around eye-level. Visitors have less reason to look down unless they are told that there are exhibit elements on the floor. As for the Push Button, it is located between the two Peepshows out of the main path of visitors. From our qualitative observations, we noticed that many visitors either did not see the button or were hesitant to press it, perhaps because they thought it would make a noise or that it was not intended for visitor use. The limited visits to the watercolor may stem from our visitor tracking methodology, as the person tracking visitors sat on a stool beside the watercolor, which potentially made visitors feel as if they were being watched.

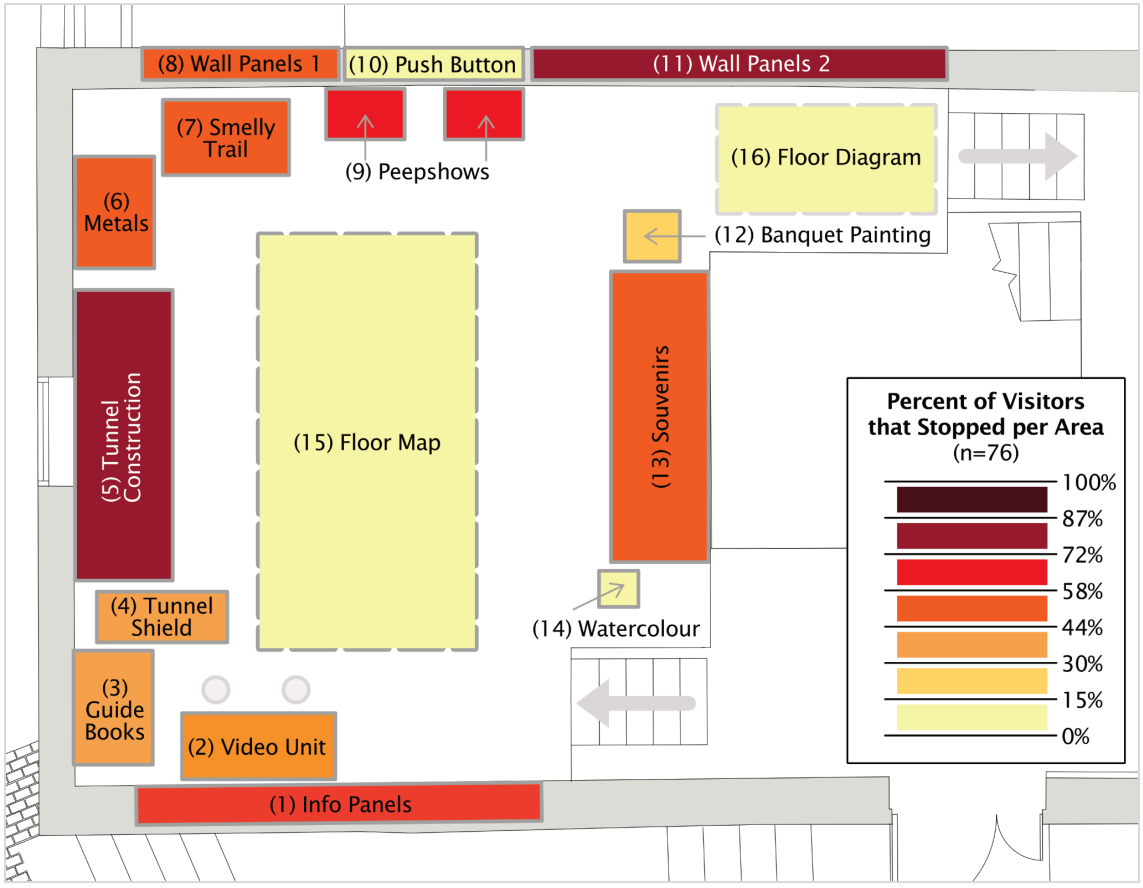

Figure 5: Heat map visualising exhibit attraction.

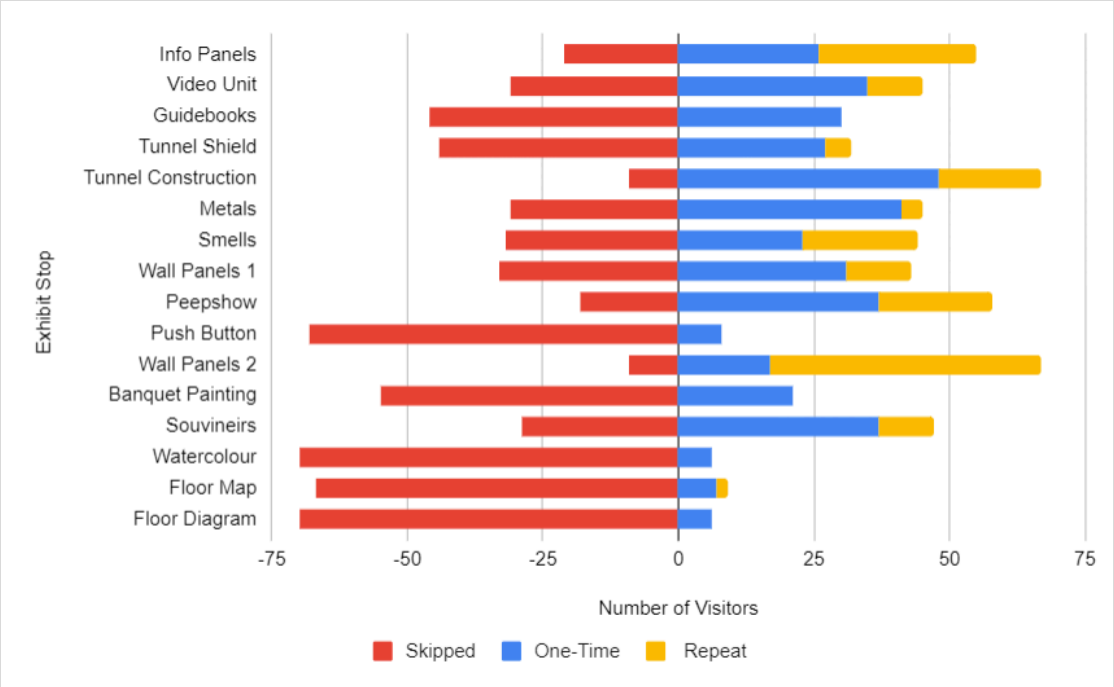

Figure 6: Number of visitors who stopped at each exhibit once, more than once, or not all.

Figure 7 presents data on the average time each visitor spends at a particular exhibit (i.e., dwell time). This heat map does not take into account visitors that skipped stops and only accounts for visitors who stopped at a location for more than five seconds. Figure 7 shows that visitors spend more time at the Info Panels and Video Unit compared to other areas. The amount of information presented on the Info Panels is slightly less than on Wall Panels 2, but visitors spend almost twice the time on average at the Info Panels than the Wall Panels 2. This may be because when visitors first enter the exhibit space, they are more apt to read the larger sections of text presented by the Info Panels. By the time they get to Wall Panels 2, they may be less focussed and tend to only skim the information presented. These data also show that although the Push Button is one of the least visited stops, when people do find and press the Push Button, they are engaged with it for a long period of time. From our qualitative observations, we noticed many responses such as “woah” or “wow” when the button was pressed, illuminating the images above, and there was typically an ensuing conversation between visitors about the images.

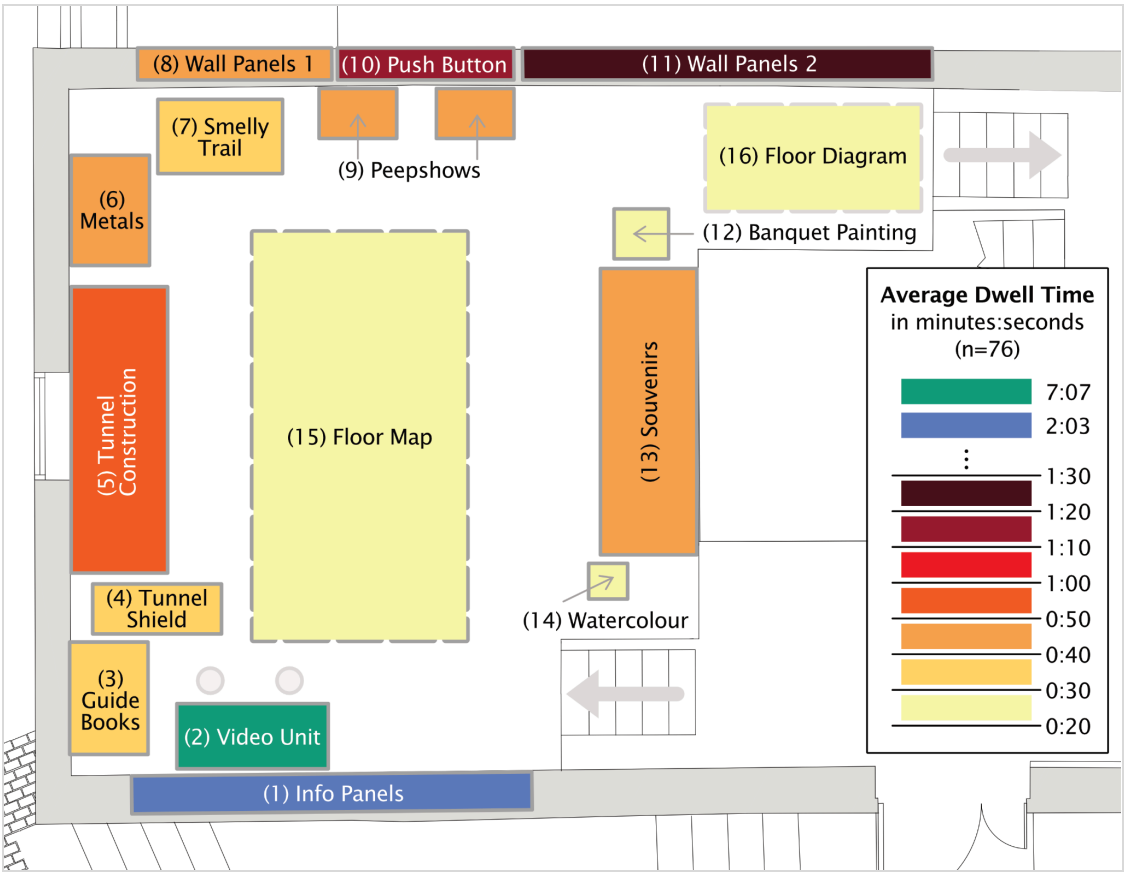

Figure 7: Heat map visualising dwell times.

Figure 8 shows the pathways the tracked visitors took through the exhibit space and whether the intended path, moving chronologically through the process of designing and building the Thames Tunnel, was followed. The density of pathways at each exhibit reflects the attractive power of each exhibit shown in Figure 5. As in Figure 5, the Push Button, Banquet Painting, Watercolour, Floor Map, and Floor Diagram have lower visitor interest and more visitors skip them entirely. The intended path around the museum brings the visitor through exhibits 1 to 16 in numerical order and tells the story of the Brunels and the Tunnel chronologically. We found that most visitors generally follow the intended path, skipping stops that they are less interested in on the way. For example, the four most common first stops after entering the exhibit space are the Info Panels, Video Unit, Tunnel Construction, and Souvenirs with the Info Panels being the most popular of the four. This observation suggests that most visitors follow the intended path while a select few decide to go to the more visually appealing or interactive elements first, such as the Video Unit, Souvenirs Case, and Tunnel Construction

Model. Figure 8 shows that few visitors cross the center of the room and most visitors follow the perimeter of the room in a clockwise direction.

From our qualitative observations, we noticed that the majority of those that travel around the exhibits in a seemingly random way and cross through the center of the room many times, are under 15's. Adults usually try to go through the museum chronologically in order to understand the story while under 15's jump between stops that seem the most interesting to them, usually ending at the text panels that are less interactive or visually stimulating.

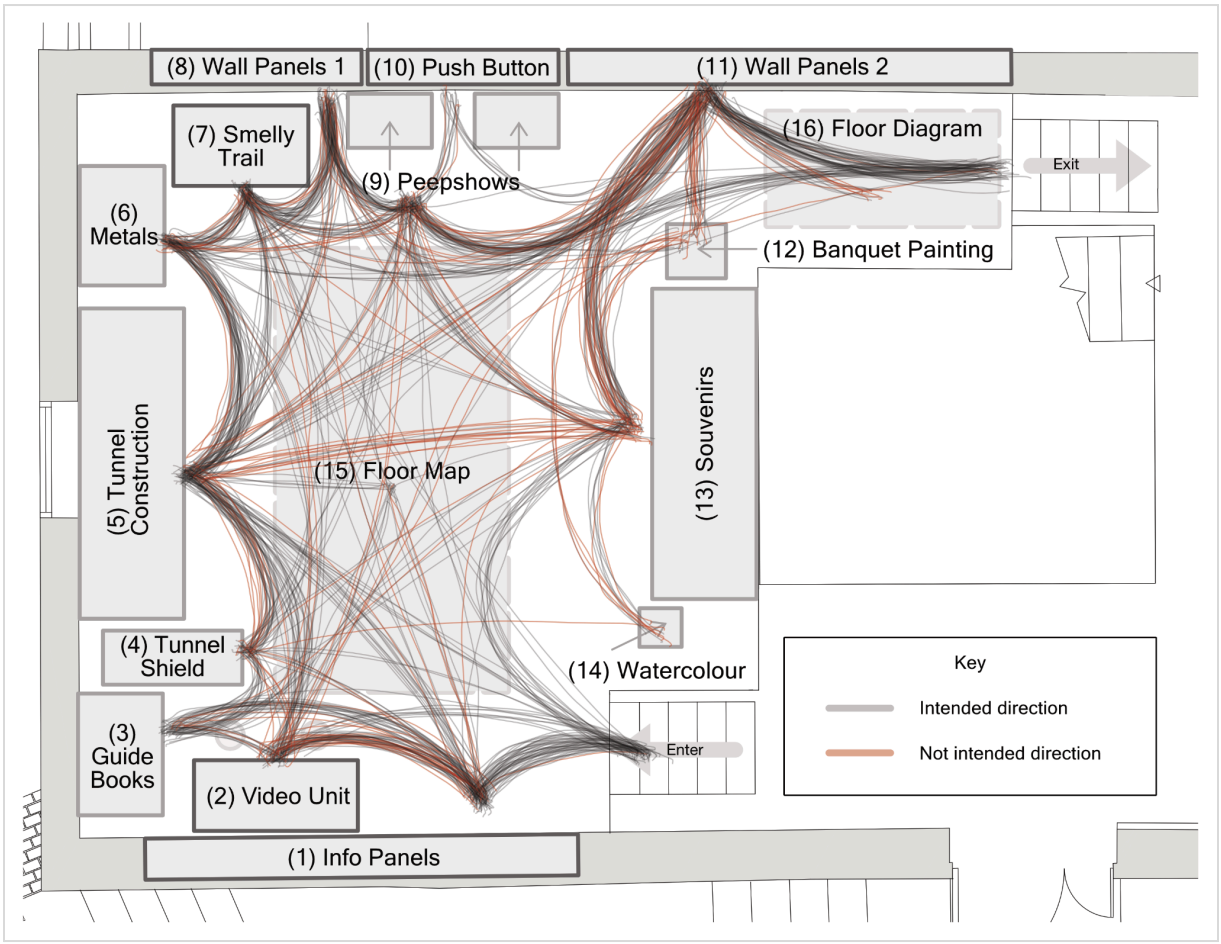

Figure 8: Visitor pathways through the Engine House exhibit space.

Evaluation of Audio Guides at Other Museums

Table 1: Summary of Audio Guides at Other Museums.

Museum; Audio Guide Name	Platform	Tour Length	Stop Length	Audio Elements	Navigation	Content
The National Gallery	Smartify	30 min	1 - 1.5min	-	-	History of objects
The National Portrait Gallery; *Meet the Portraits*	Bloomberg Connects	1 hr	2 - 3min	Music	Pictures/video, Map	Stories about people
Churchill War Rooms	Acoustiguide Opus+ Multimedia Guiding System	1.5 hr	2 - 3min	Music, Historical soundscapes (background sounds), Sound effects	Pictures/video, Audio instructions, Label at each stop	Stories about people
Bank of England Museum; *Highlights Tour*	Smartify	15 min	1 - 1.5min	-	Pictures/video	History of objects
HMS Belfast	Acoustiguide Opus+ Multimedia Guiding System	1.5 hr	30sec - 1min	Historical soundscapes (background sounds), Sound effects	Audio instructions, Labels at each stop	Stories about people
Tower of London; *Crown Jewels*	Acoustiguide Android devices with touch screens	45 min	2 - 3min	Music, Historical soundscapes (background noise)	Pictures/video, Written instructions, Audio instructions	History of objects
Tower Bridge	Smartify	45 min	1.5 - 2min	Music, Historical soundscapes (background sounds), Sound effects	Written instructions	Stories about people
The Chiswick House & Gardens	Guide ID Podcatcher	1 hr	1.5 - 2min	Music, Sound effects	Audio instructions	Stories about people
Freud Museum London	Museum website with audio hosted on Podbean	30 min	> 3min	Music	Audio instructions, Written instructions, Labels at each stop	Stories about people
The Roman Baths	Acoustiguide Opus+ Multimedia Guiding System	1 hr	2 - 3min	Music, Historical soundscapes (background sounds), Sound effects	Labels at each stop	History of objects

As part of our field research in London, we visited 10 museums to evaluate their audio guides. We used our form in Appendix G to assess the timing, navigation, audio elements, delivery methods, and content of the audio guides. We visited the following sites in this order: The National Gallery, The National Portrait Gallery, the Churchill War Rooms, the Bank of England Museum, the HMS Belfast, the Tower of London, Tower Bridge, The Chiswick House and Gardens, The Freud Museum, and the Roman Baths. Refer to Table 1 for a summary of the information covered in this section.

We had our first full audio guide experience with the National Portrait Gallery (NPG). The gallery was one of the first museums in London to use the Bloomberg Connects audio guide feature. We found that the NPG excelled in the implementation of their audio guide and could serve as a benchmark for best practices in the field. They maintained three different audio guide experiences: *Meet the Portraits* (21 stops), *Self-Portraits by Women* (10 stops), and *Changemakers and Campaigners* (14 stops). We chose to experience the *Meet the Portraits* guide and the *Changemakers and Campaigners* guide which presented a well-rounded view of the guide offerings at the NPG.

Diving deeper into the timing, navigation, audio, access, and content of these tours provided clarity into what made them engaging to us as visitors. The first thing we noticed was that stops longer than three minutes led to declining engagement while the medium-length stops balanced presenting the material to the visitor while not making the visitor feel lost or bored. The Bloomberg Connects app incorporated an interactive map to guide the visitor around the museum without giving specific paths or instructions. This approach allowed the visitor to slowly wander to the next stop on the tour and experience the rest of the exhibits on their way. At many of the stops, the tour also used a narrator to direct the listeners' attention towards other portraits in the room as well as particular aspects of portraits that one might not otherwise notice. This aspect made each stop more engaging because the visitor did not have to focus on one portrait for the entirety of the stop; rather they were encouraged to explore the exhibition space while listening to the guide in the background.

Two things that stood out about this audio guide were: (1) it was narrated mostly by museum staff; and (2) despite the overall lack of diversity in the collection, the audio guide focused the visitor's attention on the diverse portraits present. This diversity perspective was especially noticeable in the salon-style hang room that boasted a portrait by Joshua Reynolds of Mai, the first Polynesian to visit Britain, where the visitor was encouraged to explore the hang as a whole while also paying special attention to the importance of Mai as an acquisition for the museum.

Following our audio guide experience, we reached out to Emily Tarry, NPG Production Assistant, who gave us an in-depth tour of their audio guide and facilities while answering many of our questions about audio guide development and implementation. The NPG approach entailed speaking with curators, developing a map of stops, writing scripts, recording the audio,

editing, and then publishing the tour. When speaking to curators, she reminded us to ask what they would like to highlight in the tour, whether it is specific objects or people. Ms. Tarry told us that one thing that made their development process easier was the ability to re-format some of the existing in-person guided tour stops to fit a self-paced audio-guide. She also stressed that when developing a tour map, both the content and the order in which it is presented is important. The map should include important works or themes that make sense in the context of the museum.

We asked Ms. Tarry how the NPG, a museum with a broad array of visitors, targeted the guide to different audiences. Ms. Tarry explained that the overarching goal of an audio guide is to cater to all audiences, but it is important to be realistic about which types of audiences will most likely use the guide. For example, the NPG does not have a children's audio guide, but they do have other children's activities. The NPG assumed that most children would not have their own devices and they would not be as engaged by an audio format as much as other formats, such as written or picture-based activities. Ms. Tarry also emphasized that if a tour is too technical, some audiences may be alienated. This advice is especially pertinent for museums like the Brunel Museum that have strong technical themes.

As we continued our research, we visited two major historic sites run by the Imperial War Museums (IWM): the Churchill War Rooms and HMS Belfast. The Churchill War rooms audio guide was designed to be the core means by which visitors experienced the site. While there were text panels in the Churchill Museum section, essentially another museum within the Cabinet War Rooms, the remainder of the War Rooms were largely free of any signage, making the audio guide the only source of interpretation. The guide told the story of the spaces, who used them and the functions of the various rooms throughout the underground bunker. At times they also included first-hand accounts in the form of recordings of various individuals that worked in the War Rooms during WWII. The guide was made using Acoustiguide and was deployed on a physical device similar to a telephone. The majority of the stops were between two and three minutes, and the total tour took approximately 1.5 hours.

At HMS Belfast on the other hand, the audio guide was more of an additional option instead of a necessary part of the experience. The stops on the ship were all under one minute in length but, because the tour encouraged visitors to explore the site along the way, the total duration of the experience was around 1.5 hours. The exploratory component also led to

significantly higher engagement. As is the case in the National Portrait Gallery, the option for the visitor to explore at their own pace reinforced that, it is important to give the visitor some flexibility in how they want to tailor their listening experience.

Following our visit to the HMS Belfast, we met Lucy Tindle, Exhibitions and Interpretation Manager at the Imperial War Museums, to discuss the development and implementation of their audio guides. We discovered that the nature of both sites prevented the Imperial War Museums from using spatial technologies, such as Bluetooth beacons, to trigger guide audio. They also designed the duration of the guide stops in the Churchill War Rooms to minimize congestion at pinch points. These examples show how the IWM were able to adapt to unique limitations related to their sites. The IWM also recognized that when HMS Belfast was in service, the Royal Navy prohibited women from serving on ships. As a result, all the sailors aboard HMS Belfast were male. To counter this lack of gender diversity, they had the audio guide read by female voice actors and included stories about the families of the crew, who were crucial to their morale. The story of the Brunel Tunnel is similarly dominated by male characters, but the Brunel Museum might present greater diversity by adopting a similar strategy as the IWM.

The last museum we visited was the Freud Museum London (FML) where we discussed the design and development of their in-house audio guide with Iveta Rozlapa, the Retail Manager. A QR code is used to access the guide, which is hosted on the FML's own website using Podbean audio software. All aspects of the guide, including floorplans, stops, and language options, were embedded on a single page which allowed for easy navigation. Like the National Portrait Gallery's approach, museum staff featured in the guide were introduced before they elaborated on stories about the museum's history, which made the guide more personal. Being a community-oriented organization, Brunel could implement a similar strategy in their audio guide by introducing volunteers and staff before they talk about artifacts in which they have a particular interest. This approach can create a stronger sense of personalization, because some days the staff in the museum interacting with visitors may be those that recorded parts of the guide, making visitors more comfortable in asking questions and starting a dialogue.

We evaluated several other audio guides, but did not interview museum staff members. These additional guides helped us to better understand the range of audio guide offerings around London and gather inspiration for the Brunel Museum audio guide.

At the National Gallery we found that navigation while using the audio guide was difficult because the museum had re-hung many of their galleries since the guide was produced and had not updated the guide or associated signage. This was an important experience for us because it showed the importance of making a guide that is easy to update as the exhibits within the Brunel Museum change.

The Bank of England Museum offers two audio guides titled the *Highlights Tour* and *The Future of Money*. We found it difficult to locate objects in the Highlights Tour given the organization of the museum. However, in *The Future of Money*, a large temporary exhibit, wayfinding was much easier as the names of the stops on the guide matched the names written on physical displays. This tour was different from the ones we had experienced previously because it featured many voices at each stop sharing opinions about different topics such as cryptocurrency and contactless payment. Interestingly, while navigation was easier, we found this guide's content more difficult to follow because the speaker changed frequently. The guide might benefit from shorter stops, as well as short introductions of the various voices who provided opinions about the topic areas to give them credibility. We also found that it was difficult to engage both with the audio guide and the exhibit content because the exhibits were mostly text-based and reading while listening proved difficult. From this observation, we took away that our tour may function better employing narrator introductions and clear navigation.

At Tower Bridge we noticed that the durations of the audio guide stops were mixed with shorter stops towards the end, perhaps in anticipation of the waning attention spans of the audience. Regardless, the timings of the tour stops may benefit from the Churchill War Rooms' approach to limit congestion in popular areas. For example, the walkway between the towers could have tour stops before entering and no stops after the exit in order to slow visitor influx and not impede their exit, thus decongesting the walkway. This may be easily implemented in the case of this site because we observed that the guide stops were not tied to particular locations within the Bridge, but rather were stories about the construction and the people who maintain it.

We took three additional tours that used physical devices instead of personal phones or tablets. One was the Roman Baths in Bath, England, which was the only audio guide we experienced outside of London. They had a plethora of audio guides for a large variety of visitors including those who speak different languages, children, and those who want to hear expert opinions about different aspects of the baths. We reviewed the general adult and children's guides

within the museum. They were both nonlinear add-ons to the experience, meaning they were not core to the experience of the space and were not presented in a set order. All visitors were given an audio guide device to start but had the choice whether they wanted to use it at any of the stops. This guide used many soundscape elements, such as music, to introduce each stop as well as sound effects at appropriate times. The children's tour additionally included interviews with fictional historical characters within the baths. These elements made the tour more engaging as they broke up the monotony of experts speaking on different topics. This is especially interesting for the Brunel Museum, which is a family-oriented museum that could benefit from a potential children's tour in the future.

The Tower of London had multiple shorter tours, one per building, that used Acoustiguide touchscreen Android devices. This tour was also presented as an add-on to enhance the visitor experience instead of a necessity for all to use. Our prototype audio guide will follow a similar add-on format where visitors have the option to scan QR codes near various objects to learn more while being nonlinear so visitors have the freedom to skip any stop they choose.

The audio guide at the Chiswick House used Podcatchers devices by Guide ID. These devices allowed us to tap on different stops to hear them through our devices. This system was compelling because it was very easy to use and allowed us, as visitors, to focus more on the experience of the museum. The Chiswick House also implemented clear signage to help visitors navigate between guide stops and, like many guides that utilized soundscapes, they introduced many of the stops with music. As a result of having provided devices, they are also able to implement a children's tour which uses elements such as questions or physical tasks to keep the listener engaged. This experience helped us to better understand how to use questions and audio components within our guide to enhance visitor engagement while listening to longer stops.

Evaluation of Audio Guide Platforms

As our team visited museums, we noticed several platforms are commonly used for audio guides, namely Bloomberg Connects, Smartify, Guide ID, and Acoustiguide. We reached out to each company to understand more about their platforms and met with representatives for the first three platforms. Several other companies, including Acoustiguide, did not respond to any communication, so we based our research on publicly available information.

Table 2: Audio guide platform comparison.

Criteria	**Bloomberg Connects**	**Smartify**	**Guide ID**	**Acoustiguide**
Relative price	0	₤₤	₤₤₤	₤₤₤₤
Estimated minimum ₤/year	₤0	₤1800	₤3350	Quote Required
Offers proprietary devices	X	X	✓	✓
Available via downloadable app	✓	✓	X	X
Available via website	In development	✓	X	X
Audio playback w/ background image	✓	✓	✓	✓
Multimedia playback	✓	✓	In development	Depends on Platform
Tour freely editable by museum anytime	✓	✓	X	X

A representative of Art UK, a UK museum network, explained that Bloomberg Connects can serve as a multimedia guide for visitors at the museum and also as a way to experience the museum remotely. Bloomberg Connects features audio guides with stops shown on a custom map. It can also show additional content about the museums or specific exhibits, such as embedded videos and research papers. Art UK has partnered with Bloomberg Connects to

onboard and assist its member museums with the adoption and ongoing support of their digital guides. Importantly, Bloomberg Connects is completely free to all institutions and visitors.

We also met with a sales representative from Smartify to broaden our search. They showed us the platform's features, both as an audio guide system and as a platform for additional multimedia content. Uniquely, Smartify has an in-house content development team that can be contracted to create guides, immersive experiences, and other interactive elements on Smartify's platform for an extra cost. We noticed a lack of navigation instructions in the Smartify tours we reviewed at the Tower Bridge, the Bank of England and the National Gallery, and most guides incorporated only an audio description with an accompanying image. This may be because the museums chose to develop their tours in this fashion, since the Smartify sales representative demonstrated more elaborate arrangements including navigation views, interactive activities, and other unique features. Smartify is priced as a subscription model starting at £1800 at the time of writing, and additional features incur additional charges, which may explain why the tours we experienced were more limited in functionality.

The Guide ID sales representative explained that their Podcatcher device is available for long-term lease, while a completely digital offering is a complimentary add-on. The Podcatcher devices are unique in that visitors begin a section by tapping the device against physical tags throughout a museum. This tap-to-select feature allows the devices to be very simple and suitable for less technically inclined audiences. Few customers have expressed interest in Guide ID's mobile only option, so they do not have standardized pricing available. A long-term loan of Podcatcher devices starts at £3350 per year, not including any tour design or equipment configuration costs.

The last company we investigated was Acoustiguide. They also provide a physical proprietary audio tour device for well-resourced museums. The company offers multiple models of their handsets as part of their platform. Some units are similar to a household touch-tone phone with a 12-key number pad and are intended to be held to the head, while others are similar to Android smartphones with headphones provided to visitors. In addition to proprietary devices, Acoustiguide also develops custom mobile phone apps for museums and heritage sites. App design and development appear to be a custom service and few details are available online.

Evaluation of the Hayra Audio Guide Script and Guided Tours at the Brunel Museum

As part of our research, we analyzed the previous audio guide script produced by Hayra for the Brunel Museum and shadowed three guided tours with different volunteer guides (Jill, Sue and Kal). While the Hayra script and guided tours may not directly mirror the style of our audio guide prototype, our primary goal was to understand the tone used to convey information to museum visitors.

We first reviewed the Hayra script which covered the entire site starting in the Engine House. Our analysis revealed that the guide effectively makes connections between historical information to today's context, aiding listeners in understanding the tunnel and Brunel's significance. For example, the tour addressed the changes in the tunnel's use from originally being a foot tunnel to becoming part of the East London Line and now being part of the London Overground. Hayra's choice to begin the tour outside the tunnel shaft space provides participants with a glimpse into the history of Rotherhithe. It highlights landmarks like the Prospect of Whitby, which claims to be the oldest riverside tavern dating from 1520, as well as the transformation of maritime warehouses into luxury apartments. In our audio guide for the Brunel Museum, we aim to utilize a similar tone that brings relevance to historic artifacts and makes them accessible and engaging for the audience.

The script also goes beyond pure description or interpretation, presenting a comprehensive narrative that includes a description of tunnel features and historical significance, stories about the challenges miners, laborers and bricklayers faced as well as an overview of Marc and Isambard Brunel's lives and timeline. We learned that to effectively captivate an audience, a balance of description and interpretation is critical. It became evident that weaving a description of a physical element following a larger section of interpretative audio helps to bring a participant's attention back into the narrative.

To enhance audience comprehension, Hayra utilizes a series of mental images to bring ideas to life. For example, Hayra wrote "Some stories at the time claimed that a person could in fact cross the river at Rotherhithe by simply hopping from ship to ship as the river was so overcrowded" (Appendix B). This reference has been used consistently in multiple places including at the Archive Talks of the Thames Tunnel Watercolours as well as by several tour

guides on Guided Tour weekends. This use of mental imagery is an effective way to bridge the differences in the understanding of different visitors, such as those with existing knowledge of the time and those without.

To understand where visitors may look for more information about the narrative and construction of the tunnel, we shadowed guided tours. Common areas of inquiry from audience members pertained to the construction of the tunnel. This contributed to the decision-making when determining the location of audio guide stops and led us to ultimately include the Tunnel Shield. Other questions asked by audience members revolved around why a bridge was not built instead of a tunnel and where the waterline of the Thames is in relation to the depth of the tunnel. Like these examples, many questions were related to technical aspects of the tunnel.

While observing the guided tours led by Jill, Sue, and Kal, we noted the similarities and differences in their storytelling and emphasis on different features. Jill tailored her tour to suit the background and interests of her audience, especially when children were present, while Kal delved into more detailed explanations of the technical aspects surrounding design and construction. In contrast, Sue focused more on the lives of the Brunels compared to other tours. All three tour guides engaged their audience by asking questions such as “Does anyone know how long [tunnel construction] took?” (Kal). This audience questioning was something that Hayra used as well. When designing our audio guide signage, we opted to prompt participants with questions as we observed that this increased engagement.

Our Audio Guide

Design Specifications

Based on our background discussions and research, we developed a user interface using pages integrated into the pre-existing Brunel Museum website. Maintaining an app or physical device for audio delivery is generally more difficult and expensive for untrained staff due to requirements for specialized technical skills. On the other hand, a website is easy to use for visitors, as well as easy to maintain for museum staff. The website includes features such as photos of the objects, ability to track number of visits, and a simple design for easy navigation. From a visitor perspective, the guide includes signage with QR Codes posted in front of artifacts. This signage includes design elements such as large text, rounded corners, color-coding, and

leading questions (as shown in our style guide in Appendix K). The choice to use larger text and rounded corners allowed us to soften the appearance of the signs and make them seem more approachable for visitors. The colors we used for the outlines of the QR Codes correspond with the proposed color codes as specified in the Reinvented Project documentation. From our research with other museums, we also found that prompting visitors with a leading question at audio guide stops increases visitors' interest in learning more about the displayed objects. We chose to keep questions relatively open-ended, but also specific to the audio guide stop they were targeting as shown in Appendix L.

Content

When developing the content for the audio guide, we first selected the stops we wanted to include and determined stop content. To identify these stops, we spoke to the Collections Access Coordinator at the Brunel Museum to talk through which objects within the exhibit space could be suitable for an audio guide interpretation format. The two most important factors when choosing the objects for the prototype audio guide were (1) not already having extensive written interpretation and (2) the museum staff had an interest in the objects.

Writing the script for each stop was our next step in the audio guide creation process. During this stage, we adhered to a few important guidelines. First, we ensured that the narrator introduces themself with their first name and position within the museum. This format allows listeners to feel more connected to the narrator, fostering a sense of involvement with the museum’s staff and volunteers. Another guideline that we followed was to not use complex language when plain language could be used in its place. For example, when talking about the animal that Brunel designed his Tunnel Shield after, we chose to use its common name, Shipworm, instead of its scientific name, Teredo Navalis. This is not always possible to do as some complex words are important in describing certain objects in the museum collection, but, when possible, it is important to use plain language. The final guideline we made for script development was to always relate the artifacts to people and stories. Instead of simply describing what the object is, visitors appreciate understanding the historical context and significance. This approach invites visitors to engage with the objects on a deeper level, connecting them back to their own daily lives.

Initial Results

During the weekend of April 12-15, 2024, we performed a trial run including two stops of our audio guide as shown in Appendix L (lower two). Over that time, we recorded 14 total unique scans using the audio guide out of the 88 people who visited the museum. Nine people scanned the stop about the history of the plates in the Souvenir stop and five people scanned the QR code for the Peepshows. The plates have very little written interpretation or signage, likely prompting more people to scan the QR code in search of more information. The Peepshows, on the other hand, do have signage with some basic explanations of how they work and what they were used for in addition to being an interactive element themselves. An interesting aspect of these data is that, even though the Souvenirs stop is much less visited generally compared to the Peepshows stop, the Souvenirs stop garnered more scans. We can infer from this observation that visitors look for more interpretation for the objects within the souvenir case, which suggests that these objects may see more visitation if they had more interpretation available.

Conclusions and Recommendations

Based on our findings above, we draw several conclusions regarding the exhibits in the Engine House based on our visitor tracking and observations as well as current best practices in the use of audio guides. We make several recommendations for exhibit and audio guide design that the Brunel Museum might consider during its Reinvented Project. We also provided the visitor tracking tool, four prototype audio guide stops and a presentation to volunteers and staff summarizing our key findings.

Exhibit Design, Placement, and Interpretation

Based on our tracking and observation data, we found that exhibits featuring interactive elements, such as the video unit, the visual illusions of the Peepshows and the large Tunnel Construction model attracted far more visitors than other exhibits like the Watercolour and Banquet Painting. Thus, we recommend that interactive exhibits should be included throughout the new exhibit layout. The placement of the exhibits should also be carefully considered to encourage visitor flow between exhibits. These recommendations are in line with our tracking data and the museum's current exhibit improvement plans for the Reinvented Project, which features the addition of numerous interactive exhibits and updates to the various text panels.

We also recommend, based on our data regarding the Floor Map, that the museum avoids exhibit elements at floor level unless they include eye level signage directing the visitor’s attention to the floor element. Increasing the lighting in the exhibition space, as much as is practical around sensitive artifacts, would also increase the visitor’s interest in and awareness of various exhibits as they could refine additional details that might intrigue them.

Lessons From Current Audio Tour Practices

Audience Engagement

Based on our findings from our evaluations of audio tours at other museums and from the implementation of our audio guide, we found several key lessons to improve audience engagement. We recommend the museum continue to use staff and volunteers to narrate future

audio guide sections and include music and soundscapes to increase engagement. At the beginning of each section, the narrator should introduce themselves to form a more personal connection between visitors. Using their voices in the audio guide is an effective way to foster a welcoming environment and encourage conversations between visitors, volunteers, and staff. Additionally, the museum should begin audio guide stops with a brief section of historically relevant music, such as classical compositions by Mendelssohn, since he visited the tunnel and knew the Brunel family personally. Beginning with music sets the tone of the tour and keeps listeners engaged by breaking up longer sections of information.

We also recommend the museum keep all guide stops under three minutes in length. We found 1.5 to 2.5 minutes to be a good length to share content without losing visitors' attention. If there is more content than can fit within 3 minutes of audio, we recommend adding optional stops to dive further into specific subjects. When crafting a script, each section of the guide should include a mix of interpretation and description. Towards the middle-to-end of a stop, we recommend adding an instruction to look at a particular item or area in the exhibit, such as an artifact or display. Audience attention often drifts after 2 minutes of audio, and drawing attention to a physical object helps to bring listeners back into focus.

Accessibility

During the Brunel Museum's closure for the Reinvented Project, one of their primary objectives is to enhance accessibility. To further enhance accessibility in the Engine House, the audio guide for the exhibit space could be translated into multiple commonly spoken languages based on census data from the local council. These translations could also be added to the webpage as transcriptions for visitors who are hearing impaired.

Currently the platform at the top of the staircase, added in 2016 in the Tunnel Shaft, offers an accessible option for visitors to view the Tunnel Shaft space. The Chiswick House has similar accessibility concerns to the Brunel Museum and has implemented virtual tours of its inaccessible historical spaces. We recommend the Brunel Museum adopt a comparable approach for its less-accessible Tunnel Shaft space. Utilizing scanning technology, such as the devices offered to museums by Matterport, 3D scans could be created and provided via iPads to visitors who are unable to access the space physically.

Platform and Style Choice

Based on our analysis, we recommend that the Brunel Museum adopt Bloomberg Connects as the future platform for their audio guide. From our discussions with Bloomberg Connects, Smartify, Guide ID and research on Acoustiguide, we constructed the comparison chart shown in Table 2. The table indicates that Bloomberg Connects is the most cost-effective option that still includes features that would benefit the Brunel Museum, such as the ability to edit the guide at any time. Its implementation would also be supported by Art UK with whom the museum already has a relationship. This option fits the museum's budget while providing ample tech support through both Art UK and Bloomberg Connects to relieve staff from maintaining the software. It also offers professional guidance in the development of content for the guide, as well as increased exposure through the Bloomberg Connects community.

We also considered options for the format and style of a future audio guide. Due to the nature of the exhibition space, we recommend that the Brunel Museum structure its audio guide as a self-guided experience rather than one that leads visitors along a predetermined path. This approach avoids the downfalls we have seen while testing audio guides at other museums, namely that having to listen to a stop that the visitor finds less interesting can adversely impact their engagement for the remainder of the guide. However, in this format, identical to the scheme of the prototype guide, the visitor has the choice to listen to information they want to listen to.

The Immediate Future

Although we are recommending the adoption of the Bloomberg Connects software, we think that it will be best for the Brunel Museum to continue using the current website-based audio guide until they close in October for renovations. While the museum is closed, museum staff should transfer recordings from the prototype guide to Bloomberg Connects and add additional audio stops and information from the museum's existing collections page. Ideally, the guide on Bloomberg Connects would be completed (as part of the 13-week setup and onboarding process hosted by Art UK) before the museum reopens in the summer 2025.

Upon reopening, we recommend that the museum update the museum layout within the visitor tracking spreadsheet tool so that they can begin using it to collect visitor data. Using this tool, the museum staff can learn about which exhibits visitors find most engaging, understand the

paths they take through the museum, and make informed adjustments to the layout of the exhibits as needed.

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Appendices

Appendix A: Insights from findings on the story, navigation, and social interaction perspectives, and implications for design as set forth in *Flow, Staging, Wayfinding, Personalization: Evaluating User Experience with Mobile Museum Narratives* (Roussou & Katifori 2018).

Story Perspective (Plot & Flow)	
Positives	Narrative constructs such as humor, links to everyday contemporary life, an informal tone, and unconventional characters.
Drawbacks	Story too informational and "static", even after improvement.
Implications for design	• Balance the immersive qualities of fiction with authoritative factual interpretation of the past but do not overflow the visitor with information. Use the engagement power of fiction to spark visitor interest on the facts. • Keep story sections short, provide a "story progress bar", inform visitor whether content is related or not to exhibits. • Give the visitor (the illusion of) control.

Navigation Perspective (Wayfinding & Navigation)	
Positives	• Almost all visitors were able to locate the exhibits even though no localization system was in place. • Photo and descriptive instructions for navigation were seen as a more explorative and appealing way to navigate, by some users.
Drawbacks	• In some cases, visitors were lost or found a different exhibit than the one indicated without realizing it. • There was too much standing still in one place.
Implications for design	• Take into account: ○ Visiting style (e.g., ant vs. grasshopper/butterfly) ○ user's preferred level of interactivity (guided vs. explorative) ○ that visitors participate in an experience on-site, standing up and moving in physical space. There is only so much time before they get tired, physically or mentally so keep the stories short (short enough to be completed in one visit) • Exploration: ○ No need to be too explicit, make it a game ○ encourage visitors to move back and forth, to revisit/pass by exhibits they can now see from a different point of view, having heard their story ○ avoid narration while the visitor is walking towards a goal; it adds to one's cognitive load and can be distracting • Orientation: ○ Detecting a user's orientation (e.g., with a compass or even AR) makes things easier • Take into account the options of QR codes or NFC tags as ways for the user to check in at a specific location indoors during the experience.

Social Interaction Perspective	
Positives	The stories were perceived by some visitors, who visited the museum alone, as companions.
Drawbacks	The stories were individual experiences, not designed for social interaction.
Implications for design	• Offer frequent and meaningful choices as part of the plot. Make the group think and explore, give them challenges, make their choices have moral weight. Ensure that their actions influence how the story unfolds and its outcome. • Include activities that promote social interaction and collaboration (e.g., every member of the group should have a role to play in order to reach a goal). • If more devices are available, provide each group member the opportunity to experience a different story. For example, they may follow a different central character that has a different point of view and information to share. Visitors can be prompted to exchange information from each in order to piece together a bigger picture.

Appendix B: Hayra Audio Guide Script.

1. Introduction and biography of Marc Brunel

Walk up the stairs to the mezzanine level until you're facing the painting on the back wall

Hello and welcome to the Brunel Museum, where we celebrate the story of an engineering family that changed the world and the Thames Tunnel, the first tunnel constructed under a navigable river anywhere in the world.

While it's a little hidden away, and certainly an understated piece of London's history, the Thames Tunnel was a great feat in Victorian engineering, so much so that it was often referred to as the 'eighth wonder of the world'.

The Thames Tunnel has certainly stood the test of time. Today it is still used by the London Overground line stretching from Rotherhithe on the south, to Wapping on the north side of the river. Perhaps you've travelled through it on the train today already!

You're currently standing in the Engine House – purpose built and completed in 1842 to store the steam engine and boiler that powered the tunnelling machinery after the tunnel was opened to the Victorian public. Now an Ancient Monument, it was first opened as a heritage site in 1980 and now houses the exhibition commemorating the Brunel family, the tunnel and those who built it.

If you look at the portraits in front of you you'll see one of the two great engineering minds behind the tunnel, talented French mechanical engineer, Marc Isambard Brunel.

While often overshadowed by his more famous son, Marc Brunel was an engineering pioneer, and while Isambard was very much the poster boy of the Victorian industrial revolution, the Thames Tunnel was a triumph for Marc, a masterwork for which he was knighted by Queen Victoria in 1841.

Marc Brunel led a very colourful life prior to coming to London and his work on the Thames Tunnel. Born into a wealthy farming family in Hacqueville, Normandy in 1769, Marc showed a great talent for music, mathematics and art from a young age. He was sent to a seminary in Rouen and later trained as a naval cadet. In 1789, with Marc a mere 20 years old, the French Revolution began. This saw great bloodshed throughout France, and an effective purge of the monarchy and aristocracy, with many of his naval superiors executed as suspected royalists. Marc himself was an outspoken royalist sympathiser. Having openly criticised Maximilien Robespierre – one of the revolution's most prominent leaders – he was forced to flee the country, narrowly escaping with his own life. Leaving behind a young governess named Sophia Kingdom – the woman who later became his wife and mother to Isambard – Marc boarded a ship bound for the United States. He was appointed Chief Engineer of New York City in 1796. Three years later he moved to London where he was reunited with Sophia and married shortly after. Thames Tunnel is perhaps Marc Brunel's greatest masterpiece, but he is also widely revered for his creation of machines that produced pulley blocks used on mass in

Royal Navy ship rigging, which you can see behind him in the print ahead of you.

Model of the Tunnelling Shield and Tunnel

You are now looking at a model of the Great Tunnelling Shield. various engineers had tried and failed to construct a subterranean tunnel under the Thames. So we have to ask ourselves what was so different, innovative and successful about Marc Brunel's approach?

The real ingenuity behind Marc Brunel's project was the creation of a novel form of tunnelling machinery, eventually known as the 'Great Shield'.

Marc's design for the tunnelling shield structure was apparently inspired by his observation of a species of shipworm known as Teredo navalis – a mollusc with a hardened shell at its head which it used to bore through a ship's timbers simultaneously reinforcing the hole lining behind it with the debris it excreted. He adapted this dynamic into a mechanical form and produced a patent in 1818 for a device for 'forming drifts and tunnels underground'.

While this machine underwent a series of changes, originally intended to be cylindrical, the final result is shown in the model in front of you.

The shield measured 36 ft x 12ft 4in - that's about the size of a two-story house. The structure consisted of 12 iron frames divided into 3, amounting to 36 individual working cells. A miner was placed in each of these, faced by a row of horizontal wooden polling boards held in place by iron rods behind which lay the working face. Then, each miner had the painstaking task of removing one of these boards at a time, digging out 4 inches of earth – no more than a brick's width – replacing it, and then screwing it forward into the new position. When each miner had excavated his part of the face, his cell was propelled forward by the 'screw jacks' at the rear of the shield; in essence, the 'travelling shield' walked forwards on mechanical claws.

As the miners excavated the earth, it was passed back to an army of labourers and bricklayers behind who were carting the excess away and also simultaneously reinforcing the lining of the tunnel with brick.

In the case to the right of the model is a cheque bearing Marc Brunel's signature. Despite his undeniable talent as an engineer, Marc did become involved in a number of failed projects and as a result, was held in Southwark debtors' prison for 88 days. During this time Marc contacted Tsar Alexander I of Russia suggesting that he might work for him. Perhaps fearing Britain would lose such a great engineer, the government intervened and Marc was released. Marc even developed his early ideas for the Thames Tunnel while in prison, with a series of rough sketches.

Now, turn around and descend the staircase. As you leave, take note of the painting of Isambard Kingdom Brunel pictured with his trademark top hat, waistcoat and cigar. Isambard would go on to design a great many buildings, bridges, railways and ships throughout Britain including much of the Great Western Railway, the Clifton Suspension Bridge and the SS Great Eastern to name but three. However, his illustrious career began right here in Rotherhithe,

serving as the Thames Tunnel's chief resident engineer at only 20 years old.

Now, please head outside through the entrance where you came in, walk down the short ramp and turn to your right until you are facing the large blue and green mural. When you have done this, please click the continue button.

2. Watercolour mural.

This mural is a copy of one of Marc Brunel's watercolour paintings from 1835, on display in the Engine House. It depicts a cross-section of the Thames Tunnel. In the centre of the mural on the water's surface, there is a rowing boat where you can see the familiar figure of Isambard seated on the right. Marc Brunel stands in the left tunnel arch with his cane. And on the right, Marc's eldest child Sophia and her husband Benjamin Hawes. Sophia Brunel, named after her mother, was intelligent and artistic like her younger brother and a great engineering mind in her own right. Lord William Armstrong, another prominent Victorian engineer, stated that she was a "remarkably talented woman who understood her father and brother's plans", and even nicknamed her 'Brunel in petticoats'. One wonders just what she could have achieved if the opportunities had been open to her. Instead, she was effectively barred from higher education given the social restrictions imposed upon the women of Victorian England.

The mural also shows us the detailed stratified layers of London's earth. Already this gives the impression of what an enormous technical challenge it would have been to construct and dig on such complex terrain, softened by river water.

Now turn around walk over to the black railing at the river's edge and look over to the river. When you have reached this point, press continue.

3. The river

You are now looking across the river Thames. On the other side of the river is an area of London called Wapping – the end point of the original Thames Tunnel. From the sixteenth-century, Wapping was home to sailors, tradesmen and shipbuilders but was also the site of the infamous 'Execution Dock' where many pirates were hanged – their bodies often left dangling above the river for days. On the far left, you'll notice the 'Captain Kidd' – a pub named after William Kidd, a Scottish sea captain who served as a privateer for the East India Company but was later convicted and executed for piracy on that same site. To the right of this and all along the riverfront you'll notice many maritime warehouses. They are now mostly luxury apartments, many of them restored following the devastating bombing during the Second World War, known as the London Blitz. The warehouses historically served as stores and foundries for the bustling trade on the Docklands. Wapping was also where the first ever official policing body was founded. The Thames River Police was formed in 1789 to protect importers and cargoes from theft. Finally, at the far right you'll see a white building – this is the Prospect of Whitby; another famous pub that claims to be the oldest riverside tavern dating from 1520.

Why build a tunnel under this stretch of the river at all? In the earlier nineteenth century, the

London Docklands were a bustling trade centre and undergoing rapid development to the extent that the Thames was becoming overwhelmed and densely packed with cargo ships and merchant vessels. The nearest crossing was much further west at the fairly antiquated London Bridge over a mile away and with hefty toll charges. Some stories at the time claimed that a person could in fact cross the river at Rotherhithe by simply hopping from ship to ship as the river was so overcrowded.

Other than individual boatmen rowing a few passengers across the river at a time, there was clearly a need to relieve the pressure on this eastern section of the river. A new bridge seemed impractical given the height of the ships' masts at this point, with the pioneering design of Tower Bridge still a generation or so away. A tunnel, therefore, seemed the next best thing.

It is unsurprising then that when Marc Brunel formally proposed ideas of a tunnel under the Thames it was met with wide-reaching support and investment from all sides, including the Duke of Wellington – who envisioned military applications – the Institute of Civil Engineers, the King, and Parliament who assented to the project passing a bill for its construction in 1824.

There had been earlier attempts to build tunnels beneath the river though these invariably failed, largely due to the enormous technical challenges of digging through 'soft ground'. A particularly frustrating case was a tunnel designed and constructed by engineers and founders of the Thames Archway Company, Robert Vazie and Richard Trevithick, in 1808. Stretching from Rotherhithe to Limehouse, the tunnel collapsed only 200ft short of its destination and was subsequently abandoned.

Now, from the riverside, please turn around and walk back towards the mural. When you reach the mural, walk to the right hand side and down the steps between the two buildings where you will then encounter a sign that reads 'Tunnel Shaft this way'. Follow the slope down until you see a stone wheel embedded into the brick path. When we are looking at the stone wheel, please press continue.

4. Tunnel Shaft Path

The wheel you are looking at is from 1858 and is a grinding wheel from the Shipyard used to build the Great Eastern. At the time, the SS Great Eastern was the largest ship ever built; designed by Isambard Kingdom Brunel as his last project before his death at the age of 53. Wooden beams from the launch site of the Great Eastern still remain at Masthouse Terrace near Island Gardens on the north side of the river – not far from Rotherhithe, making this eastern area of London, the site of both Isambard's first and last works as a civil engineer.

If you look to your right, you'll see a large metal sculpture. This is called the Ship of Blueprints. It's a community artwork that resembles the body and mast of a ship with a table in the centre that's topped with a series of blue tiles, each of which features an engineering drawing designed by local school children back in 2004.

Now, follow the path until you've reached the large black door, please walk through this door and take a left until you come to the viewing balcony of the Tunnel Shaft. When you are here,

please face outwards along the right-hand rail, then press continue.

5. Tunnel Shaft - Viewing balcony/staircase

The large underground chamber that you're looking at is the Tunnel Shaft and the first piece of construction for the Thames Tunnel below - the means of getting underground to begin tunnelling. Once known as the Grand Entrance Hall, it is half the size of Shakespeare's Globe and has been opened up again after 150 years. The staircase you're standing on was completed in 2016 and is free-standing so as to not damage the walls of the shaft – which is today a Grade II* listed site.

In engineering terms, the entire structure is known as a 'caisson' and is the worldwide first of its kind. The cylindrical shaft was built above ground on a huge cast iron ring and sunk into the soft soil under its own sheer weight rather like a pastry cutter or apple corer. It initially weighed around 1000 tons and it was 15 metres tall and 15 metres in diameter.

The construction and subsequent sinking of the shaft took around four months, and during this time it became a popular and fashionable sight in London and a landmark in its own right, known as 'the sinking tower of Rotherhithe'. The works were even personally inspected by the Duke of Wellington, checking on his investment, no doubt. With the foundations complete for the shaft, and the walls lined by a team of bricklayers, an opening facing north was left for Brunel's innovative tunnelling shield. A reservoir known as a "sump" was also fitted at the base. A steam-driven engine and an adjacent boiler house were installed to drive the water pumps collecting the excess from the sump and also to bring up the excavated earth in a bucket chain system.

If you continue to look out from the balcony you'll see a large black pipe to the left – this is part of the modern pump mechanism and still draws water away from the reservoir at the tunnel base and propels it into the river. So don't be alarmed if you hear gushing water in the tank above or the humming, whirring sound of the motor
powering it.

Now you can head down the staircase to the concrete floor of the shaft below. As you descend, you'll notice various names on the stairs – these are the donors and funders for the staircase when it was first fitted in 2016. Today the Museum receives no local authority and government funding and relies on donations for its activities. When you have reached the bottom of the staircase please make your way to the picture board that is furthest to the left. When you have reached this, please press continue.

6. Tunnel Floor

Once the shaft itself was in place, actual tunnelling began in November 1825, with the entire project forecast to take 3 years to reach the Wapping side of the river, around 365m away. In reality, the project took 18 years to complete owing to various setbacks including major floods, worker strikes and financial shortfall. While overseen by a charismatic and well-respected Isambard in the tunnel's early years, the workforce faced dangerous and foul conditions below

ground. Aside from the claustrophobic nature and poor lighting of the workers' cells within the shield, the risk of contracting a disease from the foul air and sewage water was high, as was the threat of striking marsh gas that would ignite the men's oil lamps, causing fires.

Impaired vision, fainting spells and chest pains were common ailments for the workers; while the official 'death toll' of those involved in the tunnel numbers a little over ten, remarkably small for a project of this scale, we of course have no way of measuring how many more succumbed to the ill effects of the tunnelling conditions later in life.

Though progress was steady, disaster first struck in April 1827 when the tunnel suffered its first major flood as Thames water came crashing through its roof. While this first flood – or 'inundation' as they were sometimes referred to – had no fatalities, the damage was nonetheless substantial, with Isambard inspecting the riverbed himself by descending in a diving bell and then rowing into the flooded tunnel with a lantern to inspect further. The holes were mended and sealed with huge quantities of bagged clay dropped from above and with work resuming after lengthy repairs in October 1827.

Undeterred by this setback and determined to restore faith amongst the tunnel's investors to secure further funding, Isambard puts on a great show of bravado and confidence by presiding over a grand banquet held within the tunnel arches. With the investors seated in their red coats and the sound of the Coldstream Guards band playing, the event would have been quite a spectacle. Although some original paintings from this time show Marc Brunel in attendance with his son, we know in fact that Marc Brunel was not in attendance at the dinner due to ill health. The workers, however, did attend and were seated in the second tunnel arch.

Despite this impressive show, catastrophe struck again only a few months later in January 1828 with a second major flood. Water burst in drowning six men, with Isambard himself narrowly escaping with his own life. Knocked unconscious and temporarily trapped under the collapsed wooden platform at the tunnelling shield, Isambard was carried by a wave of flood water to the shaft where he was rescued by some of his men.

Soon after, Isambard departed from the project, sent to convalesce first in Brighton and then later in Bristol where he went on to produce a great number of works including the Clifton Suspension Bridge, The Box Tunnel, Temple Meads Station and much of the wider Great Western Railway Network.

While the damage and debris were eventually cleared, the tunnelling was placed on hiatus for around 7 years, minus its resident engineer, several workers and critically, lacking funding to continue. In the meantime, it was bricked up and rather ingeniously fitted with a giant mirror at the end which created a neat visual illusion of a 'completed tunnel'. This was opened to the public, paying an admission fee, but was little more than a minor visitor attraction.

After much negotiation with the Thames Tunnel Company directors alongside his lobbying of Parliament, Marc Brunel eventually secured a government loan of £270,000 in March 1836 and work resumed.

Now, look at the black and white illustration of the Grand Entrance Hall which is the next illustration to the right of the Great Tunnelling Shield

The tunnel was finally complete and officially opened in 1843, where Londoners flocked to pay a penny to walk under the river from Rotherhithe to Wapping for the very first time. In its opening three months, there were over a million estimated visitors with Queen Victoria herself visiting in its opening year, arriving by royal barge.

The image in front of you depicts what the entire chamber once would have looked like when it served as the ornate entrance to the pedestrian tunnel. While it may take a little bit of imagination, if you look around the shaft walls today, you can still see the grooves left by the pedestrian staircases descending in a spiralling pattern.

The only inaccuracy with this illustration is the presence of horses and carts. While the Thames Tunnel was originally conceived to accommodate cargo and horse- drawn transport, this would have required two additional chambers – one on each side of the river – five times the size of this shaft, with wide spiral ramps to allow the horses access.

If you now look to the right of the grand Entrance Hall painting, you can see these additional chambers in an early schematic drawing of the tunnel. This shows two larger shaded circles representing the wider and financially unviable transport shafts. In fact, it is this feature, or rather lack of it, that prevented the tunnel from reaching its expected commercial potential.

Despite the initial intrigue and popularity of the Thames Tunnel, with contemporary accounts heralding it as the ‘eighth wonder of the world’, the novelty of a subterranean foot tunnel wore off rather quickly. Nevertheless, the tunnel did serve as the world’s first underwater shopping arcade with retail stalls lining the tunnel arches between the two carriageways, selling a range of souvenirs such as silk scarves, porcelain figures and plates – examples of which are displayed in the Engine House’s museum exhibition.

If you look at the next poster on the right, you’ll see an advertisement for one of the annual ‘Fancy Fair’ carnivals hosted in the tunnel featuring an array of attractions including musicians, industrial showpieces, dancers and tightrope walkers. Yet even these events were not enough to save the fortunes of the pedestrian tunnel.

Its reputation was in decline and the tunnel soon became a seedy hive of criminality, frequented by pickpockets, thieves and sex workers. In addition, many of Victorian London’s homeless would shelter in the arches, paying their admission fee and simply staying in the tunnel overnight. It is no wonder that the tunnel at this period was sometimes referred to derogatorily as the ‘Hades Hotel’.

Eventually, the Thames Tunnel Company board made the decision to sell the foot tunnel, admittedly at a loss, to a consortium of railway companies in 1865 who converted its floor to tracks, forming part of the newly created East London Line. If you look to the last image in the row of picture boards, you’ll see one of the first passenger trains running in 1869 arriving at the Wapping platform. Like the staircases, the steam trains have left their mark. If you look at

the shaft walls you will see many blackened areas. This is actual Victorian soot from the tunnel's first passenger trains.

The reinforced concrete floor you're standing on was fitted in the late 2000s and separates the upper shaft from the live train line below. While people can no longer walk through the tunnel – except on very rare occasions scheduled around planned engineering works – you can still travel through it by train. Even now you can hear and feel the rumble of the carriages of the London Overground Line, converted from the East London Line in 2009, running beneath your feet. Incidentally, the equivalent tunnel shaft at the other side of the river is actually incorporated into Wapping station, so if you visit that side, you can walk the original pedestrian route down the spiralling staircases and view the original double arch shape from the short train platform below.

In terms of scale, the entire chamber here measures 68ft from top to bottom with walls over 1.5m thick. You're standing about two-thirds of the way down.

If you look up, you'll notice a thick metal roof. The shaft was exposed to the skies until it was capped in the 1940s during the Blitz – both to protect the live train line and prevent the tunnel lighting from attracting enemy aircraft, especially as the Docklands area of London was already a substantial target.

Overall, while the Thames Tunnel might not seem a success story, with its delays in construction and its failure as a commercial venture, it remains a ground-breaking piece of Victorian engineering and still standing not as a mere relic but as a fully functioning train line. Moreover, it is a landmark that has inspired and revolutionised the development and design of all of London's subterranean tunnels – including the early twentieth-century Rotherhithe Tunnel, Greenwich Foot Tunnel to the east and many tunnels further afield that all have used Brunel's pioneering boring mechanism, though now of course, largely automated.

Today, the tunnel shaft here at Rotherhithe is not only used for the Brunel Museum's guided tours but also serves as a unique venue space hosting school groups, film screenings, a regular classical concert series and even weddings.

You have now reached the end of our tour. We would like to thank you for visiting the Brunel Museum and hope you've enjoyed our audio tour. We encourage you to look around the rest of the museum, which can be found in the engine house, where you purchased this tour. Please enjoy the rest of the museum displays at your leisure and if you have any questions, just ask one of our friendly guides at the front desk.

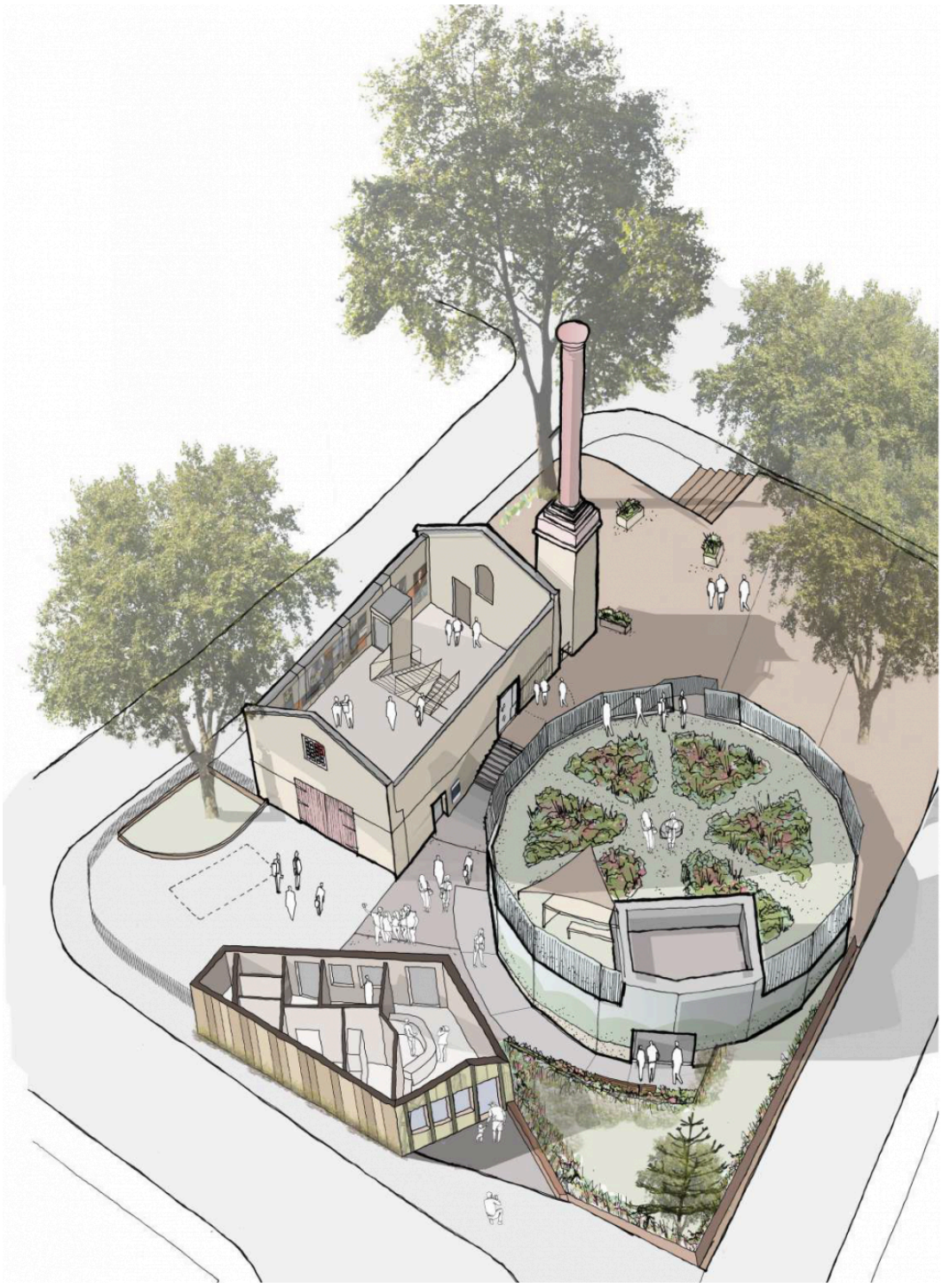
Until next time, goodbye.

Appendix C: The Engine House at the Brunel Museum with current exhibits.

Appendix D: Exterior of the Brunel Museum, showing the garden roof of the Tunnel Shaft and adjacent Engine House (*The Brunel Museum*, n.d.).

Appendix E: The Tunnel Shaft at the Brunel Museum. (*One Of London's Quirkiest Museums Is Making A Comeback*, n.d.)

Appendix F: An overview of the proposed building layout for the Brunel Museum Reinvented Project. (*The Brunel Museum*, n.d.)



Appendix G: Audio Guide Evaluation Checklist

- Timing
  - How long does the tour spend at each stop (on average)?
    - <30sec
    - 30sec - 1min
    - 1 - 1.5min
    - 1.5 - 2min
    - 2 - 3min
    - >3min
  - What was the mixture of short (<2min) and long (>2min) stops?
  - (<2min) 1 - 2 - 3 - 4 - 5 (>2min) How long (approximately) was the tour experience?
    - <15min
    - 15min
    - 30min
    - 45min
    - 1hr
    - 1.5hr
    - 2hr+
  - Other timing notes:
    - Short-answer
- Navigation
  - How does the tour know where the listener is located?
    - Bluetooth Beacon
    - QR code
    - Visitor input
    - It Doesn't
    - Other ___
  - How does the tour help the listener navigate to specified locations?
    - Pictures/Video
    - Map
    - Written instructions
    - Audio instructions
    - Other ___
  - Other navigation notes:
    - Short-answer
- Audio
  - What type of narration is used?
    - AI voice
    - Museum Staff
    - Voice Actor/Narrator
    - Other ___
  - What audio elements are present in the tour?
    - Music
    - Historical soundscapes (background noise)

        - Sound effects
        - None
        - Other ___
    - Other audio notes:
        - Short-answer
- Access
    - What delivery method is used?
        - App
        - Website/Online resource
        - non-phone/tablet device
        - Other ___
    - What is the name of the app/website/program used?
        - Short-answer
    - How is the tour meant to be listened to?
        - Out-loud
        - With personal headphones
        - With given/purchased headphones
        - Other ___
    - Other Access Notes?
- Content
    - Is the audio guide more of a description or an interpretation?
        - (description) 1 - 2 - 3 - 4 - 5 (interpretation)
    - What does the audio guide choose to focus on?
        - Stories about people
        - History of objects
        - Other ___
    - Other Content Notes?

Appendix H: Other Museums' Audio Guide Interview Outline

We are a group of students from Worcester Polytechnic Institute (WPI) conducting a research project in collaboration with the Brunel Museum to evaluate visitor engagement for the development of a prototype audio tour for the Brunel Museum.

We would be delighted if you would answer some questions about your experiences evaluating visitor engagement and audio tour development. Your participation in this conversation is completely voluntary, and you may stop at any time. We will be taking notes as we talk and may wish to quote you in our final report.

Do you mind if we quote you by name, or would you prefer we anonymize your responses? We will, of course, give you an opportunity to review any quotations prior to publication. We will also be happy to provide you with a copy of our report when it is completed. Do we have your permission to record this interview? Thank you for your support in this research.

Do you have any questions before we begin? If you have any concerns or questions after the interview, you can contact us at gr-lon_d24_brunel@wpi.edu or our faculty advisor, Dominic Golding, at golding@wpi.edu.

The key points listed outline interview conversations questions discussed with museum professionals:

- Motivation for an audio guide
- Different tour audiences
    - Experts, family, child, etc
    - Languages
- Experience
    - Role of tour (core versus add-on)
    - Format of tour (linear versus free flow)
    - Type of content
- Devices & Delivery Method
    - Physical vs app/QR code
    - Owning, leasing, maintaining
- Development Process
    - Voices
    - Content
    - Unique & protected spaces
    - Visitor Feedback

Appendix I: Visitor Exit Survey Questions and Informed Consent Statement

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting a survey to evaluate visitor engagement for the Brunel Museum.

Would you be willing to take 5 minutes to answer a few questions? Your participation in this survey is completely voluntary. You may skip any questions you prefer not to answer, and you may withdraw at any time. The survey is anonymous -- we will not be collecting your name or any personal, identifying information.

This is a collaborative project between the Brunel Museum and WPI, and your participation is greatly appreciated. If you have any questions about the research or would like a copy of the published report, please contact us at gr-lon_d24_brunel@wpi.edu. Do you have any questions before we begin?

- *Which of the following best describes you?
  - My job is linked to STEM (Science, Technology, Engineering and Mathematics)
  - I am studying STEM subjects at school/further education/higher education
  - I used to work in a STEM related job
  - I have no knowledge of STEM subjects/topics;
  - I have a basic knowledge of science, technology, engineering, math related subjects
  - I have a formal qualification in science, technology, engineering, math related subjects
- *Was this your first visit to the Museum?
  - Yes
  - No
- *Where did you find out about the museum?
  - Museum website
  - Museum social media
  - London Press (Londonist, Metro, Time Out - Please specify)
  - Local Press (South London Press, Bermondsey Biscuit, Wharf Life)
  - Word of mouth - Friend, Family, or Colleague
  - Flier in local cafe or site - please specify
  - Fantastic for Families website
  - The List website
  - Google Search
  - Google Maps
  - Mentioned by someone else on social media (Please specify platform)
  - Museum newsletter
  - Other (please specify)
- *How likely is it that you would recommend the museum to a friend or colleague? [NOT AT ALL LIKELY—EXTREMELY LIKELY]
  - 0-1-2-3-4-5-6-7-8-9-10

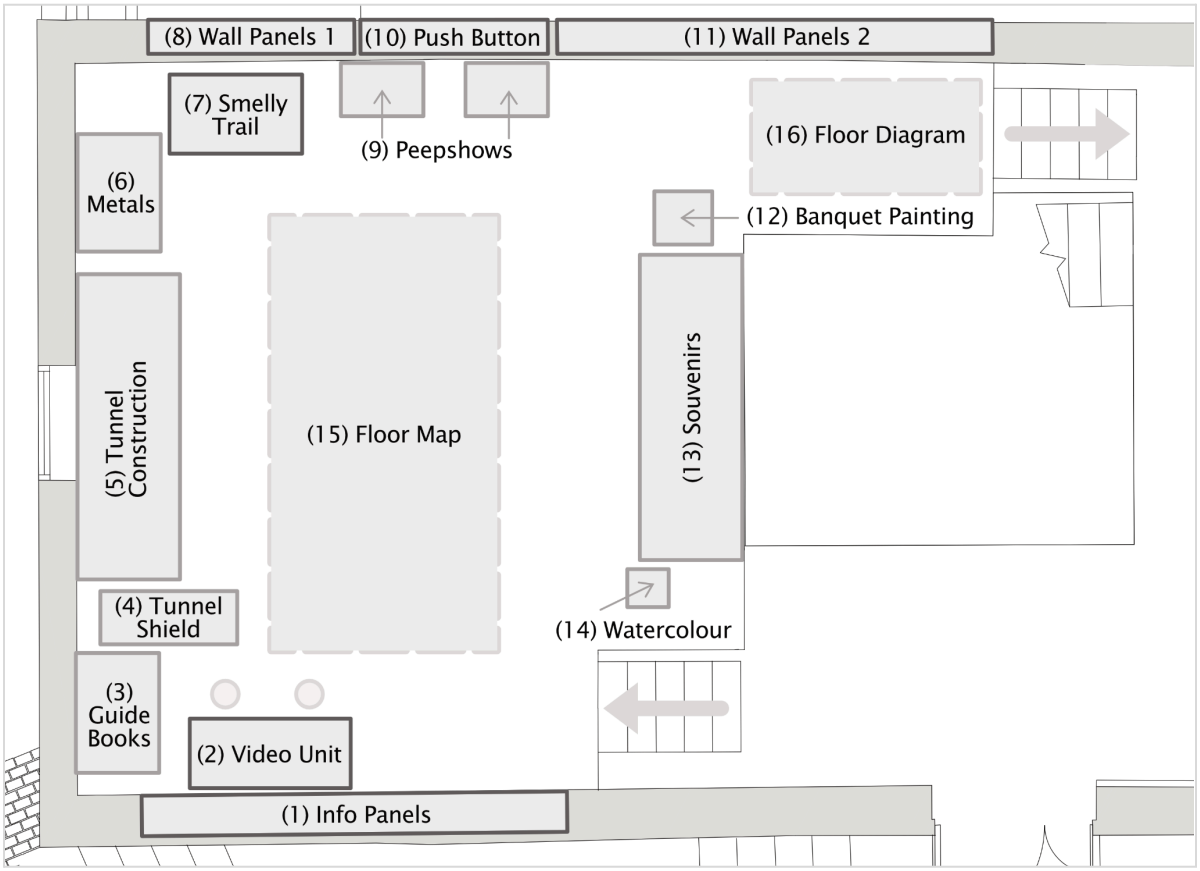
- *Who are you visiting with? Include yourself and tick all that apply
  - Individual
  - Couple
  - Family
  - Friends
  - Other
- *Who are you visiting with? Include yourself and tick all that apply
  - Under 15
  - 16-25
  - 26-35
  - 36-45
  - 46-55
  - 56-65
  - 66-75
  - Over 75
- *How long did you spend at the Museum today?
  - Less than half an hour
  - 30 minutes to 1 hour
  - Between 1 and 2 hours
  - Between 2 and 3 hours
  - More than 3 hours
- *Please tick all of the following that apply
  - Live in Rotherhithe (SE16)
  - Work in Rotherhithe (SE16)
  - Live in Southwark
  - Work in Southwark
  - Live in other London Borough
  - Work in other London Borough
  - Live in rest of UK - Please specify town or city
  - Live in Europe - Please specify country
  - Live in rest of World - Please specify country
  - Other (please specify)
- *How do you define your ethnic group?
  - Asian
  - Black
  - Mixed
  - Other
  - Prefer not to say
  - White
- *What is your primary language?
  - English
  - Bengali
  - Polish
  - Turkish
  - Other ____

- *Are you
  - Male
  - Female
  - Non-binary
  - Prefer not to say
  - Prefer to self describe
- Please indicate what you thought about the descriptions that accompany each exhibit:
  - Text
    - (Not enough text) 1 2 3 4 5 (Too much text)
  - Clarity
    - (Content was very unclear) 1 2 3 4 5(Content was all clear)
  - Engagement
    - (Text wasn't at all engaging)1 2 3 4 5 (Text was very engaging)
- Do you typically use audio tours in other museums?
  - (Never) 1 2 3 4 5 (Always)
- In the **Tunnel Shaft**, would you be interested in listening to an audio tour?
  - (Very uninterested) 1 2 3 4 5 (Very interested)
- In the **Engine House**, would you be interested in listening to an audio tour?
  - (Very uninterested) 1 2 3 4 5 (Very interested)
- Which are you interested in hearing about in an audio tour? (multi-select checkbox)
  - Stories about the Brunels
  - Stories about the workers
  - Histories of objects
  - History of London at the time of construction
  - Engineering/Design of the tunnel
  - Other ___
  - N/A
- Do you own a smartphone or tablet?
  - Yes
  - No
- Are you familiar with scanning QR codes?
  - Yes
  - No
- *What did you learn during your visit today? Tick any/all that apply
  - The Thames Tunnel was the world's first successful underwater tunnel
  - Sir Marc Isambard Brunel created a revolutionary mechanism for tunneling which is still used today
  - Sir Marc was the father of Isambard Kingdom Brunel
  - It took Brunel 18 years to Tunnel under the Thames
  - Anything else:
  - I didn't learn anything new today!
- *On a scale of 1 (Poor Value for Money) - 10 (Excellent Value for Money), was your visit to the Museum good value for money?

- 0 1 2 3 4 5 6 7 8 9 10
- ➢ *What one thing would have improved your visit to our museum?
- ➢ *Would you like to be added to our mailing list?
  - Yes
  - No
- ➢ *Please add your email below:
- ➢ *We want to know what topics you'd like to see in the Museum. Tell us how interested you would be in seeing the following topics at the Museum.

* indicates a question from past Brunel Museum visitor surveys (for continuity)

Appendix J: Labeled floor plan for the Engine House with numbers corresponding to ID numbers on the visitor tracking tool.



Appendix K: Audio Guide Signage Style Guide.

See design on Canva here.

Audio Guide Signage Style Guide

Steps to use Design:

1. Copy the label design below
2. Click on the "..." option and select "Edit Design"
3. Change the text based on what stop the sign is for
4. Change the color of the QR Code box based on the Color Guide below
5. Add a QR-Code into the box using this website

Colors:

1. Primary Color Pallet
   a. Brunel Dark Blue
      i. 83/71/53/60 or #111e30
      ii. Outer Border Color and Text Color
   b. Theme #1
      i. 22/100/100/20 or #9f0000
      ii. Tunnel as the Eighth Wonder of the World
   c. Theme #2
      i. 64/32/20/10 or #539cb8
      ii. Design and Construction of the Tunnel
   d. Theme #3
      i. 19/43/95/0 or #cf910d
      ii. The Brunel Family and Society at the Time
   e. Theme #4
      i. 24/65/83/09 or #b05127
      ii. The Legacy of the Thames Tunnel

Font:

1. Question Font
   a. **Arial Nova**
   b. Size 57
   c. bold
2. Scan Here Font
   a. Arial Nova
   b. Size 48

Appendix L: Audio Guide QR-code Signage.