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Design Factors of a Mobile Museum Navigation System: The Case of National Palace Museum in Taiwan

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Abstract:

With the integration of cultural tourism and digital technology, tourists are no longer passively content with pre-arranged tours. How to integrate a mobile museum navigation system into smart phones to increase the learning experience of tourists is increasingly important to museum tourism. This study used visitors of the National Palace Museum in Taiwan as research participants and derived 7 design guidelines with 38 influence factors based on an extensive literature review and a detailed analysis of personal digital navigation systems. Using analytic hierarchy process, the study identified that information quality in navigation systems and convenience of communication between users and the system are the two most critical design factors for a successful navigation system.

Keywords: Heritage tourism, success factors of navigation system, smart phones, museum navigation system, analytic hierarchy process.

Introduction

Culture is a major motivational factor for tourism and also an important factor in determining tourist destinations. Many countries around the world have made the commitment to combine tourism and culture, design cultural tourism systems, and strengthen activities that promote cultural tourism. Via new technology, culture and tourism are expected to be marketed more effectively. The combination of digital technology and cultural tourism is a growing trend that has important potential in developing business opportunities.

Cultural tourism comprises a major proportion of world tourism demand. According to the World Tourism Organization's survey, 37% of international tourist activity is motivated by cultural tourism and the demand for cultural tourism will grow by 15% annually. Heritage tourism is a part of cultural tourism. Ryan and Dewar (1995) indicated that heritage tourism is one of the fastest-growing tourism market segments. Museums, national parks, and historical monuments have all seen a gradual increase in the number of tourists and it has been realized that cultural tourism can bring significant economic benefits to museums and heritage attractions (Ashworth, 2000; Chang & Yeoh, 1999; Cossons, 1989; Richards, 1996; Shackley, 1997).

Successful guided tours are a necessary condition for achieving a high-quality service and may also be the key to the effective management and preservation of cultural heritage; furthermore, they may create prospects for sustainable tourism (Moscardo, 1996). To bring high-quality experiences to visitors, a tour guide must meet the needs of those visitors in exploring the historical artifacts and must also act as a representative of the museum in conveying information, through its studies, collections, displays, educational functions, and leisure functions, to its visitors. The most dynamic interpretive function is undoubtedly a tour guide, available in addition to textual explanations of the artifacts, at all of the contact points between the museum's showpieces and the visitors. A tour guide's clarity of statement, presentation skills, and professional knowledge will not only affect the visitors' understanding of the exhibits and their perception of the museum, but also serve as the key factors affecting the quality of the navigational instructions of the tour guide.

Driven by today's new technology, there is a tremendous change in the way visitors navigate; they are not limited to the transfer of information from pieces of text, but expect more information feedback and two-way communication through human-computer interfaces. Some scholars (e.g., Shen & Liang, 2000) have pointed out that future navigation will change from the current "static" type to a "collection of heavy sensual" type; museums are already beginning to change their navigation types to "semi-static" and will move toward "dynamic" navigation in the future. Dynamic navigation exploits interactive behavior arising from contact with the audience to make exhibits more memorable, through providing a profound recreational experience

to visitors and further enhancing the recreational functions of the museum.

Due to the mature technological environment, digital concepts have gradually expanded the types of exhibit available to visitors. For the public, the museum is no longer a place where static artifacts are on display, but where they may experience a variety of sensory stimuli in an integrated experience (Chesapeake Bay Maritime Museum, 2014). Tourists are no longer passively content with pre-arranged tours, but navigate more selectively. How to embed a mobile museum navigation system (MMNS) into a smart phone to encourage tourists to use such a system, rather than traditional voice navigation, and increase their learning experience thus needs to be investigated.

According to the “2011 Survey of Taiwanese Wireless Network Usage” report, 50.73% of Taiwanese people own smart phones and one-third of the population uses smart phones to surf the Internet. The survey had 3,553 respondents who were more than 12 years old, already owned a smart phone, and would purchase a new smart phone in the future. Of these 3,553 respondents, 59.32% (2,107) used their smart phone to access the Internet. Of these 2,107 people, 89.20% regularly used their smart phone to access the Internet. In the past, mobile Internet usage was low for Taiwanese people, but the market for mobile phones to be used to access the Internet has dramatically grown during the past few years.

This study used visitors of the National Palace Museum in Taiwan as research participants. We first derived 7 design guidelines with 38 influence factors based on a review of the literature and an analysis of personal digital navigation systems in various domestic and foreign museums. An analytic hierarchy process (AHP) was then used to rank those influence factors to provide a reference for building a smart phone mobile navigation system. The specific objectives of the research were as follows. We expect the results to provide smart phone navigation system design guidelines for system developers and to become the basis for the planning of museum exhibitions.

1. Collect the desired and required functions of a museum navigation system from industry experts, scholars and tourists, as representatives of the field.
2. Analyze the status of navigation systems for museum operations.
3. Investigate the influence factors that affect tourists’ use of navigation systems from an expert point of view, and
4. Determine the priority of those influence factors.

Relevant Studies

Museum Navigation

In a museum, “navigation” carries the meanings of “guide” and “interpretation.” As “guide,” it has the important role of providing instruction on museum operations,

giving guidance and inspiration and indicating directions for viewing beautiful artifacts. As “interpretation,” its role is to provide a meaningful arrangement of museum exhibits for educational purposes, presenting these to visitors so that they may absorb knowledge through personal participation.

Tilden (1957) proposed six principles of interpretation for exploring the relationship between museums and visitors.

1. Any interpretation that does not somehow relate what is being displayed or described to something within the personality or experience of the visitor will be sterile.
2. Information, as such, is not interpretation. Interpretation is revelation based on information, but they are entirely different things. However, all interpretation includes information.
3. Interpretation is an art, which combines many arts, whether the materials presented are scientific, historical, or architectural. Any art is in some degree teachable.
4. The chief aim of interpretation is not instruction, but provocation.
5. Interpretation should aim to present a whole rather than a part and must address itself to the whole man rather than any phase.
6. Interpretation addressed to children (say up to the age of twelve) should not be a dilution of the presentation to adults, but should follow a fundamentally different approach. To be at its best it will require a separate program.

Recently, Yorke Edwards described interpretation as a series of services, including information, guiding, education, entertainment, propaganda, and inspiration (Sharpe, 1982). In an information service, interpretation must be able to provide both information on appropriate display themes and an interesting message. This information directly contributes to the enriching of visitor experiences. Guiding services can help people to avoid feeling lost at the beginning of a visit to an unfamiliar environment and can provide a complete description of the history and facilities of the location. In an educational service, interpretation allows people from different backgrounds and of different ages to interact with exhibits. It acts as a catalyst by not only providing people with the right information, but also by inducing a thirst for knowledge. Good interpretation can also provide people with a pleasant, relaxed, and wonderful experience by achieving the goals of an entertainment service. In a propaganda service, interpretation can be seen as a way of improving public image and seeking public support, increasing the level of mutual understanding between the people and a museum. Furthermore, for local people good interpretation may evoke pride in the natural or cultural heritage of their area.

In summary, “navigation” can be viewed as a process of interpretation; it can make things better understood or give something special significance (Edson & Dean,

1994).

Museum Navigation Systems

Navigation can be simply divided into the following six categories according to differentiation by media vehicle.

1. Guides

Guides provide interpretation directly to tourists, either throughout the visit or through regular guided tours at set times and set locations. Guided tours provide high levels of interaction with tourists, with highly flexible and elastic arrangements.

2. Brochures

Using brochures for museum navigation can reduce the space occupied by explanation boards; not only can the brochures provide extra information or pictures, but they can be taken home after the visit.

3. Video clips

Due to the need to set up display equipment, video clips are not widely used. However, they provide good sound and light effects and lively animation, and thus readily attract the attention of visitors. An advantage lies in combining television features with special multi-media effects.

4. Computer kiosks

The general reason for including a kiosk in an exhibition is to provide advisory services or an overall introduction. Because a computer can hold and present a wealth of information, an exhibition kiosk can provide a more detailed and diverse explanation of each of the themes of the exhibition. Visitors may even participate in interactive games at the kiosk or perform a self-learning assessment of their knowledge relating to the exhibition.

5. Voice

Voice navigation can be provided through various carriers, such as cassette recorders, MP3 players, or specially designed equipment. The voice content can be played throughout the exhibition, on demand, or at regular intervals.

6. Briefing slides

Using slides to provide exhibition information may be seen as a type of video or voice navigation. However, slides are usually presented in a conference hall or briefing room rather than in the exhibition, to give enough space for a large number of visitors and groups of visitors. Groups of visitors can also book the briefing room for a video navigation or multimedia introduction.

Each of the six navigation modes has its own advantages, but there are also shortcomings, listed in Table 7.1. To overcome those shortcomings, the current study

aimed to identify the key impact factors through investigating all of the possible design factors discussed in the literature that might influence the success of a museum navigation system.

<Table 7.1 HERE>

Design Factors for a Mobile Museum Navigation System

We collected and reviewed the research data and literature, at home and abroad, that was related to navigation systems, exhibition spaces, and culture and creation. We also considered scenarios using the latest smart phone applications and the promotional requirements of the museum. We attempted to list all of the factors that might affect whether visitors will use an MMNS and developed a hierarchical architecture of the design factors for an MMNS.

Infrastructure

Signal stability: In a digital learning study performed in a museum, Schwabe and Göth (2005) found that a system must have the ability to respond in a timely manner, whether the venue is indoors or outdoors. Signal stability is thus very important for an MMNS.

Coverage: Wireless network signal coverage is a key indicator for competitive digital environments and development opportunities (Intel, 2005a; ITU, 2007). The level of wireless network signal coverage provided by the museum will thus affect the museum's opportunities and capabilities for using information technology.

Ubiquitousness: In addition to the coverage and signal stability of a wireless network, whether visitors are able to roam between hot spots is also a critical indicator of the adequacy of the infrastructure and service competitiveness.

Broadband connection speeds: Intel (2005a) held that to support the promotion of wireless services, the network bandwidth must be able to meet demand. Because the museum's navigation system contains a wealth of audio and video content, the infrastructure must be able to provide sufficient bandwidth to ensure that the navigation system operates properly.

Near-field detection: Context-aware technology, which can help visitors with learning that is not limited by place and time, and near-field detection technology can work together in the museum's navigation facilities to provide visitors with a more realistic and rich navigation experience (Chen & Huang, 2012). Context-aware technology also provides visitors with an interactive experience with the exhibits and freedom of choice during the visit (Huang, Wang & Sandnes, 2011).

Compatibility: An open wireless network environment may involve many different brands of device and different operating systems. Thus, whether a wireless network environment is compatible with a variety of terminal equipment is a key factor of an Internet service (Intel, 2005b).

Security: Security mechanisms for information infrastructure are able to ensure that data can be securely transmitted on the Internet and prevent leakage of confidential information from mobile Internet devices (Intel, 2005b). Furthermore, to provide users with more secure protection, mobile navigation application services must have safety certification.

Human-Computer Interface

Information richness: Information quality plays a key role in the success of a website (Liu & Arnett, 2000). There is a very rich cultural knowledge contained within a museum's collection. If that cultural knowledge can be delivered by media vehicles with the ability to pass on a wealth of information, exhibits can show the full content, thus reducing vagueness in the information and enhancing the accuracy and richness of the information.

Information presentation: How to present museum exhibit information appropriately on handheld devices is a major challenge. On the one hand, the information must be easy to read, so it must use large fonts on the device's screen, producing low-density information; on the other hand, it must provide as much rich information as possible on the limited screen, and must therefore rely on an explicit order for the information (Ziefle, 2010).

Icon design: An icon is an abstract symbol of text and information. To avoid mistakes and the confusion of users, icons for navigation should not be too complicated to allow users to easily identify them (Horton, 1994).

Screen menu design: With a navigation system on a limited screen space, insufficient detail in the information shown is likely to cause users to become lost. The mobile navigation system must therefore make good use of the scroll function and consider the appearance of the information when designing the system interface (Jones, Jones, and Marsden, 2005). For mobile phones, Beck, Han and Park (2006) proposed a design concept menu containing sub-menus to provide users with highly efficient operation within the space limitations of the mobile phone screen.

Multi-language support: The museum navigation system must be capable of supporting several languages, to assist foreign tourists to visit and interact with the museum (Cui & Yokoi, 2012).

Search function: In terms of information system use, information-seeking behavior can be divided into searching and browsing (Marchionini, 1997). In addition

to allowing browsing, a complete mobile navigation system should also have a search function.

Content Design

Timeliness: Bailey and Pearson (1983) proposed 39 indicators associated with information systems for assessing user satisfaction, including the correctness of the information, timeliness (output timeliness), reliability, completeness, relevance, and accuracy. Of these, the timeliness of an information system is key to its success or failure (DeLone & McLean, 1992).

Interactivity: Museum visitors spend an average of thirty seconds at an exhibit (Cone and Kendall, 1978). The use of mobile internet devices in the museum can create a seamless environment for visitors to explore within. The visitors can explore via creative thinking before coming to the museum, then experience the exhibits in the museum, and continue their individual research after leaving the museum. In designing an interactive function, care must be taken to avoid treating the handheld device merely as a mini workstation; instead, the design should be based on a model that can change the system of interaction with visitors to assist with learning, collaboration, or teaching (Hsi, 2003).

Locational notification: The interests, background, experience, and so on of each museum visitor may differ greatly and they may therefore have different needs. The design of a navigation system should take into account the actual needs of the visitors and permit flexible adjustment. Ghiani et al. (2009) proposed a multi-device navigation system with location-aware technology that allows users to obtain more detailed information or other services; the system also provides individual or multi-player games via a big screen, to enrich the museum visit journey. Through this multi-device environment, visitors can hold the navigation device while moving around freely and at any time can connect to a nearby desktop computer with a big screen.

Browsing history: A history function can give users access to recently visited pages, favorite pages, and bookmarks at any time and may use different colors to distinguish clicked from never-clicked hyperlinks, allowing users to store specific page addresses for future use. This function allows users to tell if they have visited a particular page and to revisit their use of the website (or navigation system) (Rosenfeld & Morville, 2007).

Information download/pre-download: Wang, Su and Hong (2009) proposed a campus navigation system that combined indoor RFID and outdoor GPS position detection. When users are outside the navigation area, they can use the Internet to navigate the campus via the system. A pre-download mechanism can be used to

reduce waiting times and browse scenes more smoothly. When users carry their mobile device into the scene, the system automatically determines their path of movement, pre-downloads the required information so that the users do not need to wait, and then provides seamless navigation.

Site map: A site map is usually used to show website content with a top-down architecture. It provides an overview of the website and allows users convenient access to the website content they want. The site map can be graphical or a series of text links, so that users can link directly to a specified web page. In addition, the site map can direct a search engine to important pages, so is useful in search engine optimization (Rosenfeld & Morville, 2007).

User Experience

Satisfaction: Bailey and Pearson (1983) pointed out that user satisfaction may significantly affect the use of an information system and its success rate; thus, an MMNS should be designed to improve user satisfaction as much as possible.

Utilization: McLean (1993) believed that learning is an individual behavior with its own tempo in a museum and thus the learning model of each visitor is different. A museum exhibition should provide diversified learning modes and content for all types of visitor, to increase the number of people visiting the exhibition. Similarly, the museum navigation system should also provide users with a variety of exhibition modes to increase the utilization of the system.

Ease of use: Davis (1989) demonstrated that the usefulness and the ease of use of an information system had a strong positive correlation with the use of the system. Museum navigation systems should therefore be designed to allow visitors easy access at any time to the information they need and this goal should be achieved in as simple a way as possible.

Personalization: Young (2009) suggested that a museum navigation system with a recommendation function can provide an adaptive navigation mechanism to attract visitors and increase the length of time an exhibition is viewed. An MMNS can provide personalized information services to permit individual control in accordance with users' needs.

User needs: Museum navigation aims to provide instructions, answers to inquiries, contact, participation, commentary, and other functions based on individual visitor needs. The navigation system must therefore meet visitors' needs, coordinate with route planning, and meet the demands of personal navigation design (Zeng, 2005).

Service

Professional knowledge: In providing professional services, people with the appropriate professional knowledge are the core of a service company, because they directly influence the quality of the services, the price, and the company's image. Guides are thus required to have suitable expertise for providing services and presenting information to visitors. Similarly, an MMNS needs to contain the appropriate professional content to offer to visitors to browse (Ellis & Mosher, 1993).

Service attitude: Parasuraman, Berry and Zeithaml (1991) revealed that regardless of the type of service company—insurance companies, hotel services, or repair services—customers want a more personalized service and a closer relationship with the service provider. Relationship building is an intensive process that must provide immediate and reliable responses that demonstrate empathy. Museum staff must therefore be able to listen attentively to visitors talking about how to use the navigation system and maintain a positive attitude when teaching them how to operate the system.

Quick response: Johns and Clark (1993) indicated that the process of travelers visiting a museum has five stages: preview, transportation, entry, service experience, and leaving. During the service experience, desk staff must be able to solve problems or answer various queries regarding ticketing, and even provide entertainment suggestions for visitors.

Service customization: Customers want to have a more personalized service and a closer relationship with service providers (Parasuraman et al., 1991). Williams et al. (2005) indicated that providing services with a customized theme helped to improve the potential value of those services. Therefore, museum staff who provide customized services according to the needs of different types of visitors will be able to enhance the value of a navigation service.

Service proactiveness: Museums should choose exhibition themes carefully to effectively develop new audiences and attract visitors. Fronville (1985) explored marketing tools for analyzing various activities provided by museums, such as school visits, seminars, travel guides, videos, and books, in terms of their effectiveness in marketing, and found that these activities significantly enhanced the effectiveness of marketing. Museums should therefore provide regular information about activities through the museum navigation system.

Promotion: Chen (1998) believed that museums should actively use new marketing methods and tools to effectively and appropriately spread their message to their target market. He categorized seven marketing methods: database marketing, channel marketing, event/theme marketing, joint promotion, Internet marketing, marketing, publications marketing, and promotion. Of these, promotion had a significantly positive effect on financial indicators.

Exhibition Space

Space saving: The arrangement of a museum's exhibition spaces, in terms of circulation, may be roughly divided into the following types: linear, radial, random, and open. Different circulation arrangements are appropriate for different themes and several types of arrangement can be combined in accordance with the requirements (Matthews, 1991). If a museum's exhibition space is limited, visitors can be allowed to preview the exhibition and related content through an MMNS. Such a system can thus provide a more flexible way of managing visitor circulation.

Visitor routing: Bitgood (1994; 1995) found that museum visitors had specific behaviors, typically goal-oriented moving, being attracted to an exhibition or item that is tagged with a description, being attracted by an open door, and following the existing direction of movement. If none of these behavior options were observed, visitors tended to follow a right-turn circulation. Therefore, in designing an exhibition, visitors' behavior and preferences should be taken into account to create the most appropriate circulation route for the exhibition. Recommending a particular route to visitors through an MMNS may contribute to a positive visitor experience.

Exhibition information: Huang (2007) found that if there was no buffer space between an exhibit and the associated descriptive text, the position of the exhibit description was not obvious, or the description was placed at the end of an exhibit showcase, the description was often ignored or the visitor moved on to the next exhibit. In other words, if exhibit information was placed in the path of the visitor and directly facing him or her, the proportion of visitors who paused to read it increased. An MMNS is an excellent method of displaying exhibit information, with a clear screen and minimal distance from the visitor.

Direction signs: To avoid visitors adopting a "missing" or "ignore" visit behavior, or even a wayfinding behavior, a clear direction needs to be indicated to them, particularly at a crossroads formed by the arrangement of exhibits and where there are path choices in an exhibition space. Huang (2007) revealed that inappropriate content and placement of direction signs was an important factor affecting circulation in the National Palace Museum and also an important reason for wayfinding behavior. An MMNS must therefore be able to clearly indicate the best direction on a screen.

Cultural and Creative

Knowledge provision: Kravchyna and Hastings (2002) found that the information needs of visitors in a museum website included recent exhibitions, museum collections, news about special events, museum instructions, digital images

of collections, research required, contact information, gifts for purchase, ticket information, etc. The application of information technology in museum exhibitions should not focus purely on the technology itself: it is important to provide an integrated, new entertainment concept for exhibition information and knowledge.

Aesthetics: Aesthetics often receives little attention, even from media producers, but plays a key role in the field of website design. Aesthetics does not just involve creating images required by the website publisher and to comply with the website's style, but must also support the presentation of website content and functionality, and thus encourage the target audience to browse (Thorlacius, 2002; 2007). The design of an MMNS must thus involve aesthetic concepts.

Creativity: After interviewing 1,200 visitors, Marty (2008) found that up to 87.4% of museum visitors looked forward to learning more about a museum through its navigation system. From this perspective, the value of the museum lies not only in managing collections, but also in providing a place in which to share knowledge with the public (MacDonald & Alsford, 1991).

Humanities: Reynolds, Walker and Speight (2010) found that hand-held navigation devices offered visitors a variety of imaginative views of exhibition spaces and exhibits, and provided additional information for enhancing the user's knowledge of and interest in the exhibitions. Museum exhibitions can help visitors of different ages to understand and appreciate the great cultural achievements that the exhibits represent and to acquire the skills, attitudes, and knowledge associated with the exhibits (DCMS, 2000).

Research Design and Methodology

There are many factors that affect whether tourists will use an MMNS. Due to personal, subjective opinions and the personal acceptance of such a system by tourists, opinions may differ widely regarding how to design an effective MMNS that takes these factors into consideration. This study collected from relevant studies a comprehensive list of impact factors that may affect the design of an effective MMNS, and used an analytic hierarchy process (AHP) to determine the weights and rankings of those factors, with the aim of evaluating the importance of the various impact factors and the design dimensions.

The work in this study can be divided into five steps:

- (1) Explore impact factors and the overview of an MMNS. Review the literature on design factors that affect the use of an MMNS and analyze these with reference to past and present MMNSs.
- (2) List all possible impact factors. Review the relevant literature and aggregate the factors to explore all possible factors.

- (3) Build a hierarchical structure. Develop a hierarchical architecture based on the above factors.
- (4) Calculate factor weights. Construct an AHP questionnaire, collect and integrate the results from expert groups, and calculate the factor weights.
- (5) Discussion and suggestions. Use the results of the weight calculations to inform the discussion. The results should provide a reference source and recommendations for agencies involved in the future design of an MMNS.

Analytic Hierarchy Process

The AHP was developed in 1971 by Thomas L. Saaty, an American scholar at the University of Pittsburgh. Saaty (1980) edited the AHP approach and published it in a book. The AHP is mainly applied to decision-making and problem-solving under conditions of uncertainty that have multiple criteria; the problems are influenced by a number of factors that may be tangible or intangible, qualitative or quantitative, and may affect each other. The AHP is readily adapted by academic research units, because of its simplicity and practical value. It is commonly used to solve priority determination, resource allocation, resource planning, prediction of results, risk assessment, generation of alternatives, choice of the best solution, decision-making, conflict resolution, performance measurement, and optimization problems, and ensuring the stability of a system during its design.

The AHP approach involves simplifying a complicated problem so that decision-makers can readily make an appropriate decision, for example when solving an unstructured economic, social, or management science issue. First the decision-makers set the overall goal for the issue, develop secondary-level goals contributing to the overall goal, and iteratively develop the next sub-level (third-level) goals that contribute to the previous ones (secondary-level goals) until the most detailed level of goals is reached. The goals in the final level are called impact factors. Next, the impact factors are pairwise compared using nine scaled question items, eigenvectors are calculated as the weight needed to evaluate each factor, and the higher-level goals are prioritized by ranking the sum of sub-factor weights for each. Finally, the decision-makers make their decision based on the priorities thus revealed.

AHP Analysis Process

According to Saaty's (1980) proposal, the AHP analysis process for decision-making is as follows.

- I. Model the research problem as a hierarchy

Establish a hierarchy for the current complex research issue. Although there is no specific procedure or rule for constructing the hierarchy, the highest-level element of the structure is the final goal of the research issue; the lowest-level elements are the most detailed items used to assess the research issue; elements with similar importance with respect to the final goal are organized on the same level; there should be no more than seven elements within the same level of the hierarchy; and each element in the same level of the hierarchy is independent of the others.

II. Design a questionnaire and form a pairwise comparison matrix.

The principle of pairwise factor comparison involves comparing the influence of pairs of subordinate elements, those on the same level and below a particular superior element, on the superior element. The scale used for comparison of elements is usually a nominal scale, comprising the response categories for each question item (i.e., equally, moderately, strong, very strong, extremely), plus four intermediate response categories that lie between the five categories above, giving a total of nine categories (see Table 7.2). A research issue with N factors requires $N(N-1)/2$ comparisons to be performed to create a pairwise comparison matrix.

<Table 7.2 HERE>

III. Estimate consistency.

This step involves investigating whether there is any inconsistency among the pairwise comparisons and whether any contradictions exist in the results of the comparison. In AHP research, the consistency of all comparison results must be tested and the consistency index (C.I.) calculated. The formula for the consistency index is defined as follows, where λ_{\max} is the maximum eigenvalue of the matrices and n is the number of assessment factors:

$$C. I. = \frac{\lambda_{\max} - n}{n - 1} .$$

When $C.I. = 0$, the pairwise comparisons have been judged consistently; larger $C.I.$ values indicate greater inconsistency. Saaty suggested that as long as $C.I. \leq 0.1$, the consistency of the pairwise comparison matrix can be considered acceptable; otherwise, the responses to the pairwise comparison questionnaire are determined to be invalid.

The consistency ratio (C.R.) is another indicator for judging whether the responses are adequate for the research problem. C.R. is the ratio of C.I. to the corresponding random index (R.I.), where R.I. is the average C.I. of randomly generated pairwise comparison matrices; different numbers of leaf elements result in different values of R.I. (see Table 7.3). Saaty (1980) suggested that if the number of

leaf elements is 3, the C.R. should be less than 0.05, if the number of leaf elements is 4, the C.R. should be less than 0.08, and a C.R. of less than 0.1 is usually acceptable if the number of leaf elements is more than 5. Otherwise, the decision will not be adequate.

$$C. R. = \frac{C.I.}{R.I.}$$

<Table 7.3 HERE>

IV. Calculate priority vectors

Place the measurements resulting from the pairwise comparison of n elements in the upper triangular matrix of the full pairwise comparison matrix (Matrix A); the value of each measurement might be 1/9, 1/8, ..., 1/3, 1/2, 1, 2, 3, ..., 8, 9 (see Table 7.4). To the lower triangular matrix, assign the reciprocal of the upper triangular matrix, that is, $a_{ij} = \frac{1}{a_{ji}}$. The complete pairwise comparison matrix is thus:

$$A = \begin{bmatrix} 1 & \cdots & a_{1j} \\ \vdots & \ddots & \vdots \\ 1/a_{i1} & \cdots & 1 \end{bmatrix}.$$

<Table 7.4 HERE>

To determine the priority of each element in a level of the hierarchy, the eigenvalue method, which is commonly used in the field of numerical analysis, is applied to the comparison matrix to calculate the eigenvector and the eigenvector is taken to be a priority vector. If the eigenvector does not sum to one, normalize the eigenvector to obtain the priority vector. The order of the priority vectors represents the relative importance of each factor. The formula for eigenvalues in the priority vector is:

$$w_i = \frac{[\prod_{j=1}^n a_{ij}]^{\frac{1}{n}}}{\sum_{i=1}^n [\prod_{j=1}^n a_{ij}]^{\frac{1}{n}}}$$

V. Determine the overall priority of the alternatives.

Not only must the priorities of the factors in each level of the research problem hierarchy be determined, but a best solution also has to be chosen from among the

alternatives. A pairwise comparison matrix of problem goals and alternatives is constructed for calculating the priorities of alternatives. Finally, the overall priority of an alternative is calculated by multiplying its priorities with respect to each criterion by the priority of the corresponding criterion and summing the results.

Demographics

This study investigated the factors that affect the success of an MMNS using the AHP. We used an AHP questionnaire to interview experts in the domain, comprising five people from each of the following categories: system development companies experienced in museum navigation systems, senior volunteer docents, academic staff, and visitor representatives; a detailed list is given in Table 7.5. Wherever possible we conducted face-to-face interviews, but also carried out email interviews with experts who were too busy to participate in a face-to-face interview; in those situations, we described the research issue and question items clearly via email. Data collection took place between May 1, 2012 and June 10, 2012.

<Table 7.5 HERE>

Reliability and Validity

In the AHP approach, researchers use a consistency test to check for reliability. Accordingly, C.I. and C.R. were calculated to verify consistency in this study, with reference to Saaty's (1980) suggestion that the C.I. values should be less than 0.1. Table 7.6 gives the C.I. values for each impact dimension by respondent and shows that the responses from all 20 experts in this study have good consistency.

<Table 7.6 HERE>

Saaty (1980) further suggested using reference C.R. values to check for consistency between respondents. This study had seven factors in the infrastructure dimension, so the C.R. values for each respondent in this dimension should be less than 0.1. There were six factors in the human-computer interface dimension, the content design dimension, and the service dimension, so the respective C.R. values should be less than 0.1. There were five factors in the user experience dimension, so the respective C.R. values should be less than 0.1. There were four factors in the exhibition space dimension and the cultural and creative dimension, so the respective

C.R. values should be less than 0.8. All of the responses in this study complied with the theoretical constraint on consistency, indicating that this study had good reliability(see Table 7.7)..

<Table 7.7 HERE>

In terms of validity, all of the factors identified in this study as being associated with MMNSs have been explored in the relevant literature and via current navigation systems operating in museums. We also carried out interviews with industry experts, senior volunteer docents, academic staff, and visitor representatives. This process enabled the accurate assessment of the research issues and, as a result, the study has good content validity and good expert validity.

Analysis and Discussion

Synthesizing the Judgment of Criteria (Design Dimensions)

After completing the consistency check on the responses collected in the expert interviews, we calculated the eigenvalue as a weight of each design dimension for every respondent and ranked the design dimensions by the average weights of each dimension. These values are given in Table 7.8. The respondents assessed the dimensions differently, based on their personal experience and knowledge, and the ranking of each dimension therefore also differed between the respondents. Overall, the results showed that the most important criterion was the cultural and creative dimension (0.194), the second was the human-computer interface (0.188), the third content design (0.168), followed by infrastructure (0.157), exhibition space (0.130), user experience (0.089), and service (0.073). In the experts' view, service was the design dimension that would least affect the successful design of an MMNS.

<Table 7.8 HERE>

Synthesizing Judgment of the Sub-criteria (Design Factors)

The judgments were broken down into the sub-criteria of our research problem, in the sequence infrastructure, human-computer interface, content design, user experience, service, exhibition space, and cultural and creative.

Infrastructure

Seven design factors were used to categorize the infrastructure dimension; Table

7.9 gives the factor weights for those seven factors for each respondent. The average weight of each factor indicated its relative importance to the infrastructure dimension. The ranking with respect to the importance of the seven factors, in sequence, was security (0.215), signal stability (0.213), coverage (0.191), near-field detection (0.103), broadband connection speed (0.100), ubiquitousness (0.099), and system compatibility (0.080). The domain experts generally considered security to be the most important factor within the infrastructure dimension affecting the success of an MMNS, with signal stability and coverage having a similar level of importance. Compatibility was considered to be of the lowest importance (the lowest average weight), but some of the academic staff believed that compatibility was also of considerable importance.

<Table 7.9 HERE>

Human-Computer Interface

Six design factors were used to categorize the human-computer interface dimension; Table 7.10 gives the factor weights for these six factors for each respondent. The average weight of each factor indicated its relative importance to the human-computer interface dimension. The ranking in terms of the importance of the six factors, in sequence, was information presentation (0.317), icon design (0.186), information richness (0.141), screen menu design (0.129), multi-language support (0.115), and search function (0.113). The domain experts deemed that in the human-computer interface dimension, it was first necessary to focus on the design of information presentation to design a successful MMNS. The average weight of the information presentation factor placed it significantly ahead of the others, as this was most important for attracting tourists to use the system. The next most important considerations were icon design, information richness, and screen menu design. Multi-lingual support and search function were much less important.

<Table 7.10 HERE>

Content Design

Six design factors were used to categorize the content design dimension; Table 7.11 gives the factor weights for these six factors for each respondent. The average weight of each factor indicated its relative importance to the content design dimension. The ranking in terms of importance of the six factors, in sequence, was timeliness

(0.242), locational notification (0.224), interactivity (0.213), site map (0.148), information download/pre-download (0.094), and browsing history (0.079). The top priority in the content design dimension, according to the domain experts, was to make it possible for visitors to receive real-time information. The weights of timeliness, locational notification, and interactivity were high, above 0.2, indicating that these three factors dominated over site map, information download/pre-download (0.094), and browsing history in the content design dimension.

<Table 7.11 HERE>

User Experience

Five design factors were used to categorize the user experience dimension; Table 7.12 gives the factor weights for these five factors for each respondent. The average weight of each factor indicated its relative importance to the user experience dimension. The ranking in terms of importance of the five factors, in sequence, was ease of use (0.287), satisfaction (0.224), utilization (0.195), user needs (0.184), and personalization (0.110). The domain experts believed that ease of use was the most important consideration within the user experience dimension; if visitors felt that the system was easy to use, they would be encouraged to reuse the system. In the domain experts' view, personalization had the lowest priority within the user experience dimension, because adjusting the navigation system based on visitors' preferences is cumbersome, and most tourists visit infrequently.

<Table 7.12 HERE>

Service

Six design factors were used to categorize the service dimension; Table 7.13 gives the factor weights for these six factors for each respondent. The average weight of each factor indicated its relative importance to the service dimension. The ranking in terms of importance of the six factors, in sequence, was service attitude (0.317), quick response (0.219), professional knowledge (0.180), service customization (0.141), service proactiveness (0.088), and promotion (0.056). The domain experts believed that service attitude represented the most important factor within the service dimension. The service attitude of museum staff determines visitor satisfaction after visitors have asked museum staff for help with an operational problem in the

navigation system. Minor considerations were quick response, professional knowledge, service customization, and service proactiveness. The promotion factor was assessed as having the lowest weight of all six factors, as visitors do not care about what type of promotion channel is used for the navigation system.

<Table 7.13 HERE>

Exhibition Space

Four design factors were used to categorize the exhibition space dimension; Table 7.14 gives the factor weights for these four factors for each respondent. The average weight of each factor indicated its relative importance to the exhibition space dimension. The ranking in terms of importance of the four factors, in sequence, was visitor routing (0.333), direction signs (0.214), exhibition information (0.266), and space saving (0.187). The domain experts determined the visitor routing factor to have a major influence within the exhibition space dimension, with route planning being of high importance. How to quickly and accurately direct a visitor using an MMNS, whenever that visitor enters an unfamiliar space, is an important consideration in the future design of an MMNS.

<Table 7.14 HERE>

Cultural and Creative

Four design factors were used to categorize the cultural and creative dimension; Table 7.15 gives the factor weights for these four factors for each respondent. The average weight of each factor indicated its relative importance to the cultural and creative dimension. The ranking in terms of the importance of the four factors, in sequence, was knowledge provision (0.348), humanities (0.284), creativity (0.201), and aesthetics (0.167). The domain experts believed that the reason why visitors use an MMNS is that they want to obtain more knowledge and thus intangible value arising from that knowledge, from the system; knowledge provision was therefore given a very high weighting in the cultural and creative dimension.

<Table 7.15 HERE>

Relative Weights of the Criteria and Their Sub-criteria

In this section, we summarize all of the weights of the criteria and their sub-criteria in Table 7.16, for reference.

<Table 7.16 HERE>

Conclusion and Recommendations

This study explored the relevant literature and current museum navigation systems to compile a set of design factors. It constructed a hierarchical structure for those factors via an AHP pairwise comparison questionnaire to address the research problem and synthesized judgments of the importance of each design factor and dimension provided by 20 participants from four groups of domain expert: industry experts, senior volunteer docents, academic staff, and visitor representatives. According to this synthesis, the four top-ranking dimensions were cultural and creative, human-computer interface, content design, and infrastructure. Overall, the domain experts attached more importance to the cultural and creative dimension, then the human-computer interface, followed by content design and then infrastructure.

Within the cultural and creative dimension, knowledge provision was ranked as the most important sub-criterion. The experts all agreed that knowledge provision was the most influential of the design factors. The experts deemed that visitors use a mobile navigation system during visit to a museum because they wish to obtain valuable knowledge, both tangible and intangible, from the system and hope that this knowledge will enrich their journey even after the visit is over. The major role of the navigation system is to act as a docent to interpret and deliver knowledge relating to exhibitions for visitors to the museum. Accordingly, system developers must pay attention to enriching knowledge relating to exhibits and exhibition themes in an MMNS rather than concentrating on the functionality of the system.

The human-computer interface was also critical in influencing the success of an MMNS; information presentation and icon design were the major sub-criteria within this dimension. The experts believed that when deciding to purchase or use an object, most people will intuitively judge whether they like the object, whether it is appropriate for them, and whether they intend to use the object at the first glance, before understanding the implied value of the merchandise in depth. Accordingly, information presentation directly affects whether an MMNS will be accepted. Additionally, icons are not only more attractive than text descriptions, but are also understood more clearly and are easier to accept. An analogy is traffic signals along

the road; few of these use words, mostly delivering information through illustrations. For these reasons, information presentation and icon design are important considerations.

In this study, the word “content” in content design means the functionality, presentation, and arrangement of system functions in an MMNS, which are crucial to a software system. Of the factors within the content design dimension, timeliness was the most important. The domain experts viewed a visit to a museum as a dynamic moving flow of watching, with visitors watching different exhibits during different time slots. Accordingly, exhibition information delivered to visitors must be displayed in real time and accurately correspond to the item the visitor is viewing. In addition, in a wide exhibition space, it is not easy for visitors to correctly judge their location and even more difficult to locate an exhibit far away from them. Visitors rely on a location sign in an exhibition hall, or a location-aware MMNS, to inform them. Moreover, interactivity allows visitors to operate the MMNS more flexibly and thus they may use the system to freely explore the exhibitions. Locational notification and interactivity are therefore important considerations.

Although the infrastructure dimension was only ranked fourth, there is no doubt that the system environment and infrastructure are crucial to a smart phone mobile application. Within the infrastructure dimension, security and signal stability were assessed as the important factors by the domain experts. To prevent user resistance to a system, it must not only improve the way in which users communicate with it, but also address any safety issues that users might be concerned about. In addition, the domain experts believed that the most attractive service will offer users stability and the convenience to use the system wherever they are.

The contributions of this study include not only an up-to-date summary of the relevant literature and an analysis of current museum navigation systems, but also a focus on the elements accompanying the system itself, such as museum staff and promotions, and addressing of the modern trend toward smart phone applications. We expect the research findings to provide design criteria for system developers and to act as a reference guide for museum staff. We also believe that our findings comprise a useful reference for scholars.

References

- Ashworth, G. J. (2000). Heritage, tourism and places: a review. *Tourism recreation research*, 25(1), 19-29.
- Bailey, J. E., & Pearson, S. W. (1983). Development of a tool for measuring and analyzing computer user satisfaction. *Management science*, 29(5), 530-545.
- Beck, J., Han, S. H., & Park, J. (2006). Presenting a submenu window for menu

- search on a cellular phone. *International Journal of Human-Computer Interaction*, 20(3), 233-245.
- Bitgood, S. (1994). Designing effective exhibits: Criteria for success, exhibit design approaches, and research strategies. *Visitor Behavior*, 9(4), 4-15.
- Bitgood, S. (1995). Visitor circulation: Is there really a right-turn bias. *Visitor Behavior*, 10(1), 5.
- Cameron, F. (2003). Digital Futures I: Museum collections, digital technologies, and the cultural construction of knowledge. *Curator: The Museum Journal*, 46(3), 325-340.
- Chang, T. C., & Yeoh, B. S. (1999). "New Asia–Singapore": communicating local cultures through global tourism. *Geoforum*, 30(2), 101-115.
- Chen, C. C., & Huang, T. C. (2012). Learning in a u-Museum: Developing a context-aware ubiquitous learning environment. *Computers & Education*, 59(3), 873-883.
- Chen, Z. X. (1998, December). Market research and audience development. In *New directions for the new century : proceedings of the conference on Museum Marketing* (pp. 88-110), Taipei: National History Museum.
- Chesapeake Bay Maritime Museum*. (2014). Retrieved September 30, 2014, from <http://www.stmichaelsmd.org/pages/MaritimeMuseum>.
- Cone, C. A., & Kendall, K. (1978). Space, time, and family interaction: Visitor behavior at the Science Museum of Minnesota. *Curator: The Museum Journal*, 21(3), 245-258.
- Cossons, N. (1989). Heritage tourism—trends and tribulations. *Tourism Management*, 10(3), 192-194.
- Cui, B., & Yokoi, S. (2012, April). Promote visitor interactions by smart devices in museum learning scenario. In *Computing Technology and Information Management (ICCM), 2012 8th International Conference* (Vol. 1, pp. 376-379). IEEE.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 13(3), 319-340.
- DeLone, W. H., & McLean, E. R. (1992). Information systems success: the quest for the dependent variable. *Information systems research*, 3(1), 60-95.
- Department for Culture, Media and Sport. (DCMS) (2014), The Learning Power of Museums ~ A Vision for Museum Education*. Retrieved September 30, 2014, from http://dera.ioe.ac.uk/4551/2/museum_vision_report.pdf.
- Edson, G. & Dean, D. (1994), *The Handbook for Museums*, London:Routledge.
- Edwards, Y., (1982), 'An overview of interpretation' , In Sharpe, G.W., (ED.), *Interpreting the Environment (2nd ed.)*, John Wiley and Sons, New York.

- Ellis, B., & Mosher, J. S. (1993). Six Ps for Four Characteristics: A Complete Positioning Strategy for the Professional Services Firm-CPA's. *Journal of Professional Services Marketing*, 9(1), 129-145.
- Fronville, C. L. (1985). Marketing for Museums: For-Profit Techniques in the Non-Profit World. *Curator: The Museum Journal*, 28(3), 169-182.
- Ghiani, G., Paternò, F., Santoro, C., & Spano, L. D. (2009). UbiCicero: A location-aware, multi-device museum guide. *Interacting with Computers*, 21(4), 288-303.
- Horton, W. K. (1994). *The icon book: Visual symbols for computer systems and documentation*. John Wiley & Sons, Inc.
- Hsi, S. (2003). A study of user experiences mediated by nomadic web content in a museum. *Journal of Computer Assisted Learning*, 19(3), 308-319.
- Huang, Y. P., Wang, S. S., & Sandnes, F. E. (2011). RFID-based guide gives museum visitors more freedom. *IT Professional*, 13(2), 25-29.
- Hung, C. C. (2007). Museum visit access design : case study of the National Palace Museum display space. Unpublished master's thesis, Department of Fine Arts, National Taiwan Normal University, Taipei, Taiwan. [Please add the reference list, as for the other chapters.]
- Intel. (2005a). *Intel digital community framework whitepaper*. Intel.
- Intel. (2005b). *Core Technologies for Developing a Digital Community Framework*. Intel.
- ITU. (2007). *ITU Digital Opportunity Index*. ITU.
- Johns, N., & Clark, S. L. (1993). Customer perception auditing: a means of monitoring the service provided by museums and galleries. *Museum Management and Curatorship*, 12(4), 360-366.
- Jones, S., Jones, M., Marsden, G., Patel, D., & Cockburn, A. (2005). An evaluation of integrated zooming and scrolling on small screens. *International Journal of Human-Computer Studies*, 63(3), 271-303.
- Kravchyna, V., & Hastings, S. (2002). Informational value of museum web sites. *First Monday*, 7(2).
- Liu, C., & Arnett, K. P. (2000). Exploring the factors associated with Web site success in the context of electronic commerce. *Information & management*, 38(1), 23-33.
- MacDonald, G. F., & Alsford, S. (1991). The museum as information utility. *Museum Management and Curatorship*, 10(3), 305-311.
- Marchionini, G. (1997). *Information seeking in electronic environments* (No. 9). Cambridge University Press.
- Marty, P. F. (2008). Museum websites and museum visitors: Digital museum resources and their use. *Museum Management and Curatorship*, 23(1), 81-99.

- Matthews, G. M. (1991). *Museums and art galleries: a design and development guide*. Butterworth Architecture.
- McLean, K. M. (1993). *Planning for people in museum exhibitions* (Vol. 1).
- Moscardo, G. (1996). Mindful visitors: Heritage and tourism. *Annals of tourism research*, 23(2), 376-397.
- Parasuraman, A., Berry, L. L., & Zeithaml, V. A. (1991). Understanding customer expectations of service. *Sloan Management Review*, 32(3), 39-48.
- Reynolds, R., Walker, K., & Speight, C. (2010). Web-based museum trails on PDAs for university-level design students: Design and evaluation. *Computers & Education*, 55(3), 994-1003.
- Richards, G. (1996). Production and consumption of European cultural tourism. *Annals of tourism research*, 23(2), 261-283.
- Rosenfeld, L., & Morville, P. (2007). *Information architecture for the world wide web (3rd ed.)*, O'Reilly Media, Inc.
- Ryan, C., & Dewar, K. (1995). Evaluating the communication process between interpreter and visitor. *Tourism Management*, 16(4), 295-303.
- Satty, T. L. (1980). The analytic hierarchy process.
- Schwabe, G., & Göth, C. (2005). Mobile learning with a mobile game: design and motivational effects. *Journal of computer assisted learning*, 21(3), 204-216.
- Shackley, M. (1997). Saving cultural information: The potential role of digital databases in developing cultural tourism. *Journal of Sustainable Tourism*, 5(3), 244-249.
- Shen, E. S., & Liang, C. C. Y. (2010). Research of interactive Exhibition Design for the Web-based Virtual Reality Museum. *Journal of Educational Media & Library Sciences*, 37(3), 275-298.
- Thorlacius, L. (2002). A model of visual, aesthetic communication focusing on web sites. *Digital Creativity*, 13(2), 85-98.
- Thorlacius, L. (2007). The role of aesthetics in web design. *Nordicom Review*, 28(1), 63-76.
- Tilden, F. (1957) *Interpreting our Heritage*. University of North Carolina Press, North Carolina
- Wang, C. S., Su, Y. H., & Hong, C. Y. (2009). A 3D Virtual Navigation System Integrating User Positioning and Pre-Download Mechanism. *World Academy of Science, Engineering and Technology*, 40, 172-176.
- Williams, D. A., Wavell, C., Baxter, G., MacLennan, A., & Jobson, D. (2005). Implementing impact evaluation in professional practice: A study of support needs within the museum, archive and library sector. *International journal of information management*, 25(6), 533-548.

Ziefle, M. (2010). Information presentation in small screen devices: The trade-off between visual density and menu foresight. *Applied ergonomics*, 41(6), 719-730.

Table 7.1: The shortcomings of common museum navigation systems

Type of System	Shortcomings
Guides	<p>High human resources cost.</p> <p>High job training cost.</p> <p>Inconsistent quality of personnel.</p> <p>Difficulty in assembling an entire group of visitors at a certain location in the exhibition at the same time.</p> <p>Live interpretation tends to cause congestion in visitor traffic along the exhibition route.</p>
Brochures	<p>High cost of printing.</p> <p>Cannot be reused.</p> <p>Environmentally unfriendly.</p>
Video clips	<p>High production cost.</p> <p>The length of a typical video restricts the amount of information that can be included.</p>
Computer kiosks	<p>High hardware cost and high maintenance cost.</p>
Voice	<p>The expense of producing the voice content dominates the overall cost.</p> <p>Frequent use leads to the equipment becoming damaged and increases maintenance costs.</p> <p>Lack of interaction with users.</p> <p>Image information is hard to express due to the purely aural format.</p> <p>When exhibition themes change frequently, voice navigation is often not ready in time.</p>
Briefing slides	<p>Services cannot be provided for individuals, as briefings have to be at set times.</p>

Table 7.2: Nominal scale used in the AHP

Scale	Definition	Description
1	Equally	The two comparisons have the same importance or make the same contribution to the superior element.
3	Moderately	Moderately preferred to the other element according to experience or judgment.
5	Strong	Strongly preferred to the other element according to experience or judgment.
7	Very strong	Very strong tendency to dominate over the other element.
9	Extremely	Extremely certain that one element dominates over the other.
2, 4, 6, 8	Intermediate judgment values	Whenever you need a compromise between two neighboring judgment scales.

Source: Saaty (1980)

Table 7.3: Random Index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.(n)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Table 7.4: An example of the factors preparedness questionnaire

F A C T O R	Ratio Scale														F A C T O R			
	Extremely preferred (9 : 1)		Very strongly preferred (7 : 1)		Strong preferred (1 : 5)		Moderately preferred (3 : 1)		Equally Preferred (1 : 1)		Moderately preferred (1 : 3)		Strong preferred (1 : 5)			Very strongly preferred (1 : 7)		Extremely preferred (1 : 9)
F _A							V											F _B

F _A									V								F _C
F _A											V						F _D

Table 7.5: Interviewee list

Expert category	Respondents
Industry expert (from museum navigation systems development companies)	Industry Expert 1 (Company A), Industry Expert 2 (Company B), Industry Expert 3 (Company C), Industry Expert 4 (Company D), Industry Expert 5 (Company E).
Senior volunteer docents (in Taiwan's National Palace Museum)	Senior Volunteer 1, Senior Volunteer 2, Senior Volunteer 3, Senior Volunteer 4, Senior Volunteer 5.
Academic staff (scholars from colleges and researchers from government)	Academic Staff from: (1) Dept. of Information Engineering, (2) Dept. of Information Engineering, (3) Dept. of Information Engineering, (4) Dept. of Business Administration, (5) Dept. of Cultural Affairs, Taipei City Government.
Visitor representatives (to Taiwan's National Palace Museum)	Visitor Representative 1, Visitor Representative 2, Visitor Representative 3, Visitor Representative 4, Visitor Representative 5.

Table 7.6: Consistency Indexs

Design Criteria Respondents	Infrastructure	Human-Computer Interface	Content Design	User Experience	Service	Exhibition Space	Cultural and Creative
Industry Expert 1	0.07	0.1	0.1	0.09	0.1	0.034	0.06
Industry Expert 2	0.03	0.02	0.07	0.08	0.09	0.06	0.01
Industry Expert 3	0.1	0.087	0.082	0.086	0.06	0.034	0.07
Industry Expert 4	0.043	0.03	0.02	0.03	0.02	0.054	0.05
Industry Expert 5	0.02	0.02	0.025	0.023	0.03	0.01	0.053
Senior Volunteer 1	0.065	0.071	0.091	0.08	0.098	0.06	0.062
Senior Volunteer 2	0.1	0.084	0.09	0.079	0.071	0.02	0.028
Senior Volunteer 3	0.07	0.09	0.07	0.03	0.07	0.03	0.069
Senior Volunteer 4	0.09	0.08	0.043	0.06	0.062	0.02	0.07
Senior Volunteer 5	0.06	0.08	0.09	0.04	0.1	0.03	0.066
Academic Staff 1	0.1	0.07	0.07	0.071	0.063	0.034	0.071
Academic Staff 2	0.08	0.01	0.01	0.01	0.01	0.01	0.01
Academic Staff 3	0.1	0.1	0.09	0.1	0.1	0.03	0.07
Academic Staff 4	0.09	0.06	0.1	0.09	0.09	0.01	0.02
Academic Staff 5	0.09	0.09	0.085	0.1	0.087	0.023	0.07
Visitor Representative 1	0.047	0.1	0.1	0.08	0.1	0.055	0.069
Visitor Representative 2	0.1	0.098	0.093	0.1	0.076	0.056	0.065
Visitor Representative 3	0.092	0.1	0.1	0.09	0.09	0.05	0.66
Visitor Representative 4	0.1	0.1	0.08	0.06	0.084	0.034	0.043
Visitor Representative 5	0.08	0.06	0.1	0.078	0.08	0.05	0.06

Table 7.7: Consistency ratio values

Design Criteria Respondents	Infrastructure	Human-Computer Interface	Content Design	User Experience	Service	Exhibition Space	Cultural and Creative
Industry Expert 1	0.053	0.081	0.081	0.080	0.081	0.038	0.067
Industry Expert 2	0.023	0.016	0.056	0.071	0.073	0.067	0.011
Industry Expert 3	0.076	0.070	0.066	0.077	0.048	0.038	0.078
Industry Expert 4	0.033	0.024	0.016	0.027	0.016	0.060	0.056
Industry Expert 5	0.015	0.016	0.020	0.021	0.024	0.011	0.059
Senior Volunteer 1	0.049	0.057	0.073	0.071	0.079	0.067	0.069
Senior Volunteer 2	0.076	0.068	0.073	0.071	0.057	0.022	0.031
Senior Volunteer 3	0.053	0.073	0.056	0.027	0.056	0.033	0.077
Senior Volunteer 4	0.068	0.065	0.035	0.054	0.050	0.022	0.078
Senior Volunteer 5	0.045	0.065	0.073	0.036	0.081	0.033	0.073
Academic Staff 1	0.076	0.056	0.056	0.063	0.051	0.038	0.079
Academic Staff 2	0.061	0.008	0.008	0.009	0.008	0.011	0.011
Academic Staff 3	0.076	0.081	0.073	0.089	0.081	0.033	0.078
Academic Staff 4	0.068	0.048	0.081	0.080	0.073	0.011	0.022
Academic Staff 5	0.068	0.073	0.069	0.089	0.070	0.026	0.078
Visitor Representative 1	0.036	0.081	0.081	0.071	0.081	0.061	0.077
Visitor Representative 2	0.076	0.079	0.075	0.089	0.061	0.062	0.072
Visitor Representative 3	0.070	0.081	0.081	0.080	0.073	0.056	0.733
Visitor Representative 4	0.076	0.081	0.065	0.054	0.068	0.038	0.048
Visitor Representative 5	0.061	0.048	0.081	0.070	0.065	0.056	0.067

Table 7.8: The relative weights of each design criteria dimension

Dimension Respondents	Infrastructure	Human-Computer Interface	Content Design	User Experience	Service	Exhibition Space	Cultural and Creative
Industry Expert 1	0.112	0.225	0.272	0.139	0.049	0.114	0.094
Industry Expert 2	0.083	0.155	0.115	0.028	0.054	0.186	0.379
Industry Expert 3	0.101	0.101	0.140	0.236	0.268	0.032	0.122
Industry Expert 4	0.156	0.385	0.260	0.021	0.091	0.054	0.033
Industry Expert 5	0.161	0.349	0.239	0.029	0.066	0.084	0.072
Senior Volunteer 1	0.173	0.320	0.039	0.072	0.059	0.110	0.227
Senior Volunteer 2	0.230	0.101	0.199	0.090	0.075	0.043	0.262
Senior Volunteer 3	0.032	0.116	0.155	0.073	0.039	0.316	0.269
Senior Volunteer 4	0.039	0.087	0.114	0.362	0.058	0.146	0.194
Senior Volunteer 5	0.064	0.305	0.261	0.061	0.100	0.049	0.160
Academic Staff 1	0.227	0.060	0.110	0.038	0.073	0.173	0.319
Academic Staff 2	0.170	0.202	0.140	0.058	0.069	0.195	0.166
Academic Staff 3	0.060	0.227	0.233	0.109	0.051	0.177	0.143
Academic Staff 4	0.228	0.098	0.211	0.085	0.080	0.038	0.260
Academic Staff 5	0.083	0.155	0.115	0.028	0.054	0.186	0.379
Visitor Representative 1	0.325	0.174	0.125	0.065	0.032	0.099	0.180
Visitor Representative 2	0.378	0.165	0.096	0.031	0.043	0.121	0.166
Visitor Representative 3	0.304	0.170	0.196	0.102	0.061	0.058	0.109
Visitor Representative 4	0.050	0.170	0.205	0.099	0.065	0.228	0.183
Visitor Representative 5	0.169	0.203	0.138	0.060	0.068	0.196	0.166
Average Weight	0.157	0.188	0.168	0.089	0.073	0.130	0.194
Ranking	4	2	3	6	7	5	1

Table 7.9: The factor weights within the Infrastructure dimension

Infrastructure Respondents	Signal Stability	Coverage	Ubiquitousness	Broadband Connection	Near-field Detection	Compatibility	Security
Industry Expert 1	0.069	0.211	0.039	0.042	0.074	0.051	0.514
Industry Expert 2	0.161	0.161	0.161	0.139	0.139	0.161	0.079
Industry Expert 3	0.277	0.113	0.142	0.265	0.082	0.046	0.075
Industry Expert 4	0.390	0.261	0.153	0.092	0.054	0.026	0.024
Industry Expert 5	0.354	0.240	0.104	0.159	0.068	0.031	0.045
Senior Volunteer 1	0.079	0.212	0.028	0.052	0.064	0.055	0.510
Senior Volunteer 2	0.256	0.171	0.152	0.108	0.190	0.076	0.048
Senior Volunteer 3	0.200	0.330	0.079	0.085	0.141	0.040	0.125
Senior Volunteer 4	0.413	0.228	0.157	0.045	0.098	0.033	0.026
Senior Volunteer 5	0.138	0.082	0.136	0.144	0.037	0.096	0.367
Academic Staff 1	0.207	0.331	0.072	0.087	0.142	0.038	0.124
Academic Staff 2	0.243	0.176	0.104	0.114	0.097	0.087	0.179
Academic Staff 3	0.084	0.023	0.052	0.064	0.045	0.224	0.510
Academic Staff 4	0.096	0.110	0.062	0.098	0.041	0.220	0.373
Academic Staff 5	0.080	0.126	0.220	0.040	0.372	0.098	0.064
Visitor Representative 1	0.190	0.343	0.057	0.042	0.082	0.055	0.232
Visitor Representative 2	0.342	0.181	0.056	0.031	0.042	0.089	0.258
Visitor Representative 3	0.172	0.175	0.034	0.211	0.054	0.089	0.265
Visitor Representative 4	0.251	0.305	0.061	0.080	0.151	0.040	0.112
Visitor Representative 5	0.264	0.042	0.113	0.097	0.079	0.041	0.364
Average Weight	0.213	0.191	0.099	0.100	0.103	0.080	0.215
Ranking	2	3	6	5	4	7	1

Table 7.10: The factor weights within the human-computer interface dimension

Human-Computer Interface	Information richness	Information presentation	Icon design	Screen menu design	Multi-language support	Search function
Respondents						
Industry Expert 1	0.064	0.441	0.248	0.15	0.031	0.066
Industry Expert 2	0.061	0.368	0.143	0.143	0.143	0.143
Industry Expert 3	0.052	0.105	0.34	0.144	0.073	0.285
Industry Expert 4	0.102	0.368	0.254	0.162	0.068	0.045
Industry Expert 5	0.1	0.381	0.256	0.158	0.064	0.041
Senior Volunteer 1	0.093	0.058	0.046	0.402	0.252	0.149
Senior Volunteer 2	0.061	0.309	0.276	0.121	0.133	0.101
Senior Volunteer 3	0.243	0.428	0.133	0.084	0.063	0.049
Senior Volunteer 4	0.167	0.087	0.08	0.054	0.384	0.228
Senior Volunteer 5	0.082	0.436	0.16	0.157	0.061	0.104
Academic Staff 1	0.063	0.276	0.282	0.127	0.148	0.104
Academic Staff 2	0.133	0.333	0.172	0.138	0.109	0.114
Academic Staff 3	0.243	0.425	0.048	0.133	0.092	0.06
Academic Staff 4	0.067	0.23	0.274	0.095	0.233	0.1
Academic Staff 5	0.05	0.36	0.067	0.127	0.164	0.232
Visitor Representative 1	0.194	0.402	0.192	0.084	0.06	0.069
Visitor Representative 2	0.409	0.273	0.064	0.032	0.053	0.17
Visitor Representative 3	0.231	0.335	0.254	0.073	0.034	0.073
Visitor Representative 4	0.242	0.426	0.047	0.133	0.084	0.07
Visitor Representative 5	0.16	0.293	0.38	0.07	0.044	0.053
Average Weight	0.141	0.317	0.186	0.129	0.115	0.113
Ranking	3	1	2	4	5	6

Table 7.11: The factor weights within the content design dimension

Content Design Respondents	Timeliness	Interactivity	Locational Notification	Browsing History	Information Download / Pre-Download	Site Map
Industry Expert 1	0.114	0.518	0.123	0.088	0.104	0.053
Industry Expert 2	0.252	0.297	0.143	0.102	0.149	0.058
Industry Expert 3	0.154	0.126	0.293	0.115	0.255	0.057
Industry Expert 4	0.160	0.250	0.382	0.101	0.064	0.043
Industry Expert 5	0.149	0.253	0.379	0.112	0.060	0.047
Senior Volunteer 1	0.311	0.327	0.044	0.055	0.095	0.168
Senior Volunteer 2	0.082	0.077	0.322	0.061	0.278	0.180
Senior Volunteer 3	0.303	0.124	0.182	0.055	0.069	0.266
Senior Volunteer 4	0.137	0.310	0.346	0.101	0.062	0.044
Senior Volunteer 5	0.300	0.220	0.240	0.102	0.052	0.086
Academic Staff 1	0.299	0.126	0.183	0.059	0.078	0.255
Academic Staff 2	0.253	0.211	0.214	0.084	0.099	0.139
Academic Staff 3	0.311	0.327	0.044	0.055	0.095	0.168
Academic Staff 4	0.072	0.056	0.470	0.152	0.039	0.211
Academic Staff 5	0.082	0.039	0.460	0.130	0.056	0.233
Visitor Representative 1	0.365	0.294	0.173	0.030	0.055	0.083
Visitor Representative 2	0.418	0.220	0.130	0.034	0.049	0.149
Visitor Representative 3	0.488	0.207	0.054	0.034	0.088	0.129
Visitor Representative 4	0.229	0.175	0.096	0.061	0.097	0.343
Visitor Representative 5	0.353	0.104	0.195	0.054	0.042	0.252
Average Weight	0.242	0.213	0.224	0.079	0.094	0.148
Ranking	1	3	2	6	5	4

Table 7.12: The factor weights within the user experience dimension

User Experience Respondents	Satisfac- tion	Utiliza- tion	Ease of Use	Personali- zation	User Needs
Industry Expert 1	0.284	0.120	0.470	0.062	0.064
Industry Expert 2	0.306	0.195	0.187	0.124	0.187
Industry Expert 3	0.471	0.229	0.100	0.100	0.100
Industry Expert 4	0.095	0.155	0.451	0.060	0.239
Industry Expert 5	0.099	0.162	0.420	0.066	0.252
Senior Volunteer 1	0.189	0.048	0.139	0.089	0.535
Senior Volunteer 2	0.106	0.071	0.487	0.096	0.240
Senior Volunteer 3	0.147	0.363	0.264	0.094	0.132
Senior Volunteer 4	0.413	0.054	0.161	0.210	0.161
Senior Volunteer 5	0.399	0.042	0.114	0.159	0.285
Academic Staff 1	0.235	0.075	0.208	0.076	0.407
Academic Staff 2	0.228	0.183	0.300	0.115	0.174
Academic Staff 3	0.157	0.383	0.264	0.084	0.112
Academic Staff 4	0.106	0.071	0.487	0.096	0.240
Academic Staff 5	0.056	0.239	0.095	0.391	0.218
Visitor Representative 1	0.417	0.265	0.194	0.076	0.048
Visitor Representative 2	0.144	0.201	0.493	0.105	0.058
Visitor Representative 3	0.156	0.442	0.268	0.087	0.047
Visitor Representative 4	0.178	0.423	0.234	0.068	0.098
Visitor Representative 5	0.288	0.180	0.395	0.049	0.089
Average Weight	0.224	0.195	0.287	0.110	0.184
Ranking	2	3	1	5	4

Table 7.13: The factor weights within the service dimension

Respondents	Service					
	Professional Knowledge	Service Attitude	Quick Response	Service Customizatio	Service Proactiveness	Promotion
Industry Expert 1	0.036	0.336	0.172	0.258	0.099	0.099
Industry Expert 2	0.086	0.272	0.316	0.232	0.039	0.055
Industry Expert 3	0.101	0.314	0.282	0.094	0.084	0.126
Industry Expert 4	0.101	0.382	0.250	0.160	0.064	0.043
Industry Expert 5	0.104	0.386	0.236	0.173	0.062	0.039
Senior Volunteer 1	0.273	0.269	0.172	0.157	0.088	0.041
Senior Volunteer 2	0.138	0.431	0.214	0.084	0.088	0.046
Senior Volunteer 3	0.271	0.340	0.162	0.083	0.095	0.049
Senior Volunteer 4	0.279	0.398	0.121	0.102	0.052	0.047
Senior Volunteer 5	0.076	0.162	0.112	0.167	0.405	0.078
Academic Staff 1	0.265	0.282	0.149	0.197	0.065	0.042
Academic Staff 2	0.165	0.340	0.224	0.136	0.078	0.056
Academic Staff 3	0.270	0.279	0.175	0.157	0.078	0.041
Academic Staff 4	0.087	0.271	0.326	0.222	0.039	0.056
Academic Staff 5	0.088	0.270	0.324	0.221	0.037	0.061
Visitor Representative 1	0.230	0.264	0.322	0.047	0.089	0.047
Visitor Representative 2	0.279	0.293	0.222	0.105	0.056	0.045
Visitor Representative 3	0.268	0.377	0.146	0.071	0.094	0.044
Visitor Representative 4	0.273	0.329	0.171	0.070	0.097	0.059
Visitor Representative 5	0.202	0.339	0.281	0.084	0.054	0.041
Average Weight	0.180	0.317	0.219	0.141	0.088	0.056
Ranking	3	1	2	4	5	6

Table 7.14: The factor weights within the exhibition space dimension

Exhibition Space Respondents	Space Saving	Visitor Routing	Exhibition information	Direction signs
Industry Expert 1	0.110	0.408	0.211	0.271
Industry Expert 2	0.096	0.368	0.368	0.168
Industry Expert 3	0.104	0.332	0.390	0.174
Industry Expert 4	0.098	0.503	0.159	0.240
Industry Expert 5	0.160	0.467	0.277	0.095
Senior Volunteer 1	0.053	0.308	0.132	0.506
Senior Volunteer 2	0.070	0.285	0.315	0.330
Senior Volunteer 3	0.131	0.395	0.202	0.272
Senior Volunteer 4	0.119	0.220	0.201	0.460
Senior Volunteer 5	0.280	0.116	0.516	0.087
Academic Staff 1	0.155	0.193	0.606	0.046
Academic Staff 2	0.175	0.355	0.269	0.201
Academic Staff 3	0.120	0.418	0.191	0.271
Academic Staff 4	0.079	0.288	0.307	0.327
Academic Staff 5	0.146	0.415	0.346	0.093
Visitor Representative 1	0.246	0.575	0.117	0.062
Visitor Representative 2	0.553	0.148	0.054	0.245
Visitor Representative 3	0.103	0.488	0.157	0.251
Visitor Representative 4	0.511	0.209	0.177	0.102
Visitor Representative 5	0.438	0.163	0.320	0.079
Average Weight	0.187	0.333	0.266	0.214
Ranking	4	1	3	2

Table 7.15: The factor weights within the cultural and creative dimension

Cultural and Creative Respondents	Knowledge Provision	Esthetics	Creativity	Humanities
Industry Expert 1	0.654	0.053	0.164	0.130
Industry Expert 2	0.375	0.125	0.375	0.125
Industry Expert 3	0.399	0.174	0.111	0.316
Industry Expert 4	0.462	0.134	0.103	0.301
Industry Expert 5	0.116	0.458	0.240	0.185
Senior Volunteer 1	0.429	0.161	0.085	0.325
Senior Volunteer 2	0.065	0.373	0.249	0.313
Senior Volunteer 3	0.540	0.067	0.252	0.142
Senior Volunteer 4	0.201	0.094	0.191	0.514
Senior Volunteer 5	0.433	0.293	0.077	0.197
Academic Staff 1	0.457	0.205	0.051	0.287
Academic Staff 2	0.342	0.159	0.205	0.294
Academic Staff 3	0.431	0.159	0.086	0.324
Academic Staff 4	0.082	0.368	0.242	0.308
Academic Staff 5	0.151	0.075	0.265	0.509
Visitor Representative 1	0.519	0.166	0.244	0.072
Visitor Representative 2	0.171	0.077	0.231	0.521
Visitor Representative 3	0.625	0.059	0.209	0.107
Visitor Representative 4	0.154	0.082	0.494	0.270
Visitor Representative 5	0.348	0.064	0.139	0.449
Average Weight	0.348	0.167	0.201	0.284
Ranking	1	4	3	2

Table 7.16: Relative weights of the criteria and their sub-criteria (The numbers in brackets represent the importance rankings)

Design Dimensions/Criteria		Design Factors/Sub-criteria	
Dimension	Weight	Factor	Weight
Infrastructure	0.157 (4)	Signal Stability	0.213 (2)
		Coverage	0.191 (3)
		Ubiquitousness	0.099 (6)
		Broadband Connection Speeds	0.100 (5)
		Near Field Detection	0.103 (4)
		Compatibility	0.080 (7)
		Security	0.215 (1)
Human-Computer Interface	0.188 (2)	Information Richness	0.101 (3)
		Information Presentation	0.317 (1)
		Icon Design	0.186 (2)
		Screen Menu Design	0.129 (4)
		Multi-language Support	0.115 (5)
		Search Function	0.113 (6)
Content Design	0.168 (3)	Timeliness	0.242 (1)
		Interactivity	0.213 (3)
		Locational Notification	0.224 (2)
		Browsing History	0.079 (6)
		Information Download/Pre-download	0.094 (5)
		Site Map	0.148 (4)

User Experience	0.089 (6)	Satisfaction	0.224 (2)
		Utilization	0.195 (3)
		Ease of Use	0.287 (1)
		Personalization	0.110 (5)
		User Needs	0.184 (4)
Service	0.073 (7)	Professional Knowledge	0.180 (3)
		Service Attitude	0.317 (1)
		Quick Response	0.219 (2)
		Service Customization	0.141 (4)
		Service Proactiveness	0.088 (5)
		Promotion	0.056 (6)
Exhibition Space	0.130 (5)	Space Saving	0.187 (4)
		Visitor Routing	0.333 (1)
		Exhibition Information	0.266 (2)
		Direction Signs	0.214 (2)
Cultural and Creative	0.194 (1)	Knowledge Provision	0.348 (1)
		Aesthetics	0.167 (4)
		Creativity	0.201 (3)
		Humanities	0.284 (2)