Key factors and network model for location-based cultural mobile game design

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Abstract

The use of smart devices as media for digital learning constitutes a new-generation digital learning paradigm. Therefore, context-aware game-based learning has attracted considerable attention. Location-based games have not only positive effects on learning but also pronounced effects on culture and history. Accordingly, focusing on railway cultural heritages, we attempted to assess interdependent relationships between key factors crucial for the design of a location-based mobile game for cultural heritages. We adopted the analytic network process (ANP) for our assessment. We initially performed a literature review to generalize relevant criteria and elements and developed a questionnaire based on the fuzzy delphi method (FDM); which lead to the selection of key factors, namely 3 criteria and 15 elements. We also applied an online ANP-based questionnaire; on the basis of the experts' opinions, we established a network model and determined the priority order of the key factors. The results revealed that experts considered "culture learning" to be of the highest importance, with the most important three elements being "prior knowledge", "challenge levels," and "cultural narrative." Moreover, culture learning exhibited a strong interaction with content design. In addition, each element had a considerable influence on the remaining elements that could provide references for the construction of location-based cultural mobile games in the future.

Introduction

Through the context-aware applications of smart devices, mobile learning can enable learners to interact with external environments and capture the corresponding learning materials. Liu and Hwang (2010) indicated that ubiquitous learning has become a new paradigm of digital learning and has influenced the general trend of the future learning field. Studies have confirmed that context-aware game-based learning strategies, such as those involving the use of instructional pervasive games (IPGs), have positive effects on education quality. Specifically, studies have revealed that IPGs could improve learning outcomes, motivation, and achievements (e.g., Huizenga, Admiraal, Akkerman, & Dam, 2009; Liu & Chu, 2010; Su & Cheng, 2015).

Practitioner Notes

What is already known about this topic

- Context-aware game-based learning, such as instructional pervasive games, improves quality of learning.
- Location-based games help learners achieve better learning outcomes, learning potential, and learning interest.
- Most studies on location-based, cultural exploration games mainly emphasize their design and development of the game scheme. However, the key factors that make a success of the game are overlooked.

What this paper adds

- We identified key factors (3 criteria; 15 elements) and developed a network model based on analytic network process (ANP) for location-based cultural mobile game design.
- The priority order of key factors for designing a location-based railway cultural game is derived.
- The strengths, relationships, and influences among identified key factors were analyzed.

Implications for practice and/or policy

- The results of this study provide validated guidelines for further development of effective location-based cultural exploration games.
- Our study findings enable designers to prioritize or demote reference factors for construction, according to relative strengths and weaknesses of design factors.

In contrast to general pervasive games or context-aware games, cultural heritage games target certain areas with abundant cultural information; this can motivate players to perceive cultural heritage elements from a different perspective, enabling the construction of personal narratives while creating a personal exposition (Coenen, Mostmans, & Naessens, 2013). Scholars have discovered that location-based learning games focusing on historical heritages could considerably improve learning outcomes, learning potential, or learning interest (e.g., Avouris & Yiannoutsou, 2012; Ebling & Cáceres, 2010; Rubino, Barberis, Xhembulla, & Malnati, 2015).

In addition, with global system for mobile communications (GSM) and location-based service (LBS) such advancements in mobile devices, various interactive systems have been developed at cultural heritage sites (e.g., Economou & Meintani, 2011; Giannakas, Kambourakis, Papasalouros, & Gritzalis, 2018). For example, Kim, An, Keum and Woo (2015) created a location-based game and let players wear a head-mounted display to explore a historic site; Haahr (2017) developed a location-based AR game for cultural heritages wherein they added visuals and audio for a better immersion experience; and Jones, Theodosis and Lykourentzou (2019) constructed a blended-reality historical environment where users interacted, shaped, and interpreted the city.

However, few studies have focused on key factors associated with the design of location-based cultural mobile games and the interdependent relationships between such factors. Specifically, studies have mostly emphasized designing pervasive games without focusing on key factors for the design of such games; instead, researchers in such studies have only summarized factors through literature reviews and personal experiences (e.g., Gustafsson, Bichard, & Combetto, 2006; Jegers, 2009; Walther, 2005). Moreover, in location-based pervasive games, features such as GSM and LBS may be generalized or ignored. Accordingly, one of the objectives of the current study was to explore key factors (namely criteria and elements) for the design of location-based games for cultural recognition.

For designing IPGs, studies have incorporated educational theoretical frameworks into diverse design models; however, design factors for such games have been referenced from earlier studies (Gentes, Guyot-Mbodji, & Demeure, 2010). Factors associated with cultural recognition are also affected by reliability and validity concerns (Chen & Shih, 2012). Therefore, another objective of the current study was to construct a new network model comprising data collected from experts in three different fields. As mentioned, most scholars have not probed the interdependent relationship or priority order of key factors for game design (Chen, Guo, & Shih, 2012).

From the perspective of game developers, making trade-offs between elements or criteria during game design might be impractical. To address this concern, Saaty (1996) proposed the analytic network process (ANP), which can be used to solve the problems of determining the interdependence between design elements or factors; through the ANP, scholars can design questionnaires to collect the opinions of experts from different fields about key design factors, evaluate the questionnaire data to determine the priority order of the key factors, and determine interdependent relationships between the factors (Saaty, 2016). Accordingly, the current study applied the ANP to determine the priority order of key factors for the design of location-based cultural mobile games; railway cultural heritages were considered in this study.

Literature review

In the first phase of the current research project, the authors (Li & Wang, 2018), conducted the literature review before FDM to identify some factors for the design of a location-based cultural mobile game. The identification of 4 criteria were "culture learning," "context requirements," "system structure," and "content design" together with 20 elements.

Culture learning

Culture learning refers to the inclusion of essential points learned in cultural pedagogy. From the perspective of educators, Laine, Sedano, Joy, and Sutinen (2010) proposed developers should collect a sufficient amount of user data in advance, such as their perspectives, skill levels and prior knowledge. In their discussion of gaming methods, Gentes et al. (2010) indicated that team exploration is favorable for instructional location-based games. Furthermore, researchers have considered that the cultural content should be designed with input from people who have local cultural knowledge (Chen et al., 2012). Cultural narratives also constitute a crucial element; providing such narratives can assist players develop an advanced organizer (Chen & Shih, 2012). Accordingly, 5 factors are defined for evaluating culture learning in this study, namely "prior knowledge," "team exploration," "outcomes evaluation," "cultural narrative," and "collaborative contents.

System structure

System structure refers to the overall system configuration and involves physical and virtual designs. Such designs comprise several elements, including game mechanics. Game mechanics refer to processes that can enable game engines to monitor and correct virtual and realistic links (Walther, 2005). Moreover, a mixed-reality mechanic enhances game-specific, visual behavior and immersion (Raptis, Fidas, & Avouris, 2018). Jegers (2009) developed the Pervasive GameFlow Model, which emphasizes that pervasive games should support players as they switch their concentration between tasks of the gameplay and surrounding factors. Additionally, facilitating players to develop lightweight creations is a crucial element (e.g., Han, tom Dieck, & Jung, 2018; Neustaedter, Tang, & Judge, 2013). Accordingly, "game mechanics," "game entities," "mixed reality," "game rules," and "control skills" are defined as major factors that influence system structure.

Content design

Content design refers to the content factors of pervasive games. Regarding the gaming experience, Heinrich, Jannicke Baalsrud and Ioana Andreea (2017) proposed that the gameplay should balance players' skills and the game difficulty to provide a supportive challenge. Regarding the game background, IPGs should have a sequential storytelling system, which enable users to learn the place (Jones et al., 2019). In addition, Bekele, Pierdicca, Frontoni, Malinverni, and Gain (2018) suggested that games should allow users to adapt the heritage experience according to their preferences. On the basis of the GameFlow Model created by Sweetser and Wyeth (2005), Jegers (2009) proposed that players should receive feedback on their progress toward their goals. McGookin et al. (2019) advocated that the accessing content should be primarily supported through short micro-interactions. As a result, we consider "challenge levels," "story arrangement," "game immersion," "clear goals," "game feedback," and "competition and interaction" to be 6 impacting factors in content design.

Context requirements

Context requirements refer to features exhibited by pervasive computing devices. Context requirements comprise the following four elements that constitute the four axes of pervasive gaming proposed by Walther (2005): "distribution," "mobility," "persistence," and "transmediality." Distribution refers to the ability to distribute gaming information extensively through networks. Mobility refers to the flexibility of pervasive games (Chen & Shih, 2012). Moreover, persistence refers to constant availability of pervasive games (Chen et al., 2012). Transmediality refers to the transfer process between media. Chen and Shih (2012) suggested that new media can connect virtual community networks in multiple manners.

Methods

Proposed model

This study involved two phases, namely phase 1 (Li & Wang, 2018) and phase 2, as demonstrated in Figure 1. During the literature review, we identified 4 criteria and 20 elements, as presented in Table 1. To streamline the literature review in phase 1, we referred to the research model proposed by Wei and Chang (2008) and designed the FDM questionnaire (see Appendix A) to investigate the importance values and interdependent relationship of key factors. 9 experts were invited as the FDM evaluators. These evaluators consisted of 4 professors who recently carried out major research in related areas, 3 research practitioners who were acquainted with mobile game programming or research processes, and 2 industry experts who were familiar with the mobile game markets. All evaluators invited have 2 to 10 years of experience in developing location-based cultural mobile games or systems. After distributing copies of the FDM questionnaire to 9 experts, we reviewed questionnaire responses and calculated consensus values with two triangular fuzzy numbers. Then, we screened the criteria and elements by using a scree plot.

Subsequently, on the basis of the result in phase 1, we developed an ANP model referred to that developed by Chen, Shih, Shyur, and Wu (2012). We applied the ANP model to design an online questionnaire with a total of 195 questions (see Appendix B) and distributed copies of this questionnaire to the same 7 experts in phase 1. Two experts were unable to participate in phase 2. Finally, a series of pairwise comparison matrices were constructed for each criterion and element, including the goal of current study, namely "design a railway culture location-based game;" thus, supermatrices were established and analyzed to obtain the weight of each criterion and element.

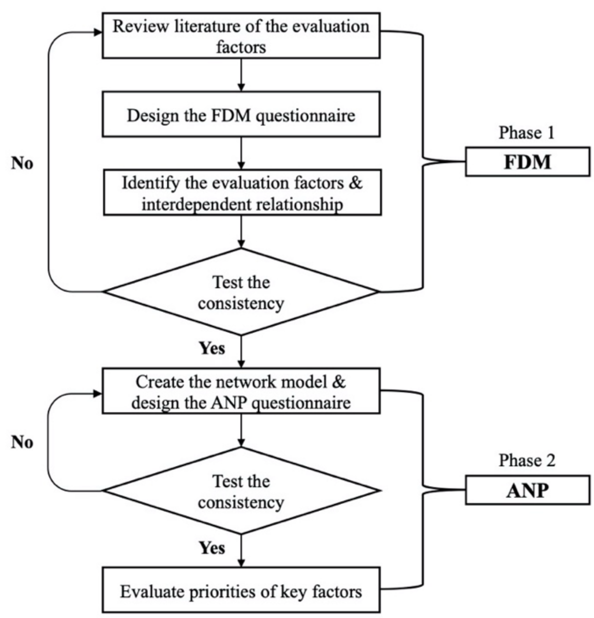

Figure 1: The procedure of the proposed model

Table 1: Key factors for design of location-based mobile game for cultural heritages

Criterion		*Element*		*Definition*	*Reference*
C1	Culture learning	e11	Prior knowledge	Understand player backgrounds to measure the learning strategies.	Laine et al., 2010
		e12	Team exploration	Integrate team power in problem-solving.	Chen & Shih, 2012; Gentes et al., 2010
		e13	Outcomes evaluation	Evaluate learning outcomes with a trusted analytical approach.	Laine et al., 2010
		e14	Cultural narrative	Game contents are provided by the local culture.	Chen & Shih, 2012; Gentes et al., 2010
		e15	Collaborative contents	The content is designed by people with local cultural knowledge or living in the game area.	Chen et al., 2012; Gentes et al., 2010
C2	System structure	e21	Game mechanics	Monitor dynamic and modify virtual links.	Neustaedter et al. 2013; Walther, 2005
		e22	Game entities	The abstract object that can be moved and drawn over a game map.	Gustafsson et al., 2006; Walther, 2005
		e23	Mixed reality	Achieve seamless integration of virtual and real world.	Ihamäki, 2014; Jegers, 2009; Raptis et al., 2018
		e24	Game rules	Formulate fair rules such as playing time.	Jasper et al., 2003; Jegers, 2009; Walther, 2005
		e25	Control skills	A platform that players can easily control and get started with.	Han et al., 2018; Jegers, 2009; Neustaedter et al., 2013; Sweetser & Wyeth, 2005
C3	Content design	e31	Challenge levels	Consider factors to design the appropriate level of challenge.	Heinrich et al., 2017; Jacob & Coelho, 2011; Jasper et al., 2003
		e32	Story	Sequential story arrangements and design of climactic	Gustafsson et al., 2006; Ihamäki, 2014;

			arrangement	or conflicting plots.	Jones et al., 2019
		e33	Game immersion	Allow players to focus on the surroundings and feel immersed.	Bekele et al., 2018; Chen et al., 2012; Jegers, 2009; Sweetser & Wyeth, 2005
		e34	Clear goals	The goals need to be clear and presented in advance.	Jegers, 2009; Sweetser & Wyeth, 2005
		e35	Game feedback	Players receive timely and relevant feedback as they move toward the goal.	Jegers, 2009; Sweetser & Wyeth, 2005
		e36	Competition and interaction	Triggering contexts encourage players to interact or compete with each other.	Ihamäki, 2014; Jegers, 2009; McGookin et al., 2019; Sweetser & Wyeth, 2005
C4	Context requirement	e41	Distribution	The combination of embedded computing, dynamic network and information sharing.	Chen & Shih, 2012; Chen et al., 2012; Walther, 2005; Gustafsson et al., 2006
		e42	Mobility	Mainly refers to the computing mobility.	Chen & Shih, 2012; Chen et al., 2012; Walther, 2005;
		e43	Persistence	Total availability all the time.	Chen & Shih, 2012; Chen et al., 2012; Walther, 2005;
		e44	Transmediality	New media platforms can connect to the virtual social network in multiple ways.	Chen & Shih, 2012; Walther, 2005

Note. modified from Li and Wang (2018).

FDM analysis methods

The FDM questionnaire (see Appendix A) had a scale of 1 to 10, including the conservative value C^i, single value a^i, and optimistic value O^i. After receiving responses, we excluded extreme values outside the double standard deviation. We calculated the minimum conservative values C_L^i, their geometric means C_M^i, and their maximum values C_U^i; likewise, we calculated the optimistic values O_L^i,O_M^i, and O_U^i. Figure 2 shows the relative positions of six values and the gray zone; additionally, the axis μ is the subordinate degree; axis χ is the cognitive value; and G^i is the consensus value.

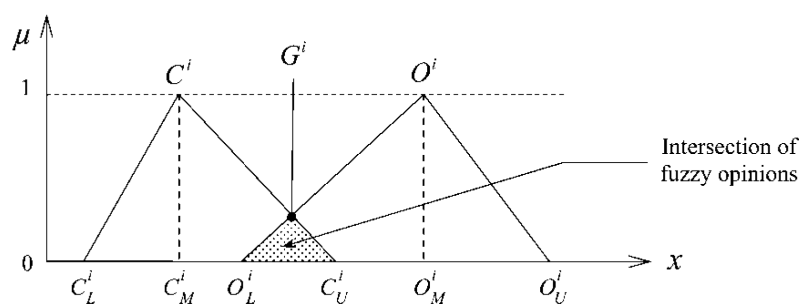

Figure 2: Two triangular fuzzy numbers. (Wei & Chang, 2008)

Two cases could achieve consistency. In one case, if $C_U^i \leq O_L^i$, G^i is the arithmetic mean of C_M^i and O_M^i. In another case, if $C_U^i > O_L^i$, the overlapping area is defined as Z^i, wherein $Z^i = C_U^i - O_L^i$; in addition, the range of the geometric mean of C^i and O^i is defined as M^i, wherein $M^i = O_M^i - C_M^i$. The consistency happens only when $Z^i < M^i$. In this situation, we had to calculate the calculus equations as follows:

$$F^i(\chi_j) = \left\{ \int_x \{min[C^i(\chi_j), O^i(\chi_j)]\} \, dx \right\} \tag{1}$$

$$G^i = \chi_j / \max \mu_{F^i}(\chi_j) \tag{2}$$

When G^i of all elements were acquired, they were presented in a linear graph. We observed the steep slope that was the threshold of consensus values. In the current study, criteria and elements above or equal to the threshold value were regarded as key factors eventually.

ANP analysis methods

After collecting ANP questionnaire responses, we evaluated the relative importance of the criteria and elements on the basis of the 9-point scale proposed by Saaty, Figueira, Greco, and Ehrogott (2005). Pairwise comparison matrices of the criteria and elements can be expressed as follows:

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \cdots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \end{array} \tag{3}$$

$$= [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{4}$$

where $A_1, A_2, \cdots, A_n$ represent n elements in a criterion; w represents criterion j or element j under the premise of another criterion i or factor i . In addition, $a_{ij} = w_i/w_j$. Subsequently, we calculated the geometric mean of each column vector in the matrix and then approximated and normalized it, as indicated by the following equation:

$$w_i = \frac{\sqrt[n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{i=1}^{n}\left(\sqrt[n]{\prod_{j=1}^{n} a_{ij}}\right)} \quad , \quad \forall i, j = 1,2,\ldots,n \tag{5}$$

To control the transitivity within an acceptable range during the pairwise comparison, we calculated the consistency index (C.I.) by using the following equation proposed by Saaty (1996):

$$C.I. = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

where λ_{max} represents the maximum eigenvalue and n represents the number of elements. Furthermore, we applied the consistency ratio (C.R.) proposed by Saaty (1996) to test the consistency. The calculation of C.R. first looked up the Table 2 for the random index (R.I.). C.I. divided by R.I. is C.R. A C.R. value of ≤0.1 (and a corresponding C.I. value of ≤0.1) was considered to indicate satisfactory consistency in this study.

Table 2: R.I. comparison table

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

Saaty *et al.* (2005)

Subsequently, we derived a supermatrix W, which is expressed as follows:

$$W = \begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_k \\ e_{11}\, e_{12} \cdots e_{1n} & e_{21}\, e_{22} \cdots e_{2n} & & e_{k1}\, e_{k2} \cdots e_{kn} \end{array} \\ \begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n} \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n} \end{array} \\ \vdots & \vdots \\ C_k & \begin{array}{c} e_{k1} \\ e_{k2} \\ \vdots \\ e_{kn} \end{array} \end{array} & \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1k} \\ w_{21} & w_{22} & \cdots & w_{2k} \\ \vdots & \vdots & & \vdots \\ w_{k1} & w_{k2} & \cdots & w_{kk} \end{bmatrix} \end{array} \tag{7}$$

where k denotes the number of criteria, presented as $C_1, C_2, \ldots, C_k$, with $C_k = \{e_{k1}, e_{k2}, \ldots, e_{kn}\}$ and e representing the number of elements n in C_k. After constructing the supermatrix, we multiplied the priority vectors in the unweighted supermatrix by the weights of the pairwise comparison matrices. Thus, we derived a weighted supermatrix W^a. Finally, we conducted a power calculation for the weighted supermatrix W^a; a limit supermatrix W^n could then be derived as follows:

$$W^n = \lim_{a \to \infty} W^a \tag{8}$$

Finally, we evaluated the weights of the criteria and elements in the limit supermatrix and then sorted the evaluated weights in the descending order; thus, we could determine the priority order of the key factors.

Results

Statistics of FDM and scree plot

After receiving the FDM questionnaires, we obtained the consensus values G^i of all elements; thus, the consistency was verified (see Appendix C). In the scree plot, the first highest slope was between e12 and e43 based on consensus values. Therefore, G^i of e12 was set as the threshold value, namely 6.30, resulting in the deletions of e43, e44, e41, e42 (which all belong to context requirement), and e15, which were below the threshold. The result is presented in Figure 3.

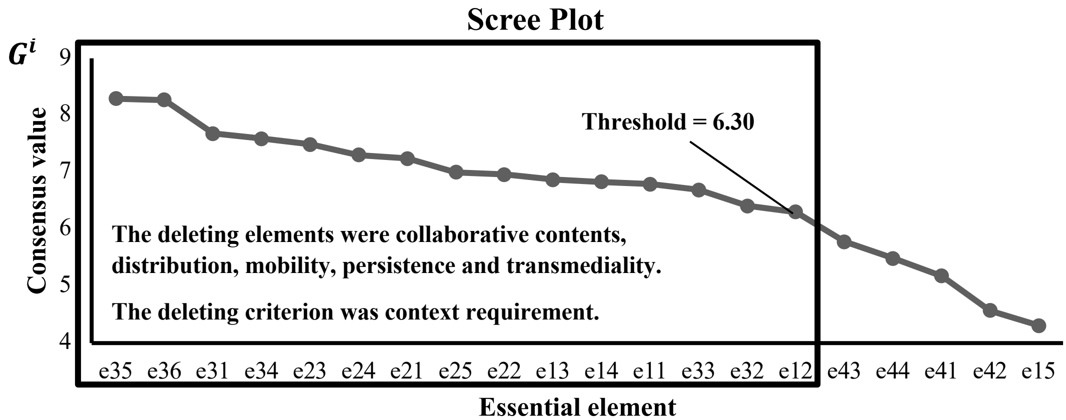

Figure 3: Result of the scree plot

ANP network model

Depending on the result of multiple-choice questions in the FDM questionnaire, we found that most of the experts approved that there were interdependent relationships between all criteria and elements. Thus, we could build an ANP network model based on the results of phase 1 study (Figure 4), where two-way arrows represented external relationships between the criteria and curved arrows represented internal relationships between elements in the same criterion.

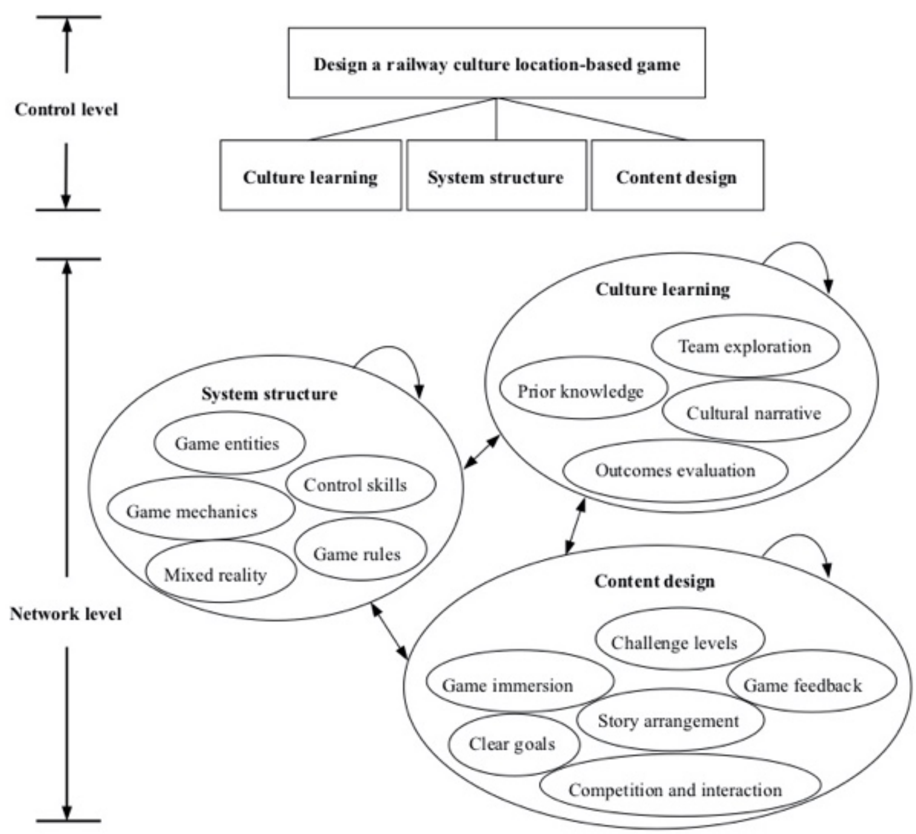

Figure 4: ANP model for the design of a location-based game for railway cultural heritages

Consistency tests of ANP

According to the consistency data (see Appendix E), all C.I. and C.R. values were ≤0.1, validating the consistency of the criteria and elements. In addition, calculating the C.R. of the three criteria was not necessary because the R.I. values were all 0.

Pairwise comparison matrices

Pairwise comparison matrices were established for three kind, namely "goal," criteria, and elements (see Appendix D). First, goal was established in the control layer to explore the effects of the three criteria: culture learning, system structure, and content design. The weights of matrix established for goal showed culture learning had the highest level of importance, followed by content design and then system structure. Second, we assumed that culture learning, system structure, and content design influenced each other. According to the weights of matrices for the three criteria, content design had a greater influence on the importance of culture learning than did system structure. These relationships are presented in Figure 5.

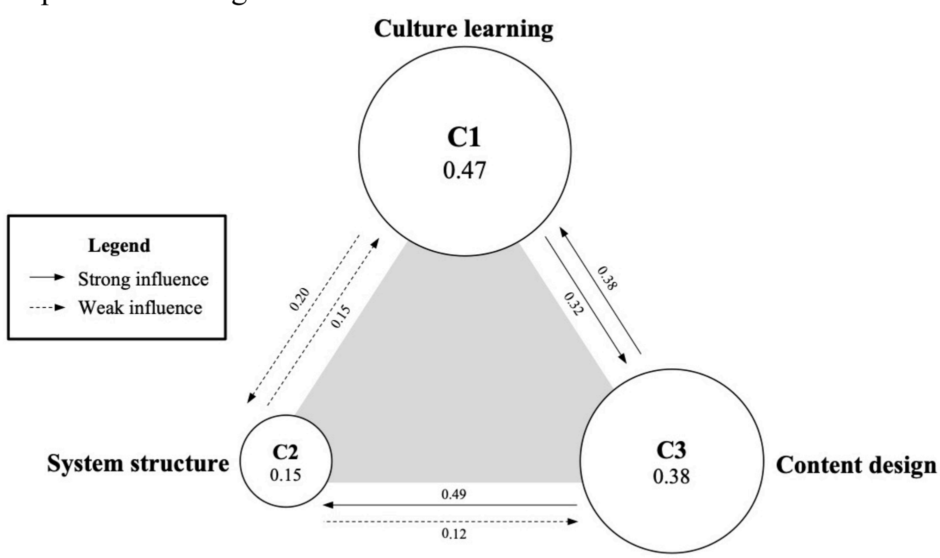

Figure 5: Strength of the criteria

As illustrated in the Figure 5, culture learning and content design exhibited a closer interaction.

Third, we established pairwise comparison matrices for the 15 elements on the basis of the premise that one element in a criterion would affect the remaining elements in the same criterion. The effects of all criteria and elements in this study are illustrated in Figure 6.

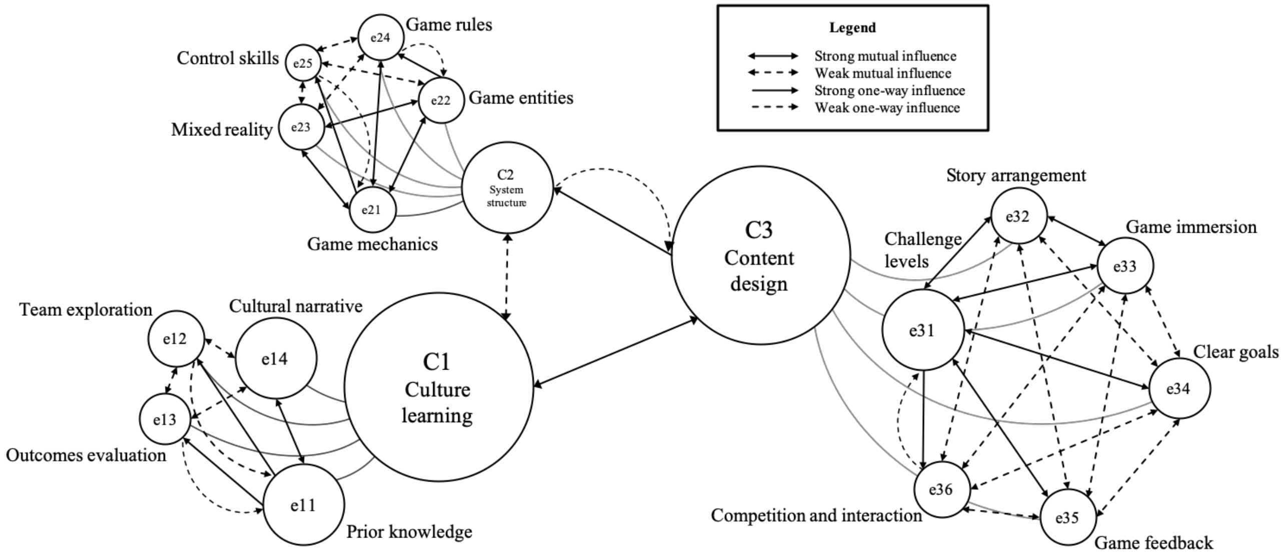

Figure 6: Strength of the elements

By observing the relative importance of the elements in culture learning, we found that e11 had the strongest influence on e12–e14; we also observed a bidirectional relationship between e14 and e11. Furthermore, we observed the relative importance of the elements in system structure and determined that e21 had the strongest influence on the remaining elements in system structure. In addition, e22 exhibited the second strongest influence on the remaining elements in system structure. By observing the relative importance of the elements in content design, we noted similar results to those observed for the elements in culture learning and system structure. Specifically, we noted that e31 had the strongest influence on the remaining elements in content design; on the average, the remaining elements, also had a strong influence on e31, except for e36.

In summary, this study determined the degrees of importance of each criterion and element in the study framework, in contrast to previous studies that have rarely analyzed the degree of importance of factors influencing an outcome of interest.

Priority order of key factors

The values of a limit supermatrix (see Appendix F) were defined as the weight values of the overall criterion and element, which served as the basis for the ranking of key factors in this study. We normalized the weight of all key factors and ranked the overall weights in descending order, as presented in Table 3.

Table 3: Overall priority order of key factors

Criterion		***Element***		***Overall weight***	***Overall order***
C1	Culture learning	e11	Prior knowledge	0.11865	1
C3	Content design	e31	Challenge levels	0.11059	2
C1	Culture learning	e14	Cultural narrative	0.10030	3
C3	Content design	e34	Clear goals	0.08396	4
C1	Culture learning	e12	Team exploration	0.07767	5
C3	Content design	e32	Story arrangement	0.07765	6

		e33	Game immersion	0.07105	7
		e35	Game feedback	0.07021	8
		e36	Competition and interaction	0.06992	9
C1	Culture learning	e13	Outcomes evaluation	0.05769	10
C2	System structure	e21	Game mechanics	0.03859	11
		e22	Game entities	0.03467	12
		e23	Mixed reality	0.03166	13
		e24	Game rules	0.03032	14
		e25	Control skills	0.02708	15

Discussion

Key factors for location-based mobile game for cultural heritages

We conducted this study to determine key factors for location-based cultural mobile games. The study involved two phases. In phase 1, the experts deleted several criteria and elements. The reasons for the deletions are provided as follows. First, Walther (2005) proposed the four axes of pervasive gaming, and these axes correspond to the four elements that constitute the criterion context requirements; since the execution of this study, considerable technological changes have been achieved. Specifically, smart devices and wireless network had not reached a mature development stage in 2005. Accordingly, some of the criteria and elements might have been deleted from this study because of their irrelevance to current smart devices and technologies.

Second, some studies citing the four axes have modified the concept. For example, Chen, Shih, and Ma (2014) retained only mobility as one of the design elements. Furthermore, Valente, Feijó, and Leite (2017) determined that a part of axes is necessary characteristics for confirming pervasive mobile games. As indicated by the aforementioned studies, scholars have modified or partially omitted the four axes of pervasive gaming. Third, some of the factors used by Chen et al. and the current study have different names but might overlap in terms of definition; for example, mobility could be regarded as one of the elements belonging to system structure. Accordingly, context requirements and the corresponding four elements might be replaced by other key factors, such as game mechanics and mixed reality.

Finally, according to Valente et al. (2017), the four axes of pervasive gaming are suitable for studies identifying design factors for the same type of pervasive game. We consider that the concept of the four axes proposed by Walther (2005) might be feasible for the same types of games because each element in Valente's study is fully supplemented by multiple questions, thus preventing misinterpretations in terms of the name or context of the elements. Accordingly, another reason for the deletion is that their interpretations were relatively simple, which may cause the experts to misunderstand or fail to determine the precise meanings of the criteria and elements.

Network structure for and interrelationships between factors for location-based cultural games

In this study, the participating experts considered that all criteria and elements were interrelated, thus forming a network structure suitable for ANP analysis (see Figure 4). This network model is consistent with models constructed in previous studies. For example, Laine et al. (2010) proposed a technology integration–based model including the factors of instruction, context, and design for IPGs; they also indicated that these factors were interrelated from the perspective of technology integration, and they demonstrated the strengths of such interrelationships in their model. In addition, Chen and Shih (2012) developed a new metamodel emphasizing that context, instruction, and design factors overlapped with each other and were not mutually exclusive. According to these studies, the criteria and elements in the present study were determined to be mutually related and dependent, consistent with the experts' evaluation results.

Priority order of key factors for development of location-based game for railway cultural heritages

In general, the priority order of key factors for the design of a product can be determined through a decision-making approach. Through such an approach, the order of the factors for product design can be determined. A similar approach was applied in this study. Specifically, the experts considered that among the three criteria, culture learning was of the highest importance, followed by content design and then system structure. Among the elements belonging to the criterion culture learning, the experts considered that prior knowledge was of the highest importance, whereas outcome evaluation was of the lowest importance. Additionally, among the elements belonging to the criterion content design, challenge level was of the highest importance, whereas competition and interaction were of the lowest importance. Finally, among the elements belonging to the criterion system structure, game mechanics was of the highest importance, whereas control skills was of the lowest importance.

We also observed the gaps in the weight values of the elements. Our observations revealed that the gaps for the four elements under the criterion culture learning were evenly distributed; by contrast, the gaps observed for the elements under system structure were relatively small, signifying that the elements exhibited similar degrees of importance. In content design, the gaps between challenge levels and the other five elements were relatively large. The preceding results demonstrate that the experts had a clearer priority order for the elements in culture learning. However, they considered that the elements belonging to system structure were not too different with respect to importance. Moreover, according to the experts, challenge level was possibly the most representative element in content design, but the remaining elements were determined to have similar degrees of importance.

Considering the overall priority order of elements determined by the experts, the top five elements can be ranked as follows in descending order (i.e., from first to third): prior knowledge, challenge levels, and cultural narrative. The bottom five elements (i.e., 11th to the 15th elements) all belonged to criterion system structure: game mechanics, game entities, mixed reality, game rules, and control skills. Notably, the weight values of the top three elements were considerably greater than those of the remaining 12 elements. We did not observe significant gap in weight values between the fourth (i.e., clear goals) and ninth (i.e., competition and interaction) elements or between bottom five elements (see Figure 7). This result reveals that the experts assigned the top three elements to the first-level element group, assigned elements with no considerable difference in weight values to the second-level element group, and finally assigned the bottom five elements to the third-level element group.

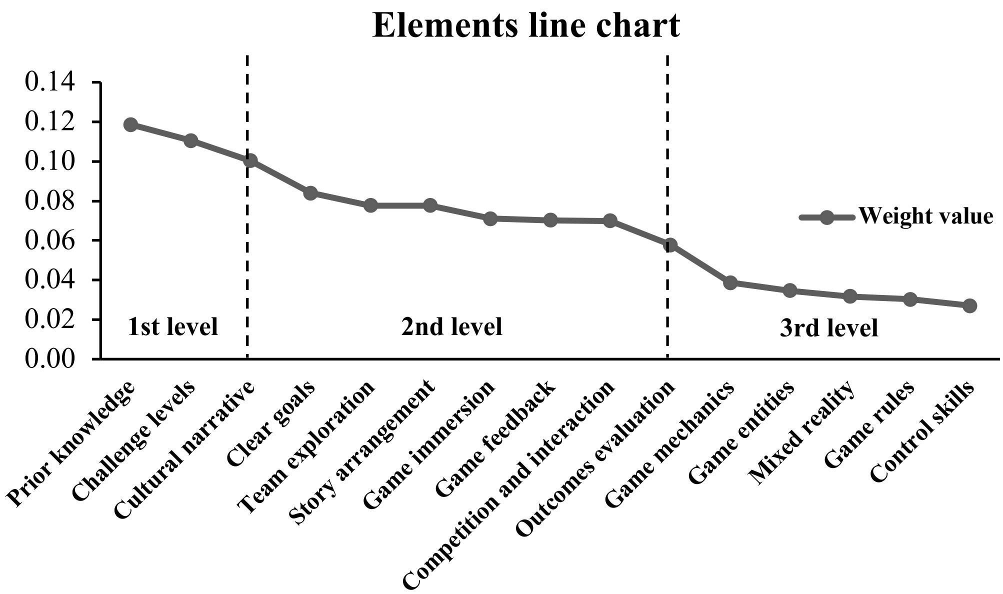

Figure 7: Line chart of overall weighting values of elements

Conclusions

This study was performed to identify key factors associated with the design of a location-based mobile game for railway cultural heritages. The study involved two phases, namely phase 1 and phase 2. In phase 1, the following criteria and the corresponding elements were deleted: context requirements (along with the corresponding four elements) and collaborative contents. Three possible reasons for the deletion of these elements and criterion were technological advancements, changes in meanings of elements, and expert misunderstandings. Furthermore, our model is consistent with those constructed by previous studies. In phase 2, we determined the priority order of the criteria which could be prioritized as follows (in descending order): culture learning, content design, and system structure. We also identified the relative priorities of the elements in each of the criteria. The elements belonging to culture learning had a clear hierarchical order. Moreover, in content design, the most representative element was challenge level.

This study suggests that the development of location-based mobile games for cultural heritages should primarily focus on culture learning and content design. Developers should also prioritize the evaluation of the prior knowledge of each learner to construct an effective learning strategy. Furthermore, challenge levels should be prioritized in game design to ensure that the designed games meet players' different knowledge levels. Developers should also adapt the information of cultural heritages to the narrative content of their designed games, thus tailoring the designed game maps to certain areas. This study also suggests that games should enable players to realize their goals in advance by using appropriate and immediate feedback. Games should also encourage players to compete with each other during gameplay; this can be achieved by developing a captivating story that can provide players with an immersive experience while maintaining their awareness of their surroundings. Finally, this study suggests that game system structure should be considered in game design. Specifically, developers should consider game mechanics that can always synchronize a game's environment with other players' environments as well as modifying virtual and realistic links.

Suggestions for future research

First, this study adopted only quantitative analysis methods to evaluate and present the research results. We suggest that future research can supplement with interviews to obtain a clearer understanding of collected data. Second, phase 2 of this study included only one expert from industry; this is because companies developing location-based games for cultural heritage are rare in Taiwan. Nevertheless, we recommend that future studies control the number of participants from different backgrounds for the purpose of objectivity. Finally, according to the result of this study, system structure was of the least importance among the three criteria; each criterion also included one or two elements with relatively weak interdependent relationship. This thus raises the question as to whether the consideration of numerous factors in the design of location-based cultural games is useful. We hope that researchers can modify ineffective factors by conducting comprehensive literature reviews.

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Statement on open data, ethics and conflict of interest

The data used in this study can be accessed by written request to the corresponding author.

We followed the ethical guidelines of the corresponding university for data collection. In order to protect the privacy of experts, their names and contact information were not revealed during the research process as well.

There is no conflict of interest resulting from the research work in current study.

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