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The MUSETECH Companion: Navigating the Matrix

INTRODUCTION

The MUSETECH model was originally published in the JOCCH Special Issue “The Evaluation of Digital Heritage Resources”, under the title:

“The MUSETECH model: A Comprehensive Evaluation Framework for Museum Technology.”

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The original publication is accompanied by the present document, “The Companion”.

The “Companion” provides step-by-step guidance to the MUSETECH model, devised as a tool for planning the evaluation of technologies applied in museums and heritage settings. We use the term “museum technology” to refer to any type of online or onsite interactive, application or installation encountered in museums or other heritage institutions. The MUSETECH model offers an exhaustive list of 121 Evaluation Criteria that may guide the evaluation of various embodiments of museum technology.

Underpinning the model is the belief that planning for successful museum technologies involves three different perspectives. These three perspectives are symbiotic and complementary in planning, deploying and evaluating museum technology. The three different “Perspectives” are the following:

1. The perspective of the Cultural Heritage Professional (CHP)
2. The perspective of the Museum as an Institution (M)
3. The perspective of the Visitor (V)

The model also considers four different phases or constituents in the life-cycle of any museum technology embodiment. We call these “Quartiles”. These are the following:

- The Design Quartile (D)
- The Content Quartile (C)
- The Operation Quartile (Q)
- The Compliance Quartile: (MP)

Each Quartile contains a number of Evaluation Criteria (ECs), thematically grouped in categories, called “Clusters”. The Perspectives, Quartiles and Clusters are depicted in the MUSETECH Wheel (Figure 1). In addition to the MUSETECH “Wheel”, the model also provides the “Matrix”.

The Matrix is essentially a table listing all 121 Evaluation Criteria by:

- Perspective
- Quartile
- Cluster

Within the Matrix, each Evaluation Criterion (EC) is identified by a unique ID, based on a system of coordinates. Each ID-coordinate reveals the exact place of each criterion in the Matrix. All criteria are therefore listed and arranged by Quartile, Cluster and Perspective.

Each Coordinate is constructed as follows. A letter-number combination reveals the quartile and the cluster: D1, D2, D3 and D4 point to the Design Quartile. C1 and C2 are used for ECs from the Content Quartile. O1 to O5 are attributed to ECs from the Operation Quartile. MP1, MP2 and MP3 are used for the Compliance Quartile. The letter P, M or V then follows, revealing whether the EC falls under the CHP (P), the Museum (M) or the Visitor (V) Perspective. For each group, an alphabet number is used to complete the unique ID for each EC. Therefore, D1Ma denotes a criterion of the Design Quartile (D) belonging to the first cluster (D1: Design and product ideation), for the Museum (M) perspective, the first one (a) identified among its peers. This coordinates system is used for naming all 121 ECs of the Matrix (see the Appendix for the full-fledged version of the MUSETECH Matrix).

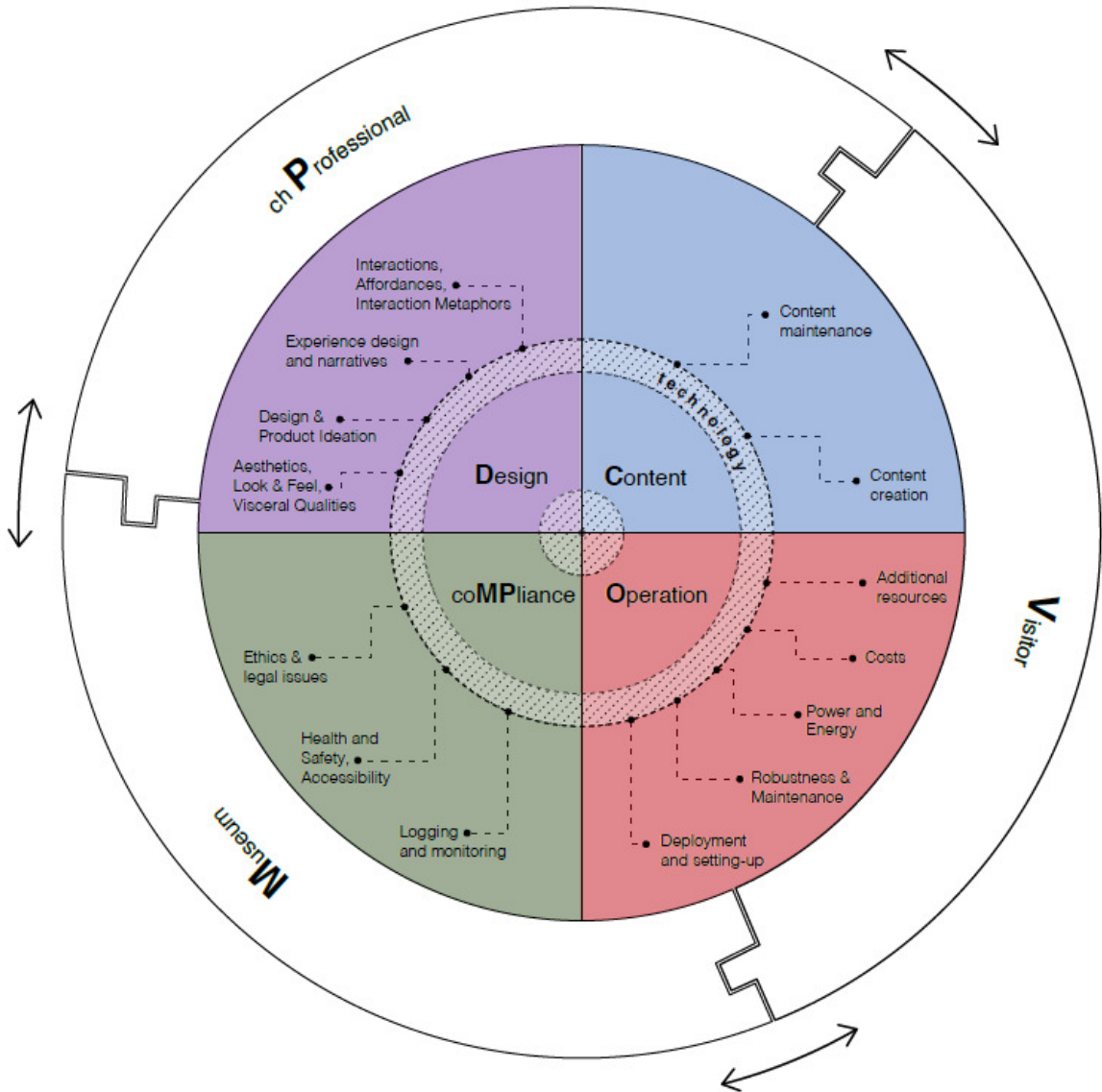


Figure 1: The MUSETECH Wheel

This Companion provides short definitions for all 121 identified Evaluation Criteria (ECs) following the order used in the Matrix, i.e. by Quartile (Design, Content, Compliance, Operation), Cluster and Perspective (Cultural Heritage Professional, Museum, Visitor).

The Matrix can be used in different manners. Perhaps you will navigate the Matrix using a linear fashion, getting acquainted with all criteria, by Quartile and Perspective. Or you may choose to focus on one single Perspective (Cultural Heritage Professional, Museum, Visitor) or a specific Quartile, i.e. Technology Phase (Design, Content, Operation, Compliance).

The DESIGN Quartile

Design is “the deliberate shaping of the environment in ways that satisfy individual and societal needs” [1]. In our framework, the design phase corresponds to the initial phases of a museum technology program: the “what”, “why”, “how”, “when”, “with whom” and “for whom” needs to be considered. The evaluation criteria of the Design Quartile have been classified under four clusters:

- D1. Design and product ideation**
- D2. Experience design and narratives**
- D3. Interactions, affordances, interaction metaphors**
- D4. Aesthetics, look and feel and visceral qualities**

D1. Design and Product Ideation

CHPs usually drive the early design process. The Museum as an institution will have additional concerns, to be added to these of the CHP. In this initial stage, visitors might also be able to play an important part in the design process.

Quartile	Clusters	ch Professional	Museum	Visitor
Design	D1 Design & Product Ideation	<ul style="list-style-type: none"> a Design concept b Integration with exhibition c Integration with other ICT d Balancing physical with digital e Understanding of the fabrication process f In-house technical knowledge 	<ul style="list-style-type: none"> a Innovation, business intelligence b Brand name, uniqueness, originality c Integration with other ICT d Budget e Staff acceptance 	<ul style="list-style-type: none"> a Co-design, front-end evaluation & visitor acceptance
	D2 Experience design and narratives	<ul style="list-style-type: none"> a Experience added value b Relevance to audience c Tailored content d Attentional Balance e Social Interaction f Before and after the visit support 	<ul style="list-style-type: none"> a Interpretive, educational, learning potential b Personalisation potential c Public outreach and communication d Big data potential 	<ul style="list-style-type: none"> a Engagement b Personalisation c Learning, entertainment, edutainment d Attentional Balance e Affective Impact f Social interaction g Ability to follow usage on other platforms h Sense of belonging to a community
	D3 Interactions, Affordances, Interaction Metaphors	<ul style="list-style-type: none"> a Affordances b interaction metaphors c Interface design d Clarity of navigation e Follow-up usage on other platforms f Multisensoriality 	<ul style="list-style-type: none"> a Follow-up usage on other platforms b Brand name, uniqueness, originality 	<ul style="list-style-type: none"> a Utility, usability, ease of use b Intuitiveness, learnability, learning curve c Responsiveness d Clarity of navigation e Personalisation f Social interaction g Follow-up usage on other platforms h Multisensoriality
	D4 Aesthetics, Look & Feel, Visceral Qualities	<ul style="list-style-type: none"> a Look and feel 	<ul style="list-style-type: none"> a Brand name, uniqueness, originality 	<ul style="list-style-type: none"> a Look and feel

Figure 2: MUSETECH matrix detail. The Design Quartile.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - D1P

D1Pa. Design concept. The main design concept and understanding of what is to be achieved with a specific technology idea or application. Emerging, cutting-edge technologies for which no precedents exist are particularly challenging in fleshing-out the idea to a concrete design proposal [2].

D1Pb. Integration with the exhibition. This criterion considers how a selected technology will fit with the exhibition and visiting space, the exhibits, the objects or interactives on display.

D1Pc. Integration with other ICT. Integration with other Information and Communication Technologies used in a museum setting highlights the importance of understanding how a selected technology will merge with other onsite and online digital technologies or offerings. How will the selected technology dialogue with other technologies in the museum?

D1Pd. Balance of physical with digital. This criterion refers to striking the right balance between the physical, i.e. the museum objects and the museum exhibition and the digital. Several types of technology have been scrutinized in terms of “overshadowing” the connection of the visitor with the exhibition and real objects on display, e.g. [3]

D1Pe. Clear understanding of the fabrication process. This criterion examines whether the process of fabrication, installation and deployment is clear for the CHP from start to finish.

D1Pf. Level of in-house technical knowledge. This criterion considers whether the requisite knowledge of the technology to be deployed is contained within the institution. This will influence whether external contractors or other digital media and ICT specialists should be consulted.

THE MUSEUM - D1M

D1Ma. Level of innovation and business intelligence. What is the added value of the selected approach in terms of innovation level and business intelligence? Will the new digital medium help to better understand visitors’ needs? Will it help make more interactive and engaging exhibitions? Will it help to attract more or new visitors and audiences, contribute to visitor satisfaction or assist in understanding better visitors’ needs?

D1Mb. Brand name, uniqueness and originality. This criterion is about examining whether the technology serves the museum concerns, ideas and outward look, supporting its brand reputation [4].

D1Mc. Integration with other ICT. Like the CHP, the museum would also question whether and how the technology to be employed fits with the existing underlying digital ecosystem. At a time when most museums invest in a wide array of digital technologies, issues of compliance, support and interoperability are also to be examined.

D1Md. Budget. Budget refers to financial issues questions which might appear alongside the initial design phases. Will the technology be a good value for the investment? Will the benefit outweigh the costs?

D1Me. Staff acceptance. Staff acceptance, points to the importance of examining whether the technology will be embraced or just barely tolerated by the museum staff principally in charge of it.

THE VISITOR - D1V

D1Va. Co-design, front-end evaluation and visitor acceptance. This criterion points to initiatives that involve museum visitors in the early design phases [5]. This encourages early exploration on how visitors would be disposed to the suggested approach, idea, concept, technology.

D2. Design as Experience Design and Narratives

Sometimes the design process may begin with questions around what is to be communicated both in terms of message as well as in terms of experience. In this sense, design is also about designing appropriate narratives and mediated experiences. CHPs have an important role to play in this process. Though trying to draw an artificial line between the CHP and the Museum's preoccupations is often tricky, we believe that the benefits of scrutinizing both the museum's and the CHP's perspective are important. For the museum and the CHP to take well-informed decisions about investing in technology, the visitor perspective should also be considered.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - D2P

D2Pa. Experience added value. This criterion is about examining the added value of any museum technology. For example, an interactive, collaborative tabletop application mediates a different experience compared to a mobile Augmented Reality (AR) display. Two-way communication with the audience via social media platforms may support other types of interactions and exchanges. Each technology embodiment acts as a unique prism through which the cultural experience will be refracted.

D2Pb. Relevance to Audience. Relevance is about making sure that what it is to be said, communicated and staged will be relevant personal, meaningful, memorable for the audiences targeted.

D2Pc. Tailored content. Tailored content points to the ways through which CHPs will articulate and fine-tune the targeted experience and communicated narratives to different visitors' profiles. For example, one might need to adjust a narrative to different visitor ages, interests or learning needs.

D2Pd. Attentional balance. Attentional balance refers to striking the right balance when interweaving the physical with the digital. Not striking the right balance might make the visitor overly absorbed by the digital only, missing or skipping altogether the real museum artefacts.

D2Pe. Social Interaction. Technology may play an important role in facilitating, encouraging or regulating social interaction in real and virtual museums. Social interaction is about exploring how technology may mediate, facilitate or alter the way we communicate and interact with visiting companions or other visitors present in the physical or digital exhibition space.

D2Pf. Before and after the visit support. This criterion considers the potential of the technology for linking to pre and post-visit activities.

THE MUSEUM – D2M

D2Ma. Interpretive, Educational, Learning Potential. The Museum as an institution will also have to look at the interpretive, learning, and educational potential of the digital medium to be adopted.

D2Mb. Personalization potential. From the museum perspective, this criterion points to scrutinizing the potential for personalizing the visitor experience through personalization mechanisms. We use the term "personalization" to denote a digital tool behavior, whether this is customization, context-awareness or adaptivity [6], reserving the use of the term "tailored content" to talk about a process carried out by the CHP to customize content to the visitors' needs.

D2Mc. Public Outreach and Communication Potential. The public outreach and communication potential of the technology is another important aspect. In this "connect anywhere, anytime" era, museums increasingly use digital media to communicate their activities, advertise their offer and link with their communities.

D2Md. Big Data Potential. Big Data potential refers to the logging features that many technology solutions contain, ones that can provide useful insights as to the preferences of the visitors, helping the museum to better understand what works well or what could be improved.

THE VISITOR - D2V

D2Va. Engagement. Engagement refers to the opportunities offered for engaging the visitor. Engagement can be physical, emotional, intellectual, social, cognitive, or proprioceptive [7].

D2Vb. Personalization. For the museum visitor, personalization of the content, narratives or messages should contribute to increased engagement. Successful personalization is both about the quality of tailored content as well as the sophistication of the underlying personalization mechanisms.

D2Vc. Learning, Edutainment, Entertainment. Engagement with what is offered will result in learning, entertainment or edutainment, a recent neologism referring to experiences that are both instructive and entertaining [8]. Pleasant, positive experiences and memories are favored over unpleasant ones in our memory [9].

D2Vd. Attentional Balance. Attentional balance refers to how the visitor distributes attention to the physical object and its digital surrogate. Ideally, the visitor should be wondering about the experience and the cultural resource, not about the technology mediating the connection with it.

D2Ve. Affective Impact. Affective Impact centers on the emotional responses that a digital learning resource may invoke. The potential of affect for cognition and learning is still undervalued for heritage learning despite an increasing number of studies pointing to the importance of emotion and affect for learning [10, 11].

D2Vf. Social Interaction. Social interaction from the visitor perspective can be associated with the relevant criterion in the CHP perspective (D2Pe).

D2Vg. Ability to follow usage on other platforms. This criterion is about thinking how the content or messages revealed can be revisited, enacted or experienced on other spaces than the one initially experienced, often enough in different digital contexts and environments. For example, visiting the database of a museum on a mobile prior to the visit is different than using the same database from a fixed terminal installed in the gallery floor.

D2Vh. Sense of belonging to a community. Sense of belonging to a community is about empowering visitors to interact with others as well as to feel member of a larger community that can be local, regional, national or international [12].

D3. Interactions, Affordances, Interaction Metaphors

This cluster covers aspects related with the interaction design, the affordances and interaction metaphors the museum interactive provides the visitors with. The criteria have been articulated from the CHP, Museum and Visitor Perspective.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - D3P

D3Pa. Quality of Affordances. “Affordances” refers to the intrinsic properties of things or objects that provide “strong clues” about how something can be operated [13]. For example, a drawer that can be opened by the visitor to examine stored objects implies that the visitor has to open the drawer to examine the objects exposed there.

D3Pb. Suitability of interaction metaphors. Suitability of interaction metaphors on the other hand refers to whether the physical form of an interactive can communicate its function. For example, a zoom lens on tabletop displaying a museum object conveys the message that if this zone is touched, a zoom-in will be performed on the museum object.

D3Pc. Interface design. Depending on the nature of the digital technology employed, the term interface design may refer to an application, an installation or any other type of device. A question to ask in this phase could be whether the interface is clean, clear and comprehensible.

D3Pd. Clarity of navigation. Clarity of navigation is about how successfully and intuitively one can navigate within contents or –in the context of museum visit- physical spaces while using an application for navigation and orientation in the physical space, such as a mobile guide.

D3Pe. Follow up usage on other platforms. Within this cluster, this criterion (also seen in D2Vg) refers to interactions or interaction metaphors which will allow the visitor to consult, share or follow-up content on other platforms, devices or media. Sharing over social media platforms content consulted from a mobile multimedia guide onsite is one example.

D3Pf. Multisensoriality. Last but not least, presence of multisensoriality refers to proposed interactions, involving additional senses to just seeing, reading or hearing something. An interesting example comes from the “Strike a Pose” installation of the Cleveland Museum of Art where an installation encourages visitors to imitate sculptures’ poses, with a Kinect measuring how successful they are in doing so [14].

THE MUSEUM - D3M

D3Ma. (Ability to) follow-up usage on other platforms. Ability to follow up usage on other platforms (also visited in criteria D2Vg and D3Pe) refers here to the interactions proposed by the new technology. The real-life replicas of WW2 objects used in Museon for the temporary exhibition Atlantic Wall could be used both to activate audio contents for each section of the display as well as for printing out a souvenir postcard at the end of the visit, containing a unique code which allowed visitors to log in a special web site after the visit [15].

D3Mb. Brand name, uniqueness, originality. This criterion is about how an interactive communicates the values and inspirations of the museum. Interactives may be designed to recognize what is specific or distinctive about an individual museum.

THE VISITOR – D3V

D3Va. Utility, usability and ease of use. This criterion looks at what the visitor can achieve and get out of the interactive. Utility focuses on whether the interactions proposed by the digital learning resource are meaningful. Once it has been established whether the technology product or byproduct has an actual utility, one has to look on whether it is usable as well as easy to use.

D3Vb. Intuitiveness, learnability and learning curve. Digital tools and applications always include an initial learning phase. It helps if the digital interactive is intuitive, using familiar affordances (D3Pa) and interaction metaphors so that it can be mastered quickly. The time-span within which a visitor has to grasp how to actually use an interactive is very short. Visitors will not bother in spending valuable time to figure out how something works [16].

D3Vc. Responsiveness. Because visitors’ time is valuable, the responsiveness of a device or application, else providing direct feedback to the visitor is crucial. This criterion also reminds us to question whether the interactive does what is intended to do and if it can recover and resume its function quickly in case of an unfortunate, accidental manipulation. Other responsiveness examples involve visual or audio cues providing feedback that the visitor’s action has indeed been taken under account by the system [17].

D3Vd. Clarity of navigation. Clarity of navigation, examines whether the visitor can easily navigate in the digital environment, interface and application as well as in the physical space navigated (e.g. the museum) if the digital resource is used on-the-move during a visit.

D3Ve. Personalization. Personalization is about how successfully the tailored content (see also D2Pc) covers the individual visitor’s needs, interests, motivations filtered and channeled through the underlying personalization mechanisms (as examined in D2Mb). For example, an audio commentary delivered through a mobile multimedia guide may come with the option to read something instead or in addition to hearing it.

D3Vf. Social interaction. Social interaction examines how the technology shapes or mediates interactions with others, distant or collocated peers, for example, The Glen Douglas interactive mimicking a locomotive train at the Riverside Museum in Glasgow requires collaboration among at least two visitors to properly function [18].

D3Vg. Ability to follow-up usage on other platforms. The ability to follow-up usage on other platforms here refers to the potential of museum technology for “revisiting” the visiting experience once the visit is over or even for encouraging the visitor to come back for more.

D3Vh. Presence of multisensoriality. This criterion points to the potential of encouraging interactions and engagement using different senses.

D4. Aesthetics, Look and Feel and Visceral Qualities

There is a part in design that concerns our senses and how these relate to the aesthetics of the objects or things we use in our everyday life, including technology. For a long time, scientists and designers neglected the role of aesthetics, attractiveness, beauty and our immediate, hardwired, emotional reaction to them. There is now scientific proof that attractive, aesthetically pleasing objects work better and findings suggesting that attractive things make people feel good and think more creatively [19].

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - D4P

D4Pa. Look and feel (materials, textures, colours, weight). In addition to the design concept and idea or learning potential of a given museum technology, other, more visceral aspects such as materials, textures, color, weight are important to consider.

THE MUSEUM

D4Ma. Brand name, uniqueness, originality. For the Museum, aesthetics, look and feel and visceral qualities may resonate with some of the intrinsic values and qualities, the vision, or the outward image of the institution. The use of technology in museum shops for getting a tangible souvenir from the museum visit is a good example. The challenge here is to provide something the visitor could not get elsewhere. Museofabber for example, proposes 3D printed-on-demand museum artefacts that hold the potential of also offering a connection with the museum’s web and mobile applications [20].

THE VISITOR

D4Va. Look and feel. From the visitor perspective, the look and feel of a digital device, application, interactive or installation may be paramount for the actual invoked experience, paving the way to even more engagement, enjoyment and learning. The “tondos” installation presented at the “Feint: The Illusion of Movement in Ancient Greek Art” exhibition in Allard Pierson Museum involved interacting and manipulating a 3D printed replica of a Kylix (ancient Greek drinking vessel in clay) as a controller for interacting with the 3D characters of a virtual symposium taking place at the exhibition space [21].

The CONTENT Quartile

Content creation is now multimedia, multi-platform and multi-device. Content may be consumed in pervasive, cross-context and cross-platform ways, onsite as well as online. The Content quartile is divided in two clusters, content creation and content maintenance. The criteria identified in each cluster for all three entities signal important issues that need to be considered for CHPs, museums and museum visitors.

C1. Content Creation

The Content Creation process is often one of the most challenging ones. This phase is crucial for the success of any museum technology embodiment and often overlooked. CHPs are most usually engaged in multifaceted tasks for creating content. Several criteria have also been identified for the Museum and Visitor perspective.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - C1P

C1Pa. Utility, usability and ease of use. Within the Content Quartile, utility, usability and ease of use points to the backbone of the system via which a CHP creates digital content. An interactive tabletop comes with a different content creation system compared to a tweet or the experience of being immersed in a 3D reconstruction of an archeological site.

C1Pb. Learnability and learning curve. This criterion refers to how easily or quickly a CHP can master content-creation for a given technology or medium.

C1Pc. Personalization and adaptation. Mechanisms, tools, algorithms, approaches, strategies used to adapt contents and narratives to different visitors' profiles according to different criteria.

C1Pd. Multilingualism. Within the Content Quartile, multilingualism qualifies as a personalization and adaptation mechanism, examined separately as the vast majority of museums around the world produce learning resources in several languages. For example, the Anne Frank museum audio guide comes in 12 languages.

C1Pe. Community Support. Community support, inside and outside the museum, may facilitate adopting museum technology: communities of users supporting each other may result in embracing or forever abandoning a specific software or hardware.

C1Pf. Technology knowledge and support in the house. Emerging technologies such as Augmented Reality or Virtual Reality might need support from specialists outside the museum. It is important to identify early on in the process whether the in-house skills are sufficient for managing all content creation processes.

C1Pg. Interoperability. Interoperability, the ability to work across systems or different application, may refer to platform interoperability (same services or data running on different platforms), data interoperability (services working on the basis of a common data representation) or network interoperability, (e.g. connected to a 3G/4G or Wi-Fi network).

Quartile	Clusters	ch Professional	Museum	Visitor
Content	C1 Content creation	a Utility, usability, ease of use b Learnability and learning curve c Tailored content d Multilingualism e Community Support f In-house technical knowledge g Interoperability	a Continuity of content usage b Logging	a Perceived content quality b Visitor created content creation and curation
	C2 Content maintenance	a Changes in-house b Documenting and archiving	a Staff acceptance b Interoperability and modularity	a Personalisation b Social Interaction & Sharing c Continuity of content usage

Figure 3: MUSETECH matrix detail. The Content Quartile.

THE MUSEUM - C1M

C1Ma. Continuity of usage. From the museum perspective, continuity of usage is analogous to platform interoperability but also considering the temporal dimension of the pre, during or post-visit phase. Can the consulted content be revisited using different platforms before, during or after the visit is over, online and onsite? One of the earliest examples is the Cité+ system proposed by the Cité des Sciences et de l'Industrie in Paris [22]. After the onsite visit finishes, a post-card souvenir with a unique code is given to the visitor, who can then re-visit using a web browser the actual trail followed during the onsite visit, the order by which content was activated and the content itself.

C1Mb. Logging. Logging mechanisms can provide the possibility to statistically analyze the content consulted or more preferred by the visitors. This helps in understanding visiting patterns which provide insights on what works well or what can be improved.

THE VISITOR – C1V

C1Va. Perceived Content Quality. Communicated content targeting the audience is filtered by the unique meaning-making mechanisms of the visitors and judged more or less relevant and interesting to them. We name this criterion “perceived content quality”.

C1Vb. Visitor-created content, creation and curation. Visitor created and generated content is more and more widespread. In addition to content generated through social media through visitor-owned mobile devices, alternative, hybrid approaches also exist. For example, the Museum of Modern Art in New York (MOMA) created the “I visited MOMA and...” invited visitors to use pencils and post-it notes to write down their impressions from the visit. These were scanned onsite, immediately projected at a large interaction surface at the lobby of the museum. Alongside such approaches, deontology and IPR/copyright issues also emerge [23]. For clarity reasons, such issues are examined under the Compliance Quartile.

C2. Content Maintenance

Once content is up and running, tweaking, and fine-tuning is often needed. This time and resources consuming dimension of employing museum technology is often overlooked. This cluster highlights issues related with content maintenance.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - C2P

C2Pa. Ability to make changes in-house. Digital museum interactives are often outsourced. This criterion assists in assessing whether content updates and changes can be performed by the in-house staff. For example, if an object commented on an audio tour, is loaned to another institution, will it be possible to also suppress it from the tour or will an outside contractor will be needed?

C2Pb. Potential for Documenting and archiving. Documenting and archiving digital content prompts us to examine the modalities of archiving, documenting and preserving born digital objects, such as digital audio or multimedia guides, games, New Media Art or other digital installations. The question of keeping, preserving and documenting this new digital heritage alive, still has no satisfactory answer.

THE MUSEUM – C2M

C2Ma. Staff acceptance. Any content creation and management system should be benchmarked as to the chances it has to be accepted by the museum staff in charge of content changes or updates.

C2Mb. Interoperability and Modularity. The concept of interoperability was previously examined as of great importance for the CHP (C1Pg). For the museum, the concept of modularity was added, the possibility of reusing and building in terms of existing application modules but also in terms of equipment, devices, hardware, displays, sensors or any other physical, augmented installation component.

THE VISITOR – C2V

C2Va. Personalization. Created content is personalized on the fly to cater for perceived content quality and relevance for the museum visitor.

C2Vb. Social Interaction and Sharing. Social interaction and sharing is about monitoring and then figuring out what worked across different digital communication channels at different temporalities during the online or onsite visit.

C2Vc. Continuity of usage. Consulting, creating and using content online and onsite needs to cater for the many different temporalities of a museum visit. Continuity of usage refers to such aspects. For example, the “smart” exhibits used in the Atlantic Wall exhibition [15, 21], could activate multimedia narrations for the onsite visit and act as controllers for printing a post-card souvenir that gave access to complementary online exhibition content.

The OPERATION Quartile

The “Operation” Quartile covers criteria museums and museum professionals would investigate (often in parallel with the design ideation phase) concerning the start-up, running and maintenance of any given museum technology embodiment. This Quartile contains five clusters: deployment and setting-up, robustness and maintenance, power and energy, costs and other additional resources needed.

Quartile	Clusters	ch Professional	Museum	Visitor
Operation	O1 Deployment and setting-up	<ul style="list-style-type: none"> a Ease of use for installation b Distance monitoring c Workflow d In-house technical knowledge e Additional staff training 	<ul style="list-style-type: none"> a Set-up and start up b Modularity and interoperability c Staff and front-desk training d Distribution, recovery, guarantee 	<ul style="list-style-type: none"> a Visitor experience quality and customer care b Visitor-owned devices
	O2 Robustness and Maintenance	<ul style="list-style-type: none"> a Environmental constraints b Robustness c Maintenance required d Updating and replacing 	<ul style="list-style-type: none"> a Storage cost b Level of maintenance c Loss, deterioration, theft, replacement d Reusing and disposing 	<ul style="list-style-type: none"> a Robustness b Responsiveness c Stability d Speed & speed of recovery
	O3 Power and Energy	<ul style="list-style-type: none"> a Day to day running & maintenance b Stability 	<ul style="list-style-type: none"> a Interventions in the exhibition space 	<ul style="list-style-type: none"> a Prevent feelings of failure and frustration
	O4 Costs	<ul style="list-style-type: none"> a Workforce, time, additional staff 	<ul style="list-style-type: none"> a Financial costs and investment b Running costs 	<ul style="list-style-type: none"> a Costs (value for money and time)
	O5 Additional resources	<ul style="list-style-type: none"> a Instructions and "how to" guides 	<ul style="list-style-type: none"> a Adopting, financing, sponsoring 	<ul style="list-style-type: none"> a Uptake

Figure 4: MUSETECH matrix detail. The Operation Quartile.

O1. Operation as Deployment and Setting-Up

The criteria of this cluster cover aspects related with the start-up, installation, fixing, storing involved in making museum technology operational.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - O1P

O1Pa. Ease of use for installation. Ease of use for installation, covers the phase of installation, setting-up and deployment of museum technology. Is the process manageable by the museum staff? Will additional, specialist help be needed? Museum technology for the gallery floor (such as a mobile application or interactive installation) may fail to launch, operate or can simply underperform.

O1Pb. Distance monitoring. Distance monitoring refers to mechanisms that allow monitoring by distance technology software and hardware failures, assisting the CHPs to intervene on the right spot, at the right time.

O1Pc. Workflow. Will the daily operation of a museum interactive interfere with the CHP daily operational workflows? The interactive showcases from Museon and the meSch EU project provide a good example. This experimental installation involved a competition among objects coming from the reserves. The objects in the showcases had to be changed often. The affordances and interactions metaphors made the exposed objects dialogue with museum visitors via a tweet-feed. Both of these aspects interfered with the daily routine of the CHPs on site [24]. This installation is examined in Section 7 of our JOCCH paper “The MUSETECH Model: A Comprehensive Evaluation Framework for Museum Technology”.

O1Pd. In-house technical knowledge. This criterion reminds us to examine whether the in-house staff can work on setting up, deployment of any interactive and troubleshooting.

O1Pe. Additional staffing required. This criterion refers to specialized training that might be needed for the setting up, running and deployment process (including -if applicable- the distribution on the gallery floor) both for curators and front of house staff. The duration, costs and investment for training also need to be scrutinized and examined.

THE MUSEUM - O1M

O1Ma. Set-up and start-up parameters. Set-up and start-up parameters may include the installation of devices, software and hardware, calculating the actual number of units needed, and their fixing or maintenance. This criterion may assist in assessing how easy, straightforward or cumbersome the overall process may be. Emerging, “off-the-shelves” solutions might be more difficult to set-up on site as in comparison with commercialized solutions (mobile guides, social media, audio guides).

O1Mb. Modularity and Interoperability. Modularity and interoperability is about questioning if previously used equipment can be reused or if new equipment can be repurposed.

O1Mc. Staff and front-desk training. The museum will also need to think about staff and front-desk training. For example, if museum-owned devices or equipment needs to be distributed, will the process be managed by museum agents or by outsourcing the task to a contractor? For example, onsite kiosks, displays or interactives might be easy to use without guidance or assistance.

O1Md. Distribution, recovery and guarantee. Some types of devices might be very fancy or expensive, such as mobile devices AR or VR displays. This criterion invites us to examine how such concerns are resolved. Other types of devices and technology can be less expensive (for example RFID cards storing information about the visit) with museums relying on the good will of the visitors to be returned rather than introducing or asking for some kind of guarantee.

THE VISITOR

O1Va. Visitor experience quality and customer care. This criterion is all about the quality of the experience of the visitor in terms of customer care as well as in terms of guaranteeing a flawless, trouble-free visit.

O1Vb. Visitor-owned devices. During the last years, the proliferation of mobile devices has resulted in a “bring your own device” culture. More and more mobile applications, social media channels and websites are consulted online and onsite with visitor-owned devices. How visitors can keep and use the museum apps and their content on their devices even after the visit is over is an increasingly important consideration.

O2. Operation as Robustness and maintenance

This cluster groups aspects of robustness and maintenance and is mainly to be examined by the CHP and the Museum as institution. The impact on the Visitor experience can be significant.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - O2P

O2Pa. Environmental constraints. Heritage experiences take place outdoors in addition to indoors. Different types of constraints may appear in outdoor environments such as humidity and luminosity. Many smartphones contain brightness controls and light sensors which can play a major role on the displayed image quality, the readability of text or for preventing eye-strain. The Environmental constraints criterion examines such aspects.

O2Pb. Robustness. Robustness may point to the robustness of the hardware, equipment, devices or of algorithms used in museum technology programs as is the case with image recognition and

computer vision for museum AR systems. The nature of the interactive (tabletop, mobile multimedia guide, tangible) will result at a different set of questions in terms of robustness.

O2Pc. Level of customized maintenance required. This criterion covers aspects related with the day-to-day, short and long term maintenance of a device, application or installation depending on the equipment, devices or software used.

O2Pd. Updating and replacing. Updating and replacing covers aspects related with the update of specific software and hardware and with issues of replacement in case of failure or need for maintenance.

THE MUSEUM - O2M

O2Ma. Storage Costs. If the equipment required needs to be individually handed out to visitors how is it going to be stored? Storage costs of devices or individual components is important to be examined.

O2Mb. Level of maintenance. Level of maintenance is about onsite and online functional and operational maintenance issues, specifically how much maintenance may be required on a day-to-day basis.

O2Mc. Loss, deterioration, theft, replacement. This criterion tackles questions on what happens if part or the full museum interactive needs to be replaced, is taken, lost, stolen or broken.

O2Md. Reusing and disposing. Reusing or disposing of no longer functional or needed equipment is another question to which might preoccupy the museum as institution.

THE VISITOR - O2V

O2Va. Robustness. Robustness is important for the museum visitor experience as much as for the CHP (O2Pb).

O2Vb. Responsiveness. Responsiveness refers to how fast and responsive a technology solution is.

O2Vc. Stability. Stability is about how stable the operating environment is or feels for the visitor.

O2Vd. Speed and speed of recovery. Speed and speed of recovery, designate how quickly a running application will recover from things you did not want it to do [25].

O3. Operation as Power and Energy

Power and energy issues are a prerequisite for deploying different types of technology in a Cultural Heritage setting, indoor as well as outdoors.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - O3P

O3Pa. Day to day running and maintenance. Power and energy aspects are easy to overlook and often hard to satisfy in an already set-up, operational exhibition space. This criterion is complemented by the next one, examining energy and power related stability issues.

O3Pb. Stability. Complementary criterion to the one of “day to day running and maintenance”. For example, if an interactive shuts down at night, will it recover on its’ own to its previous state or will in need some expert intervention to resume its function?

THE MUSEUM - O3M

O3Ma. Interventions in the exhibition space. Simple things such as power sockets outlets can cause a lot of concern if not accounted for during the early design and planning phases. Potential necessary interventions in the exhibition space to resolve such issues in time might need to be examined.

THE VISITOR – O3V

O3Va. Overall experience, preventing feelings of failure and frustration. Energy issues such as battery life-time may have a considerable impact on the overall visitor experience, preventing feelings of failure or frustration. Providing solution including chargers for visitor-owned terminals could be examined.

O4. Operation as Costs

Operational aspects of museum technology need to be also examined in terms of budget and finance. Costs can translate to different types of resources, financial, human or time-related for all three entities, the CHP, the museum and the visitor. Costs were also discussed in the Design Quartile (D1Md); within the Operation Quartile they are more linked with the operational aspects of any museum interactive.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - O4P

O4Pa. Workforce, time, additional staff. For the CHP, costs can be counted in terms of workforce, i.e. workforce power and time resources in terms of person hours

THE MUSEUM - O4M

O4Ma. Financial Costs and Investment. This criterion looks into all financial costs and investment relating to operations as opposed to the Design Quartile costs-related criterion (D1Md).

O4Mb. Running and maintenance costs. Once the interactive is up and running, what is the cost involved for running and maintenance?

THE VISITOR - O4V

O4Va. Overall experience, prevent feelings of failure and frustration. Energy issues such as battery life-time may have a considerable impact on the overall visitor experience, helping to prevent feelings of failure or frustration. Providing solution including chargers for visitor-owned terminals could be examined.

O5. Operation as Additional Resources Needed

Other type of material or human resources might also be necessary for bringing a museum technology approach to fruition.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - O5P

O5Pa. Instructions and “how to” guides. For the CH professional, additional resources may involve diverse add-ons such as brochures and printed materials, other material constructions or equipment, additional staff.

THE MUSEUM - O5M

O5Ma. Impact on adapting, financing, sponsoring. For the museum, additional resources might have an impact on adapting, financing or assuring sponsorship for museum technology.

THE VISITOR - O5V

O5Mv. Uptake. Setting in place any extra resource needed for successfully engaging in interactions mediated through technology will ensure the smoothest possible uptake of the deployed technology and the experience it mediates.

The COMPLIANCE Quartile

The Compliance Quartile includes four different clusters: Health, Safety and Accessibility; Logging and Monitoring; Ethics and Legal Issues. Such issues should be examined in conjunction with all other three quartiles, i.e. Design, Content and Operation.

MP1. Compliance as Health, Safety and Accessibility

Health, safety and accessibility issues are also relevant and should ideally be brought in the picture from the early design process.

Quartile	Clusters	ch Professional	Museum	Visitor
coMPliance	MP1 Health and Safety, Accessibility	a Accessibility b Appropriateness c Safety	a Safety b Emergency management c Disposal, recycling d Hygiene, cleaning, maintenance	a Accessibility b Appropriateness c Safety
	MP2 Logging & monitoring	a Logging & monitoring	a Logs storage, access, privacy, analytics	a Personalisation b Legal compliance
	MP3 Ethics & legal issues	a Protecting audiences b Data gathering and protection	a Other legal issues b Data protection laws c Ethics for gathering data	a Trust and confidence in the museum

Figure 5: MUSETECH matrix detail. The Compliance Quartile.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - MP1P

MP1Pa. Accessibility. Accessibility is about fighting barriers that can be “physical, sensory, intellectual, financial, cultural, emotional, attitudinal” or geographical [26]. Barriers can be also linked with disabilities, including restricted mobility, a sight or hearing impairment, learning difficulties, limited strength or agility or speech and communication difficulties [27].

MP1Pb. Appropriateness. Appropriateness refers to experiences and interactions made possible through technology that are suitable for the visitor. What is appropriate for an adult will not be suitable for a child or school group. Appropriateness may imply content adaptation, for example for sensitive or young audiences.

MP1Pc. Safety. Safety refers to visitor safety while experiencing a museum technology mediated experience: For example, seeing 4DX movie comes with a minimum height of 102 cm tall. Likewise, photosensitive epilepsy (affecting 3% of epileptic people) can be triggered by flickering images or light.

THE MUSEUM - MP1M

MP1Ma. Safety. Safety issues should also be a concern for the museum as the question of safety calls for corporate-institutional accountability of the museum.

MP1Mb. Emergency Management. Emergency management refers to procedures set in place to handle emergency. If a museum interactive component or a device breaks, will it be dangerous for the visitor? The staff should be informed on how to react in case of an accident.

MP1Mc. Disposal and recycling. Disposal and recycling concerns the afterlife of used devices or pieces of equipment so that they are disposed in a responsible, eco-friendly way.

MP1Md. Hygiene, cleaning and maintenance. Hygiene, cleaning and maintenance of applications, installations or interactives is also important. For example, many audio guides offer one-use hygienic head-phone covers to guarantee a maximum level of hygiene.

THE VISITOR - MP1V

MP1Va. Accessibility. Accessibility issues and their efficient handling by the CHP or the museum enter in play for the visitor perspective guaranteeing an accessible experience.

MP1Vb. Appropriateness. Appropriateness is also relevant for the museum visitor perspective. A classical case comes from adapting content for adult vs children-friendly or appropriate content.

MP1Vc. Safety. Finally, safety is relevant for the visitor perspective too (see also MP1Pc and MP1Ma).

MP2. Compliance as Logging and Monitoring

Digital applications and devices come with sophisticated logging mechanisms that can provide valuable insights both for how well technology worked as well as for how much the experience was appreciated by the visitors.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - MP2P

MP2Pa. Logging and monitoring. Logging and monitoring, recording, analyzing and sharing data should adhere to strict rules concerning legal and ethical guidelines. Because something can be done, it does not mean that it should. Sensitive data may concern the visitor or information made publicly available for the museum objects. Logging and monitoring visitors' actions and interactions with digital heritage resources should adhere to rules pertaining to the protecting sensible object or personal data.

THE MUSEUM - MP2M

MP2Ma. Logs storage, access, privacy, analytics. There is a shared responsibility between the museum and the CHP in logging in, analyzing and making accessible visitor data. A recent example of corporate museum "responsibility" in gathering and analyzing data comes from the reactions provoked by the National History Museum and the National Gallery in the UK for tracking visitor movement using their phones wi-fi signal in order to find out more about popular exhibits [28]. Though this data does not identify individuals or personal information, this could be ethically questionable if the public is uninformed about being tracked.

THE VISITOR - MP2V

MP2Va. Personalization. If data is gathered to assist with an experience which will be tailored via personalization mechanisms, visitors should be informed as to what data will be gathered and to which end.

MP2Va. Legal compliance. Visitors should also be reassured about the legal compliance of the ways personal data will be handled.

MP3. Compliance as Ethics and Legal Issues

The last cluster regroups ethical and legal issues related with the introduction and deployment of museum technology.

THE CULTURAL HERITAGE PROFESSIONAL (CHP) - MP3P

MP3Pa. Protecting audiences. CHPs act should act as the advocates of the museum visitor. Protecting audiences points to the responsibility of the CHP to protect museum visitors.

MP3Pb. Data gathering and protection. Big data, personal data, other sensitive data must be handled with care in compliance with relevant regulations governing the use of museum technology and the carrying out audience research.

THE MUSEUM - MP3M

MP3Ma. Other legal issues. For the museum, other legal issues evolve around intellectual property rights management and copyright of the resources employed to bring a museum

technology to life. Data protection laws need also to be taken under account. Ethics for gathering, storing and analyzing data go beyond what is legal examining what is ethical.

THE VISITOR - MP3V

MP3Va. Trust and confidence in the museum. All of the above mentioned issues will be handled by the CHP and the museum may have an important effect on the overall trust and confidence of the visitor in the museum as institution.

Using the MUSETECH model and the Matrix: additional resources

The above section introduced all 121 Evaluation Criteria (ECs) constituting the MUSETECH Matrix. In addition to the wireframe version of the Matrix, provided above, a detailed Matrix version can be found after the literature list as an Appendix. The literature itself can be used to go further on specific aspects of introducing the digital in museums and heritage settings.

The detailed MUSETECH Matrix version is also provided in the main JOCCH Publication “**The MUSETECH model: A comprehensive Evaluation Framework for Museum Technology**”. We would like to invite you to visit this text too, so as to get more information about evaluating museum technology all by finding out more about how the MUSETECH model, the Matrix and the Wheel came to life.

An additional feature of the above cited text are three use-cases and examples of how MUSETECH can be used to reflect about the introduction of museum technology and the impact it has on the Cultural Heritage Professional (CHP), the Museum and the Visitor (Section 7, Using the Framework: Use-case scenarios, <https://doi.org/10.1145/3297717>). The three examples examined come from the EU – meSch – Material Encounters with Digital Cultural Heritage project and show how the Matrix can be used to think about the different constituents and phases of introducing the digital in museums and other heritage settings.

The MUSETECH model Wheel on the other hand (Figure 1), can be used to get an overview of which clusters (ECs grouped thematically) are present within each Quartile or museum technology constituent – phase all by reminding us the importance of the Cultural Heritage Professional, Museum and Visitor Perspective.

The MUSETECH Matrix can be subsequently used for identifying four to five key questions on a museum technology project. Once these have been resolved, the Matrix can be visited to identify new issues that need to be examined. We hope that the versatility and breadth of the Evaluation Criteria (ECs) included in MUSETECH will assist Cultural Heritage researchers, practitioners and policy makers to successfully plan for introducing the digital, asking the right questions at the right time, bringing in early-on in the process the needs, views and perspectives of the Cultural Heritage Professional, the Museum and the Visitor.

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APPENDIX: THE MUSETECH MATRIX

TECHNOLOGY		CH PROFESSIONAL	MUSEUM	VISITOR
QUARTILE	CLUSTER			
D ESIGN	D1 – Design & Product Ideation	[D1P] a Design concept	[D1M] a Level of innovation, business intelligence	[D1V] a Co-design, front-end evaluation & visitor acceptance
		[D1P] b Integration with the exhibition	[D1M] b Brand name, uniqueness, originality	
		[D1P] c Integration with other ICT	[D1M] c Integration with other ICT	
		[D1P] d Balance of physical with digital	[D1M] d Budget	
		[D1P] e Clear understanding of the fabrication process	[D1M] e Staff acceptance	
		[D1P] f Level of in-house technical knowledge		
	D2 - Experience design and narratives	[D2P] a Interactive experience added value	[D2M] a Interpretive, educational, learning potential	[D2V] a Engagement
		[D2P] b Relevance to audience	[D2M] b Personalisation	[D2V] b Personalisation
		[D2P] c Tailored content	[D2M] c Public outreach and communication potential	[D2V] c Learning, entertainment, edutainment, enjoyability
		[D2P] d Attentional Balance	[D2M] d Big data potential	[D2V] d Attentional Balance
		[D2P] e Social Interaction		[D2V] e Affective Impact
		[D2P] f Before and after the visit support		[D2V] f Social interaction
	D3 - Interactions, Affordances, Interaction Metaphors	[D3P] a Quality of affordances	[D3M] a Ability to follow-up usage on other platforms	[D3V] a Utility, usability, ease of use
		[D3P] b Suitability of interaction metaphors		[D3V] b Intuitiveness, learnability, learning curve
		[D3P] c Interface design	[D3M] b Brand name, uniqueness, originality	[D3V] c Responsiveness
		[D3P] d Clarity of navigation		[D3V] d Clarity of navigation
		[D3P] e Ability to follow-up usage on other platforms		[D3V] e Personalisation
		[D3P] f Presence of multisensoriality		[D3V] f Social interaction
	D4 - Aesthetics, Look & Feel, Visceral Qualities	[D4P] a Look and feel (materials, textures, colours, weight)	[D4M] a Brand name, uniqueness, originality	[D4V] a Look and feel

“The MUSETECH Companion: Navigating the Matrix, v. 1.0, January 2019” is provided as an additional resource, accompanying the JOCCH paper “The MUSETECH Model: A Comprehensive Evaluation Framework for Museum Technology”, <https://doi.org/10.114532977717>

C CONTENT	C1 - Content creation	[C1P] a Utility, usability, ease of use	[C1M] a Continuity of content usage	[C1V] a Perceived content quality [C1V] b Visitor-created content, creation and curation
		[C1P] b Learnability and learning curve	[C1M] b Logging	
		[C1P] c Tailored content		
		[C1P] d Multilingualism		
		[C1P] e Community Support		
		[C1P] f Level of in-house technical knowledge and support (content, design, fabrication)		
	[C1P] g Interoperability			
O PERATION	O1 - Deployment and setting-up	[C2P] a Ability to make changes in-house	[C2M] a Staff acceptance	[C2V] a Personalisation
		[C2P] b Potential for documenting and archiving	[C2M] b Interoperability and modularity	[C2V] b Social Interaction & Sharing
		[O1P] a Ease of use for installation	[O1M] a Set-up and start up (installation, devices' number, adopting, maintaining, fixing)	[O1V] a Visitor experience quality and customer care
		[O1P] b Distance monitoring		
		[O1P] c Workflow	[O1M] b Modularity and interoperability	[O1V] b Visitor-owned devices
	[O1P] d In-house technical knowledge	[O1M] c Staff and front-desk training		
	[O1P] e Additional staff training required	[O1M] d Distribution, recovery, guarantee		
O2 - Robustness & Maintenance	[O2P] a Environmental constraints	[O2M] a Storage cost	[O2V] a Robustness	
	[O2P] b Robustness	[O2M] b Level of maintenance	[O2V] b Responsiveness	
	[O2P] c Level of customized maintenance required	[O2M] c Loss, deterioration, theft, replacement	[O2V] c Stability	
	[O2P] d Updating and replacing	[O2M] d Reusing and disposing	[O2V] d Speed & speed of recovery	
O3 - Power and Energy	[O3P] a Day to day running & maintenance	[O3M] a Interventions in the exhibition space	[O3V] a overall experience, prevent feelings of failure and frustration	
	[O3P] b Stability			
O4 - Costs	[O4P] a Workforce, time, additional staff	[O4M] a Financial costs and investment	[O4V] a Costs (value for money and time)	
		[O4M] b Running costs		
O5 - Additional resources	[O5P] a Instructions and "how to" guides	[O5M] a Impact on adopting, financing, sponsoring	[O5V] a Uptake	
coMP LIANCE	MP1 - Health and Safety, Accessibility	[MP1P] a Accessibility	[MP1M] a Safety	[MP1V] a Accessibility
		[MP1P] b Appropriateness	[MP1M] b Emergency management	[MP1V] b Appropriateness
		[MP1P] c Safety	[MP1M] c Disposal, recycling	[MP1V] c Safety
			[MP1M] d Hygiene, cleaning, maintenance	
	MP2 - Logging & monitoring	[MP2P] a Logging & monitoring	[MP2M] a Logs storage, access, privacy, data analytics	[MP2V] a Personalisation
				[MP2V] b Legal compliance
	MP3 - Ethics & legal issues	[MP3P] a Protecting audiences	[MP3M] a Other legal issues	[MP3V] a Trust and confidence in the museum
[MP3P] b Data gathering, analytics, protection		[MP3M] b Data protection laws		
		[MP3M] c Ethics for gathering, storing, analysing personal data		

“The MUSETECH Companion: Navigating the Matrix, v. 1.0, January 2019” is provided as an additional resource, accompanying the JOCCH paper “The MUSETECH Model: A Comprehensive Evaluation Framework for Museum Technology”, <https://doi.org/10.114532977717>