Time Machine: Big Data of the Past for the Future of Europe

A proposal to the European Commission

for a Large-Scale Research Initiative

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Abstract

Time Machine is a large-scale research initiative that should be supported by Horizon Europe.

The report presents the strategic guidelines for this initiative, starting with the vision and objectives and following with detailed roadmaps, organised around science and technology, operational principles and infrastructure, exploitation avenues and framework conditions.

The implementation plan is based on an evolving governance scheme that builds on synergies with existing initiatives and funding opportunities.

The proposed initiative will have momentous socio-economic impact in multiple dimensions, including science and education, as well as strong leveraging effects on jobs, services and products in key sectors of European economy, such as ICT, GLAM, creative industries, tourism, smart cities and land use.

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Executive Summary

The rationale and the vision

Globalisation, changing demographics and the dominant position of private social media platforms threaten Europe's cultural and democratic values and sense of belonging. These unprecedented transformations compel Europe to intensify its engagement with its past, to facilitate an evidence-based dialogue between diverse histories and memories, their values and interdependencies, and to build a common path across generations.

Time Machine is a large-scale research initiative that responds to the above challenges by creating the big data of the past: a distributed digital information system mapping the European social, cultural and geographical evolution[1] across times. In the proposed approach, digitisation is only the first step in a long series of extraction processes, including document segmentation and understanding, alignment of named entities and simulation of hypothetical spatiotemporal 4D reconstructions.

Such computational models with an extended temporal horizon are key resources for developing new critical reflections on the future of our institutions and insights for historians, social scientists, creative arts professionals, policy-makers and the general public, with a significant common denominator: contributing to informed decision-making from everyday life to academic, professional and political matters. The vision is, therefore, to enable Europe to turn its long history, as well as its multilingualism and multiculturalism, into a living social and economic resource.

Time Machine comes at a time when a new technology platform is being created which will give birth to a digital information “overlay” of the physical world, a “mirror-world”, representing an up-to-date model of the world as it is, as it was and as it will be. Therefore, time will become a “palpable” fourth dimension, since it will not only be very easy to go back to the past, at any location, by reverting to a previous version kept in the log, but also to create future versions of an increased sense of reality. The mirror-world will disrupt most forms of human activity, as we know them today, giving birth to an unimaginable number of new ideas (and many problems) and creating new forms of prosperity from new forms of economic and social activity that will shape new behaviours and ecosystems. In this currently unfolding scenario, Time Machine will enable Europe to be one of the leading players, shaping the mirror-world according to its democratic values and fundamental ethics.

The fundamental ideas

The Time Machine **processing infrastructure** will be composed of a digital content processor and three simulation engines:

- a 4D Simulator that manages a continuous spatiotemporal simulation of all possible pasts and futures that are compatible with the data.
- a Universal Representation Engine that manages the multidimensional representation space resulting from the integration of extremely diverse types of digital cultural artefacts (text, images, videos, 3D).
- a Large-Scale Inference Engine that will shape and assess the coherence of 4D simulations based on human-understandable concepts and constraints.

[1] The expression Cultural Heritage in the document will often refer to every trace of European social, cultural and geographical evolution, which is wider than its current scope. A unique characteristic of this project is to design solutions respecting the cultural wealth of Europe as these developed for cultural heritage.

The Time Machine **digitisation infrastructure** will be composed of a network of digitisation hubs and will be organised on a European scale. A peer-to-peer platform will be in charge of managing and optimising digitisation strategies at European level and will also be tasked with the development of generic solutions for archiving, directly documenting the digitisation processes and swiftly putting the digitised documents online.

The whole governance is conceived around a **Time Machine Organisation** (TMO) that sets the global rules for all operations related to the initiative, including the entire set of processes, labelling systems and related infrastructure.

The Time Machine Network is organised as a large number of **Local Time Machines** (LTMs). Each LTM is anchored in the space of a city or a region and has the ambition to build a dense database of spatiotemporal information, laying the foundation of a 4D model of its physical environment. The TMO supports the regional/local actors in this process by providing technology, methodology and supporting infrastructure which facilitate the digitisation pipelines, the standardisation of the information gathered and the development of related services. Over the course of time, LTMs pass through different maturity phases, with each maturity phase enabling specific exploitation strategies. A series of events taking the form of LTM Academies will be organised to present, compare and evaluate ongoing work.

To ensure the open development and evaluation of work, a process inspired by the Request for Comments (RFC) that was used for the development of the Internet protocol will be adapted to the needs of Time Machine. **Time Machine Requests for Comments** will be freely accessible publications, identified with a unique ID, constituting the main process for establishing rules, recommendations and core architectural choices for the Time Machine components.

The plan

Time Machine proposes an integrated programme with concrete objectives to be reached in each of its different pillars and thematic areas.

Pillar 1, “Science and Technology for the Big data of the Past”, addresses the scientific and technological challenges in AI, Robotics and ICT for developing the Big Data of the Past, while boosting these key enabling technologies in Europe. A modular, layered structure of interdependent modules is adopted in three directions:

- Data, enabling persistent digital access to millennia of linked historical data
- Computing, developing AI methods to explore, connect, and simulate historical information
- Theory, focusing on SSH models of historical evidence that lead to new, plausible narratives, radically transforming the manner in which SSH engages with and interfaces with the past

Pillar 2, “Time Machine Operation”, aims to design the operational infrastructure and the sustainable management model for creating and deploying Time Machine, with particular focus on:

- Building the TM infrastructure for digitisation, processing and simulation
- Drafting the community management systems
- Setting out the principles and processes for a network of Local Time Machines

Pillar 3, “Exploitation Avenues”, will create innovation platforms in promising application areas, by bringing together developers and users to exploit scientific and technological achievements, therefore leveraging the cultural, societal and economic impact of Time Machine. The main areas explored cover:

- Scholarship
- Education

- Specific exploitation areas and uses in key economic sectors, including GLAM, Creative Industries, Smart Tourism, Smart Cities & Urban Planning, and Land Use and Territorial policies

Pillar 4, “Outreach and innovation”, will develop favourable framework conditions for outreach to all critical target groups and for guiding and facilitating the uptake of research outcomes produced in the course of the LRSI. The main areas of intervention cover:

- Dissemination
- Policy, legal issues & ethics
- Knowledge transfer
- Exploitation support structures

The path to sustainable implementation

The initiative has been endorsed by a large number of European researchers, innovators, decision makers and other stakeholders in the area of cultural heritage. The Time Machine network currently consists of over 600 European institutions from 34 countries including: close to 200 top research institutions, a huge representation – more than 100 organisations – from galleries, libraries, archives and museums (GLAM, leading large enterprises, innovative SMEs, institutional bodies and strong civil society organisations.

Time Machine will stand as a community of communities to foster not only relationships between itself and digital cultural heritage stakeholders but also among the related stakeholders themselves. Mechanisms for an intensified interaction are envisaged to foster growth in the European Research Area in Digital Cultural Heritage and to strengthen the impact of TM in technological, societal and economic domains. In this context, synergies will be created among existing European level research and innovation systems, programmes, funding schemes, instruments, projects and initiatives. Time Machine has already secured the support of major initiatives related to the digitisation of European heritage, having signed Memoranda of Understanding for common action with Europeana (also a member of the TMO Executive Board), CLARIN, and the Cultural Heritage JPI.

Time Machine is based on a realistic long-term operational roadmap with concrete objectives and milestones. The proposed integrated approach is a strong pre-requisite for the required simultaneous advances in key areas to maximise socioeconomic impact.

In order to ensure the long-term sustainability of the initiative, TM partners created the Time Machine Organisation (TMO) as an association under Austrian Law, tasked with managing and coordinating Time Machine. TMO has received a wide acceptance by the Time Machine network and at present has over 400 members, showing that the large majority (more than 80%) of the TM network partners are commited to supporting the implementation of the Time Machine roadmap.

Eventually, the TMO will make a transition from the organisation set up during the current phase to one that covers the specific needs and work flows of a much broader ecosystem that will implement the full roadmap. The proposed governance scheme is, therefore, developed following a two-stage approach:

- The “current” or "set-up" stage that covers the period where the actual scheme will grow to its fully established stage.
- The “future” or "steady state" stage, where a stable framework is reached, offering the conditions of uninterrupted long-term planning that may come from a dedicated funding instrument, like the European Partnership scheme, strategic agreements with different funders for sustained support over different programming cycles, or a combination of the above.

During the set-up stage, the key objective is to secure the necessary resources for starting the implementation of the Time Machine roadmap, so the key requirement at present is to have in place a

governance scheme that is oriented towards obtaining funding and implementing projects that contribute to the broader objectives of the Time Machine. The TMO has already secured resources to initiate Time Machine's implementation and has identified the funding resources that will support the next stages of development.

Impact

Time Machine will have strong positive long-term effects on European cohesion, economy and society, with concrete contributions to the promotion of critical thinking at all levels of decision making, to strengthening the feeling of European identity, as well as to boosting scientific and technological competitiveness, entrepreneurship and employment in knowledge intensive and creative sectors across the European Union.

Using the approach of the Theory of Change, it is shown that Time Machine will lead into:

- A more competitive EU in the fields of AI and ICT
- Improved economic resilience of European cities and regions through entrepreneurship and innovation
- New ways of working that drive greater societal relevance for Social Science & Humanities (SSH)
- Big data of the past informing more effective policy making
- EU citizens feeling more connected to their past and assured of their identity in a pluralistic Europe
- Europe's citizens being digitally literate critical thinkers

1 Introduction

Over the centuries, the national, regional and local identities of Europe have evolved in relation to one another through large swathes of transnational mobility and through dense exchanges that have shaped European languages, traditions, arts and many other aspects of human activity. These processes have largely contributed to the creation of a European culture characterised by diverse historical memories, which have laid the foundations to values and ideas harmonised by pluralistic and democratic dialogue. To-date, however, increased globalisation, changing demographics and their threat against the idea of a shared past, as well as the resurgence of unresolved conflicts deep-seated in European memory are key drivers of a 'localisation backlash' that places local and personal interests above any other. These growing trends present a clear threat to the cohesiveness of European cultural identity and sense of belonging.

Pluralistic and democratic dialogue in Europe has traditionally been facilitated by important intermediaries, such as cultural media and institutions acting as cornerstones of our shared values, principles and memories. Today, the dialogue between different actors and the historical visions they embody is complicated by the rise of private digital platforms that have created a new space of opinion-leadership, as well as new forms of political expression and participation. Managed by proprietary algorithms, such platforms may prioritise popularity and personal agendas over historical and cultural data, opening the way to fake news. The resulting crisis of authority that affects journalism, academia and politics has led many people to distrust information received from these institutions.

These unprecedented transformations create a vital need for Europe to restore and to intensify engagement with its past as a means of facilitating an evidence-based dialogue between diverse historical memories, including their values and mutual interdependencies, building a common path across generations.

Time Machine is a large-scale research initiative (LSRI) that responds to this need by building the required infrastructure and an operational environment for developing the "big data of the past" that will transform and enhance the role of history and culture across Europe. In turn, opening the way for scientific and technological progress to become a powerful ally to safeguarding European identity and democratic values, in line with Europe's long-term development and democratic principles.

For Time Machine, digitisation is only the first step of a long series of extraction processes, including document segmentation and understanding, alignment of named entities and simulation of hypothetical spatiotemporal 4D reconstructions. The hypothesis parsed by Time Machine is that such computational models with an extended temporal horizon are key resources for the development of new critical reflections on the future of our institutions, and insights for historians, social scientists, creative arts professionals, policy-makers and the general public, with a significant common denominator: contributing to informed decision-making in everyday life and in academic, professional and political matters.

This report summarises the key findings of a pan-European action to create a proposal for the Time Machine LSRI. The strategic agenda and roadmap that are presented have been developed with contributions from experts belonging to a fast-growing ecosystem currently counting over 600 organisations and covering a wide array of stakeholder groups including leading research institutions, prestigious European cultural heritage associations, large enterprises, innovative SMEs, influential business and civil society associations and both international and national institutional bodies.

Following this introduction, the document is organised as follows:

- The second section – **vision and objectives** – explains why the big data of the past is crucial for turning European history and cultural heritage into a living resource for co-creating our future and describes the objectives and basic design principles of the proposed LSRI.

- In the third section – **research and innovation plan** – the focus is on the breakthroughs that Time Machine will produce in science, technology and innovation, beginning with an extensive analysis of the state-of the-art and presenting the methodological approach and time frame for the targeted achievements.
- In the fourth section – **implementation plan** – a governance scheme is proposed that will enable the current organisational structure to evolve into one which responds to the requirements of a LSRI by building synergies and exploiting funding opportunities from different sources. An action plan is presented, aiming to initiate the Time Machine agenda by building upon the roadmaps and networks created during the CSA preparatory phase.
- The concluding fifth part – **impact** – describes the profound positive effects Time Machine will have on science, education and our everyday life, as well as on new skills, services and products which will leverage and transform European competitiveness in key economic sectors.

2 Vision and objectives

2.1 The vision and the driving concept

The scientific vision behind the Time Machine is structured around the concept of **"Big Data of the Past"**. Figure 2-1, below, symbolically represents the digital information currently available for each period of our history. By plotting the amount of digital information available today (horizontal axis) against time (vertical axis), we should expect to see a funnel-shaped figure. Information about the most recent years is abundant, forming the large plateau which represents the funnel's mouth: the Big Data of the Present. The curve shrinks rapidly as one moves down the graph and back in time (Figure 2-1A). TM aims to enlarge the stem of this funnel. Firstly, by developing the technology and infrastructure needed to conduct massive digitisation and processing of cultural heritage resources (Figure 2-1B). Secondly, this enlarged dataset will be the basis for simulating possible pasts in order to reach an unprecedented density of information: the Big Data of the Past (light grey area in Figure 1-1C); this enormous volume of data will also boost modelling capacity, enabling us to make evidence-based predictions for the future (light blue area in Figure 2-1C).

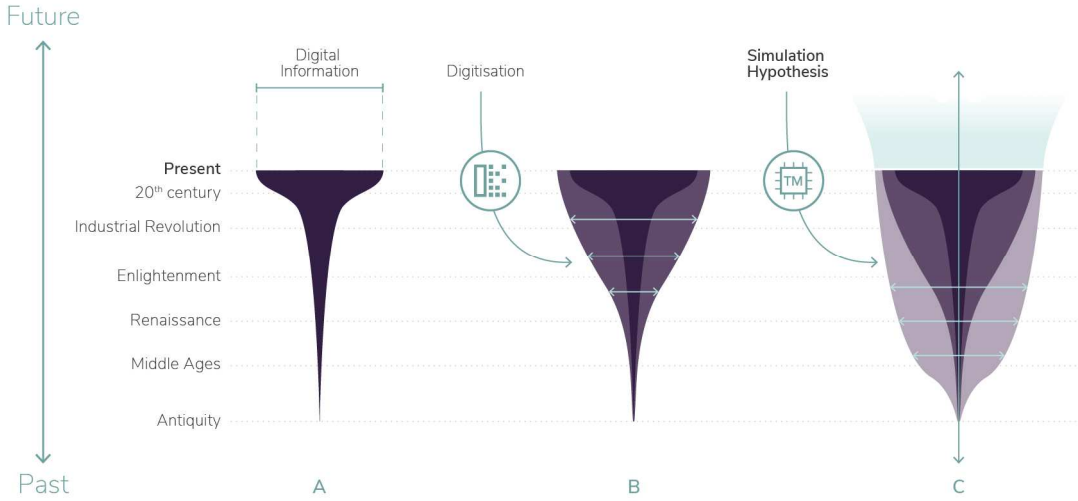

Figure 2-1: Creating the Big Data of the Past: (A) Current situation. (B) Extension based on digitisation and processing of new sources. (C) Extension based on simulation.

The conversion of billions of historical documents, large collections from museums and other geo-historical datasets, importantly also including the growing amount of our 'born digital' heritage, into a distributed digital information system associated with very powerful computing resources will enable us to set the following goals:

1. **To digitally move through time as easily as we do through space.** Time Machine's multifaceted architecture is conceived to integrate the unique amount of multi-temporal, multi-source and multimodal data about our past into a continuous pan-European multiscale information source, rendering virtual time-travelling as easy as consulting a digital map: a "slider" for digital 3D maps will show how a place was in the past, according to one or more criteria, and how it might be in a foreseeable future.

2. **To change the nature and scale of research methods in Social Sciences and Humanities.** Today, an informed usage of data is still restricted to a specialised audience, while reproducibility is possible only within specific data contexts. Time Machine will inaugurate an era of open access to sources,

making past and ongoing research open science and allowing bolder questions to be asked, new kinds of understanding to be reached and large-scale collaboration between scholars, businesses, citizens and decision-makers.

3. **To simulate possible futures and possible pasts.** Time Machine will design a new generation of Artificial Intelligence, harnessing long-term time series to reach superior forms of predictive understanding of social, cultural and economic patterns. This technology, capable of representing and exploring the multiplicity of hypothetical pasts and futures, will inform our choices for evaluating possible paths, helping citizens, companies, States and Europe itself to make better decisions for the future.

Based on this unique ambition and design, the proposed large-scale research initiative will make Europe the leader in the extraction and analysis of a new kind of strategic resource, making it feasible to use our Cultural Heritage (CH), Europe's most precious political, economic and social asset, to envision a common future.

Still, there is one more crucial reason supporting the cause of Time Machine. Subsequent to the creation of the web, which digitised information and knowledge, and the social media, which digitised people and characteristics of human behaviour, a third technology platform is being created which will digitise all other aspects of our world, giving birth to a digital information "overlay" over the physical world, a "mirror-world"[2]. The mirror-world will aim to be an up-to-date model of the world as it is, as it was and as it will be. All objects (including representations of landscapes) of the mirror-world will be machine-readable, and, therefore, searchable, traceable and available to be part of simulations by powerful algorithms. In the mirror world, time will be a fourth dimension, as it will be very easy to go back to the past, at any location, reverting to a previous version kept in the log. One may also travel in the other direction, as future versions of a place can be artificially created based on all information available that can be used to anticipate a predictable future. Such "time-trips" will have an increased sense of reality, as they will be based on a full-scale representation of the present world. At present, Time Machine is the most advanced concrete proposal to build the first version of a European mirror-world.

As with the other two platforms mentioned above, the mirror-world will disrupt most forms of human activity as we know them today, giving birth to an unimaginable number of new ideas (and many problems) and creating new forms of prosperity from new forms of economic and social activity that will shape new behaviours and ecosystems. In this scenario that is currently unfolding, Time Machine will enable Europe to be one of the leading players, shaping the mirror-world according to its democratic values and fundamental ethics such as open standards and interoperability. With Time Machine, Europe will have a powerful tool to strengthen its cohesion and sense of belonging, and, moreover, an opportunity to impose its own terms on the multinational technology giants that will fight for dominion over this new technology platform, just as those who now govern the first two platforms have done in the past.

2.2 The specific objectives

Time Machine proposes an integrated programme with concrete objectives to be reached in its different pillars and thematic areas. These are illustrated in in Figure 2-2 and further discussed below.

[2] Gelernter, D. (1993). Mirror Worlds or the Day Software Puts the Universe in a Shoebox…How It will Happen and What It Will Mean. Oxford University Press

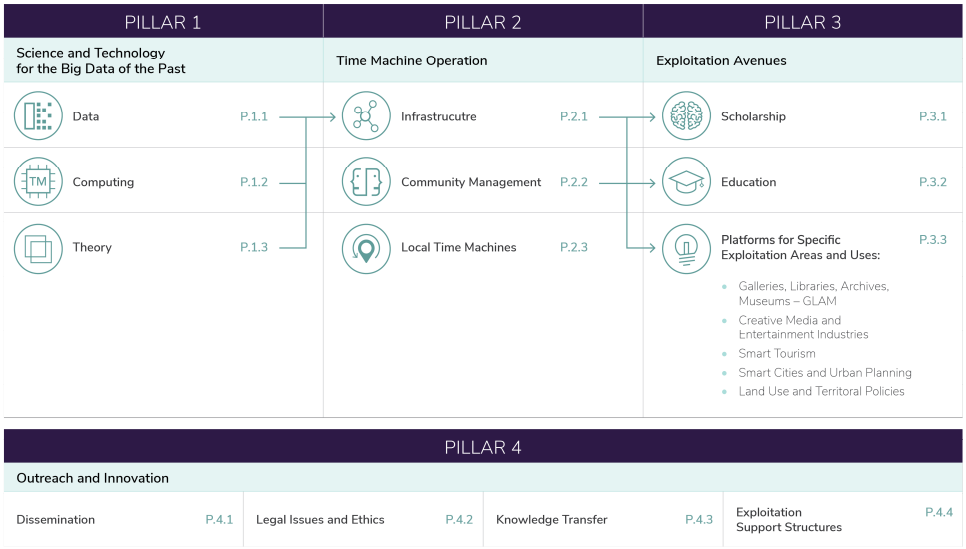

Figure 2-2: Time Machine Pillars & Thematic Areas

Pillar 1 – Science and Technology for the Big data of the Past: Addressing the scientific and technological challenges in AI, Robotics and ICT, for developing the Big Data of the Past, while boosting these key enabling technologies in Europe. Pillar 1 adopts a modular, layered structure of interdependent modules, in three directions:

- Data, enabling persistent digital access to millennia of linked historical data
- Computing, developing AI methods to explore, connect and simulate historical information
- Theory, focusing on SSH models of historical evidence that lead to new, plausible narratives, radically transforming the manner in which SSH engages with and interfaces with the past

Pillar 2 – Time Machine Operation: Designing the operational infrastructure and the sustainable management model for the creation and extensive use of Time Machine, with particular focus on:

- Building the TM infrastructure for digitisation, processing and simulation
- Drafting the community management systems
- Setting out the principles and processes for a network of Local Time Machines, defined as geographical zones with higher density of "*rebuilding-the-past activities*"

Pillar 3 – Exploitation Avenues: Creating innovation platforms in promising application areas, by bringing together developers and users to exploit scientific and technological achievements, therefore leveraging the cultural, societal and economic impact of Time Machine. The main areas explored cover:

- Scholarship
- Education
- Specific exploitation areas and uses in key economic sectors, including GLAM, Creative Industries, Smart Tourism, Smart cities & urban planning, and Land Use and Territorial policies

Pillar 4 – Outreach and innovation: Developing favourable framework conditions for the outreach to all critical target groups and for guiding and facilitating the uptake of research outcomes produced over the course of the LRSI. The main areas explored cover:

- Dissemination
- Policy, legal issues and ethics
- Knowledge transfer
- Exploitation support structures

2.3 Basic principles for the design of the initiative

Requests for Comments

Reaching consensus on the technology options to pursue in a programme as large as Time Machine is a complex issue. To ensure the open development and evaluation of work, a process inspired by the Request for Comments (RFC) that was used for the development of the Internet protocol[3] will be adapted to the needs of Time Machine. **Time Machine Requests for Comments** will be freely accessible publications, identified with a unique ID, constituting the main process for establishing rules, recommendations and core architectural choices for the Time Machine components. Their basic principles are presented in Box 2-1.

Box 2-1: Basic features of the TM Requests for Comments

The Time Machine RFC are based on the following principles

- **Accessibility:** RFCs are freely accessible, free of charge.
- **Openness:** Anybody can write a RFC.
- **Identification:** Each RFC, once published, has a unique ID and version number.
- **Incrementalism:** Each RFC should be useful for its own right and act as a building block to others and must be oriented as a contribution, extension or revision of the Time Machine Infrastructure.
- **Standardisation:** RFCs should make use of standardised terms to improve clarity.
- **Scope:** RFCs are designed contribution and implementation solutions solving practical problems; RFCs are not research papers and may not necessarily contain experimental evidence; the RFCs cover not only the technical infrastructure but data standards, legal frameworks, values and principles.
- **Self-defining process:** As with the development of the Internet, RFCs are the main process for establishing the Time Machine Infrastructure and Processes but also the processes and roles required to manage the RFCs themselves.

Time Machine Organisation

The entire governance is conceived around the **Time Machine Organisation (TMO)** which sets the global rules for all operations related to the initiative, including an entire set of processes, labelling system and related infrastructure. The organisational scheme and details of the TMO governance are discussed in section 4.1.

Time Machine digitisation and processing infrastructure

The **Time Machine digitisation infrastructure** will be composed of a network of digitisation hubs and will be organised on a European scale. A peer-to-peer platform will be responsible for managing and optimising digitisation strategies at European level and will also be tasked with the development of generic solutions for archiving, directly documenting the digitisation processes and swiftly putting the digitised documents online. The hubs will cover regional digitisation needs with standardised hardware for digitisation, storage, information exchanges and on-demand scanning, based on results of Pillar 1 and existing metadata standards, such as the one developed by Europeana.

[3] https://en.wikipedia.org/wiki/Request_for_Comments

The peer-to-peer platform will federate system integrators at European level, facilitating the deployment of this equipment. The effort will build upon existing EU Research Infrastructures (DARIAH, CLARIN) and infrastructures providing access to cultural heritage (Europeana, Archive Portal Europe, etc.).[4] TM will introduce new processing pipelines for transforming and integrating cultural heritage data contained in such infrastructures.

Documents are digitised using different kinds of acquisition machines and treated separately depending on their nature (textual and audio-visual documents, iconographic elements, maps, 3D objects and environments). Information is extracted progressively, manually or automatically, to produce elementary historical units which are connected with one another. This progressive decomposition and refinement must be seen not only as a mere automatic process but as a collective negotiation. Each intervention, either algorithmic or human, will be fully traceable and reversible. The results of the processing activities constitute the core dataset of the Big Data of the Past.

The **Time Machine processing infrastructure** is shown in Figure 2-3. It is composed of a digital content processor and three simulation engines: a 4D simulator, a large-scale inference engine and a universal representation engine:

- The 4D Simulator manages a continuous spatiotemporal simulation of all possible pasts and futures that are compatible with the data.
- The Universal Representation Engine manages a multidimensional representation space resulting from the integration of the pattern of extremely diverse types of digital cultural artefacts (text, images, videos, 3D) and permits new types of data generation based on transmodal pattern understanding.
- The Large-Scale Inference Engine is capable of inferring the consequences of chaining any information in the database. This enables us to induce new logical consequences of existing data. The Large-Scale Inference Engine is used to shape and to assess the coherence of the 4D simulations based on human-understandable concepts and constraints.

All functions of the different components can be deployed through a fully distributed solution using a storage and computation architecture aimed at an integrated, long-term and sustainable storage of the processed content. This solution embodies our strategy for the long-term availability of processed content, even beyond the lifetime of the organisations hosting it, through predefined and legally binding agreements on licensing, redundant storage, automatic hand-over policies and long-term self-supporting investment initiatives which indefinitely extend the availability of the digitised content of TM.

4 TM has/will establish formal collaborations with these platforms. See www.timemachine.eu for the ones already signed with Europeana and CLARIN

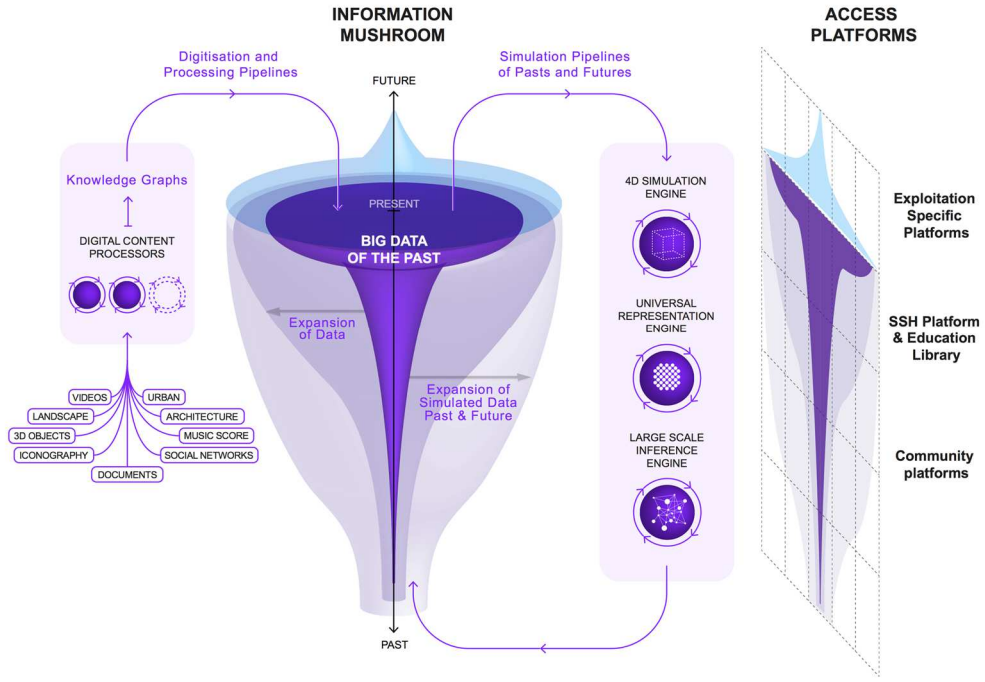

Figure 2-3: TM Digital Content Processor and the three simulation engines

Local Time Machines

As mentioned previously, the Time Machine Network is organised as a large number of **Local Time Machines** (LTMs). Each LTM is anchored in the space of a city, around which various partnerships can form, with the goal of transforming it into a zone with a higher density of *"rebuilding the-past activities*". The TMO provides support for both their launch and growth. The governance scheme for LTMs and their overall interaction with the TMO will be elaborated as a series of RFCs.

Over the course of time, LTMs pass through different maturity phases (indicatively: preparatory phase, submission phase, operation phase, with different levels of operational maturity). Each maturity phase allows us to envision specific exploitation strategies. Each LTM is based on several projects aiming to increase its density of rebuilding the past activities. Once funding is secured by the LTM partners with, when needed, the help of the TMO, they can decide to organise around a common goal and create and finance a new "Project with Time Machine Label" (PWTML – please refer to Annex A). A series of events taking the form of LTM Academies (one potential option is annual pre-TM conference workshops) will be organised to present, compare and evaluate ongoing work.

Putting the pieces together

In the mirror world approach, each city will have a 3D digital twin. This machine-readable version of the city will be annotated digitally, thus enabling the creation of a direct link between the digital information currently on the web or any social network platform to the digital copy of the city itself. The relevant information is attached to each building, shop, metro station, door and any other part of urban infrastructure.

As the city's structure and shape continuously change over time, the city's digital twin is inherently a 4D model, schematically represented in Figure 2-4.

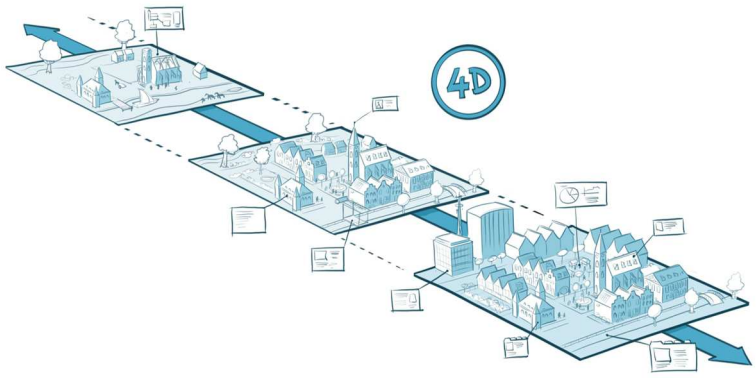

Figure 2-4: 4D model of a city's digital twin *(CC-BY-SA Europeana/JAM visual thinking)*

In the TM approach, each LTM strives to build a dense database of spatiotemporal information, laying the foundation of a 4D map. The TMO helps the city in this process by providing technology, methodology and supporting infrastructure, facilitating the digitisation pipelines, the standardisation of the information gathered and the development of related services. All these features are provided by the Time Machine Box, delivered to the institutions participating in a LTM.

To develop the various exploitation platforms, TM organises the research on novel Human-Computer interaction and visualisation, in particular developing new user-centred 4D interfaces and technology for VR/AR and mixed reality. Pillars 1, 2 and 3 contribute to the different parts of the global Time Machine ecosystem, creating self-reinforcing dynamics leading to ever denser Big Data of the Past (Figure 2-5).

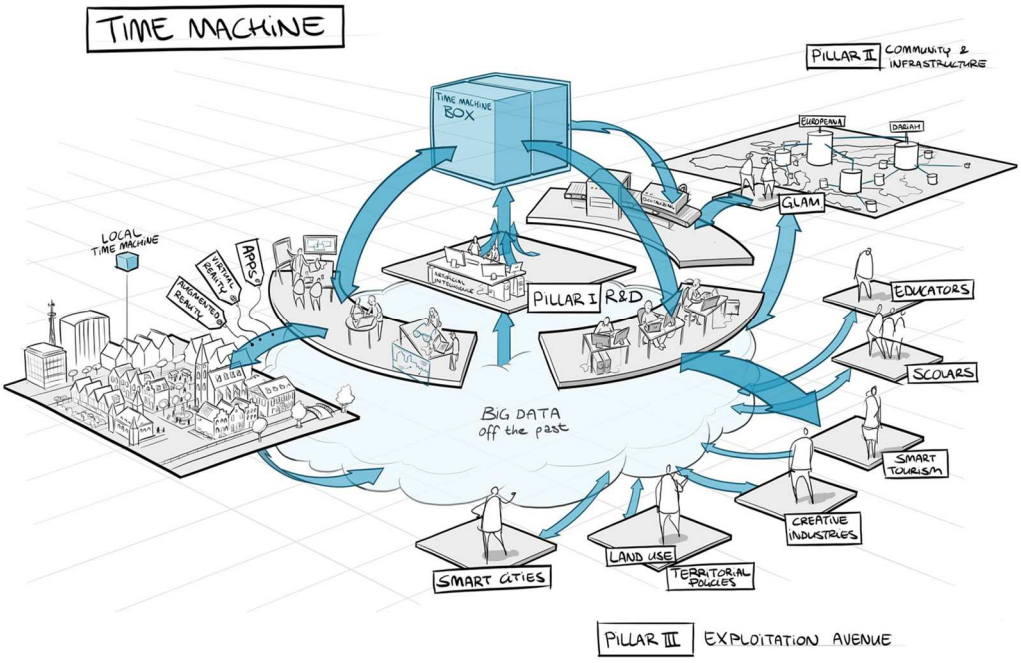

Figure 2-5: The TM overall concept *(CC-BY-SA Europeana/JAM visual thinking)*

To successfully develop the related infrastructure and services, Time Machine organises research in five complementary fields:

1. Digitisation – Research is conducted for developing innovative 2D and 3D digitisation solutions, such as tomographic approaches for scanning documents without opening them, and innovative data storage solutions including early experimentation with DNA storage.
2. Automation of mark-up – The boundaries of knowledge modelling (layered annotations, temporal and geographical characterisation) are pushed, harnessing recent success in handwritten text recognition, graphic document processing (maps, iconography), new indexing and retrieval solutions as well as modelling and reconstruction approaches.
3. Connection – The Data extracted is connected with existing infrastructures through a strong partnership with Europeana, thus establishing the "Big Data of the Past" as a distributed dataset based on shared standards.
4. AI and Simulation Engines – The three TM engines shown in Figure 2-3 enable the control and density of the dataset of information extracted from patrimonial sources, enabling scientists and other stakeholders in the SSH and cultural heritage fields to envision new methodological approaches in different fields of research.
5. Experience – To develop the various exploitation platforms, TM provides an agenda for the research on novel Human-Computer interaction and visualisation, in particular developing new user-centred 4D interfaces and technology for VR/AR and mixed reality.

3 Research and Innovation plan

3.1 State of the art

In **Pillar 1**, a variety of domains in science and technology are involved, each with their own methodological traditions and discipline-specific challenges.

A clear-cut taxonomy was developed, following the overall three-branch structure of the main thematic areas, i.e. Data, Computing and SSH[5]. In this way, it was possible to identify and to analyse the areas in science and technology which can be expected to be most relevant for the scientific and technological advances of the Time Machine initiative (Box 3-1).

Box 3-1: Taxonomy of Relevant Areas in Science and Technology (Pillar 1)

1. DATA

1.1. Data Acquisition: 2D digitisation**;** 3D digitisation**;** Audio digitisation**;** Film and video digitisation**;** Scientific analysis

1.2. Data Modelling: Knowledge Modelling**;** Data formats**;** Metadata Formats and Mapping between Standards; Annotation

1.3. Long Term Preservation: Bitstream layer**;** Functional layer**;** Semantic layer**;** Trustworthy archives

2. COMPUTING AND ARTIFICIAL INTELLIGENCE

2.1. Computer Vision and Pattern Recognition: Text recognition**;** Graphic document processing**;** Image processing and analysis**;** Indexing and Retrieval**;** Understanding and Interpretation**;** Recognition and Detection; Person, Face Identification; Modelling, Registration, and Reconstruction; Audio recognition & transcription

2.2. Natural Language Processing: Methods for Resource Scarce Languages; Orthographic normalisation and variation handling; Machine reading / Document understanding / Question answering; (Structured) Metadata extraction, manipulation, and translation/mapping; Discourse analysis

2.3. Machine Learning and Artificial Intelligence: General Artificial Intelligence**;** Supervised Learning**;** Unsupervised Learning**;** Weakly Supervised Learning**;** Transfer Learning**;** Deep Learning**;** Universal Representation Space**;** Explainability**;** Bias / Fairness / Ethics in AI

2.4. Human-Computer Interaction and Visualisation: User-centred Interfaces; Access to large-scale information retrieval and recommender systems; Virtual / Augmented / Mixed Reality; Accessibility and Learning, Adaptive, and Cognitive Interfaces; Motivational Design; Big data visualisation; User Experience; Virtual research environments

2.5. Computer Graphics: Rendering; Animation; Immersive, Virtual, and Augmented Reality; Interactive Computer Graphics and Computer Games; Procedural Content Generation

2.6. Super Computing: Scaling and distribution; Dynamic provision of computing platform; Cloud computing; Secure distributed computing

3. SOCIAL SCIENCES AND HUMANITIES

3.1. Theory: Qualitative vs. quantitative studies: resistance and acceptance**;** Increase research scope in SSH**;** Simulation studies**;** Digital methods

3.2. Disciplines: History; Language and literature; Archaeology; Art history; Media studies; Geography and demography; Musicology; Digital humanities; Urban studies

In **Pillar 2**, a detailed analysis was carried out for the different aspects related to TM infrastructure, targeted communities of users and LTMs.

For infrastructure, the focus was on current practices, available technical solutions and recent developments. The areas covered concerned:

[5] The approach and detailed findings are documented in Deliverable D2.2 of the Time Machine CSA

- Mapping of cultural heritage resources
- Digitisation infrastructure and technologies
- Storage infrastructure and technologies
- Linked open repository
- Generic document processing
- High performance computing
- Deep learning frameworks
- 4D technologies
- Inference engines

For communities, the analysis looked into the characteristics and needs of different groups comprising developers, educators, professionals in GLAM and similar economic sectors, scholars and volunteers.

For LTMs, the goal was to examine the current state of play for the key aspects required for a sustainable and synergetic pattern of operation. These aspects include data standardisation and interoperability, selection and connection of resources, legal framework, financial model and labelling system for identifying the cultural heritage resources involved. Emphasis was also payed to recording the approaches and achievements of current LTM initiatives. An overview of such initiatives is given in Box 3-2.

Box 3-2: Current Local Time Machine Initiatives

Following the example of the Venice Time Machine that was launched in 2013, several initiatives have been or are planned to be initiated. These projects are putting together the Big Data of the Past in the following cities (in parentheses are the historical periods covered):

- Venice TM (1000-2000)
- Amsterdam TM (1550-2000)
- Paris TM (1000-2000)
- Jerusalem TM (2000 BCE-2000)
- Budapest TM (1680-1990)
- Regensburg TM (1200-2000)
- Nuremberg TM (1000-2000)
- Dresden TM (1200-2000)
- Antwerp TM (1500-2000)
- Ghent-Bruges TM (800-2000)
- Naples / Campania Region TM (800-2000)
- Lower Austrian TM (800-2000)
- Vienna's St Stephen's Cathedral TM (1100-1960)
- Utrecht TM (40-2000)
- Limburg TM (1775-2000)

The TM LSRI will enable these projects to move from their current more or less regional level of operation to a European partnership scale, benefiting from a common infrastructure and framework.

The state-of-the-art analysis in Pillar 2 led to clarifying concepts, identifying operational objectives and defining the main lines of intervention for TM, including structures for the organisation / coordination of actions across the different LTMs.

In **Pillar 3**, the baseline review was organised around the three thematic areas: scholarship, education and specific exploitation avenues and uses.

For scholarship, the investigation addressed the current bottlenecks in SSH research and the limitations of existing platforms to address them. The analysis was used to obtain an overview of existing SSH research infrastructures that have taken the form of ERIC and to stress the synergetic effects of the collaborative schemes that could be developed: ERIC structures will serve to provide sustainable access to the big data of the past and to make it available to researchers and other users in various associated domains/disciplines, while TM will offer new methods and tools for digitisation and information extraction. This mutually beneficial cooperation is expected to open new research approaches and methodologies in SSH.

With regards to education, Time Machine is geared to all forms of learning, from pre-school to higher education and including lifelong learning, vocational training and all forms of informal learning. The main

target group are the educators, while the primary objective is to enable the developers of educational materials to produce new tooling within education platforms to enhance learning. Therefore, the baseline review examined: (a) the general "web of knowledge", including search engines, wikis and other open sources of information; (b) platforms and tools designed to extend educational content, such as virtual learning environments and massive open online courses; (c) tools intended to manage education environments, including teaching and studying practices; (d) tools designed to extend education skills, including critical and analytical thinking, by way of, for example, analytical tools.

The specific exploitation avenues and uses were chosen based on criteria related to their relevance for Europe, including the opportunity to develop European leadership, the potential of technology breakthroughs leading to disruptive effects and the substantial societal and economic impacts that can be expected. The specific exploitation avenues that were chosen (Box 3-3) are not to be considered as mere silos; hence open innovation can rely on transversal results.

Box 3-3: Selected exploitation avenues

- **GLAM**: With GLAM institutions acting as one of the main contributors in storing, collecting, describing, curating, discussing, exhibiting, and sharing Europe's Cultural Heritage, but also as processors and users of Time Machine data, the interplay between the Time Machine initiative and GLAM institutions is a complex and multifaceted relationship.
- **Creative industries**: The capacity of creation and mobilising people's imaginations is key to reach a future vision aligned with our values.
- **Smart tourism**: A specific domain where technology and demand are at promising levels and TM has significant potential of return on investment.
- **Smart Cities and urban planning**: Underlining the capacity (individually and as a society) to interact with the environment and design it. Most human activities are concentrated in cities, hence they are a privileged exploitation avenue.
- **Land use and territorial policies**: Shares the focus area of smart cities, but territories in general are also studied to address sustainable development challenges in the context of climate change.

In each case, the baseline analysis attemped to determine the key aspects that could be relevant to innovative business models, namely stakeholders, technology and demand readiness, as well as needs in terms of new tools and processes to be developed by TM such as processing and simulation infrastructure.

Pillar 4 tackles the framework conditions which address outreach, exploitation of the research and the innovation agenda of the TM. The state of the art analysis has been examined using multiple stages of investigation, including:

- A survey of communication strategies of 20 large-scale EU initiatives comprising EIT KICs and current FET Flagships
- A survey of the current state of copyright law at national / EU level in Europe
- An investigation on European and international certifications and standards in terms of knowledge transfer and collaboration activities
- A desk research on exploitation activities of other FET Flagships, EIT KICs, and EU funded research & innovation projects.
- An online survey to authors in core conferences in the field of digital cultural heritage which resulted in 968 partial and 406 fully completed questionnaires
- A series of five workshops with high-profile associations, businesses and researchers

The areas of intervention that have been identified for Pillar 4 are provided in Box 3-4

Box 3-4 Demands for framework conditions in Pilar 4 Outreach and Innovation

Cooperation and Network Building

Dissemination and Communication

- Strengthened bottom-up engagements and mutual communication with TM stakeholders
- Existence of full service communication agency for TM Community
- An aligned and structured communication approach for digital cultural heritage community

Partnering with Associations

- Building functional links with digital cultural heritage associations of European and international level

Legal and IPR support structure

Central Legal and IPR Support Hub

- Access to latest policies, ethics framework, legislation and regulations concerning TM research and innovation endeavours.
- Promoting demand-side innovation and community demands to standardization, policy setting initiatives and legal bodies in the EU

Knowledge Management

Knowledge and training

- Structured approach to knowledge, competency and data management both within and outside the TMO Community
- Facilitated access to new and enhanced research skills, results and innovations from extant projects
- Supporting sustainability and dissemination of technical tools
- Enhanced human resources capacity development for TM-related skills, technologies and infrastructures
- Partnering with and dissemination into existing training programmes in order to increase digital competency levels

Exploitation support structures

- Reaching sustainable avenues for funding TM R&I priorities
- Supporting evidence-based policy and programme development at European scale
- Supportive framework for converting the TM results into actual innovation platforms servicing new sectors and markets in promising application areas

3.2 Targeted achievements

Pillar 1: Science and Technology for the big data of the past

A number of specific breakthroughs and innovations are targeted to address the scientific and technological challenges related to the big data of the past. Each of these targeted achievements involves work in particular areas of expertise outlined in the taxonomy for Science and Technology developed during the state-of-the-art analysis (Box 3-1). The order of relevance of these areas of expertise towards each specific goal has been specified in the Pillar 1 roadmap, as described in detail in TM CSA Deliverable D2.2.

Data

The aim is to enable persistent digital access to more than 3 millennia of linked historical data, which requires the development of:

- The Time Machine Data Graph: The formal representation of knowledge extracted by human or automatic processes, represented with semantic web technology that requires the elaboration of: (a) criteria on priorities of objects to digitise, taking into account the different states of conservation, availability, proprietary status and degree of urgency for endangered objects; and (b)

guidelines and standards to follow related to formats and protocols for storage, querying data, and promoting trustworthiness and FAIR principles.

- Digitisation Hubs: Hotspots of local digitisation, allowing digitisation outcomes to be seamlessly aggregated into a pan-European Cultural Heritage data infrastructure, with the appropriate standards in terms of resolution, file formats, and metadata during acquisition, using dedicated scanning technologies such as scan robots and tomographic methods (Box 3-5).
- The Time Machine Box: The distributed storage system where the Time Machine Data Graph will be hosted, characterised by adapted technical server infrastructure, compliance with international standards, certification processes, de-duplication methods leveraging pattern-recognition across large datasets, together with a digital observatory and digital archive layers. In addition, connection to long-term storage, for example DNA storage, and selection of the most important data to be stored in such archives.

Box 3-5 Game-changing innovation: Scanning books without opening them

Historical documents are relics of the past, containing information about long-forgotten times. Due to ageing or external influences, many of these cultural assets cannot be further investigated, as they are too fragile to open or page-turn, so their valuable contents remain hidden.

Such documents basically consist of three parts: the cover, the pages and the ink(s). Book covers are diverse, as they were hand-made and sometimes very luxurious, using materials ranging from leather or wood to ivory, gold or silver. Parchment, papyrus or handmade paper was used as writing medium, where the latter was established in the Middle Ages. Since the Roman Empire, iron gall ink has been widely used for writing. Thomas Jefferson's 'Declaration of Independence', Goethe's 'Faust', Mozart's 'The Magic Flute' and even some of Rembrandt's sketches are just a few examples which were written or illustrated with iron gall ink.

Where opening the book is not possible, 3D X-ray CT imaging can be employed. This method has not only been used for human medicine but also for archaeological purposes such as scanning cultural heritage. Previous works show that conventional micro-CT systems can deliver good results by exploiting the various material characteristics of historical ink and paper. If the ink composition has a higher attenuation than the paper's cellulose, the ink is recognizable in the volume of an X-ray CT scan enabling the contents of a book to be known without the need to open a fragile manuscript. This is most effective in cases where metallic particles were present in the ink.

References:

Stromer, D., Christlein, V., Martindale, C. et al. (2018). Browsing through sealed historical manuscripts by using 3-D computed tomography with low-brilliance X-ray sources. Sci Rep 8, 15335 https://doi.org/10.1038/s41598-018-33685-4

Albertin, F., Patera, A., Jerjen, I., Hartmann, S., Peccenini, E., Kaplan. F. et al. (2016) Virtual reading of a large ancient handwritten science book, Microchemical Journal 125, 185-189

Computing and AI

Generic methods will be developed to explore, connect (Box 3-6), and simulate historical information, including:

- Interface for Annotation: An interface to the Time Machine Data Graph, allowing for easy but complex annotation, complying with the standards set for data modelling.
- User Interface: A central interface and templates for specific applications, enabling users of the Time Machine to access the data and materials produced, with features and requirements defined by the user communities.
- Natural Language Processing Tools for Older Language Variants: Processing tools allowing for handling documents in multiple European languages and dialects, named entity recognition in older European languages and variants, orthographic normalisation of older European language variants, as well as machine translation adapted to older European language variants.
- Digital Content Processor: Processor with capabilities that will evolve from labelling mentions of entities (Level 1), to creating labels to establish relationships between entities, improving the Data

Graph (level 2) and then to creating re-useable models that generalise from few observations and contribute to the possible understanding of the patterns behind the available data (Level 3).

- Time Machine Engines: The design of the Time Machine digitisation infrastructure and its components, as discussed in section 2-3.
- Automatic Text Recognition: General models for text recognition that work for the largest number of similar documents possible, so that no new models need to be trained to process texts in almost any European script.
- Automatic Graphic Document Recognition: Improved methods and results of automatic map recognition, including automatic music score recognition, developed using material of the Time Machine Graph.

Box 3-6 Game-changing innovation: Cadastral Computing

The cadastres established during the early years of the 19th century cover a large part of Europe. For many cities, they give one of the first geometrical surveys, linking precise parcels with identification numbers. These identification numbers point to registers where the names of the proprietor can be found. The Napoleonic cadastres include millions of parcels and, therefore, offer a detailed snapshot of large parts of Europe's population at the beginning of the 19th century.

As many kinds of computation can be done on such large objects, the neologism "cadastral computing" was introduced to refer to the operations performed on such datasets. This approach currently tested by several research groups is likely to profoundly change research in urban history. Similar approaches are conducted on directories and other highly-densed sources.

Reference:

Ares Oliveira, S., di Lenardo, I., Tourenc, B., Kaplan, F. (2019). A deep learning approach to Cadastral Computing, Digital Humanites 2019

SSH

Explanatory models of historical evidence opening the way for new, plausible narratives, radically transforming the manner in which SSH engages with the past will be elaborated, leading to:

- A new framework for researchers in historical subjects (history, literature, art, musicology, etc.) using the Time Machine Data Graph to perform quantitative historical studies with a *longue durée* perspective. Increased acceptance of quantitative studies in SSH research will be achieved by organising dedicated conferences and open calls for papers. The implementation strategy for this framework relies on tools that facilitate and enhance scientific analysis, such as the Digital Content Processor and the Simulation Engines.
- Enhanced research methods, such as agent-based simulation, using linked data from the Time Machine Data Graph. Researchers will be able to use the TM engines to perform simulation studies without having to rely on outside models and tools.

Pillar 2: Time Machine operation

Pillar 2 aims to put in place the constituent parts of the TM infrastructure along with the management principles and processes for an ecosystem of TM contributors and users extending across Europe.

Infrastructure

Specifications will be developed for the TM hardware and computing infrastructure (Box 3-7) that will define the research challenges to be addressed in Pillar 1. The research results will then be used to design and to develop:

- A network of digitisation hubs on a European scale, managed by a peer-to-peer platform responsible for managing the optimisation of digitisation strategies at European level, tasked with

the development of generic solutions for archiving, directly documenting the digitisation processes and rapidly putting the digitised documents online.

- A distributed storage infrastructure for both public and private data in the form of a fully decentralised, highly redundant architecture based on the shared resources of a purpose-built network, forming the Time Machine Infrastructure Alliance.
- The distributed super computing infrastructure for processing big data of the past as shown in Figure 2-3, equipped with specially designed content and discovery interfaces for accessing the Time Machine Data Graph for all intended uses and applications.

Box 3.7 Core software components: Data Graph, 4D Map, Code Library and Project Repository

Data Graph: The Data Graph (incrementally implemented by research in Pillar 1) is the central component of the Time Machine, containing all information modelled in the Time Machine. The graph is constructed both manually, using editing apps, and automatically through the processing of the Digital Content Processor. Apps permit the visualisation and editing of the Data Graph, thus performing internal (e.g. inclusion of nodes and links) and external operations (e.g. visualisation).

4D Map: The 4D Map is a central component of Time Machine. It plots both ongoing projects and the datasets of these projects. This means that the 4D Map is both the map where activities can be followed and the map aggregating results. The density of the 4D Map is not uniform. In particular, some zones may be modelled only in 3D, 2D and even 1D, as a list of included elements. The 4D Map includes a layer of municipalities on which LTMs can be anchored. The 4D Map can be navigated using the several 4D interfaces.

Code Library: The Code Library is accessible in several programming languages, regrouping key operators for processing data in the TM environment.

Project Repository: The Project Repository monitors all active TM projects. Projects are generally conducted by institutions, but can also be launched by individuals, and may be new or the documentation from ancient projects. Projects can mine sources and ingest their extracted data into the Data Graph. These Projects are associated with a Zone of Coverage that associates them with LTMs, producing content for GeoEntitites. Projects may also produce intermediary datasets that can be downloaded even if they are not yet integrated into the Data Graph. Projects can also develop apps that interact with the 4D Map and the Data Graph, and they can contribute to the Code Library by working on TM's GitHub repository to produce new operators. These different objectives are not exclusive from one another.

Community Management

Encompasses work dealing with the organised interaction of TM with scholars, developers, cultural heritage professionals, service providers and citizens. A system of platforms will connect TM with such external communities who will benefit from and can provide input in various forms to the TM, so the objectives are to:

- Build a strategy and an associated Community Management System, responding to well identified requirements for staff and processes leading to mutually beneficial and sustainable interactions with TM communities.
- Develop interfaces facilitating connection of TM infrastructure with that of existing communities.[6]
- Design and implement transparent mechanisms for tracking community involvement and reporting on community contributions via metrics on individual participation and overall impact on the Time Machine Data Graph.

6 For example, source code will be published on GitHub to enable direct contact to open source developers and user accounts for crowdsourcing volunteers can be connected to other social media or community accounts.

In addition, all users registered on the Time Machine Website will be given an ID that can be used to login in to third party apps. Depending on their level of activity, users may reach different status levels linked with particular privileges in terms of operations. These status levels are inspired by the Wikipedia system.

Local Time Machines

This thematic area is related to the governance scheme of the LTM network and by extension to the overall governance scheme of the TMO. The area constitutes the core of the TM sustainability model and is strongly related to the growth of the entire initiative, as it will set out the principles and processes for a network of LTMs, including:

- The LTM common framework, ensuring cohesion in the network's operation through the definition of general values, common objectives, as well as technical standards and guidelines regulating data acquisition, data sharing and data publishing.
- The support structure that will oversee the smooth development of the LTM network, so that institutions wishing to launch or to integrate into an LTM are given a clear path and guidance throughout the entire process. Particular attention will be paid to enabling existing initiatives to be aligned with the LTM framework, as well as to encouraging TM partners to launch new initiatives.
- The labelling system or value scale to be used for evaluating the progression of an LTM. The labelling system should encourage the progression of the LTMs through the different grades, while providing a means to assess member commitment towards the LTM objectives.
- The legal setting based on a coherent and standardised contract and licensing system for all LTM network operations, guaranteeing conformity with national and European policies and laws.
- The financial system to foster financial independence and, therefore, longer term viability of LTM initiatives, including shaping a LTM franchise model. In this respect, emphasis will be on utilising local assets to enhance / develop new exploitation avenues for the big data of the past (in cooperation with Pillar 3).

To enable the rapid development of the LTMs, a compromise must be found between the locally driven initiatives, linking TM technology with locally developed projects, and coordinated actions ensuring an ordered development of the global data graph.

Locally, activities are organised through projects, working at a fast and agile rhythm. The local coordination ensures that they comply to the TM rules. The projects pass through a series of certification levels.

In parallel, the LTM will set ingestion pipelines in a sequential order (Table 3-1), progressively structuring the information graph and offering ways to more easily ingest certain forms of structured sources. LTM Academy events will be organised regularly to support local communities in the use of these standard tools as they are being developed. These events will also serve as an opportunity to exchange best practices and to consolidate prototypes for future ingestion pipelines. Consolidated Time Machine Pipelines enable the building of the Data Graph in an incremental way, starting from the core information structure and progressively attaching the small branches and the leaves. Consolidated Time Machine Pipelines are also the main service that helps small LTMs that are not linked with academic research. This is the case for hundreds of cities across Europe.

Table 3-1: Indicative schedule of overlapping period of the ingestion of structured documents

2020 – 2024	Information Skeleton: Maps, Cadastres, Address Books, Simple 3D, Statistics, Genealogy, Census Data
2022 – 2026	Visuals and Environment Photos and 3D models, Engraving, Paintings, Library of Objects, Sculptures and Buildings, Photogrammetric models

2024 – 2028	Events Newspapers, Radio, news TV programs, Chronicles
2026 - 2030	2030 … all the rest (including private documentation)

The analysis of the first years of development of existing LTMs has permitted us to establish the principles for future development.

The first principle for the development of the LTM is **Openness-by-design**. The general idea is that LTMs do not have a hierarchical structure managed by a coordinator or leader but represent an aggregation of different projects, arising from different contexts and which have their own independent structure, governance, purpose, development context and method of financing.

Consequently, LTMs are areas characterised by **Density of Operations**. There is no single coordinating entity that attempts to manage all the **Projects** which have arisen in a specific area. All those involved in the various projects and activities, through their organisation charts, can converge towards a community which will have an autonomous logic of structuring and functioning which emerges locally. The projects involved can include projects with national and international grants, institutional projects having internal funding, projects financed by local administrative institutions, projects on cultural heritage held by companies benefiting from services and tools implemented by the TMO through the **LTM Infrastructure**, and also small-scale projects led by individuals.

The project-based horizontal structure has the following key advantages:

- Standard processes facilitate easy on-boarding of new projects and members. They ensure openness by-design.
- Standard operations and libraries of standard operators guarantee, by their design, the desired level of compatibility between processes and datasets.
- Centralised repositories for projects, operations and data sets enable a constantly up-to-date map of activities in progress.

The second development principle of the LTM is **Scalability-by-design**. To maximise growth of the TM environment, the right balance must be found between the portion of the infrastructure under the control of the TMO and the pieces of software developed independently. The Time Machine should be as distributed as possible but as centralised as necessary.

The TMO is responsible for the development of the **Core Infrastructure,** which includes components such the **Data Graph** or the **4D Map**. The **Apps** are pieces of software that allow users to experience and to edit the information in the Data Graph and the 4D Map, and they can be grouped into families of Apps like the **Navigators** or the **Annotators**. The way these components fit together is shown in Figure 3-1, while the way digitisation hubs can be part of the LTM infrastructure is dicussed in Box 3-8.

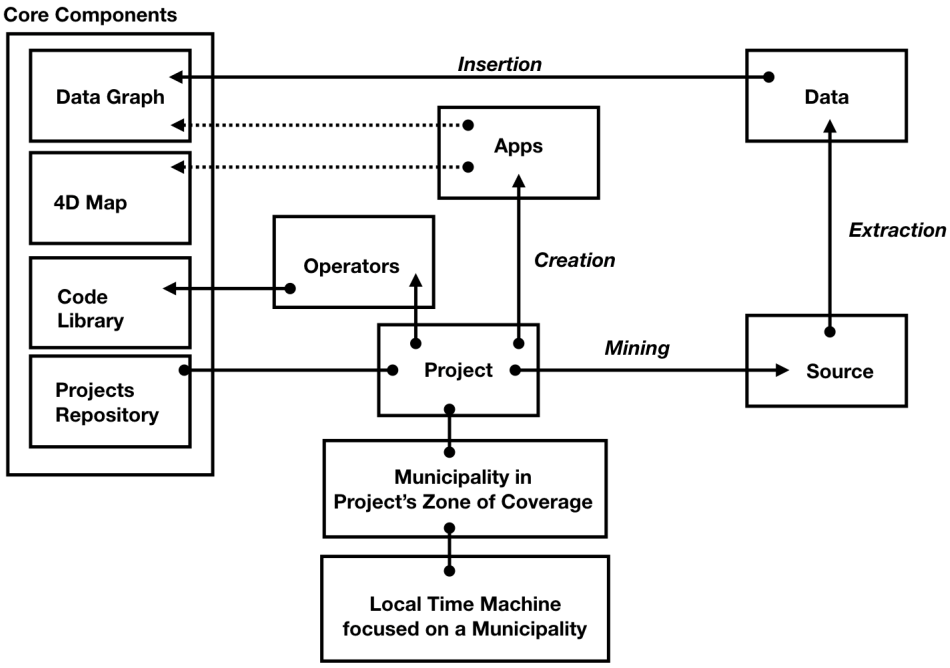

Figure 3-1:General structure of Local Time Machines and their relation to Projects, Apps and Core Components.

In this context, LTMs defined as zones of higher density of activities, correspond to parts of the Data Graph and 4D Maps, where Project activities are more intense. The level of intensity corresponds to different modes of visualisation in the Time Machine Website. This principle of development enables a cost-effective strategy in which a variety of actors can build tools and services around the activities of LTMs.

The relation of LTMs and Projects to the geographical space is complementary:

- LTMs focus on Municipalities, i.e. zones dividing the geographical territory into administratively non-ambiguous zones. The list of Municipalities as potential LTM locations is fixed and predetermined. It defines the granularity of the Local Time Machines.
- Projects focus on a Zone of Coverage corresponding to one of several GeoEntities. The list based on existing geographical entities (e.g. a list of Places documented in Open Street Map (OSM)) is defined as standard Geographical Information System objects (points - lines - polygons). Some GeoEntities can include Municipalities or be included in Municipalities. In both cases, the Project will be featured in the corresponding LTMs.

Box 3-8 How Digitisation Hubs integrate the Local Time Machine infrastructure

The Digitisation Hubs constitute an example of services that will be offered to LTMs for digitisation (e.g. scanning of documents, streets, 3D scanning).

The Digitisation Hubs will enable the seamless aggregation of new documents and metadata into a Data Graph, with the appropriate standards in terms of resolution, file formats, and metadata during acquisition. Contractual aspects will be dealt with in the Time Machine Standard Contracts.

The following steps are foreeen:

1. Creation of a Project with the digitisation Services on timemachine.eu

2. Specification of its Zone of Coverage. The Zone of Coverage will determine the LTMs in which the services will be publicised.

3. Precise definition of digitisation offers using only Standard Metrics in order to be able to determine the exact price of the operations.

4. Once the service framework is set up, creation of an App for offering the services.

This process should enable the creation of a well-functioning single European market for digitisation services, connecting operators and customers using agreed upon standards.

Pillar 3: Exploitation avenues

Pillar 3 is designed to leverage the societal and economic impact of TM. Two thematic areas, scholarship and education, focus on the disruptive effects on scholarly methods and learning respectively. The third thematic area groups sectors of activity that are important for the EU and for which the LSRI is expected to introduce new approaches and transformative business and cultural models.

Scholarship

Time Machine has the potential to realise a radical expansion of the "zooming" capabilities of scientific research from the microscopic level of historical anecdote to the macroscopic level of high-level cultural patterns and their interrelations with socio-economic trends, seen from a *longue durée* perspective. An example of current work that will lead to such developents is provided in Box 3-9. The new methods of analysis will open the way to a better understanding of the complex systems that characterise our present-day digitising and globalising cultures and societies and, thus, provide a basis for developing more meaningful solutions for the future.

Box 3-9 The Amsterdam Time Machine: locating the city's cultural heritage

The Amsterdam Time Machine is developing a geographical infrastructure to connect the cultural heritage of Amsterdam to the locations in the city where it was produced, distributed or experienced. Supported by grants from CLARIAH (the Dutch national research council sponsored contribution to the CLARIN and DARIAH ERICs) and Pica Foundation (promoting information exchange between the Dutch libraries), in 2019 the partners in the Amsterdam Time Machine consortium launched a geographical infrastructure that identifies the various locations in the city in a uniform way, transcending the various changes in street names, district and house numbering systems over time. Starting with the Napoleontic cadastral data of 1832 and extrapolating that to the 1909 modern district and street numbering system, this geographical infrastructure is currently extended back in time to 18th and 17th century Amsterdam.

Such a spatio-temporal infrastructure allows cultural heritage institutions to show where their collection items were produced, distributed and consumed over time, virtually reconnecting these collections to the locations that shaped their meaning and impact. For example, it is now possible to identify the houses where the artworks in the Rijksmuseum collection were originally located – as in the case of the portraits of regent Pieter de Graeff (1638-1707) and his wife Jacoba Bicker (1640-1695), that adorned the walls of the "Groote Kamer" (large room) on the second floor of the Herengracht 573 mansion they had built in 1665 (*). The ownership and location of such artworks and other cultural heritage items is documented in the notary acts kept in the Amsterdam City Archives, that include complete inventories of the households of most Amsterdam citizens from the 16th to the early 20th century. These acts are currently being digitized, among others, with the help of the Transkribus software for the automatic transcription of handwritten documents and with volunteers (**).

The geographical infrastructure of the Amsterdam Time Machine enables the connection of these inventory data to the historical maps of the city and to 3D models of the houses, providing an unprecedented view of four centuries of cultural consumption by Amsterdam citizens from nearly all layers of the population. As such, it demonstrates the potential of the Time Machine to query multiple types of data in a scalable manner, navigating between the broader patterns of urban life and the micro level of individual people, places and events. It also demonstrates the Time Machine's capacity to virtually bring cultural heritage from the museums, archives and libraries to the locations that matter for present-day citizens: allowing people to travel back in time to their own house, street or in their neighbourhood.

References

(*) Chiara Piccoli, 'Visualizing domestic interiors in 17th century Amsterdam: 3D/4D data integration and hypothesis testing platforms.' Virtual Interiors blog post, 12 July 2019, https://virtualinteriorsproject.nl/2019/07/12/visualizing-domestic-interiors-in-17th-century-amsterdam-3d-4d-data-integration-and-hypothesis-testing-platforms

(**) https://alleamsterdamseakten.nl/overhetproject/.

Because of its integrated approach that combines digitisation, interpretation, data gathering and management, as well as methodological innovation, the TM infrastructure will drastically speed up advances in the state of the art for most SSH fields (and probably also in ICT), by multiplying the pace and explanatory power of scholarly and scientific progress. This innovation will be supported by the conceptual and methodological framework developed in Pillar 1 for SSH research, which combines the strengths of the tradition of hermeneutic research (interpreting the complexity of human culture and society at the micro-level of individual sources, places, people or events) with the advantages of quantitative methods (seeing patterns in large datasets and analysing those with statistical methods).

This 'scalable' approach to SSH research methods will innovate scholarship in the following ways:

- The methods can be used heuristically, whereby the patterns observed lead to new hypotheses on the phenomenon under investigation, that then are subsequently analysed with traditional, interpretative methods.
- The analyses based on big data of the past can be used to empirically test existing assumptions based on smaller sample data.
- The quantitative methods, including simulation, will allow for the combination of different types of data and thus for more complex analyses.

The TM aims to contribute to the state of several academic disciplines that rely on historical data about human life. Computational techniques developed in Pillar 1 – agent or system-based simulation, simulation of cultural evolution, prediction, diachronic studies of human language and other phenomena – bring new dimensions to methods typically used in SSH. Modelling historical events, contextualising past ideas, processes and larger cultures, and using those to inform hypotheses about future scenarios all constitute methods that can be incremented by the multimodal, linked datasets and AI processing techniques offered by the TM infrastructure.

TM for Scholarship aims to contribute to European scholarship by devising three strategies:

- **Provide scholars with developer and user access to European historical and cultural data tied to GLAM institutions** through web software, compatible with current web conventions and user practices (platformisation).
- **Provide scholars with advanced computational techniques for scholarly analysis**, whether through user-friendly tools or malleable code.
- **Offer scholars regular opportunities to collaborate, innovate and present new knowledge and methods** tied to TM technology.

Education

Time Machine for Education will offer unique enquiry and experience-based blended learning, citizen science infrastructure and approaches based on revolutionary digital technologies (AI, VR, AR). In collaboration with educational service providers, pedagogical content and tooling will be developed for schools, universities and lifelong learning in a mix of free, sponsored and paid services, largely based on the big data of the past and associated simulation technologies. The emphasis will also be on accelerating the learning of SSH through the improved access to and scalable analysis of rich, linked data on a specific subject, as well as on empowering students with critical (historical) data science and coding skills.

Students will be in position to study complex societal and urban challenges and thus to learn informed decision-making, considering and balancing relevant facts, interests, values, costs and benefits. Teaching and research will also benefit, as TM will enrich teaching material associated to SSH, the sciences, health and practical technologies.

TM's personalised, localised access to the big data of the past is ideally positioned for the current trend towards more self-directed learning, whereby the nature of the instructor shifts 'from transmitter of knowledge to facilitator and curator'[7]. From that perspective, it makes sense to design an infrastructure that provides direct access to the TM data in ways that match the infrastructures for education currently in use and the new opportunities for innovating access to cultural and historical information. An example of a use case is presented in Annex B1, dealing with an application for school students of history that enables them to explore the complexity and multiplicity of perspectives of specific historical periods.

As the Time Machine is centred on the use and application of big data of the past, key advances are expected in the following areas:

- Encyclopaedic use: Granting students and educators at large with access to big data of the past through web-based reference techniques, such as a "History Look Up" function that can be activated to consult historical background information about various (or any) information students encounter.
- Engaging explorations of and experiences with the past: Providing students and educators with specific applications and interfaces through which to make use and to visualise big data of the past, including the simulation of those pasts using advanced visualisation techniques such as maps with integrated 3D models, AR/VR applications, multimodal search engines and other systems based upon big data of the past.
- Critical thinking and digital literacy: Supporting these applications are code and big data analysis training, or "Time Machine analytics", for all students and educators engaged in studying and teaching historical disciplines through data analysis. Critical thinking and digital literacy required for using such data will be developed in cooperation with Pillar 1 - Theory.

The tooling and training TM for Education offers can be summarised into three development avenues, in collaboration with Pillar 1's agenda for Computing and Artificial Intelligence:

- Web and reference platform compatible plugins and other software for **linked "encyclopaedic" access to historical and cultural data**
- **Linked, augmented applications dedicated to exploring historical and cultural sites**, particularly to facilitate first-person explorations of the past
- **Packages for critical (historical) data science skills training**

Other exploitation avenues and uses

GLAM

The largest part of European cultural heritage can be found in the many galleries, libraries, archives and museums spread across the EU. Digitisation and open access dramatically change the way these institutions operate, putting in question current business models and funding mechanisms. TM will boost, aid and accelerate many developments (Box 3-10) that are already underway in GLAM and introduce completely new transformative effects in four areas dealing with (digital) collections:

[7] EDUCAUSE Horizon Report, 2019 Higher Education Edition, page 19

- Collection Custodianship & Enrichment: (a) Larger bodies of digitised material will be made accessible to the general public according to FAIR data standards, with more affordable and flexible digitisation services; (b) The vast amount of newly acquired metadata will increase the demand for curation. TM tools will help GLAM professionals, but also the TM citizen science community, to select and further refine metadata; (c) Automated information extraction, machine learning, and AI will increase document understanding and automated translations (including translations from ancient languages to modern languages) and therefore the accessibility for all kinds of audiences.
- Collection Access: Novel query mechanisms will innovate current methods to query both digitised and born-digital content for the general public and researchers.
- Collection Curation, Engagement & Experience: TM will enable institutions to provide richer and more diverse experiences for their users, both in physical, augmented, and virtual settings. Multimodal interfaces and feedback mechanisms will give ground-breaking multisensory experiences that are elegant, authentic, nuanced, unobtrusive and customisable according to user requirements. A relevant use case is presented in Annex B2 for an accompanying application making use of TM APIs that enables GLAM users to experience different versions of the same exhibition in a way that suits their specific needs, for example, the mount of time one has available for a GLAM visit.
- Collection Linking, Reuse & Remix: (a) Through the adoption of automated data linkage based on customisable parameters, disparate data storage will be able to "communicate" and create new bodies of knowledge; (b) Customised frameworks to reuse and remix data in intuitive ways will foster exploration by humans on crowdsourcing platforms, GLAM labs, and raw data APIs or semi- and fully automated methods through the use of machine learning. These initiatives will further feed data and new knowledge back into TM's databases; (c) Monetisation and distribution of single objects and entire collections, including a discussion of "levels of openness" will introduce new business models for GLAMs.

Box 3-10 How a museum can integrate some of its collection in the Time Machine

One objective of Time Machine is to localise cultural objects in space and time. For instance, an object in a museum can be associated with several spatio-temporal references: its place of production, the various places it was stored before entering the museum, and the spatio-temporal entity it represents. One consequence is that a museum in Paris may contribute to many LTMs in the world, if it has paintings representing Venice, Madrid or Budapest. Inversely, in many cases, the evidence of reconstructing the past of a city or a site can be scattered in collections all over the world.

To enter and curate data in the Data Graph, a museum will create a **Project,** possibly jointly with other institutions, with a particular spatio-temporal anchoring objectives. For simplicity of the explanation, let's assume the collection to be ingested is already digitised. The steps are the following:

- In the Project Environment, the museum defines the approximate **Zone of Coverage** of the collection. This will define the Municipalities (and therefore the LTMs) for which the data will be relevant. Such information can be updated at later stages.
- The museum enters the repository where the **Source** collection is, typically as a IIIF repository. If the Museum does not have an IIIF solution, a physical or virtual Time Machine Box can be used. This is an example of an **App** adapted to the Data Graph. The data will remain in the chosen repository, unless the museum wants to benefit from a long-term preservation service.
- Using dedicated apps, like **Annotators**, the project partners reposition the objects of the chosen collection in space and time (for instance annotating content of paintings or documenting the steps in the trajectory of the objects)
- A **Conflict Detector tool** (another specific app) is capable of identifying any conflict in the inserted metadata which is linked to other TM operations (for instance due to an inference or a non-compatible entry). On this basis, the museum may or may not update its metadata or launch specific research initiatives to investigate the conflicting data elements further.

Being part of the Data Graph, the newly inserted collection will benefit from all other innovations the TM environment will bring.

Creative Industries

The European creative industries contribute 6.8% of GDP and 6.5% of employment to the EU[8], while at the same time offering a strong potential for stimulating innovation in other sectors with a competitive edge, such as tourism, education and advertising. TM will introduce scientific and technological breakthroughs that will significantly impact the production cycle of the creative, media and entertainment industries via impacts on the creative value chain, for example:

- Creation – elaboration of ideas, contents and products: (a) Large quantities of multimodal data made available through the use of advanced computing technologies and data visualisation techniques will support the exploration and retrieval of yet undiscovered patterns, connections and observations, which will serve as an inspiration for the development of new creative ideas; (b) The open and interoperable infrastructures for data exploration will enable creative freedom and diversity; (c) AI will support new forms of creativity, including computational creativity. A relevant example for this area is the use case presented in Annex B3, showing how TM data and resources can empower journalists to create new methods for validating the trustworthiness of data and stories in the media, thus tackling misinformation, while providing tools for them to create data-driven stories.
- Production/Publishing – the making of original, non-reproducible or reproducible work: (a) Production processes will be supported by easily searchable, high-quality resources, while smart metadata models will support the ability to combine and seamlessly integrate digital objects in different variations to tell different stories; (b) Storytelling will be enhanced using ground-breaking simulations, visualisations and possibilities to query granular properties of digital objects which will support the emergence of new kinds of storytelling techniques that appeal to different senses; (c) Reuse of data will be supported by clear copyright acquisition and licensing mechanisms, and newly developed business models will ensure that both data providers and creators can benefit from these transactions.
- Dissemination/Trade – dissemination of cultural products to make them available to consumers and distributors: Supported by new business models, licensing frameworks and high-quality resources, creative industry players will have more bargaining power to enter the market and to promote and disseminate their creative outputs. Smaller and much more diverse players are likely to emerge, further fostering creative circulation in the digital single market. Machine learning and natural language processing technologies will support the delivery of high-resolution experiences at a massive scale for broad audiences and over various platforms. Other sectors, including the tourism industry, GLAMs and education, will benefit from novel services and experiences designed for their end-users. With more creative products to offer, the role of European online platforms in the digital market will gain a prominent role and attract much more traffic and investment.
- Transmission/exhibition/reception – provisioning access to creative products for consumption: Metadata about the Intellectual Property of new works will be managed in a machine-readable way to track copyrighted content on a granular level (tracking of individual elements or excerpts) and support remuneration, rescue and reuse. Collective licensing frameworks and other security mechanisms (e.g. smart contracts) will support smaller actors in the sector and provide sustainable revenue streams. TM will also develop models that will help to incorporate user-generated content, in this way increasing cultural participation and raising awareness about the potential of cultural heritage.

[8] http://www.teraconsultants.fr/en/issues/The-Economic-Contribution-of-the-Creative-Industries-to-EU-in-GDP-and-Employment

Smart Tourism

Europe is the most visited tourist region in the world, and in the EU, tourism contributes 10% of overall GDP and creates jobs for 26 million people through its direct, indirect and induced effects in the economy.[9] To compete with strong competition from other world regions, Europe invests heavily in smart tourism, which refers to smart, innovative and inclusive approaches to touristic development, paying particular attention to cultural heritage and creativity.

Taking into consideration the Smart Specialisation Strategy (3S) framework for regional development in the EU, TM will work with territorial clusters to develop specific technological innovations and tools for local cultural-heritage experience platforms that raise smart tourism to a key local/regional priority. This approach is fully compatible with the development of LTMs (Pillar 2) that could serve as backbones to these local "smart clusters" and is expected to lead into the following achievements:

- Synergy models for core re-users, enablers and infomediaries which offer products and services that are enhanced by TM technologies that boost touristic demand based on cultural heritage.
- Innovative clusters working with LTMs to create a sustainable ecosystem for smart tourism.
- Increased awareness and respect for cultural heritage destinations driven by TM narratives.
- Economic sustainability of destinations, locations and institutions (e.g. GLAM) through the TM smart tourism model.

Smart cities, urban planning, land use & territorial policies

The objective is to use TM technologies to achieve more inclusive societies, sustainable development in our cities and territories and to support the elaboration of common visions and projects for our cities, territories and Europe based on common values. The innovative solutions to be developed will support people in understanding their environmental dynamics, identifying which choices they have to make when they design their environment (incl. European, regional and local regulations), as well as enable them to assess options, connect to other inspiring experiences and to learn how to use data and state of the art knowledge. The main targets are described below:

- Integrated, inter-connected information systems for cities and lands reaching across time, space and scales, across administrations, authorities and citizens, that support not only browsing but also queries. We target intensified and more relevant (smart) information exchange in smart cities with new data sources, including exchange between cities with comparable infrastructures and with more focus on historical depth (longitudinal perspective provided by the big data of the past).
- Multi-scale and culture friendly city and land information systems. "Culture ready" information systems that integrate cultural specificities of different information sources and contexts of use.
- Affordable and sustainable solutions to build specific municipal or regional information systems (TM projects) that integrate into a wider framework, regardless of a city or rural territory or country's resources (in terms of funds but also expertise and communities), including in emerging countries, and available for transversal themes (e.g. Glaciers Time Machine, Wetlands Time Machine, etc.).
- User-centred retrieval of facts and data from Europes history (other cities, other territories) to favour exchange and mutualisation as a bottom-up process to find solutions to sustainable development challenges, which may complete existing a top-down process driven by the state or by the European Commission. Users also require meaningful documentation of uncertainties and hypotheses.

[9] UNWTO (2018). European Union Tourism Trends: https://www.e-unwto.org/doi/book/10.18111/9789284419470

- Recommendations for decision makers to support their planning and design solutions: Suggesting connections and presenting situations from the past that are related to the present-day experience in specific localities and situations can support and inspire decision makers, citizens, scientists to invent new solutions and approaches, e.g., regarding choices in urban development or land use. TM can also support cities in finding out which other cities are facing similar challenges, for example in managing tourism, water management, social cohesion, and sharing data and solutions.
- Enhanced science – policy interface as well as scientific stakeholder interface in cities and/or in land management in general: To connect stakeholders who seek a longitudinal perspective on a present-day problem with the relevant scientific communities, which will enable them to sample historical, spatial and design training data sets related to a given issue, apply machine learning methods trained on these samples from the past, and use the Time Machine Knowledge graph to make recommendations on a specific problem.
- Debating platforms related to cities and territories design present historical information and heritage in the contexts that are relevant to the experiences of the different audiences: bringing history and heritage to the people, rather than the other way around. As such, these platforms can be leveraged to connect present-day experiences and problems to different past events that make sense to different population groups. These platforms should be 'polyvocal', allow for multiple perspectives on the past, creating room for the often-unrecorded stories of minority groups, including newly arrived citizens who may not share the dominant culture. These platforms will also benefit from the capacity to share and compare hypotheses, thanks to story-telling functionalities.
- Inclusive and transparent platforms to write and revise policies related to territories: Supporting interactions for stakeholders with different backgrounds and perspectives, considering data available to associate trustworthy dashboards to the policies.

Pillar 4: Outreach and Innovation

Pillar 4 will contribute to creating the required conditions for the dissemination and promotion of Time Machine and the uptake of the results and other outputs produced during and beyond the initiative's lifetime.

Dissemination and Communication

- Dissemination and Communication actions are designed and implemented to raise awareness and to communicate the achievements and impacts of TM, to secure engagement of all relevant TM stakeholder communities and in general to serve TM's strategic objectives.
- A sustained brand strategy is developed and implemented, which is supported by the integration and adoption of key messages across TM Community.

Policy, legal issues, ethics and IPR

- EU and Member State-related policies, legal aspects and ethical issues referring to cultural heritage are fully analysed, in particular cultural heritage protection, preservation and use for developing societal and economic benefits.
- A Central Legal and IPR Support Hub is established as a body of knowledge and to support TM members and stakeholders.
- A helpdesk is implemented to support TM operations regarding IPR and legal aspects.
- Policy recommendations and support for legal initiatives are provided concerning digitisation of cultural heritage

Knowledge Management

- A framework for managing the generation, dissemination, access, exchange and use of TM knowledge, data, skills and competencies is developed
- A demand-driven approach is adopted for the targeted achievements.

Exploitation support structures

- Exploitation support structures and related services are created to facilitate the use of the results acquired by TM for further commercialization, to boost entrepreneurship, for further research and projects, for informing related policies and for shaping and creating markets, services and products.
- Exploitation support measures are directed towards reaching sustainable funding and resources for research and innovation priorities and results of TM.

3.3 Overview of expected scientific and technological progress

In Table 3-1, an overview is provided for the scientific and technological advances targeted by Time Machine.

Table 3-2: The key advances of scientific and technological knowledge by Time Machine

TM field	State of the Art	With Time Machine
P.1.1 Data	Fragmented datasets only sparsely covering European CH.	Large sets of aligned and standardised cultural heritage data.
P.1.2 Computing	Disorganised sets of academic tools most of the time developed for specific projects based on state-of-the-art technology. Very few systems managing the temporal dimension.	Development of a unique computing infrastructure dedicated to the massive extraction of knowledge in cultural heritage sources, probably the most advanced artificial intelligence system ever built.
P.1.3 Theory	DH analysis of current practices on the role of computing for the Humanities and Social Sciences.	Largest effort ever undertaken to build a critical theory and sound epistemological concept on digital cultural heritage and multi-level historical simulation.
P.2.1 Infrastructure	A number of European coordination initiatives of cultural heritage with consortia, infrastructures and networks like EUROPEANA, Europa Nostra, DARIAH-ERIC, CLARIN-ERIC, CERL (see section 1.3e for these) and ICARUS.	Reinforcement and extension of these initiatives with shared computing infrastructure for processing and transforming digital cultural heritage at unprecedented scale. Cooperation with initiatives for optimising computing infrastructure, e.g. EuroHPC JU.
P.2.2 Community Management	Many communities dedicated to specific topics - limited exchange due to lack of shared data or concepts.	A large community of communities, sharing a standardised platform, with more empowering tools.
P.2.3 Local TMs	Uncoordinated efforts to recreate the past of several cities in Europe.	A franchise-based system enabling each initiative to benefit from the highest level of technology and rapidly develop sustainable models of development.
P.3.1 Scholarship platform	Global commercial search engines are the mediators of our access to knowledge and culture.	TM's open and transparent interfaces, not only analysing the pulsations of the present, but embracing wider geographical and temporal horizons, transforming the way we study, visualise and narrate the past and the future.
P.3.2 Education platform	Books and video about history and culture. Some online lectures.	Massive Open Online Courses, immersive and interactive experiences, engaging material for students and continuous life-long learning. Development of a dynamic new industry for the production of educative digital material, based on aligned massive datasets.
P.3.3 Specific Exploitation and Uses platforms	CH seen as a cost more than a source of innovation, with remaining silos and difficulties to manage solutions truly valorising all available data and across time. Citizens regard policies as a European burden.	Fast development of market-driven platforms of TM to develop relevant services for GLAM, the creative industries, smart tourism, smart cities, and land use and territorial policies. Users understand processes driving local regulations and give feedback to authorities.
P.4.1. Dissemination & Communication	Fragmented communication efforts and processes across digital cultural heritage community in Europe	Catalysed interactions, framework conditions and best practices for more coordinated communication efforts and community building for digital cultural heritage
P.4.2. Policy, Legal Issues, Ethics, P.4.3. Knowledge Management,	Lack of guidelines, framework conditions and tools to better handle knowledge management, legal aspects, innovation and education related processes for digital cultural heritage communities	Validated structures, instruments and frameworks to enable tailored and demand-driven legal, training and exploitation support.
P.4.4. Exploitation Support Structures	Lack of dedicated and professionalized fund raising support for digital cultural heritage community	Tailored service offered (Project Scouting) for better access to funding for the TM and it's members as well as an opener for new funding opportunities by the interaction with funders

3.4 Methodological approach

The building of the TM will require consolidated effort from all pillars which will bring their multidisciplinary and cross-sector expertise to drive innovation throughout the 10-year roadmap timeframe and beyond. In parallel, iterative consultation and collaboration with external networks working in connected fields or who could benefit from the state-of-the-art innovation is paramount to ensure that TMO can demonstrate far-reaching results from the outset and achieve a truly transformational impact.

To realise this vision, TM will adopt a **Two-Speed Methodology** which will drive research and innovation via two parallel tracks: (1) state of the art development of core foundational TM components and infrastructure at a **steady speed over the 10-year roadmap period** and (2) the **high speed, cyclical development** of capabilities driven by specific use cases and business needs from various exploitation areas. This dual approach is quite common in enterprise software development, and it helps to quickly develop customer-facing capabilities, while decoupling foundational systems for which release cycles of new functionality remain at a steady pace.[10] Figure 3-2 below summarises how TM will adopt the Two-Speed Methodology.

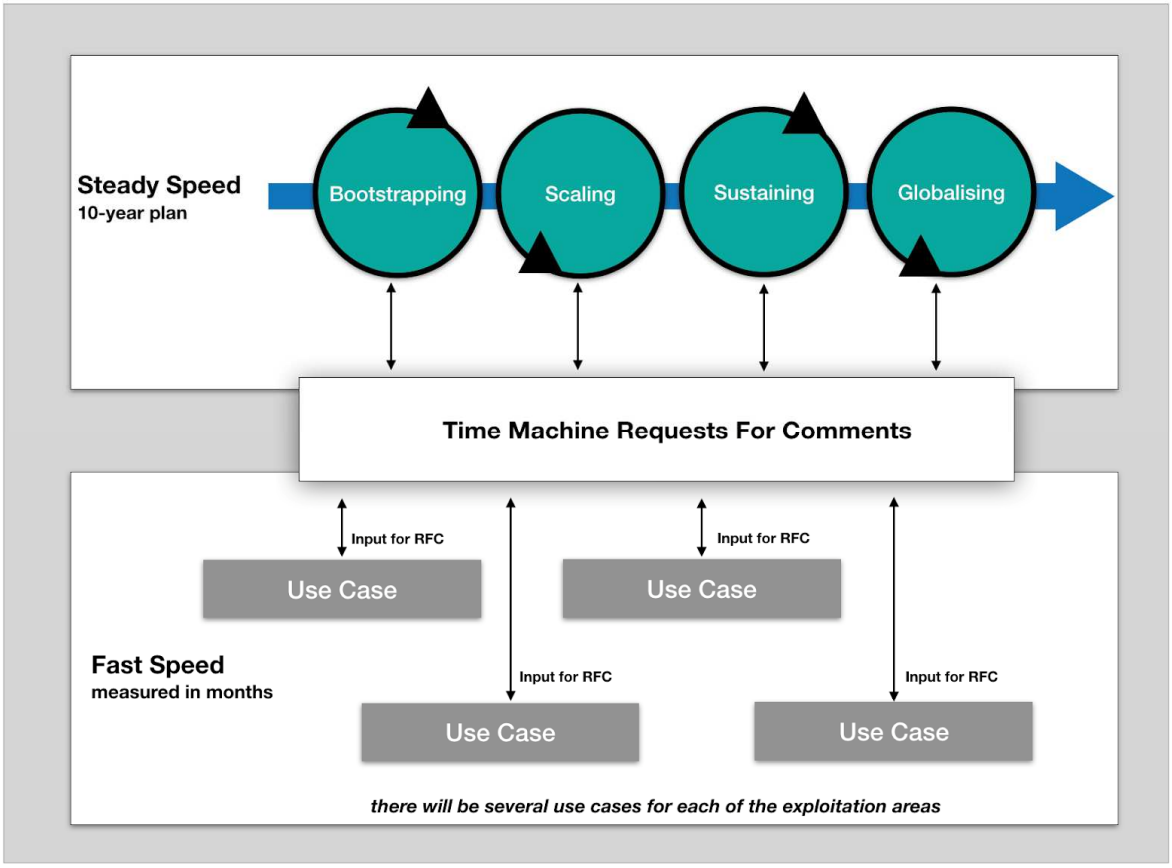

Figure 3-2: Two-Speed Methodology

The two speeds are directly interlinked: research activities in the Steady Speed area trigger new use cases and lab-experiments with TM technologies that are executed in Fast Speed, and the results of these use

[10] See https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/a-two-speed-it-architecture-for-the-digital-enterprise

cases become part of the core TM infrastructure and support further user-driven research and innovation activities performed in Steady Speed. This methodology ensures an agile development of TM infrastructure that is iteratively reinforced by smaller-scale experiments performed in collaboration with stakeholders and leads to immediate exploitation in various industries. It ties technology, design and business together and increases the impact of the TM by gathering external interdisciplinary communities to contribute towards its vision of the big data of the past for the future of Europe. This approach supports the TM becoming more self-sufficient in the long-term.

The section below outlines in detail how the two speeds operate:

Steady Speed Development encompasses the development of technological, operational, outreach and exploitation infrastructures. The core aspect of it is the Research and Innovation Agenda in Pillar 1, which will lead to the development of the state-of-the-art technological innovations that will result in the realisation of mirror-worlds. The operational infrastructure will establish LTMs across Europe. Outreach and exploitation activities will secure engagement and support from external communities and adaptation of TM results in various sectors.

The Steady Speed development is foreseen in four phases that consolidate efforts from all TM pillars:

- Bootstrapping – the first phase envisages the development of key technological components outlined in the Research and Innovation Agenda and the creation of infrastructure central to the TMO operation, including the launch of new LTMs, funding schemes and outreach mechanisms for stakeholders in key exploitation areas.
- Scaling – the second phase foresees the industrialisation of the TM technologies and their adoption at a large scale; it will oversee the development of and supporting services for LTMs across Europe.
- Sustaining – the third phase will be dedicated to addressing the challenges linked to the open-ended sustainability of Time Machine and the implementation of framework conditions for knowledge transfer and supporting the valorisation of TM's innovation output.
- Globalising – the final phase of the project will address the challenges linked with the expansion to non-European archives and patrimony, while sustaining further European densification.

During the four phases of the Steady Speed Development, **Time Machine Requests for Comments (RFC)** will be used as the main process for establishing rules, recommendations and core architectural choices for the TM components. It will act as a method to reach consensus on science and technology options that will benefit a wide range of communities and meet stakeholder requirements. Therefore, TM RFCs will act as a vehicle for bi-directional communication between the Steady Speed and the Fast Speed tracks.

Informed by scientific breakthroughs from the wider interdisciplinary communities and networks, RFCs will build on the current state of the art and use input from the broader scientific community to inform the work foreseen in the Research and Innovation Agenda. Once individual RFCs are developed, the roadmap will be implemented via a modular design covering a 10-year period, in which various **calls-for-proposals** will attract bottom-up research proposals targeting unique milestones in a specified time-frame. The draft roadmaps for Pillars 1-3 have developed lists of RFCs and research topics which will lead to the targeted achievements discussed above.

The process for writing RFCs requires long-term planning instruments which enable writers to obtain a continuously updated version of not only of past RFCs but also of future versions in planning and development stage. The RFC Tree as described in Annex B.1 aims to provide an up-to-date description of the planned RFCs with a short textual motivation for each of them, including their dependencies with other RFCs.

RFC Tree is the metaphorical description and the hierarchical representation of the **Time Machine Request for Comments** development plan that will be used as a baseline scenario to help monitor the achievements of TM over the coming decade. While the RFC Tree is itself a result of the progressive completion of RFCs through time, RFC Tree also acts as a blueprint defining the incremental steps needed to build the fully functional Time Machine Infrastructure. An initial set of 70 RFCs has been developed to plan and to organise the development of the pipeline, and each RFC has dependency with others, which results in a tree-like structure.

An RFC Editorial Committee organises the RFC publication process. The duties of the RFC Editorial Committee are to maintain the consistency of the RFC System, to appoint RFC teams to organize new RFCs and to improve on existing RFCs. The RFC Committee is also responsible for keeping track of the versioning of the RFCs, the timely and regular publication of RFCs, and the public announcement of the open review process. The goverance and organisation of the RFC Editorial Committee is itself defined in a dedicated RFC.

The initial publication pipeline will go through the following stages (Figure 3-3):

1. The RFC Editorial Committee appoints authors to write RFC planned in the RFC tree. Alternatively, authors contact the RFC Editorial Committee to propose writing a RFC (planned in the RFC tree or not).

2. The authors produce a RFC draft which is reviewed, first by the RFC Editorial Committee for coherence with the rest of the RFC corpus and then by a larger community. The RFC is revised and possibly re-reviewed.

3. Once accepted by the RFC Editorial Committee, it receives an official identifier and is officially published as an authored peer-reviewed publication.

4. The RFC tree is adapted with the published RFC and possible sub-RFC(s) planned in the writing of the new RFC.

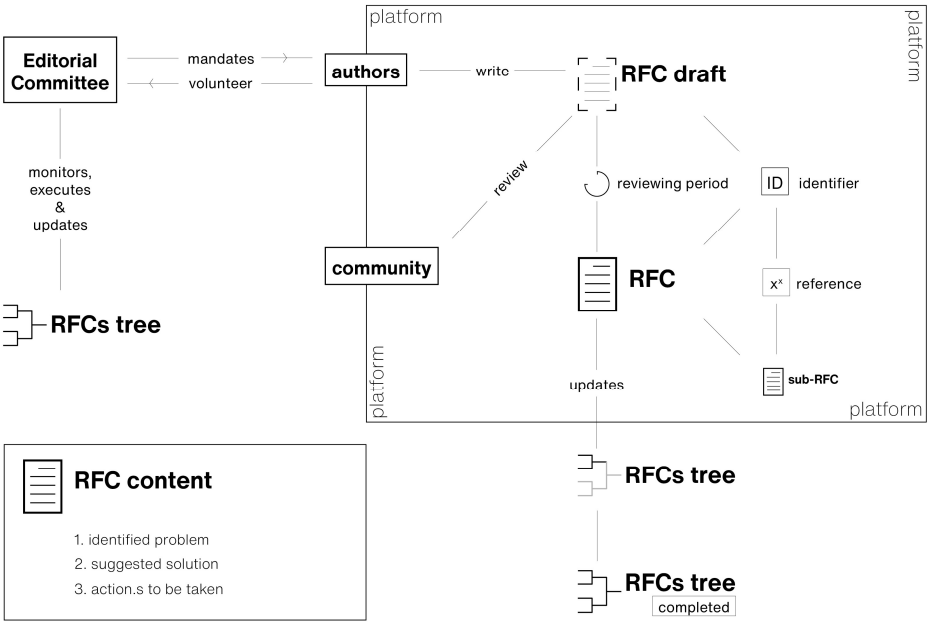

Figure 3-3: Publication workflow for the RFCs and process for monitoring and updating the RFC tree

Each RFC is classified in one of the following four categories: Framework, Infrastructure, Data and LTM. This classification and the dependencies help to build a visual representation of the RFC Tree. The detail of each

planned RFC and its dependencies are provided in Annex B. Table 3-5b in section 3.5 summarises the overall structure of the tree. The organisation of the RFC tree follows the general temporal segmentation of the TM project, divided in four phases (Bootstrapping, Scaling, Sustaining, Globalizing). In the tree, this broad segmentation matches a finer grained segmentation that corresponds to the phases of development of the TM infrastructure, as shown in Table 3-3.

Table 3-3: Segmentation for the development of the TM infrastructure

Phase	Timing (Y is year from start)	Description
Bootstrapping	Y1 - Frameworks	Definition of most of the framework for the TM development takes place
	Y2 to Y3 - Pipelines	Definition of most of the data processing pipelines for the extraction of information from sources
	Y4 - Synchronization	Alignment and distribution solution for the storage and processing of the data
Scaling	Y5 to Y6 - Engines	Definition of the main processing Engines of the Data Graph that permit to make inferences and density the 4D grid.
Sustaining	Y7 to Y8 - Mirror World	Definition of the Mirror World architecture offering an integrated interface to navigate and update the 4D Grid.
Globalising	Y9 to Y10 - Global Time Machine	Consolidation of the Global Time Machine

The initial RFC Tree organisation is likely to be adapted and densified on the basis of the fast-paced experimentation and locally developed use cases. The use cases bring a constant flux of stakeholder driven needs which can directly impact the steady speed plan of the RFC Tree structure. In this context, some RFCs may be developed sooner than initially planned. The dependency tree helps judge the possible consequences of these dynamic reorganisations.

The RFC Tree serves as a central coordination process for the LTMs. Each LTM develops projects at a local level that can help produce technological prototypes and results informing future RFCs. At the same time, the development of the TM pipelines organise the kind of media that can be processed in a standard way and therefore guarantee smooth integration with the global TM Data Graph.

The TM RFCs will be accompanied by a set of fundamental research questions that need to be clarified and validated through user studies and experiments in lab environments with stakeholder groups. This will be achieved in the Fast Speed development described below.

Fast Speed Development will operate in short-cycles (measured in months) of user-driven development that will be executed with stakeholder communities. It will serve as a catalyst for Research and Innovation performed in Slow Speed. In response to RFCs, user-driven development in Fast Speed will gather valuable input for raised research questions and will act as a testbed to evaluate and disseminate technological innovations.

Use cases will be initiated by projects within LTMs, individual TMO members or working groups of partners who are connected to stakeholders in the exploitation areas. Several use cases of varying scope, addressing different Research and Innovation questions or different stakeholder groups, will run in parallel throughout

the course of the 10-year roadmap period to iteratively provide user-driven input. Use cases are not restricted to a specific exploitation area and can combine efforts from various stakeholder groups. The focus and scope of these use cases will be aligned with input needed for RFCs and the work foreseen in Research and Innovation Agenda of Pillar 1. The scientific, technological, societal and economic impact presented in this document will guide the use cases to ensure that their results are in line with TM's overall vision and goals. Representatives from all relevant pillars will collaborate with stakeholders in order to execute the use cases. This collaborative approach guarantees an agile development that embeds user needs in TM development and creates opportunities for immediate exploitation.

The fast speed approach can be further broken down into four macro-phases, which are as follows (see figure 3-4 below):

- The **exploration** phase defines the scope and focus of the use case by addressing the questions raised during the writing of RFCs and the challenges encountered by various stakeholder groups. It identifies stakeholder communities, resources (available technologies and research, LTM capacity, external and internal funding) and actions needed to develop the use case.
- The **validation** phase serves as a lab environment to test and validate hypotheses or prototypes against stakeholder needs.
- The **execution** phase turns the validated hypotheses or prototypes into market-ready solutions that can be integrated into the TM infrastructure or exploited externally.
- The **diffusion** phase ensures involvement in the planning of dissemination and exploitation of the use case results and defines next steps that need to be addressed in Research and Innovation Agenda or explored in future use cases. The conclusions from the use case are provided as input for RFCs.

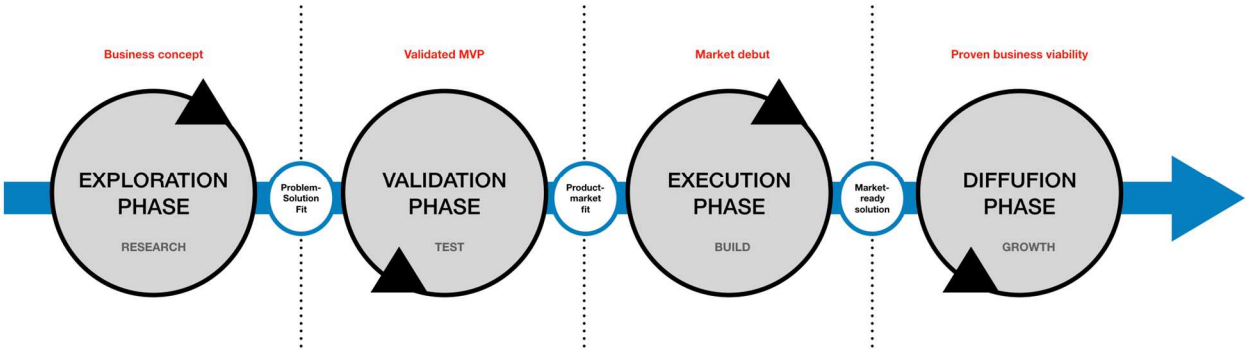

Figure 3-4 Phases of the Fast Speed Development

The fast speed approach enables a form of "natural selection" on projects based on relevance and sustainability. Only projects that successfully pass the four phases have a chance to be permanently integrated in the TM Infrastructure. This relevant feedback directly affects the steady speed development of the project, the RFC tree planning and the implementation of the core TM components.

All pillars will be active throughout the 10-year roadmap period and will contribute in different ways to support other pillars and to build the foundation for subsequent steps in future phases. The role of pillars in the methodology presented above is summarised below (the milestones of each pillar are presented in section 3.5).

The exploitation avenues will be based on a number of new capabilities or "impact facilitators" that Pillars 1 and 2 will produce:

- Cheap and cost-efficient solutions for the further digitisation of resources through standardised offers and services and easily replicable open hardware technologies.
- Generic Automation for the mark-up of these resources tagging concepts, named-entities, relations and rules.
- Intelligent connection of existing fragmented data resources using, adopting and building on existing legal frameworks and developing standards for distributed storage solutions.
- New simulation capabilities, by transforming sparse data into continuous 4D data sets capable of representing multi-worlds.
- Innovative forms of experience, by enabling new paradigms for the restitution of the data to the end-user including spatio-temporal search engines, geo-historical services and Mirror Worlds.

The availability of these resources will create opportunities for social and economic impact by potential users, which offers strong incentive for their participation in the design of solutions and their commitment in applying them. For example, one can mention the cost saving potential for economic sectors like GLAM and the creative industries, and the improved tools and access to high linked data featuring critical reference points that open new horizons for social science and humanities researchers.

The roadmaps define clear targets to be achieved for all thematic areas covered by the pillars. In most cases, these serve as intermediate steps contributing to the achievement of the overall objective of TM. The resulting implementation plan can be outlined as follows:

- Initially, Pillar 2 lays out the specifications on how to develop the basic concepts, in a way that respects the main idea of the TM: creating a distributed digital information system mapping European social, cultural and geographical evolution that can be used by a number of communities to create momentous social and economic impact. This is done through the RFC Tree, continuously update throughout the project.
- These specifications are used in Pillar 1 to define scientific and technical objectives that address the underlying challenges. The challenges are translated to research programmes, whereby leading European teams are invited to propose the solutions to address them.
- Pillar 2 designs the physical and management infrastructure and is responsible for TM operation in line with the results of the design process. Operation also includes oversight of the development and providing support to the LTMs.
- Pillar 3 brings together communities that work on exploitation avenues in three thematic areas: scholarship, education and other important sectors of activity for the EU (GLAM, creative industries, smart tourism, smart cities, urban planning, land use and territorial policies). During the Steady Speed development, Pillar 3 efforts are concentrated on establishing an infrastructure that supports exploitation. This includes outreach and strategy development, execution of pilots and creation of mechanisms to support exploitation. Pillar 3 also plays a central role in initiating and executing use cases in the Fast Speed – they will identify how RFCs could be addressed by various exploitation areas and form working groups with external stakeholders and networks to execute them. To achieve maximum impact, each exploitation avenue has defined activities that address challenges specific to their respective sectors.
- Throughout the entire process, Pillar 4 implements a dissemination programme for researchers, innovators and decision makers, addresses legal and regulatory issues related with the implementation of the TM actions, develops framework conditions for knowledge transfer and supports the valorisation of TM’s innovation output.

3.5 Milestones and time plan

As outlined in the methodology section above, the Steady Speed development of the Time Machine will be executed in four phases. The main achievements of each phase are as follows:

- Bootstrapping – Y1 to Y3 (2020-2023): During this first phase, the key technological components will be designed through RFCs (Pillar 1). This process will interact with the design of the TM infrastructure and community platforms; a number of new LTMs will be launched (Pillar 2). The Scholarship and Education thematic areas will design pilot projects for the new concepts introduced by TM in the respective fields, while the other exploitation thematic areas will develop strategic plans based on detailed user needs analyses (Pillar 3).
- Scaling – Y3 to Y5 (2023-2025): Based on research progress, the industrialisation of next generation scanning and storage techniques will start (Pillars 1 and 2), and a first version of the three simulation engines will be launched (Pillar 2). The Scholarship and Education platforms in Pillar 3 will give first results, in terms of research and education methodologies, as well as new studies and curricula.
- Sustaining – Y5 to Y7 (2025-2027): The third phase of the project will be dedicated to addressing the challenges linked with open-ended sustainability of TM (Pillar 2) and to new developments and demonstrations of the platforms for Scholarship, Education and Specific Exploitation Areas and Uses (Pillar 3). In the meantime, research in Pillar 1 will focus on the development of new integrated AI, combining progress made in the previous phases.
- Globalising – Y7 to Y10 (2027-2030): The last phase of the project will address the challenges linked to the extension to non-European archives and patrimony, while sustaining European densification (Pillars 1,2,3).

The timeline for the accomplishment of the milestones, taking place over the course of a 10-year period following the launch of the LSRI, has been developed considering the requirements of each of them and can be found in Tables 3-4 to 3-7 below.

Table 3-4: Milestones and time plan for Pillar 1

Thematic Area / Milestones	Time										
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Data											
1. Digitisation Hubs											
RFC Digitisation Hubs											
Implementation Digitisation Hubs											
RFC New Scanning Technologies											
2. TM Box											
RFC TM Box											
Implementation TM Box											
3 TM Data Graph											
RFC on Technical Charter											
RFC on Digitization Priorities and Data Selection											
Computing and Artificial Intelligence											
1. Annotation Interface											
User Studies of Current Annotation Platforms											
RFC on Annotation											
Annotation Interface Implementation											
2. User Interface											
User Studies of Current Platforms for Historical Data											
User Interface Implementation											
3. Natural Language Processing (NLP) Tools for Older Language Variants											
RFC on Classification and Planning for Languages to Address											
RFC for Named Entity Recognition											
RFC for Orthographic Normalisation											
RFC for Machine Translation											
4. Digital Content Processor (DCP)											
RFC for DCP Level 1											
RFC for DCP Level 2											
RFC for DCP Level 3											
5. Simulation Engines											
RFC for TM APIs											
RFC for Large-Scale Inference Engine											
RFC for 4D Simulator											
RFC for Universal Representation Engine											

Thematic Area / Milestones	Time										
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
RFC for Mirror World Prototyping											
RFC for Mirror World Technical Standards											
6. Automatic Text Recognition											
Call on Text Recognition											
RFC on Text Recognition and Processing Pipeline											
7. Automatic Graphic Document Recognition											
RFC for Map Recognition											
RFC for Music Scores Recognition											
Social Sciences and Humanities											
Improved Acceptance of Quantitative Methods in Historical Research											
Call for Quantitative Historical Research with TM Data Graph (1)											
RFC TM Tools for History Research											
Call for Quantitative Historical Research with TM Data Graph (2)											
Call for Quantitative Historical Research with TM Data Graph (3)											
Successful Historical Simulations using TM Data Graph											
Call for Agent-based Simulation Using Linked Data											
RFC for Improved Simulation Using TM Simulation Engines											
Implementation											
Yearly Open Calls											

Table 3-5: Milestones and time plan for Pillar 2 – (a) overall time plan; (b) RFC planning

(a) Overall time plan

Thematic Area / Milestones	Time										
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Infrastructure											
1. Core Technical Infrastructure											
Development of early RFCs											
TM search engine prototype											
TM digital hubs											
Assessment and Evaluation											
2. Deployment											
Development of engines RFCs											
Operation and scale of TM pipelines and engines											
3. Fill sustainability of infrastructure											
4. TM 4D Mirror World											
5. Globalisation of infrastructure											
Community Management											
1. Growth and consolidation											
Professional communities within TMO											
TM communities for individuals											
2. New communities											
Development based on future Mirror World services											
3. Consolidation											
Communities beyond early adopters											
4. Internationalisation											
Communities beyond Europe											

Thematic Area / Milestones	Time										
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Local Time Machines (LTMs)											
1. Bootstrapping and coordination											
Development of early RFCs											
Consolidation of 10+ LTMs											
On-boarding of new LTMs											
Development of franchise system and LTM ecosystem RFCs											
2. Transition to the Mirror World											
Development of Mirror World services											
3. Economic growth and sustainability of LTM model											
4. Extension of LTM model at global scale											

(b) RFC planning

RFC Topic	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Bootstrapping										
Frameworks										
RFC on RFC										
RFC on RFC Editorial committee										
RFC on Publication Platform										
RFC on Technical Charter										
RFC on Vision Mission and Values Charter										
RFC on Intellectual property rights and licenses										
RFC on Training										
RFC on LTM										
RFC on LTM Value Scale										
RFC on LTM Training										
RFC on Definition of typologies of digitisation interventions										
RFC on standardisation and homologation										
RFC on Digitisation Priorities and Data Selection										
RFC on Open Hardware										
Pipelines										
RFC on data lifecycle										
RFC on Operation Graph										
RFC on TM Data Graph										
RFC for TM APIs										
RFC for classification and planning of languages to address										
RFC on Annotation										
RFC on Digital Content Processor Development and Testing										
RFC on Digital Content Processor (DCP) of Level 1										
RFC on Digital Content Processor (DCP) of Level 2										
RFC on Digital Content Processor (DCP) of Level 3										
RFC on Synergy and interaction in EU Research Infrastructure										
RFC on General Standards for the Super Computing Architecture										

RFC Topic	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
RFC on Time Machine Box										
RFC Digitisation Hubs										
RFC for named entity recognition										
RFC on Text Recognition and Processing Pipeline										
RFC on Structured document pipeline										
RFC on map and cadaster Processing pipeline										
RFC on Audio Processing Pipeline										
RFC on Video Processing pipeline										
RFC on music score pipeline										
RFC on Photographic processing pipeline										
RFC on Photogrammetric pipeline										
Scaling										
Synchronisation										
RFC on Enhancing Collaboration										
RFC on Franchise System										
RFC on Solidarity										
RFC on Top-Down initiatives										
RFC on Distributed Storage										
RFC on Distributed storage system for Public Data										
RFC on Distributed Storage system for Private Data										
RFC on on-demand digitisation										
RFC on Global optimization of digitisation process										
RFC for orthographic normalisation										
RFC on Content Filtering										
Engines										
RFC on Knowledge transfer										
RFC on Smart Cluster										
RFC on Collaboration indicators										
RFC on Large-Scale Inference Engine										
RFC on the 4D Grid										

RFC Topic	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
RFC on 4D Simulations										
RFC TM tools for history research										
RFC on New Scanning Technology										
RFC on 4D Simulator										
RFC on Universal Representation Engine										
RFC for Machine Translation										
RFC on Mirror World Prototyping										
Sustaining										
Mirror World										
RFC on Legal issues linked with Mirror World										
RFC on Mirror World Extension Strategy										
RFC on Mirror World technical standards										
RFC on Virtual/Augmented Reality and Discovery										
RFC on 4D Mirror World										
RFC for improved simulation using TM simulation engines										
RFC on Large Scale Mirror World										
Globalizing										
Global Time Machine										

Table 3-6: Milestones and time plan for Pillar 3 (a) overall plan

Exploitation avenue / Milestones	Time										
	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	
Scholarship											
1. Collaboration and Strategy											
Collaboration planning											
Outreach strategy											
Pilot use case definition											
2. Exploitation Pilots											
Pilot use cases executed											
Best practices & training material											
Concertation across TM Pillars											
3. Open Calls for Proposals											

Exploitation avenue / Milestones	Time										
	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	
Open call for scalable SSH research with TM Data Graph											
Execution research projects with TM Data Graph											
Open call for SSH research with TM box components											
Execution research projects with TM box components											
Concertation across TM Pillars											
4. Large-Scale Implementation											
Joint development of TM Data Graph for SSH research with Pillar 1											
Monitoring impact of TM data and tools on SSH research											
Education											
1. Outreach and Strategy											
Stakeholder organisation											
Requirement analysis											
Definition software-curriculum update process											
2. Exploitation Pilots											
Pilots round 1											
Demonstrators											
Concertation across TM Pillars											
Pilots round 2											
Improvement of demonstrators											
Concertation across TM Pillars											
3. Infrastructures for Support and Sustainability											
TM software for education											
Customer satisfaction											
4. Large-Scale Implementation											
Rollout of TM for Education portal											
GLAM											
1. Outreach and Strategy											
GLAM Think Tank established within TMO											
Strategy for the execution of use cases in Fast Speed development											
Selection criteria defined											
GLAM pilot selected											
Test scenarios refined											
2. Exploitation Pilots											
First pilot action launched											
Pilot actions executed											

Exploitation avenue / Milestones	Time										
	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	
3. Infrastructures for Support and Sustainability											
Impact monitoring of pilot actions											
Generalised models derived from pilots											
Sustainability plan											
4. Large-Scale Implementation											
Large scale roll-out of Time Machine services for GLAMs											
Cooperation with GLAMs on a global scale											
Creative Industries											
1. Outreach and Strategy											
Creative Industries Think Tank established											
Strategy for the execution of use cases in Fast Speed development											
Case Studies											
Creative Industries Hub infrastructure established											
2. Exploitation Pilots											
Launch of Incubation activities											
Pilots with creative industries executed											
3. Infrastructures for Support and Sustainability											
Launch of Licensing Hubs to support new business models											
Impact Monitoring											
4. Large-Scale Implementation											
Large-scale roll-out of pilots across Europe											
Outreach and exploitation with Creative Industries globally											
Smart Tourism											
1. Outreach and Strategy											
Pilot region defined											
Local 3S and LTM smart tourism cluster established											
Strengths/weaknesses of local tourism											
Cultural heritage prioritised narrative refined											
2. Exploitation Pilots											
Local creative industries hub											
Launch of the pilot technology-driven products and services											
3. Infrastructures for Support and Sustainability											
Testing products and services with immediacies											
Customer satisfaction											
4. Large-Scale Implementation											

Exploitation avenue / Milestones	Time										
	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	
Building smart tourism model											
Testing smart tourism model on extended communities											
Smart cities, urban planning, land use and territorial policies											
1. Outreach and Strategy											
Thematic TM committee established											
Thematic TM Roadmaps developed											
First call for TM land-use digitisation proposals											
First call for TM land-use learning from the past proposals											
Knowledge Graph, reference datasets and guidelines published											
2. Exploitation Pilots											
Definition of use cases											
Challenge platform											
Knowledge graph associated to samples of reference specified											
Collaborative platform, and regulations and related datasets referenced on it for the use case											
Prototype of TM Land Use debating platform											
Prototyped connections existing Smart City and Land Use portals with LTMs											
3. Infrastructures for Support and Sustainability											
Sandbox for European Culture Information System connected to LTM											
Second call for TM land-use digitisation proposals											
Second call for TM land-use learning from the past proposals											
Exploitation TM Knowledge Graph in smart cities/land use											
References to TM challenge platform											
4. Large-Scale Implementation											
Master programme promoted to students											
Implementation of INSPIRE historical data and UN GGIM with TM protocols											
Survey to detect references of related work											

(c) Description of Pillar 3 Milestones

Scholarship

Milestone	Description	Means of Verification	Due
Outreach and Strategy			
M1	Plan for collaboration with existing SSH research infrastructures	Actions as listed in Memorandums of Understanding with relevant research infrastructures (CLARIN, DARIAH, EHRI, E-RIHS & Europeana) translated into concrete plans for collaboration	YR1
M2	Outreach strategy in place	The outreach strategy includes 1) appointing Time Machine Ambassadors in the SSH scholarly community; 2) developing training, mentorship and peer-teaching program; 3) regular participation (papers, workshops, demo's) in a representative number of annual SSH conferences	YR1
M3	Pilot use cases defined	Set of pilot use cases proposed by WP leaders and submitted for approval to TM General Assembly	YR2
Exploitation Pilots			
M4	Pilot use cases executed	Successful development and execution of the first round of pilot use case with selected participants from various SSH and CS disciplines	YR3-4
M5	Best practices & training materials developed	Based on use cases, a set of best practices and training materials are produced in collaboration with the Research Infrastructure communities	YR4
M6	Concertation efforts across the TMO pillars	Outcomes from the use case are discussed with Pillars 1, 2 and 4. This results in updated activity plans across the Pillars	YR5
Open Calls for Proposals			
M7	Open call for proposals for scalable SSH research with TM Data Graph	Includes the Call for Quantitative Historical Research with the TM Data Graph (2) in Pillar 1	YR6
M8	Execution of projects for scalable SSH research with TM Data Graph	Broad variety of high quality projects from SSH community selected; projects build on Pillar 1 achievement 3.1 and participate in the development of the TM Data Graph	YR7-8
M9	Open call for proposals for SSH research with TM Box components	Coordinated with calls issued in Pillar 1 for specific components	YR7
M10	Execution projects on SSH research with TM box components	Broad variety of high quality projects from SSH community selected; projects contribute to Pillar 1 achievement 3.2 and participate in the development of the TM simulation engines	YR8-9
M11	Concertation efforts across TM pillars	Outcomes from the open call projects are discussed with Pillars 1, 2 and 4. This results in updated activity plans across the Pillars	YR8-9
Large-Scale Implementation			
M12	Joint development of TM Data Graph for SSH research with Pillar 1	The pilot use cases and open call projects will test the TM Data Graph and provide requirements for its development	YR2-10
M13	Monitoring impact of TM data and tools on SSH research	Measuring the impact of TM components and infrastructure on SSH scholarship (in collaboration with stakeholders)	YR2-10

Education

Milestone	Description	Means of Verification	Due
Outreach and Strategy			
M1	Stakeholder organisation	A consultation group is established with stakeholders from: primary and secondary education (EUROCLIO); education curricula development (private education package developers; Ministries of Education)	YR1
M2	Requirement analysis	Refining analysis State of the Art and points of further improvement from stakeholder organisation	YR2
M3	Definition of software-curriculum update process	Definition of a sustainable update process based on application-curricula interdependencies. Consolidation with stakeholder organization and other pillars	YR1-2
Exploitation Pilots			
M4	First round of pilot projects	Design and execution of two pilot projects that test the TM data and tooling: 1) focus on three types of usage (encyclopaedic, engagement and digital literacy) in primary education; 2) focus on digital literacy in four levels of learning (primary, secondary, higher and informal)	YR3-4
M5	Development of demonstrators	Development of best practices and training & dissemination materials	YR4
M6	Concertation efforts across the TMO pillars	Outcomes from the first call projects are discussed with Pillars 1, 2 and 4. This results in updated activity plans across the Pillars	YR4
M7	Second round of pilot projects	Design and execution of two pilot projects that test the TM data and tooling: 1) focus on three types of usage (encyclopaedic, engagement and digital literacy) in secondary education; 2) focus on two types of usage (encyclopaedic and engagement) in higher and informal education	YR5-6
M8	Improvement of demonstrators pilot studies round 1	Set of improved best practices and training & dissemination materials tested and evaluated with stakeholder organizations	YR6
M9	Concertation efforts across the TMO pillars	Outcomes from the first call projects are discussed with Pillars 1, 2 and 4. This results in updated activity plans across the Pillars	YR6
Infrastructure for Support and Sustainability			
M10	Development of TM for Education portal	Amount of software packages released for primary and secondary schools, higher education and informal learning Presenting primary and secondary schools with user guidelines and tracking uses of demo applications	YR7-8
M11	Measuring customer satisfaction	Tracking and evaluating usage of portal and materials	YR8
Large-Scale Implementation			
M12	Rollout of TM Education portal	Diffusion strategy and business model defined and in place	YR9-10

GLAMs

Milestone	Description	Means of Verification	Due
Outreach and Strategy			
M1. GLAM Think Tank established	The GLAM Think Tank operates on an overarching strategic level and is expected to lead to a jointly shaped vision and strategy for exploiting the Big Data of the Past. We propose that this Think Tank consists of GLAM institutions' key stakeholders and representatives of the TMO and is strongly linked to Local Time Machines where applicable.	The Think Tank consists of relevant stakeholders from GLAMs and starts to operate.	YR1
M2. Strategy for the execution of use cases in Fast Speed development	The GLAM Think Tank undertakes measures to foster idea exchange between Fast Speed development and Steady Speed development. The goal is to ensure the applicability of Time Machine developments in the GLAM sector. Idea exchange happens in a well-defined structure, in the form of use cases. Formulating use cases for the GLAM domain facilitates the identification and clarification of system requirements on an operational level.	Strategies are in place to implement the infrastructure for an agile workflow to execute use cases.	YR2
M3. Selection criteria defined	The GLAM Think Tank defines a set of criteria to select GLAM institutions for pilot actions. Defining distinct scales for pilot actions is crucial in serving a range of potential partners in the GLAM sector. For pilot actions, it is essential to reduce entry barriers to allow both established institutions and smaller organizations to participate.	A set of criteria for selecting GLAMs is defined, documented and disseminated by the GLAM Think Tank for TMO members and other interested partners.	YR2
M4. GLAM pilot selected	For pilot actions, a limited number of GLAM institutions is chosen based on selection criteria. Potential selection criteria could include an institution's profile (established vs. new player), framework conditions (varying depending on location), and alignment with Time Machine's vision, mission, and values.	First GLAM institution(s) are selected for pilot actions.	YR3
M5. Test scenario refined	Tailor-made test scenarios for pilot actions are based on both top-level criteria by the GLAM Think Tank and on the specific characteristics of selected GLAM institutions.	The GLAM Think Tank and selected GLAM institution(s) agreed on concrete test scenarios	YR3
Exploitation Pilots			
M6. First pilot action launched	The methodology for executing the first pilot action is defined and agreed on by the GLAM Think Tank and selected GLAMs. Specific test scenarios can now be executed in the first pilot action and are expected to lead to new insights for subsequent pilot actions.	First pilot action starts with selected GLAM institution(s).	YR4
M7. Pilot actions executed	Ongoing pilot actions end and pave the way for generalised models. In general, GLAM institutions interact with Time Machine in three ways, or "roles": data contribution, data processing, and data use. Ideally, the designed pilot actions catered to these roles.	Pilot action for selected GLAMs ends officially.	YR7
Infrastructure for Support and Sustainability			
M8. Impact monitoring of pilot actions	Assessment measures for pilot actions and tests are based on the concept of impact, focusing on *digitization*, *indexing*, *connection*, and *experience*.	The infrastructure and methodology for impact assessment is established. Impact monitoring is established as an on-going action.	YR7-8
M9. Generalised models derived from pilots	Creating generalized models based on outcomes of pilot actions and impact assessments enables a large-scale roll-out of the Big Data of the Past.	A specified number of generalized models is derived from learnings in pilot actions.	YR6-8
M10. Sustain-ability plan	Insights of pilot actions and smaller experiments will be continuously documented in a long-term sustainability plan.	A sustainability plan is developed and subsequently disseminated.	YR7-9

Milestone	Description	Means of Verification	Due
Large-Scale Implementation			
M11. Large scale roll-out of TM services for GLAMs	Based on models and generalized principles and according to the sustainability plan, eventually, this activity will allow for large-scale EU-wide exploitation of Time Machine in a GLAM domain. The large-scale roll-out will provide data, services, and tools for the greater good of European society.	The well-tested interplay between Time Machine and GLAM institutions is now ready to be rolled-out on a large-scale.	YR 8-10
M12. Coope-ration on a global scale	The on-going outreach is ramped up for exploitation on a global scale.	The first cooperation with non-European GLAM institution is established.	YR10

Creative, Media and Entertainment Industries

Milestone	Description	Means of Verification	Due
Outreach and Strategy			
M1. Creative Industries Think Tank established	The Think Tank, consisting of key players in the industry and Pillar 3 representatives, guides the overall development of the exploitation roadmap for the Creative Industries and oversees its effective execution throughout the 10-year roadmap period.	The Think Tank established with representative from all target groups within the creative industries.	YR1
M2. Strategy for the execution of use cases in Fast Speed development	The Think Tank develops a strategy the ensure active participation of the creatives industries in the execution of the use cases in the Fast Speed development throughout the 10-year roadmap.	A strategy for outreach and collaboration with creative industries is put in place. Infrastructures that are needed to executed the use cases are identified.	YR1
M3. Case Studies	The Case Studies illustrate how Time Machine innovations create impact across the Creative Industries sector. They explore different business models for exploitation, showcase success examples and highlight how the sector could benefit from the Time Machine.	Initial round of high-impact case studies with prominent players in the creative industries are prepared. After the initial case studies in year 2, further case studies will be executed as necessary.	YR2
M4. Creative Industries Hub Infrastructure established	Time Machine connects to pre-existing creative hubs and networks to establish itself as a potential collaborator.	Stakeholders in the creative industries approached and strategic collaborations with relevant ancillary networks established.	YR3
Exploitation Pilots			
M5. Launch of Incubation Activities	To support creative entrepreneurship, LTMs will act as incubation hubs providing an environment to experiment with Big Data of the Past and test new creative products. Incubation includes activities such as ideation bootcamps and creative residencies.	Methodology established and first incubation activities around LTMs launched.	YR4

Milestone	Description	Means of Verification	Due
M6. Pilots with Creative Industries executed	A number of high-impact pilots are executed with organisation from various creative industries. The pilots use of state-of-the-art technologies made available by the Time Machine. They are user-driven and address societal challenges, ranging from fighting misinformation (journalism) to assist people with disabilities to experience cultural heritage (interaction design) to showcasing the need for responsible AI through artistic interventions.	Successful execution of pilots and exploitation of Time Machine innovations that lead to new creative products and services.	YR7
Infrastructure for Support and Sustainability			
M7. Launch of Licensing Hubs to support new business models	The hubs oversee fair licensing regulations, remuneration and provide support to its users, including training material and resources on reuse possibilities with the Big Data of the Past.	Adoption of licensing models across creative networks in Europe.	YR7
M8. Impact Monitoring	The TM Observatory monitors trends and measures the impact of exploitation in the Creative Industries. It provides recommendations for stakeholders in the Creative Industries and informs decision-making bodies.	Number, quality, representativeness of datasets in the Time Machine Observatory. Scientific evaluation of the impact assessment methodology. Number of recommendations adopted in national and EU policies.	YR8
Large-Scale Implementation			
M9. Large-scale roll-out of Exploitation across Europe	LTMs across Europe implement sustainable models for supporting exploitation at scale.	Support scheme in place for collaboration with star ups and scale ups to execute pilots via LTMs across Europe.	YR8
M10. Outreach and Exploitation with Creative Industries globally	The outreach strategy is extended to Creative Industries globally.	Collaboration established with global creative networks, strategy for global exploitation models created.	YR10

Smart Tourism

Milestone	Description	Means of Verification	Due Date
Outreach and Strategy			
M1. Pilot case defined	Following the 3S strategy, a special attention will be made to select the region whose priority is smart tourism. Moreover, the presence of a robust LTM, already well organized and with clear objectives in mind regarding its input to smart tourism should be considered a decisive parameter to play a key role in the selection. A survey of eligible regions corresponding to both requirements will be carried out.	Selection of a region with 3S prioritized strategy to Smart tourism as well as its robust LTM.	YR1
M2 Local 3S and LTM smart tourism cluster established	Interaction between the selected region and LTM for the creation of a smart tourism CH cluster. Definition of a set of priorities regarding the users' nature on the one hand (e.g. thermal or wine-industry tourists) and the region's most attractive points on the other hand, set to reshape smart tourism	Local TM and local 3S cluster define priorities regarding targeted tourist profiles, CH prioritized narratives, CH local destinations.	YR1

Milestone	Description	Means of Verification	Due Date
M3. Reaching out for the local tourist industry	The cluster proceeds to a selection of a number of local destinations to be used as pilot cases involving the local tourist industry included in the cluster.	Mapping strengths and weaknesses of local tourist destinations, priorities according to local operators.	YR2-3
M4 CH prioritized narratives refined	The newly-created smart tourism cluster selects a number of use cases based on the evaluation of a robust and willing destinations to welcome tourists or remodel their tourism industry into a more sustainable one. The creation of new narratives is tailored according to the specific properties offered by each selected destination	Piloting targeted tourist profiles through narratives to specific destinations.	YR2-3
Exploitation Pilots			
M5. Collaboration with core re-users: a local creative industries hub	Having selected the targeted destinations and spelled out their narratives, a local creative industries hub is created in order to define what core re-users expect from the cluster	Defining work pipelines, best practices.	YR4-5
M6. Launch of the pilot technology-driven products and services	Having defined the targeted destinations, their narratives and established with the creative industries' hub the working pipelines and bast practices, the pilot cases are put to test on targeted tourist profiles through the technology-driven products designed by the creative industries on the basis of the local smart tourism industry's input and using LTM's data	Testing narratives in pilot apps and technology-driven products and services on targeted tourist profiles.	YR4-5
Infrastructure for Support and Sustainability			
M7. Approaching infomediaries	Most of the tourism industry today is moving through two main channels: large-scale tourist agencies mainly responsible for guided tours and aggregating platforms. These infomediaries must be involved at the present stage in order to launch the technology-driven smart tourism products based on regional narratives and understand the communication strategy for each type of potential customer	Testing products and services' use and diffusion.	YR6
M8. Measuring customer satisfaction	Monitoring the statisfation of both infomediaries, core re-users (creative industries), and tourists themselves: measuring strategy, data used, products and narratives to understand their effectiveness	Test on end-users of products and services in destinations and use in a Life-Long Learning perspective.	YR7
Large-Scale Implementation			
M9. Building a TM smart tourism model	The regional cluster uses ETIS (European Tourism Indicators System) to measure the impact of the products and narratives have on sustainable destination management and proceed to build a model based on RFCs	measuring social, cultural and economic impact on local tourist industry according to ETIS.	YR8-9
M10. 3S local hub activity rollout	Strategy applied to other regional destination following the testing of the model's reliability	Defining diffusion strategy and business model.	YR10

Smart Cities, Urban Planning, Land Use and Territorial Policies

Milestone	Description	Means of Verification	Due Date
Outreach and Strategy			
M1	Thematic Time Machines Committee established	Mandate and composition published, as well as 1st meeting agenda	YR1
M2	3 Thematic Time Machine roadmaps developed (1 on Smart Cities, 1 on Land Use, 1 transversal)	Roadmaps aligned with other Pillars and presented at key events of the corresponding domains	YR4
M3	First call for TM land-use digitisation proposals	Number of submissions, number of selected proposals	YR1
M4	First call for TM land-use learning from the past proposals	Number of submissions, number of selected proposals	YR2
M5	Knowledge graph, reference datasets and guidelines published	Coordination with Pillar 1 development of the TM Knowledge Graph	YR2
Exploitation Pilots			
M6	Definition of Use cases associated to Thematic TM	User story available on teams and validated by other pillars	YR1
M7	Challenge platform, and one challenge published	Number of participants who take the challenge	YR2
M8	Knowledge graph associated to samples of reference datasets specified, version 0	Paper in a Semantic Web journal	YR2
M9	Collaborative platform, and one regulation and related datasets referenced on it	Access to the platform granted to TMO participants for beta testing and then open	YR4
M10	Prototype of TM Land Use debating platform, presented to EC and voting platforms	Feedback from EC and from voting platforms	YR6
M11	Prototyped connections between existing Smart City and Land Use portals and Local Time Machines	Added functions (or scope of existing functions) on existing portals based on the connection with LTM	YR5
Infrastructure for Support and Sustainability			
M12	Sandbox for European culture friendly Smart Cities and Land Use information systems, connected to Local Time Machines.	Creation of teaching material and prototypes using the sandbox	YR5
M13	Second call for TM Land Use Digitalisation Proposals	Number of submissions, number of selected proposals	YR7
M14	Second call for TM land-use learning from the past proposals	Number of submissions, number of selected proposals	YR7
M15	Exploitation of TM Knowledge Graph in Smart Cities or Land Use projects out of TMO community	Survey to detect them and report	YR8
M16	References to TM challenge platform in publications and in projects stemming from outside TMO communities	Survey to detect them and report	YR8
Large-Scale Implementation			
M17	Master program	First promotion of students	YR9
M18	Proposed implementation of INSPIRE historical data, as well as UN GGIM, using TM protocols	Official document issued by INSPIRE Working groups as well as UN GGIM Europe	YR9
M19	References to historical assets in debate and in regulation and in public debates related to Smart Cities, related to Land Use	Survey to detect them and report	YR9-10

Table 3-7: Milestones and Time Plan for Pillar 4

Thematic Area / Milestones	Time										
	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	YR1
Dissemination and Communication											
1.Dissemination and Communication Planning and Structuring											
Dissemination Plan and Strategy: initial / revised versions											
Development and implementation of Communication Hub, Design Hub, Helpdesk											
2. Stakeholder Relations and Events											
TM yearly events/workshops/meetings organized											
3. Partnering with Associations											
Partnering with associations: structures and materials: initial / revised versions											
Operation of partnering with associations											
Policy, Legal Issues and Ethics											
1. Policy and Legal Issues Analysis and Structure											
Policy and Legal Issues Analysis: initial / revised versions											
Central Legal and IPR Support Helpdesk established											
2. Support Structures and Services											
Toolkit for legal issues for TM's network operations: initial / revised versions											
TM ethical guidelines: principles & values: initial / revised versions											
Knowledge Transfer (Management)											
1. Knowledge Management Framework											
Knowledge management concepts, processes, tools: initial / revised versions											
Monitoring											
2.Project Partnering											
Project Partnering Scheme: initial / revised versions											
3.Training schemes											
Training and certificate programmes: initial / revised versions											
Exploitation Support Structures											
1. Project Scouting											
Structures and schemes: initial / revised versions											
Project Scouting Service operation											
2.Entrepreneurship Structure and Service											
Innovation Hub structures and schemes: initial / revised versions											
Innovation Hub operation											

4 Implementation plan

4.1 Time Machine Governance

The two-stage approach

Time Machine benefits from an existing governance structure: the Time Machine Organisation (TMO). The TMO idea began development during the TM CSA preparation phase and matured over the following months, enabling official launch as an Association under Austrian law in 2019.

TMO will move TM forward by securing the resources needed to begin the implementation phase of the LSRI, so the key requirement to enable immediate action was to have in place a governance scheme that is oriented towards obtaining funding and implementing projects that contribute to broader TM objectives. The target is for the "current TMO" process to reach a stage where a stable framework is achieved, offering conditions of uninterrupted long-term planning that may come from:

- A dedicated funding instrument, like the European Partnership scheme
- Strategic agreements with different funders for sustained support over different programming cycles
- A combination of the above

In the event of reaching one of the conditions listed above, a new structure – the "future TMO" – should should have the capacity to implement the larger-scale sets of research and innovation actions discussed in section 3. This transition from the current to the future governance scheme is schematically represented in Figure 4-1.

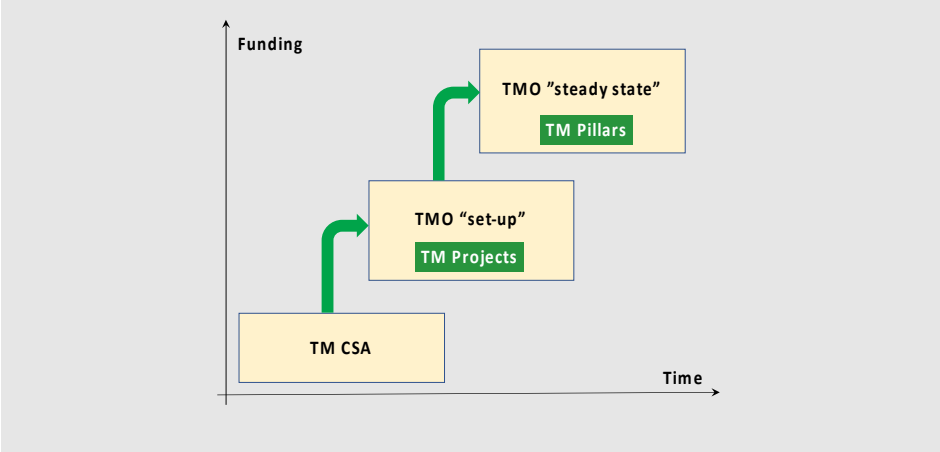

Figure 4-1: From the TM CSA to the future TMO governance scheme

Therefore, the way the TMO governance structure will evolve depends largely on the funding sources and the conditions for long-term funding that can be secured.

Three main cases can be considered at present, as discussed below.

Cases depending on funding secured	Consequence for governance scheme
A. Sufficient and sustained funding is secured, whereby TMO assumes responsibility for implementing an LSRI through a strategic cooperation with one or more major research and innovation funders such as the EC.	A new future TMO structure must be developed to cope with the requirements of a LSRI.

B. Financial support must be found via regular calls around dedicated sub-projects, which places a strong operational focus on securing funding, as in the current TMO stage.	The current TMO structure may remain unchanged
C. A hybrid scenario, where part of the funding needed for the implementation of the TM strategic agenda is secured, while some TMO sub-projects and corresponding consortium members are obliged to obtain the necessary resources through EC or national calls.	A combination of the current and future structures will need to be elaborated at a time when TMO will be in position to make a closer assessment of the long-term funding opportunities.

A decision on which way to progress should be taken when detailed plans are available for the implementation of Horizon Europe and other programmes of the next funding period (2021-2027), enabling the TMO to assess the degree to which these resources can support the TM agenda. An appropriate time for such decision is therefore projected to be during Q4 of 2020.

The current TMO

The management functions

The organisational scheme of TMO is schematically represented in Figure 4-2.

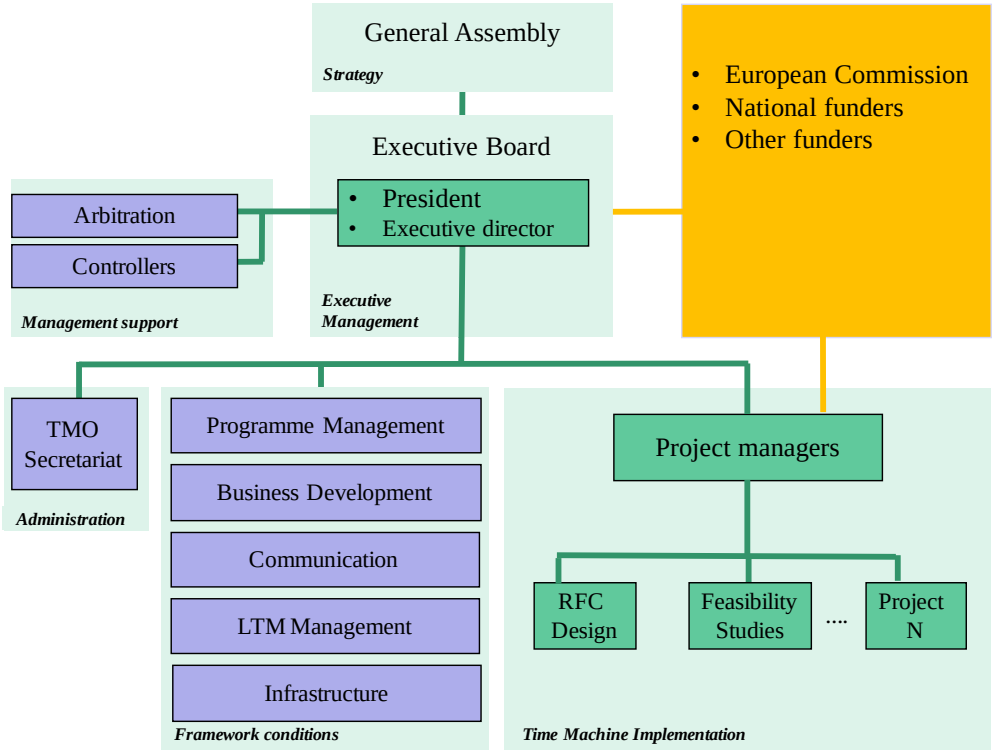

Figure 4-2: Organigram for current TMO

The General Assembly is in charge of overall strategy and governance. The Executive Board has responsibility for the implementation of the TMO strategy, while the TMO President undertakes overall management and interaction with external stakeholders, including the funding organisations. An Executive director is in charge of the day-to-day management and coordination of TMO actions.

The governance scheme also comprises:

- For implementation: management structures tasked with carrying out projects, following the hierarchy of project manager, work package leader and project team, with reporting levels and lines that are coherent with the complexity of each project. The project managers will be nominated based on profiles matching the specific project requirements.
- For management support: the Arbitration Panel functions as the highest level for resolving any issues that are escalated to the GA, and financial control functions for the audit of the TMO's financial activities.
- For framework conditions: the organisational units are (a) programme management, (b) business development, (c) communication, (d) LTM management and (e) infrastructure.
- For administration: the TMO Secretariat which deals with administrative and financial aspects of TMO operations, including the management of TMO memberships.

Box 4-1: Specific management functions for framework conditions

Framework conditions refer to actions that enable the TM research and innovation projects to be initiated, as well as to maximise their socio-economic impact. The corresponding management functions for the current TMO are described below.

Programme management

The target of the Programme management function is to maintain and to continue to build upon the Working Groups formed during the TM CSA, specifically actions related to:

- Preparing policy/position papers in relation to funding opportunities or incorporating the Time Machine agenda in different initiatives.
- Updating TM research and innovation roadmaps
- Obtaining feedback on results / other developments during the implementation of projects
- Promoting the exploitation of project outcomes

Coordination structures are foreseen in the following thematic areas of TM:

- Science and technology
- TM Infrastructure
- LTMs
- Scholarship and education
- Exploitation areas: GLAM, Creative Industries, Smart Tourism, Smart Specialisation, Spatial Components
- Policy, legal aspects and ethical issues, open data

Business development

The business development targets are defined on an annual basis, taking into account the funding needs and overall growth plans of TMO. The corresponding plans are elaborated, following an analysis of potential funding sources, as well as cooperation opportunities with other initiatives. A Business Development Manager, nominated by the Executive Board, presents proposals to reach these annual targets, in close cooperation with the Executive Board.

The Business Development Manager coordinates a business development panel formed by representatives of TMO members, with support from the Executive Director. The main task required is to collect calls and other funding opportunities from and for all partner institutions. Core activities are those related to following-up the development of the European Partnership ideas, maintaining a continuous dialogue and fostering positive interactions with related initiatives.

Communication

Communication plays a crucial role in establishing TMO as a key player in the area of cultural heritage and in supporting the development of the TM LSRI. In this framework, the communication objectives are to:

- Strengthen and expand the TMO membership base by raising understanding of the initiative itself and its expected benefits to the European and international cultural heritage communities.
- Further develop the existing Working Groups (WGs) in stakeholder networks comprising researchers, innovators, decision-makers and other members of civil society. While taking active role in the implementation of the TM agenda, these networks will produce substantial communication-multiplier effects across the EU and worldwide.
- Promote TM to the European Commission and other funding institutions, thus creating favourable conditions for its financing through Horizon Europe, Digital Europe Programme, European Structural and Investment Funds, and other regional, national, transnational and pan-European funding mechanisms and schemes for cross-border cooperation.

To ensure smooth and coherent communication with stakeholders and target groups, the professional Communication Hub established during the TM CSA will continue its operation in close cooperation with the Executive Board.

LTM management

The LTM management function is responsible for relations between the TMO and LTMs, ensuring strong collaboration with coordinators and communication flow between key stakeholders. Duties include:

- Further developing the typology of LTMs based on level of maturity
- Inventory state of the art of all existing/planned LTMs, assign Level of maturity
- Identify coordinators, manage the network
- Coordinate the organization of the LTM Academy events

This role will require close interaction with the communication and business development functions to ensure continued growth and broad dissemination of results.

Infrastructure
This management function is in charge of developing the infrastructure that will facilitate the implementation of TMO actions, including:

- Administrative infrastructure, including resource management platforms and related hardware.
- Communications infrastructure/platforms for the internal online cooperation of TMO teams (e.g. MS Teams).
- Communication infrastructure/platforms for external actions: managing development of existing websites and the creation new sites for sub-projects / conferences and similar needs.
- Infrastructure for supporting project management by TMO and external partners who provide resources.
- Infrastructure facilitating coordination, for example developing common approaches for LTM specific needs, cooperation and promotion.
- Infrastructure supporting business development, including operation of the business development panel, opportunity follow-up and partner matching services for projects.

The Executive director will be responsible for developing this management function in cooperation with the Executive Board and managers who will use the platforms and tools to be developed.

Administration

The TMO'S governance is supported by the TMO Office, which consists of a Coordinator and a Secretary, complemented by one or more assistants. The primary responsibility is to ensure technical cohesion and coordination among the different organisational units and the TMO members.

Administration, therefore, refers to the following functions:

- Internal administration and finance
- Member management

Decision making processes

TMO has decision-making mechanisms placed at different levels.

Strategic and development-focused decisions are taken at the level of the General Assembly. Such decisions may involve:

- Appointing, suspending or dismissing members of the Executive Board
- Deciding on strategies for the construction and exploitation of TM results
- Approval of the TMO work programme and annual budget
- Accession/termination of new members
- Decisions on changes of TMO's status

The implementation of the TMO strategy is undertaken by the Executive Board that has responsibility for:

- Formulating policies and plans, internal procedures, the global operational plan and budget, annual reports, and for confirming that all of the aforementioned items are adequately executed.
- Making decisions on all operational matters

The Management structures are responsible for the daily management of the activities in their field of action, in cooperation with the Executive director, as described for each management function in section 3.1.

Monitoring and evaluation mechanisms

Measuring the outputs, results and impact of the TMO is recognised as a crucial management practice. Key Performance Indicators (KPIs) will be elaborated by the Executive Board to measure the technical progress of each work stream, the outcomes of actions initiated involving the TMO, and the longer-term impact. Tools to monitor/measure these KPIs will be put in place.

The monitoring and evaluation framework will be defined by the Executive Board. The KPI monitoring and follow/up will be done at the level of managers and regular bi-annual meetings will be conducted to assess progress. On an annual basis, the Executive Board will prepare an overall assessment of progress made in relation to fixed objectives and targets for the period and present a report with main findings, as well as lessons learned and recommendations for the following reporting period.

The action plan

The implementation of TM under the current TMO will be based on a rolling programming process that is dependent on available funding resources. The process is illustrated in Figure 4-3.

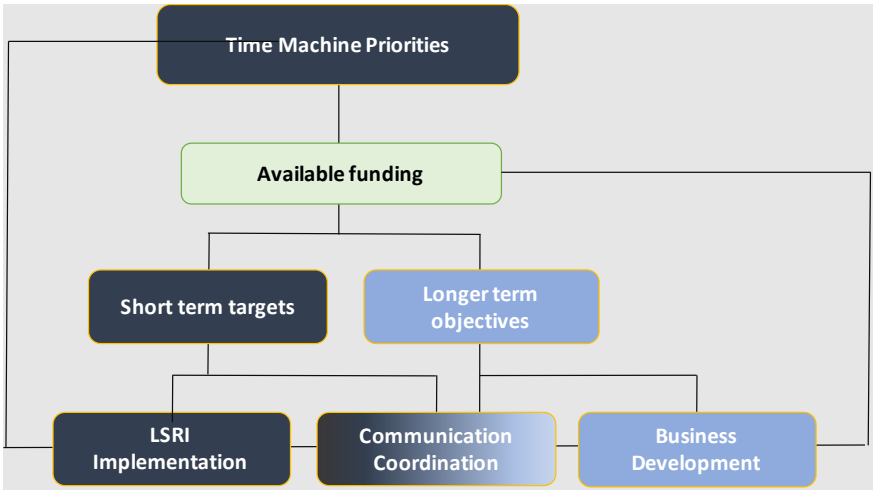

Figure 4-3: Planning process for the current TMO

The starting point for the programming cycle is the TM roadmap which defines the priority objectives to be achieved over a given period of time. Based on available funding, the Executive Board prepares a proposal to be approved by the General Assembly, defining:

- The short-term targets and the associated implementation plans for the current programming period
- The longer-term objectives that should receive attention during subsequent programming periods
- The communication and coordination actions that support implementation in the current period, as well as objectives to be reached in future programming periods

- The Business Development objectives, specifying resources to be secured for the future programming periods.

Bi-annual reporting periods are foreseen for progress assessment and work reprogramming by the Executive Board.

The key priorities of the TMO in the post-TM CSA period are aligned with priority actions identified in the TM roadmap. These can initially include[11]:

- Rules and modalities for the development of RFCs
- Rules for LTM management and coordination
- Designing the use cases to enable work on Scholarship to begin
- Feasibility studies for other exploitation areas
- Start of specific beacon projects

This priority list defines the actions / internal projects that can start being implemented. It also specifies the targets for the other Management Functions:

- The Business Development Manager has a clear focus on the search for and exploitation of opportunities, concentrating on the ones that fit with the priorities mentioned above.
- The Communication Manager designs and implements tasks for supporting the priority actions, specifically via targeted campaigns for relevant funding institutions and key stakeholders. In parallel, the goal is also to promote TMO broader objectives, in particular by planning events such as the annual TM Conference.
- The Programme Manager direct the cooperation across the expert networks in a way to support these objectives.
- The Administration manager ensures that TMO provides adequate administrative support to the above, along with the other TMO administrative tasks.

The future TMO

The management functions

The governance scheme of the future TMO, represented in Figure 4-4, is designed for the case where sufficient LSRI funding has been secured, either through a strategic partnership framework with the EC and/or other national and international funding organisations. Such strategic framework cooperation is based on the implementation of a Strategic Research and Innovation Agenda (SRIA) that may include all or the most critical parts of the TM research and innovation agenda presented in Section 3.

The implementation of the SRIA is supervised by joint governance bodies that take the form of:

- Governance fora, where senior representatives of the funding institutions and the TMO have strategic discussions aimed at synchronising activities funded by different entities and maximising synergetic effects for the benefit of the LSRI
- Steering Committees involving senior management of the parties involved, focusing on progress in the implementation of the TM agenda, forward planning and operational matters to be addressed at this level.

The future TMO has the following organisational units:

[11] Decision of the Executive Board, within a framework programme to be agreed by the General Assembly

- The General Assembly, where all partners participate as voting members, remains the highest decision-making body for both the strategy and overall governance.
- The Executive Board for the implementation of the TM SRIA.
- Research and innovation divisions for the implementation of the Time Machine Pillars.

The TMO operation is facilitated by the support functions described below:

- At the level of management support:
  - A Strategy and Business Development Unit (SBDU), in charge of elaborating strategic directions and evaluating progress
  - The Controllers, acting as auditors of the TMO's financial activities
  - The Arbitration Panel to resolve any issues that are escalated to the level of the General Assembly
- At the level of framework conditions:
  - Dissemination and promotion
  - Legal and regulatory matters
  - Knowledge and data management
  - Exploitation support

- The TMO Secretariat deals with administrative and financial tasks of TMO operations.

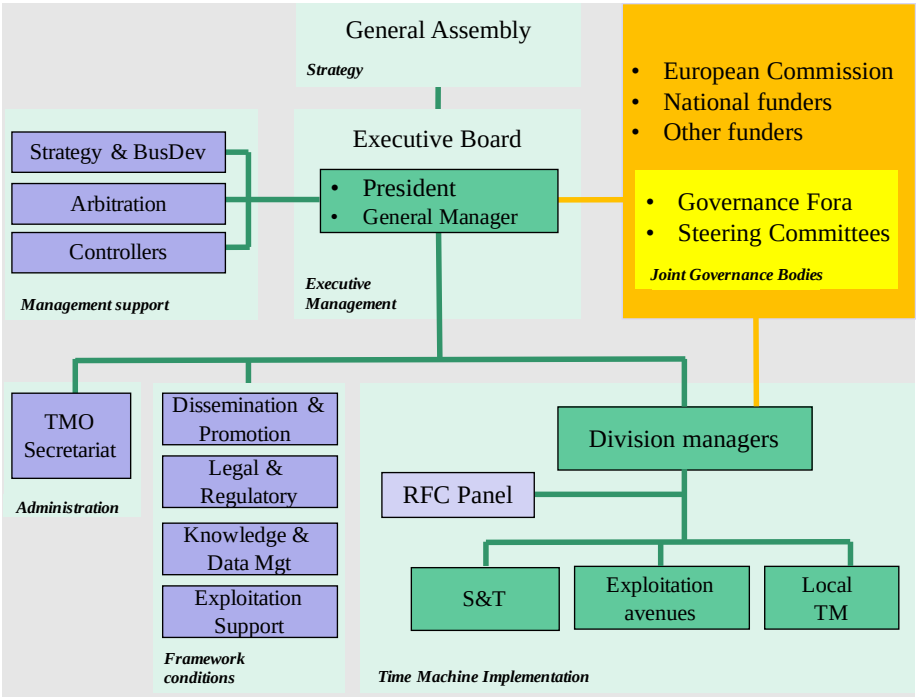

Figure 4-4: Organigram for future TMO

The new organisational structures

Implementation

Divisions are formed based on the pillars defined in the SRIA, organised around the broad topics of:

- Science and Technology
- Exploitation Avenues

- Local Time Machines

The specific objectives to be attained by each division are presented in the SRIA.

Division managers coordinate the implementation of projects under their responsibility, ensuring that broader objectives defined at Division level are achieved. The Division managers are also responsible for organising the work of the project teams under their responsibility in a way that maximises synergies across divisions.

Since the development of RFCs is an integral part in the implementation of TM, an RFC panel continuously supports the planning work in each division.

Support functions

The functions of arbitration and financial control are maintained and adapted to the more complex operational environment of the future TMO. The new element is a "Strategy and Business Development" Unit (SBDU) that will be responsible for advising the Executive Board in the different phases of strategy development, as described below.

Strategy and Business Development

The SBDU is in charge of the annual business evaluation. Conclusions of this exercise, together with an assessment of changes in the broader cultural heritage environment, are used to re-examine the Time Machine Strategic Agenda and to propose changes to the annual strategic plans. Part of this strategy document is dedicated to actions related to business development, including assessments of:

- New funding opportunities at all levels
- New exploitation platforms / use cases

Implementation of the business development actions, for example applications for funding, is coordinated with the Division Managers who identify the resources which can most efficiently contribute to the preparation of detailed proposals for new areas of action.

Advisory panels

The Executive Board can also benefit from advisory panels composed of senior representatives from partners that are not represented in the Executive Board and/or external parties that have a leading position in certain scientific or business fields that are particularly relevant to TM's activities. The panels may have a term of the same or shorter duration as the Executive Board and are nominated by the GA following a proposal by the Executive Board to work under specified terms of reference. The panel's key tasks are to advise on strategic aspects related to important scientific and business issues which may need to be examined / adopted by the TM.

<u>Framework conditions</u>

Dissemination

A central TM Communication Hub will be tasked with developing and implementing the overall communication strategies, action plans and associated material. The Hub will be also responsible for initiating, coordinating and supervising a network of national and stakeholder/domain level subsidiaries. A Dissemination Helpdesk will be established and maintained to support practical implementation of dissemination actions.

Policy Legal Issues and Ethics

The following structures are envisaged:

- A de-centralized first level support helpdesk, operated jointly with extant service providers such as libraries / associations etc. (first level support)
- A central legal hub which operates and coordinates the first level support, assigning tasks to third level of support and commissions. (Second level support)
- A network of legal experts / consultants on a national, domain-specific level to answer questions and investigate specific issues (third level support)
- Commission for Law and Ethics: Regularly meeting commissions for assistance with strategic decisions and supervision

Knowledge Transfer

An IP Management Hub will be created, and principles and workflows will be handled in the IP Management Plan. This plan will be developed in order to set guidelines and principles for the process from IP creation to exploitation. It will deal with IP Management in three strands: IP Commercialization, IP Asset Management and IP Protection Plan. The plan will also endeavour to assess the innovation potential and capacity of IP.

Exploitation

An Exploitation Advisory Board will coordinate and align the exploitation strategies and activities of the TMO, including LTMs. The board will ensure proper implementation of the strategy and its continuous adaptation to the changing needs of TMO and its target markets/sectors/exploitation avenues.

The TMO Exploitation Hub will serve as the executive arm of the Exploitation Advisory Board and will be responsible for the operation of the exploitation structures, services and mechanisms of TMO. The main objective around which this Hub will be designed is to support all forms of exploitation of TM outputs and outcomes with sound advice and hands-on assistance, as required, provided by experienced professionals engaged to cover the different thematic areas of TM.

4.2 TM ecosystem and synergies with existing/planned initiatives

The TM network comprises more than 600 organisations from 34 countries (as of December 2019), including members that have stated their strong commitment to participate in the LSRI:

- Europe's top-level academic and research expertise – close to 200 academic and research institutions – for all key science and technology challenges in the project.
- A huge representation – more than 100 organisations – from GLAM, providing cultural, historical and geographic material and expertise to the TM.
- Private sector partners – about 100 companies – that will contribute to the actual implementation of TM infrastructure and/or the development of services around TM.
- Institutional bodies, including:
    - the Italian Ministry of Culture and the French Ministry of Ecological Transition and Solidarity
    - the Regional Office for Science and Culture in Europe of UNESCO
    - several national cultural heritage agencies (Belgium, Netherlands, among others)
- Strong civil society and industry associations, including:
    - Europa Nostra, an NGO with a long contribution to the development of heritage-related policies at EU level in cooperation with the EU institutions and the Council of Europe
    - the Big Data Value Association (BDVA) that represents 190 EU Data Users, Data Providers, Data Technology Providers and Researchers

A strong indication of TM's sustainability potential comes from the fact that more than 80% of these

organisations have agreed to be part of the TMO, thus providing active support for the continuation of the initiative.

As mentioned previously, Time Machine intends to position itself as a community of communities, fostering relations not only between itself and digital cultural heritage stakeholders but also among the related stakeholders themselves. Mechanisms for an intensified interaction are planned which will foster the European Research Area in Digital Cultural Heritage and strengthen the impact of TM in technological, societal and economic domains.

The actions and initiatives of TM are built upon the impact of existing initiatives, programmes and projects. Existing efforts and achievements will be reinforced to bring additional stimulus to current initiatives with complementary roles and goals. TM will focus on creating synergies among existing European level research and innovation systems, programmes, funding schemes, instruments, projects and initiatives.

TM has already secured the support of major initiatives related to the digitisation of European heritage, having already signed Memoranda of Understanding for common action with:

- Europeana (also a member of the TMO Executive Board)
- CLARIN
- The Cultural Heritage JPI

Relations will be further strengthened by the following initiatives that support Time Machine:

- Archives Portal Europe
- The Digital Research Infrastructure for the Arts and Humanities (DARIAH)
- The European Research Infrastructure for Heritage Science (E-RIHS)
- EUscreen – European collaboration of Broadcast and Audiovisual Archives
- The European Spatial Data Research (EuroSDR)
- The Consortium of European Research Libraries (CERL)
- The International Image Interoperability Framework (IIIF)
- The European Association for Urban History (EAUH)
- The Common Lab Research Infrastructure for the Arts and Humanities (CLARIAH)

A number of actions are planned to promote synergies with other actors and initiatives, such as those described below :

- TM initiated a survey to understand the regional, national and European level schemes in the area of cultural heritage related research and innovation, including policies, funding programmes, projects, initiatives, skills, future trends and actors. The survey results provided a basis upon which TM will configure its exploitation support structures and initiatives to reinforce existing measures.
- The state of the art with regards to complementary initiatives and projects are analysed in two ways. Best practices of large scale European research and innovation initiatives are analysed, for example current FET Flagships. Moreover, the projects of similar and complementary themes to TM are analysed with respect to their achievements. This information provide the background needed to develop activities that would reinforce existing efforts, providing greater impact and positioning TM to develop valuable synergies.
- It is envisioned that TM will inform and enable international and European associations on technologies available to support their requirements for digital transformation and organizational change. In addition, TM will incorporate their perspectives and competencies as part of the TM development process and leverage synergies in relevant fields. In this respect, and framed by the TM principles and values, the following sub-actions are proposed:

    - Implementation of an advisory board of European and international level organisations/associations
    - Frequent consultation panels/workshops to analyse the needs of organisations/associations, to determine synergies and to develop joint actions towards common goals where prudent
    - Enabling a joint membership option that will allow members of partner organisations to jointly register as a member of the TM organization
- TM plans to disseminate key messages and outputs via training programmes and events. Training programmes for researchers, GLAM professionals and PhD students will be developed and maintained, while partnering mechanisms for educational programs and events will also be initiated. These efforts will be refined by maintaining an overview of all training programs of relevance for the TM as well as developing mechanisms to place relevant TM topics in syllabuses and include them in key events.
- Recommendations and support for legal initiatives concerning digitisation of cultural heritage will be provided. TM aims to propose a legislative and regulative framework to lead authorities and the TM community, providing consultancy services for implementing the content produced into EU wide practices and framework conditions for digitisation of cultural heritage.

4.3 Funding

The required extensive, long-term and sustained effort to reach TM's ambitious objectives exceeds by far what can be achieved in typical national or European research and innovation projects. Moreover, as digital preservation of cultural heritage is a priority in almost every EU member state, it is crucial to align national research agendas and manage multiple projects and networks in different European countries and cities.

Time Machine was initially conceived as a FET Flagship, which would receive half of its funding from Horizon Europe and the other half from alternative sources. The TM partners have, therefore, examined different forms of funding from the very beginning of the project. Table 4-1 below indicates the different sources of funding, taking into account the current state of design of the various financial instruments that will be available in the upcoming programming period (2021-2027).

Most activities of TM Pillar 1 and the more research oriented contributions needed for TM Pillar 3 relate to the Horizon Europe (HE) clusters Digital, Industry and Space and Culture, Creativity and Inclusive Society (HE Pillar II). For the former cluster, TM will develop multimodal historical and geographic datasets of an unprecedented semantic complexity that will give a new impetus for big data research, methods and application fields. Due to its transversal nature as a backbone for critical technologies, TM is expected to contribute to many other areas of HE, including AI, big data and machine learning in Pillars I and II of HE, and to give a strong boost to SSH topics across HE Pillar III.

Time Machine is particularly relevant to the Digital Europe programme's broad area focused on ensuring the wide use of digital technologies across the economy and society which has a pillar specifically dedicated to education and culture. A number of activities in TM Pillars 2 and 3 are fully aligned with these objectives. The TM agenda will also have synergies with other areas, including supercomputing, AI, and advanced digital skills.

The TM approach offers concrete methodologies and tools in line with the objectives of the Creative Europe successor programme. In this respect, TM will also be crucial in giving a more active role to civil society and in developing a structured dialogue among communities of users, based on online collaboration opportunities.

Time Machine will also establish synergies with the Regional Development and Cohesion Funds that are well adapted to support the growth of LTMs, as well as actions related to developing the TM infrastructure as well as the exploitation avenues and uses considered in Pillar 3.

Moreover, there are opportunities for raising private funding, especially in TM Pillar 2 and Pillar 3 actions. Such private investments are expected to be leveraged by specific instruments in next programming period, including the successor to COSME and the future InvestEU Fund, particularly in digital infrastructure, digital transformation of small businesses, research on digital technologies and helping the social economy to benefit from digital transformation. Related funds will be relevant for developing TM infrastructure, initiatives related to new education programmes, as well as the specific application areas for GLAM, creative industries, smart tourism and smart cities.

Table 4-1: Possible funding sources for the Time Machine pillars

Time Machine Pillar	**Funding sources**							
	Horizon Europe			Erasmus	Digital Europe	Creative Europe (II)	ESIF	Private funds
	Pillar I	Pilar II	Pillar III					
Pillar 1								
Data	x	x						
Computing	x	x						
Theory	x	x	x					
Pillar 2								
Infrastructure					x			x
Community Management					x	x		
Local TM						x	x	x
Pillar 3								
Scholarship		x					x	x
Education		x		x			x	x
Exploitation areas & uses								
GLAM		x	x		x	x	x	x
Creative industries		x	x		x		x	x
Smart tourism		x	x		x		x	x
Smart cities & related areas		x	x				x	x
Pillar 4								
Dissemination	x	x	x	x	x	x	x	
Policy, Legal Issues			x		x	x	x	
Knowledge Transfer	x		x	x	x	x	x	x
Exploitation Support	x	x	x		x	x	x	x

Other sources of funding include:

- **Industrial funding and entrepreneurship** to valorise and co-finance the TM. Sources of funding are investments in research and development via cooperative sub-projects or contracted research as well as valorisation of outcomes via venture capital or start-ups.
- **Exploitation support** such as valorising results in terms of IPR, data or labour force will leverage the outcomes of the TM and therefore add value to TM projects. The process will be facilitated by incubators or other technology transfer intermediaries that will specialise in the big data of the past and required resources, structures, competencies and selection mechanisms. Additionally, innovative formats to support entrepreneurship such as co-creation labs, on-site co-design workshops, e-participation platforms and massive open online trainings or mobile games may be developed.
- **Philanthropic organisations and sponsors** that make important contributions to work related to cultural heritage will be invited to provide direct or indirect support.

4.4 Action plan

The immediate priorities

Time Machine is a large-scale, mission-oriented, multidisciplinary mega project with a broad engagement of actors from Europe and Worldwide. TM's work plan aims to produce a transformative impact on research, technology, economy and society. Its efforts are grounded in multifaceted action areas, due to its broad spectrum of scientific domains, interdisciplinary communities and local engagements. TM requires large scale and continuous funding, resources, skills and collaborations to manage this complex system and to attain its ambitious objectives. Thus, sustainability of resources and collaborations have significant influence on generation of desired outcomes.

The TM implementation process is backed by concrete support mechanisms and services designed from the TM CSA phase onwards. These support structures are intended to reach and to attract various funders, contributors, projects, investors, supporters and collaborators. A coherent strategy to access funding, resources and skills will be implemented in close cooperation with TM's communication and exploitation support mechanisms to drive greater success.

During the bootstrapping phase (2020-2022), we will aim to build components of the TM through available project funding and to create some immediate services for the members. The following priorities are set for TM's bootstrapping phase:

1. Developing and establishing governance structures and mechanisms for the operation of the TM as an LSRI, with the structures planned and launched during the CSA phase being further enhanced. The RFC tree contains specified measures for the establishment and operation of TM governance structures and mechanisms.
2. Organising the community and the growth of TMO:
    - TM aims to harmonize cultural heritage related initiatives in Europe and beyond. This is to enable an innovative, integrated and coordinated approach to cultural heritage related research, innovation and business. TM has already built a strong community base during the CSA phase, and the bootstrapping phase will witness further strengthening of the community through a tailored communication strategy developed for the LSRI.
    - Regionalisation and scalable approaches are among the TMO's growth priorities, and particular attention will be paid to strengthening the activities of and ties with LTMs.
    - To make the TMO attractive to potential stakeholders, we will provide concrete benefits for members. Among those are: the provision of access to network & knowledge base; events (conferences, workshops etc.); tools & technologies; consulting services; infrastructure (servers, databases etc.) and project development support (design, funding instruments, finding partners etc.), as well as the right to benefit from potential Time Machine sub-projects. The communication strategy, the funding hub ervice and the LTMs serve as access points for stakeholder benefits.
3. Implementing parts of the TM roadmaps and planning:
    - To reduce risk and lack of flexibility due to uncertainty of access to large-scale funding, extant schemes will be utilized to access to public and private resources. The impact prototypes, Project Partnering mechanism, RFC Tree and Funding Hub will all be utilised in a coordinated manner in a variety of actions geared towards making progress in this priority area.
    - Use Cases produced by the LTMs during the Fast Speed development will provide visible results with immediate impact and highlight needs for future research in the Steady Speed phase.

4. Realising the strategic aims of the TM in terms of long term funding: The Funding Hub will sharpen its activities to support strategic objectives of the TM. The RFC Tree is organised in such a way that there will be timely launch of actions towards the strategic research and innovation aims of TM.

Actions in the period 2020 - 2022

Based on the TM priorities the following action areas have been identified:

The Funding Hub

Description

The Funding Hub is designed to (a) enable the TMO's financial sustainability via participation in project consortia, (b) support the close connection between TMO and funders and (c) provide additional value to TMO members.

The scope and content of support structures, services, objectives, functions and tasks foreseen for the Funding Hub is based on investigations of (a) Horizon 2020 National Coordination Structures of Member States, (b) European Initiatives (e.g. Graphene FET Flagship, EIT KICs, ECSEL, CLEANSKY, etc..) and (c) Project Support services of European universities, companies and TTOs.

The Funding Hub is designed to initiate competitive proposals for third-party funds, to identify project partners, to provide comprehensive information on funding and funding politics, as well as to offer formal and strategic review of TMO applications. This service also includes actions to gather input for shaping calls for proposals at national or European levels. Services include (Figure 4-5):

- Pre-Proposal Support Service: identification of target group, raising awareness, preparation for partnerships
- Proposal Support Service: proposal preparation, guidance for participation, partner management
- Networking: mapping analysis, partnering events, consultancy

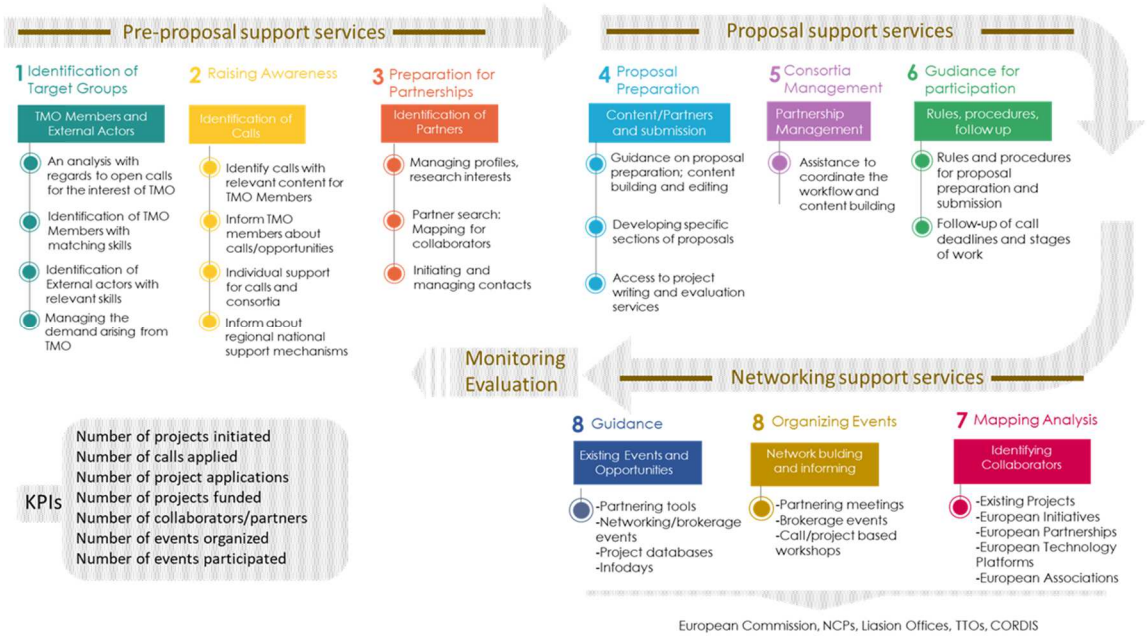

Figure 4-5: Services provided by the Funding Hub

Organisation

The Funding Hub consists of following governance elements:

- The **Project Scouting Team** which serves as an operational unit to execute the proposed services
- The **Executive Director** heads the team
- The **Advisory Board** for supervision and support on strategic decisions.

For operations, a **project participation scheme** defines the conditions under which the TM will participate in or support project consortia. The scheme provides workflows, definitions and instruments to evaluate project participation requests.

Actions

1. Develop and operate the project participation and evaluation schemes
2. Enable and prototype the project scouting service
3. Establish operational structures including the advisory board and the project scouting team
4. Develop and operate strategic initiatives under targeted funding programmes (regional, national, European and international innovation schemes)

Phasing

- March 2020: Scheme for project participation is developed and approved
- May 2020: Basic operation of project scouting service is enabled
- August 2020: Definitions, board and evaluation scheme brought in operation
- April 2021: Review and amendment of hub services undertaken

Funding

The Project Scouting Team will be fully financed and operated by the TMO. National start-up support is currently in progress to co-finance the conception and bootstrapping of services.

Communication

TM`s scientific, technological and societal endeavours are highly interrelated with strong community management implemented from the beginning. Thus, the dissemination and communication strategy was developed and tested during the TM CSA phase and will continue to be expanded and refined as part of TMO operations during the bootstraping phase 2020-2022. The dissemination strategy not only targets building awareness of TM's goals and achievements but also at securing the engagement of all stakeholders, including: research institutions (curricula in Digital Humanities, publications), organisations involved in the management of patrimony (fully integrated platforms for crowdsourcing and citizen science), the private sector, decision-makers and the general public.

TM´s scientific efforts are built on establishing mutual linkages of communication and influence between TM and its stakeholder groups. This will be supported by the central TM Communication Hub. A timely and targeted engagement with a wide range of stakeholder groups: scientists, national and European authorities and funding bodies, private sector, LTMs, national, European and Global cultural heritage associations, philanthropic organizations, citizens is required, and, as such, the progress TM's thematic fields and project implementation, especially via open calls, RFCs, digitization hubs and community management efforts will be managed through the Communication Hub. The strategy foreseen for exploitation avenues, taking place through the stages of collaboration strategy, use case definition and execution, best practice development, prototyping and training, launch of incubations and expansion across TM will also be supported by the Communication Hub in various ways.

TM`s policy of openness from early phases of research, allowing public use of its results, will be enhanced via constant communication actions. Openness will help foster the high level of participation needed to smoothly run TM's scientific and technological endeavours, adopt new concepts and technologies, onboard promising actors to TMO in a timely manner, offer TM results in a useable form to relevant stakeholders, and enable TM's ability to benefit from external expertise in the fullest way.

TM Communication Hub

The TM Communication Hub will continue to ensure smooth and coherent communication with stakeholders and target groups. It is comprised of an expert team on communication strategy and managing all external TM communication. The Communication Hub sets tone and direction so that all communication activities, products and dissemination materials work harmoniously to reach the defined objectives. The communication team guides and supports the dissemination of TM by providing specified services for TM network members, requiring high-quality and coherent information materials and messaging. Furthermore, the Communication Hub works closely with key internal and external stakeholders (TMO Executive Team, network partners, TM professional communities, LTM managers, TM Ambassador network, target audiences etc.) to ensure buy-in, relevance of activities and to offer opportunities for co-creation. It is vital for the Communication Hub to function to its utmost potential to achieve TM's ambitious goals, so the establishment of internal project communication workflows will be prioritised to form a base for long-term sustainability.

Organisational Structure Communication Hub

In order to ensure seamless planning and delivery of communication activities, a clear organisational structure for communication and promotion is needed.

The Communication Team is led by the Chief Communications Officer, who works in close cooperation with the TMO administrative team and the TMO Executive Board.

In concrete terms, this means:

- Ensuring that the defined dissemination rules are followed
- Controlling the content and flow of messages published by TM and partners
- Monitoring and refining internal communication workflows
- Coordinating external communication activities (event participations, presentations, etc.)
- Ensuring dissemination services are available and relevent for partners
- Acting as first point of contact for external requests

The Communication Team acts on various levels: (1) on behalf of the TM network on a pan-European level, (2) with the help of the network partners on a national level in EU Member States and (3) on the level of various stakeholder groups.

Within the TM consortium **National TM Ambassadors** as well as **pan-European TM Ambassadors** have been identified. The TM Ambassadors serve as points of contact for specific national or pan-European requests and inquiries by audiences/policy makers. In addition, the national and pan-European representatives of the TM disseminate relevant key messaging and results on national/regional as well as European level.

Therefore, in each Member State one central contact institution is appointed that collects and delivers relevant information for dissemination to the Communication Team and in turn also promotes TM messages which are prioritised for dissemination in various Member States. The same concept applies for certain stakeholder groups that are organized at an international level.

TM Internal Communication Workflow

In order for the Communication Team to manage content effectively, in particular via the website and social media accounts, internal TM network communication workflows must be established. Ideally, everything concerning the project (news, event participation, comments on topics etc.) should be channelled via the workflows through the TM dissemination channels first and foremost.

A **centralized pool collecting all relevant TM activities** from which the Communication Team can draw from and use to develop communication campaigns must be established.

This will be done by setting up an **online form accessible to all TM consortium members** where all necessary information on upcoming events, research results/updates, conference/workshop participation, important cultural heritage events and/or initiatives/projects that the TM should engage with etc. can be deposited and made available for the Communication Team. This will ensure the Communication Team has all relevant information to prepare and execute effective communication actions.

Using this repository and information flow, the Communication Team will incorporate relevant material into various channels in line with the overall strategy, including: web, social media, press, events, webinars, newsletters, blog posts, print etc.

A system will also be set up with which the Communication Team can manage the **onboarding process for new stakeholders**. This will help to ensure engagement and foster an atmosphere of collaboration in the network.

The Communication Hub will continue to manage both internal and external dissemination and communication processes, and the management of conferences, events and meetings actions and training sessions are among the responsibilities.

TM Communication Hub: Services

The Communication Team provides strategic guidance and operational support in various communication activities for TM partners as well as offers various services for partners in order to support them with their dissemination work. For example, the distribution of materials, press releases or project presentations at various events. Furthermore, the Communication Team will:

- Support the TMO Executive Board with the development of a set of TM principles and values, which will be published on the TM website
- Run campaigns to enlarge the network, including both institutions and individuals
- Maintain extant networks / TM professional communities developed during the CSA phase
- Showcase Use Cases (Fast Speed) from various exploitation avenues
- Ensure smooth internal communication (managing TM Ambassadors, maintain an inventory of member competencies, member profiles, regular internal TMO network updates)
- Facilitate external communication
- Support the organisation of events such as the annual international TM conferences and national TM Info Days with the help of TM Ambassadors
- Support the LTM team with on-boarding of new LTMs, for example via the production of instructional videos on LTMs
- Support the Project Scouting Team with the internal/external communication needs
- Provide templates for PowerPoint presentations
- Support the production of further promotional video material and media cooperation for European storytelling
- Provide visual material for dissemination

- Produce press releases for major events, milestones etc.
- Produce enhanced dissemination material (online and/or print) to demonstrate TM´s progress (brochures, posters, roll ups, give-aways, animated videos etc.)
- Provide templates of printed material in English to be translated and adjusted for national or other specific purposes
- Provide templates for production of banners, flags, brochures etc.
- Support with personal briefing on key TM messages for National and pan-European TM Ambassadors

Phasing

- 1st phase (March-April 2020): **Consolidation of the TMO Administration Team**: The communication workflows and activities already established during the CSA will continue to run, such as: social media presence, regular newsletter, regular international TMO network updates, campaigns to attract new members, communication and cooperation with TM Ambassadors to organise national TM Info Days and inclusion Time Machine Supporters' profiles on the TM website.
- 2nd phase (May 2020 onwards): **Designing and Implementation of new Communication Structures:** Set-up of a system to maintain communication and contact with TM professional communities, either using mailings or another suitable system, creation of newly adapted dissemination material, production of dissemination/instructional videos, development of LTM communication/on-boarding support services, cooperation with national and international media (European storytelling etc.), organisation international TM conference for 2020.

Funding

All activities by the Communication Hub are funded through membership fees and national start-up support.

Request for Comments (RFC)

Description

Time Machine Requests for Comments are freely accessible publications, identified with a unique ID, constituting the main process for establishing rules, recommendations, core architectural choices for the Time Machine components. The RFC Tree defines incremental steps to the building of the fully functioning Time Machine Infrastructure. It already includes more than 70 planned RFCs (section 3.5, Annex C, RFC-2).

- RFC Tree and Use Cases: The initial RFC organisation of the tree is likely to be adapted and densified on the basis on the fast-paced experimentation and locally developed use cases. The use cases bring a constant flux of stakeholder driven needs can directly impact the slow paced planification of the Tree structure. In this context, some RFC may be developed sooner than initially planned. The dependency tree helps judge the possible consequences of these dynamic reorganisations.
- RFC Tree and LTM: Like for the use cases, the RFC tree serve as a central coordination process for the LTM. Each LTM locally develops projects that can help produce technological prototypes and results informing future RFCs. At the same time, the development of the TM pipelines organise the kind of media that can be processed in a standard way and therefore guarantee smooth integration in the global TM Data Graph.

The current state of the RFC development can be followed on the Time Machine Git Hub repository: https://github.com/time-machine-project/requests-for-comments

Actions

For the year 2020-2022, the objective is to establish a sustainable process and workflow for (1) planning, writing and reviewing RFCs and (2) for transforming some RFCs into services. Targeted results are:

- Establishment of the full process for RFC Writing and Reviewing (RFC on RFC (RFC0), RFC on RFC Editorial committee (RFC3), RFC on Publication Platform (RFC4)
- Writing and publication of the RFC planned in the RFC Tree (defined and updated on the RFC on RFCs Tree (RFC2)). Current list includes 15 planned RFC for 2020 and 13 for 2021 (see below)
- Implementation of the RFC Platform using an open-source publishing system.
- Creation of the RFCs committee and appointment of the RFC Editorial Director
- Publication of the RFC0 defining the rules and process for the RFCs.

Organisation

The general management of the RFC publication process will be done by the TMO but the essential functions of writing, reviewing and editing will be done by the TM community. The hiring of a dedicated RFC Editor is under discussion.

Phasing

- Full implementation of the RFC writing and review workflow using GitHub and OpenReview.net (July 2020)
- Evaluation and update of the list of RFCs currently planned for 2020-2021 (RFC-2) (July 2020)
- Recruiting of the writers for the planned RFCs
- Follow-up of the RFC writing (2020-2021)
- Establishment of the workflow to structure the RFC to Infrastructure Pathway (August 2020)
- Continuous follow-up of the Implementation (2020-2021)

Funding

Activities are funded primarily via TMO membership fees.

Local Time Machines

Description

The Time Machine Network is structured as a virtually unlimited amount of **Local Time Machines** (LTMs). Each LTM is anchored in the space of a city or a region and has the ambition to build a dense database of spatiotemporal information laying the foundation of a 4D model of its physical environment. The TMO helps the regional/local actors in this process by providing technology, methodology and supporting infrastructure facilitating the digitisation pipelines, the standardisation of the information gathered and the development of related services.

Local Time Machines will play a big role in TM's Fast Speed development, as outlined in Section 4.3 (methodological approach). It is anticipated that several use cases of various scope will run in parallell. These user-driven use cases will develop concrete solutions in the various exploitation avenues, and, in effect, serve to embed user needs in the TM's development.

Organisation

The Local Time Machines follow the rules of the TMO, elaborated as a series of RFCs. The TMO provides assistance for their launch and growth, which will result in the identification of several *offices*.

The governance scheme for LTMs and their overall interaction with the TMO will be elaborated as a series of RFCs, and LTMs respective operations will be accurately mapped and monitored.

A Local Time Machines Manager will be engaged in 2020. They will:

- Further develop the typology of LTMs based on level of maturity
- Perform an inventory of state of the art of all existing/planned LTMs, assign level of maturity
- Manage the LTM network
- Coordinate the organisation of the LTM Academy events

Actions

- The LTM common framework ensuring cohesion in the network's operation, through the definition of general values, common objectives, as well as technical standards and guidelines regulating data acquisition, data sharing and data publishing.
- The support structure that will oversee the smooth development of the LTM network, so that institutions wishing to launch or integrate an LTM are given a clear path and guidance during the whole process. Particular attention will be paid to enabling existing initiatives to be aligned with the LTM framework, as well as encouraging TM partners to launch new initiatives.
- The labelling system or value scale to be used for evaluating the progression of an LTM. The labelling system should encourage the progression of the LTMs through the different grades, while providing a means to assess member commitment towards the LTM objectives.
- The legal setting based on a coherent and standardised contractual and licensing system for all LTM network operations, guaranteeing conformity with national and European policies and laws.
- The financial system to foster financial independence and, therefore, longer term viability of the LTM initiatives, including shaping a LTM franchise model. In this respect, emphasis will be on utilising local assets to enhance / develop new exploitation avenues for the big data of the past (in cooperation with Pillar 3).
- Creation of the Project and LTM Environment in the timemachine.eu website
- Development of the App and Operators Environment
- Consolidation of 10+ LTMs in the new environment.
- Onboarding of new LTMs
- Examine the current state of play for the key aspects required for a sustainable and synergetic pattern of operation. These aspects include the data standardisation and interoperability, the selection and connection of resources, the legal framework, the financial model and the labelling system for identifying the cultural heritage resources involved.
- Clarifying concepts, identifying operational objectives, and defining the main lines of intervention for TM, including structures for the organisation / coordination of actions across the different LTMs.
- Deployment of the first ingestion pipeline for the information skeleton common to all the LTMs, progressively structuring the information graph and offering ways to more easily ingest certain forms of structured sources.

Phasing

- A series of LTM Academy events, perhaps taking the form of annual pre-TM conference workshops, will be organised to present, compare and evaluate ongoing work.

Funding

The LTM Hub is funded through membership fees.

Funding from LTM comes from various sources, including:

- Funds from participating organisations
- External funding for the execution of specific use cases.
- Sponsorship from local and/or regional governments
- Public-private partnerships

They will be supported by the Funding Hub by providing consultancy and support (e.g. via LoS).

Exploitation support

Description

In the bootstrapping phase, support is dedicated to prototyping and bootstrapping an exploitation of TM results on a structural and action level. The objectives for this phase are:

- Enable structures and best practices for exploitation and public-private-partnerships
- Utilize extant instruments and mechanisms to leverage the impact of the TM
- Prototype and launch activities in order to achieve parts of the roadmaps
- Increase TM visibility and gain additional resources

Exploitation support comprises:

- Exploitation projects are activities on an European, national or LTM scale to prototype specific facets of TM. Currently two projects of European scale are operated in cooperation with Ubisoft and the European Broadcasting Union respectively.
- Exploitation structures are dedicated to support to enable business chains, servicing models and transfer instruments for the TM. As a prototype the *Digital Management Agency* was registered in 12/2019 as European Cooperative Society in foundation (SCE i.G.) and is currently financially backed by eight companies from two countries. It is proposed to reach full operation in June 2020. The SCE is projected to run independently and will connect to the TM via contracts and mandates.
- Exploitation instruments for the bootstrapping phase are based on the utilisation of extant support structures and instruments to leverage TM activities as well as co-branding as a benefit for TM members and subsidaries. This comprises, for example, the integration of EU-wide services (e.g.the *IPR helpdesk*, *Digital Hubs* for entrepreneurship support) and programs (e.g. *Codeweek* for education) in the TM ecosystem.

Organisation

- Supervision by the Exploitation Manager of the TMO Executive Board
- Coordination of the activities is done by the TM Executive Director
- Execution on the TM side via the Funding Hub (in terms of funding support), LTM Manager (in terms of LTM activities)
- Operation of the activities and structures takes place as independent units

Actions

- Identification and integration of extant exploitation instruments, services and programs in the TM ecosystem via cooperation / co-branding agreements
- Operation, management and assessment of exploitation projects
- Prototyping and launching of exploitation structures

Phasing

- From 2020: Operation of several self-financed project activities

- Until mid-2020: foundation of the DMA SCE as prototypic, self-financed structure for enabling business chains, servicing models and transfer instruments.
- Continously: Identification of exploitation instruments and listing / co-branding for the TM ecosystem.

Funding

Hub operation is financed by TMO member fees. All activities are self-financed via industry / 3rd party funding.

Strategy for funding

In the bootstrapping phase, TM will cover its costs with available resources:

The membership fees of the TMO and TMO-related co-funding by national subsidiaries (e.g. via startup-funds) are dedicated to bootstrap and operate basic TMO-wide actions and services:

- Creating a basic office infrastructure (hiring an Executve Director, administrative support, office space, etc.)
- Organising the community (Communication Manager, LTM manager, Programme Manager)
- Offering a basic level of concrete services with direct benefits to partners (technical infrastructure, project scouting services)
- Solidify the strategic aims of TM in terms of long term funding

EU-scale funding (Horizon Europe, ESIF, Digital Europe, etc.) will be utilised via proposals for participation in project consortia, consortium initiation and project partnering to: (a) achieve parts of the R&I agenda via extant calls, (b) scale-up and increase the quality of services, (c) participate in strategic initiatives. This will be managed via the Funding Hub.

National and regional funds will be used on to implement and to deliver LTM activities. This will be supported by the Funding Hub on a structural level, for example with regards to structural funds.

Service specific funding (innovation & startup funds, entrepreneurship funds) will be used to bootstrap and scale-up services, as well as to support transfer activities. This will be supported by the Funding Hub as well as based on a co-branding strategy utilising and offering extant schemes for the TM Members.

Industrial funding and philantrophy will be used to bootstrap and prototype exploitation by:

- Bootstrapping specific industry financed exploitation activities
- Prototyping exploitation platforms to support the transfer of results into business

5 Impact

In this section, we set out the Time Machine vision for impact throughout Europe and explore the first glimpses of how we can observe the impact manifesting itself.

5.1 An impact framework for Time Machine

Threaded through each element of the Pillars of the TM Roadmap is a common purpose to drive change throughout the EU in how it creates, shares and uses the big data of the past. The impact framework for TM seeks to bring the most significant changes together and to build a broad picture of what this looks like from our current vantage point, drawing upon elements from the Pillars to illuminate important examples of impact.

Impact comprises the **c**hanges that occur for stakeholders or in society as a result of activities for which the organisation is accountable

To develop this line of thinking, a methodological approach has been followed based on the Impact Framework[12] created by Europeana Foundation, starting with the exploitation avenues as representatives of stakeholders who are most immediately able to benefit from Time Machine, as a base to detect and envisage impact. The model and framework was developed and validated through a series of stakeholder consultations. The result is a Theory of Change (ToC) that connects at a high level the impact of TM and the TMO, with the activities, services and outcomes that are envisaged through Pillars 1 to 4.

The starting point for the ToC, is the statement of impact: an overarching description of the intended or perceived impact possible through Time Machine Research and Innovation, implemented through the TMO.

Impact Statement for the Time Machine

Time Machine will contribute to a more economically competitive and dynamic EU, where society is more open and fair and where policy-making takes into account cultural diversity and environmental sustainability, allowing citizens of the EU to have a strong sense of their European identity and live more peaceful, comfortable, creative and prosperous lives.

The Theory of Change connects the intended outputs of the Pillars with the most significant changes envisaged to be possible over the short, medium and long term. It documents a series of interconnected areas of impact, each with their own distinct connection with the development of the Pillars, as represented in Figure 5-1. The ToC provides us, therefore, with a visualisation that we can use to enable the evaluation of the potential impact of Time Machine. And we can use it to draw observe that there are six common areas of impact:

1. A more competitive EU through publicly funded development in the fields of AI and ICT
2. Improved economic resilience of European cities and regions through entrepreneurship and innovation
3. New ways of working drive greater societal relevance for Social Science & Humanities (SSH)
4. Big data of the past informs more effective policy making
5. EU citizens feel more connected to their past and assured of their identity in a pluralistic Europe
6. Europe's citizens are digitally literate critical thinkers

[12] https://pro.europeana.eu/page/impact

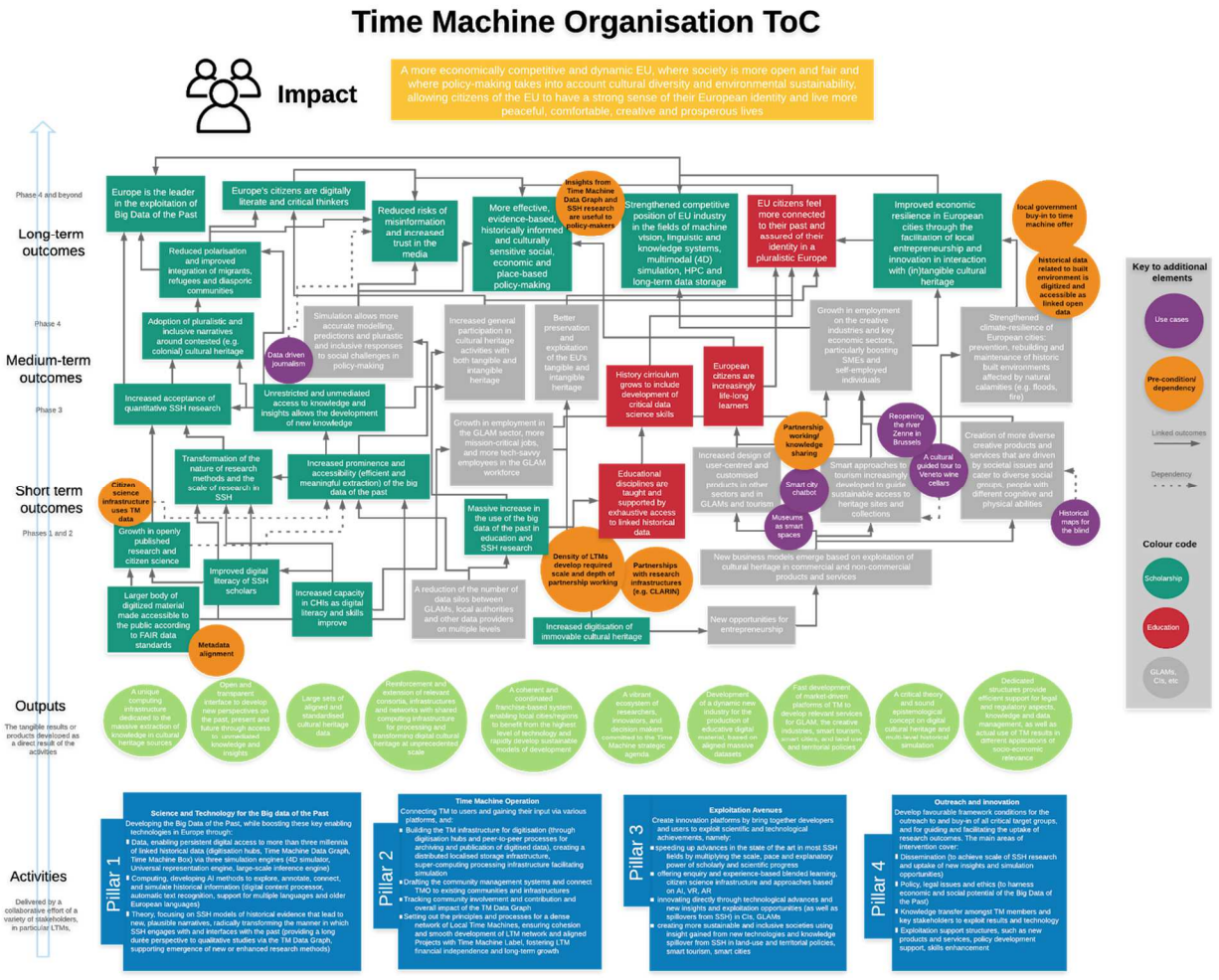

Figure 5-1: **Theory of Change for Time Machine Organisation v2.02.20, illustrating the impact models in the areas of Scholarship and Education**

Each of these areas of impact will be further explored from three strategic perspectives[13];

- **Economic impact:** estimates the changes in employment, income, or levels of business activity that may result from a proposed project or intervention.
- **Innovation impact:** A state in which the activities represent or enable innovation which itself supports social, economic or operational benefits.
- **Social impact:** A state in which activities lead to stakeholders and wider society being affected and changed in a beneficial fashion.

Using these perspectives allows us to maintain our focus on the elements of the impact framework that are most significant for TMO to address. As well as consider the impact that TMO can be accountable for, and what is beyond the accountability line. We also consider that the ToC represents our current understanding of our environment and the potential for change.

[13] Drawn from the Balanced Value Impact Model for assessing the impact of digital resources, simon Tanner, 2012 https://www.kdl.kcl.ac.uk/fileadmin/documents/pubs/BalancedValueImpactModel_SimonTanner_October2012.pdf and further doucment in Definition from Europeana Impact Playbook available at www.impkt.tools ,

Each of these areas of impact are explored further in the following sections, drawing from examples developed as use cases within the project and from research undertaken within the Pillars themselves. Whilst the impressions and forecasts of impact we can draw using this framework are grand, we also seek to bring them to a more practical conclusion through presenting a group of outcomes and indicators that could provide growing evidence of impact. This is further support by Annex D, where recommendations for practices to integrate impact measurement and assessment into the Time Machine Organisation and supporting operations are made. In particular, to ensure it maintains its relevance in the evaluation of TMO, it is recommended that it is considered a dynamic resource and refined regularly.

5.2 Economic Impact

Economic impact estimates the 'changes in employment, income, or levels of business activity that result from a given activity...to show that there is a fiscal return on investment that is specific and directly or indirectly measurable'[14].

This type of impact can be felt and evidenced at disparate levels by the multiple stakeholders in Time Machine, ranging from the individual businesses capitalising on newly available and open data to the competitive edge given to the EU in the global AI race.

A more competitive EU through publicly funded development in the fields of AI and ICT

Providing the framework and infrastructure for research and innovation, Time Machine will facilitate publicly funded technologies to strengthen the competitive position of the EU industry in the global tech industry and AI race.

Time Machine roadmaps for research & innovation present an opportunity to explore how Big Data of the Past can strengthen the position of EU industry in the global AI race, currently being led by the US and China[15]. Investment into AI & emerging technologies such as machine vision, linguistics and knowledge systems and multimodal stimulation will reveal possibilities for unlocking this data, thus addressing the gap in the market for tools that can make sense of the volume and variety of historical and contemporary data being produced.

Forecast - the value of AI

By 2030, Europe's GDP will increase by 10.3% due to AI, against 21.6% for China and 4.5% for the USA – Price Waterhouse Coopers 'Seizing the prize: What's the real value of AI for your business and how do you capitalise on it?' (2017)[16]

If left unaddressed, the gap in the market leaves open the risk in the increase of 'monopolist tendencies' where big companies - while not producing content - 'dominate at crucial points along media value chains, most notably in terms of interface and infrastructure'[17]. TM provides a way to work towards addressing

[14] https://www.kdl.kcl.ac.uk/fileadmin/documents/pubs/BalancedValueImpactModel_SimonTanner_October2012.pdf pg 15

[15] https://www.scmp.com/tech/science-research/article/3040893/second-place-china-overtake-us-global-ai-race-five-10-years, https://www.datainnovation.org/2019/09/infographic-who-is-winning-the-global-ai-race-china-the-eu-or-the-us/, https://www.forbes.com/sites/cognitiveworld/2020/02/09/why-the-race-for-ai-dominance-is-more-global-than-you-think/#58b869f8121f

[16] PWC (2017). 'Seizing the prize. What's the real value of AI for your business and how can you capitalise?' - Sizing the prize.

[17] https://www.mediaroad.eu/wp-content/uploads/2019/10/Vision-Paper-2_Future-and-emerging-technologies-for-the-European-Media-Sector.pdf

this gap by developing a structure that exploits linked open data that is already – or should be – freely available to citizens, allowing the exploitation of this data for economic growth and the wider public good. All the core components create a legacy of code that can be corrected, reused and adapted for continuous development and deployment.

Open source coding will ensure that knowledge is repurposed to support Europe's global competitive position in the fields of machine vision, linguistic and knowledge systems, multimodal (4D) simulation, HPC and long-term data storage, contributing to a stronger and more dynamic economy. This supports one of the priorities of the European Framework for Action on Cultural Heritage, namely, mobilising innovative knowledge and research for all[18].

Many of the advances developed by TM to achieve this would require advanced software, an area in which many European companies have world leading roles. Europe will further enhance its leadership through scientific and technological achievements in rapidly growing segments of the global ICT industry. TM technological breakthroughs will also have a strong impact on the European software and software-based services industry, one of the top drivers of Europe's industrial performance and a key contributor to EU growth[19].

For example, TM digital scanning tools will allow Europe to compete and gain from the expanding Document Processing Outsourcing market as well as the global AI race[20]. Importantly, TM AI technologies will be able to advance beyond digital scanning to exploit the full potential of this content, with AI allowing disparate datasets to be understood, translated automatically and linked to other datasets, making sense of the data and enriching it after digitisation on a scale previously not seen anywhere worldwide.

Example**s** of impact in the creative industries include:

- Design: where rapidly advancing simulation tools will increase profitability and collaboration opportunities, and
- Gaming and film industries: where mass-scale digitisation will remove spatial and temporal barriers to cultural heritage, allowing the use and customisation of complex 3D models constructed from rich heterogeneous sources.

EdTech can transform the administration and organisation of education, contributing to broader digital transformation in the public sector, leading to stronger outcomes thanks to increased teacher time (reduced administration), better learning outcomes for students and increased efficiency in delivery. This feeds into the areas of action identified in the Digital Education Action Plan[21], which includes better data analysis, educational delivery and foresight planning through artificial intelligence as well as training in digital skills.

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[18] https://op.europa.eu/en/publication-detail/-/publication/5a9c3144-80f1-11e9-9f05-01aa75ed71a1/language-en/format-PDF/source-101251729

[19] With average annual growth of 3% in the period 2015-2020, the EU software industry will reach € 290 billion by 2020 (DG CNECT (2017) SMART 2015/0015 - https://ec.europa.eu/digital-single-market/en/news/economic-and-social-impact-software-and-services-competitiveness-and-innovation)

[20] A recent study foresees that by 2030, Europe's GDP will increase by 10.3% due to AI, against 21.6% for China and 4.5% for the USA - PWC (2017). 'Seizing the prize. What's the real value of AI for your business and how can you capitalise?' - Sizing the prize.

[21] https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en

Improved economic resilience of European cities and regions through entrepreneurship and innovation

Local governments, cities and regions are core beneficiaries of TM developments. Structural changes, like talent clustering[22] and brain drain, have created low employment prospects in Europe's regions that can contribute to a loss of talent and widening economic disparities[23]. Young people, faced with a choice of media and entertainment from across the world, may lose a sense of the value of their local heritage.

TMO and LTMs would help local governments embed many of the identified policy recommendations, such as 'cooperation between cultural heritage and other sectors (e. g. moderation of matching platforms on city level)"[24]. The final outputs of the European Commission-funded ROCK Project on the valorisation of cultural heritage[25], for example, sets out a framework in which policy makers can exploit cultural heritage as a driver for sustainable and smart growth (also relevant to the 2030 SDGs)[26].

Local Innovation with Time Machine: Amsterdam Municipality

The Engineering Office of Amsterdam Municipality is responsible for the maintenance of the bridges and quays of the canals, which are in bad shape. For this maintenance, they require access to historical data held at different departments and archives. The Time Machine provides the means to digitize all relevant data and the infrastructure for connecting them to the locations of each individual bridge and quay. As such, it will generate a 'Digital Twin' of the city that provides a central access point for engineers working on maintenance and allows them to explore those data in the context of the (virtual) historical inner city.

Time Machine will contribute to the ongoing need to strengthen GLAMs – as the key institutions preserving and making available much of the Big Data of the Past – by offering these institutions and their collections new smart ways of exploitation and meaningful, customised audience engagement (both physically and digitally), supporting multiple elements of the European Framework for Action on Cultural Heritage[27]. The increased scanning capacity made possible by TM will vastly increase the amount of digitised material available and importantly, as mentioned above, improve the findability, accessibility and openness of this material through automated enrichment and indexing of collections.

TM will connect heritage data with the data of governments (local and national) and much more, for the first time, under the framework of the Big Data of the Past. TM drives metadata alignment (interoperability) and the reduction of silos between all providers of Big Data of the Past. This will allow new models to emerge based on exploitation of this diverse data in commercial and non-commercial products and services.

All of this is dependent on the facilitation of interactions between intangible and tangible cultural heritage, SSH research and entrepreneurs and creatives. The new possibilities provided by the TM infrastructure will provide the context for growth in a national economy, but more importantly, in a local creative economy,

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[22] https://www.cer.eu/publications/archive/policy-brief/2019/big-european-sort-diverging-fortunes-europes-regions

[23] https://www.europarl.europa.eu/news/en/agenda/briefing/2017-11-13/12/stopping-population-decline-in-vulnerable-eu-regions

[24] https://rockproject.eu/uploads/news/documents/OKYe2YkE0bZZXfOc5UlgXMkhdPbGZkYCj2V8vZwz.pdf

[25] https://rockproject.eu/news-details/210

[26] https://unesdoc.unesco.org/ark:/48223/pf0000371562

[27] https://op.europa.eu/en/publication-detail/-/publication/5a9c3144-80f1-11e9-9f05-01aa75ed71a1/language-en/format-PDF/source-101251729

and in particular, the SMEs and self-employed individuals who make up the majority of the sector's workforce[28].

> *Cultural heritage is a key component and contributor to the attractiveness of Europe's regions, cities, towns and rural areas in terms of private sector inward investment, developing cultural creative quarters and attracting talents and footloose businesses — thereby enhancing regional competitiveness both within Europe and globally.*
>
> Europa Nostra, Cultural Heritage Counts for Europe (2015)[29]

An open source approach offers an unparalleled resource and massive additional value for the wider creative industries with the resulting economic benefit for regions, nations and the EU. Noting the clustering benefits of the creative industries, there are benefits to this local interaction particularly for smaller regions and cities, where such new opportunities will provide a boost to transforming de-industrialising economies, by diversifying local economies or boosting 'economies in decline'[30], with the potential effect of reducing the flow of young creative workers to larger metropolitan centres (as suggested in the 2015 report Cultural Heritage Counts for Europe[31]). Interaction, connection with and pride in one's local heritage sets the conditions for a more connected and cohesive EU. Areas of specific impact for land use and territorial policies include food safety, clean water, biodiversity, climate change mitigation and adaptation.

Indicators of economic impact

Time frame	Outcome	Indicator
Short-term	Growth in employment in the GLAM sector, more mission-critical jobs, and more tech-savvy employees in the GLAM workforce	Job creation directly attributable to Time Machine GLAM employment trends over time (Enumerate)
Long-term	Improved economic resilience in European cities through the facilitation of local entrepreneurship and innovation in interaction with (in)tangible cultural heritage.	Number of urban startups supported by public-private funding centered around big data of the past

[28] Estimated in 2016 that over 90% of businesses in the CCIs had up to 9 employees Boosting the competitiveness of cultural and creative industries for growth and jobs | Internal Market, Industry, Entrepreneurship and SMEs

[29] http://blogs.encatc.org/culturalheritagecountsforeurope//wp-content/uploads/2015/06/CHCfE_REPORT_ExecutiveSummary_v2.pdf

[30] https://en.unesco.org/creativity/policy-monitoring-platform/culture-regional-development-0

[31] http://blogs.encatc.org/culturalheritagecountsforeurope//wp-content/uploads/2015/06/CHCfE_REPORT_ExecutiveSummary_v2.pdf

5.3 Innovation impact

Innovation impact describes a state in which the activities that lead to impact represent or enable innovation to occur, which itself supports social, economic or operational benefits. Traditional metrics of Return on Investment (ROI) will not effectively evaluate the disruptive effects TM technological advancements[32]. Instead, this section identifies the cross-sectoral innovation that TM's tools and knowledge will drive in wider society and the economy, illuminating the cross-sectoral innovation that results from technological innovation.

New ways of working drive greater societal relevance for Social Science & Humanities

Providing advanced technological developments and infrastructure, such as the large scale simulation engines, TM has the potential to transform the scale and scope of SSH studies. Facilitating the embedding of SSH research in EU funding programmes[33].

TM offers a unique proposition in bringing together the much-desired[34] areas of technological innovation together with SSH at the very core of the project model, and facilitates knowledge transfer to other sectors. TM tools used to develop new SSH insights will be transferable and open source coding will ensure that knowledge is repurposed to support Europe's global competitive position in the fields of machine vision, linguistic and knowledge systems, multimodal (4D) simulation, HPC and long-term data storage, contributing to a stronger and more dynamic economy. This supports one of the priorities of the European Framework for Action on Cultural Heritage, namely, mobilising innovative knowledge and research for all[35].

Increase in scale, increase in scope

An average project considers ten artefacts (e.g. manuscripts), TM could allow that same project to consider +10,000 artefacts under the exact same conditions. Such scale should increase the legitimacy and added value of the SSH and exploit its already acknowledged added value.

The massive availability and efficient and meaningful extraction of the Big Data of the Past, combined with the partnership working with Universities and heritage institutions, benefits from a parallel up-skilling of the GLAM and SSH workforce, who will be encouraged – and by the pace of developments, required – to adopt new digital skills to fulfil the potential of the heritage and knowledge under their custodianship. The EU's position as a world-leading role-model in heritage studies and heritage preservation will be further strengthened, as will its contribution to the preservation of heritage at conflict through digitisation, increased valorisation and cultural diplomacy efforts. This spills over as greater social impact that would be unachievable through technological development alone.

[32] e.g. Metrics for measuring innovation

[33] https://ec.europa.eu/research/social-sciences/index.cfm?pg=library&lib=other_pub

[34] https://op.europa.eu/en/publication-detail/-/publication/f094a641-30dd-11e9-8d04-01aa75ed71a1/language-en/format-PDF/source-86826299

[35] https://op.europa.eu/en/publication-detail/-/publication/5a9c3144-80f1-11e9-9f05-01aa75ed71a1/language-en/format-PDF/source-101251729

"technical solutions are often a precondition for a new policy outcome but may not be sufficient to produce a meaningful societal impact, which also requires the insight of social sciences and humanities"

Integration of social sciences and humanities in Horizon 2020 (2019)[36]

Time Machine, then, will harness the potential of the SSH for exploitation and knowledge transfer to other sectors. The extensive collaborative structure (already demonstrable through existing LTMs) gives a perspective into the wider governmental and civil society actors that could both benefit from the tools and insights created as well as to transfer this value right across society.

It is widely acknowledged at EU-level that investing in higher education is investing in jobs and growth[37]. We expect TM to lever massive additional investment in SSH thanks to the wider acceptance of quantitative research methods in the research sector and the increased scale of research made possible through TM.

Perspective: The ripple effect of innovation throughout SSH

The impact areas described throughout this framework are all reliant on the empowerment of the SSH sector and the new collaborative, cross-sectoral and multidisciplinary ways of working that TM offers to SSH scholars to capitalise on the potential transformative impact of the Big Data of the Past. There are no similar open initiatives offering such multi-faceted value for the wider public and institutions at this scale in Europe. It will create a Europe that is the leader in the exploitation of the Big Data of the Past.

Big data of the past informs more effective policy making

TM tools and partnerships create new possibilities for improved evidence-based policy making, culturally-sensitive planning or development (avoiding negative side-effects[38]). Efficiencies can be introduced by new tools that will result in a transformed public sector. There is potential to inform across multiple policy areas.

Environmental sustainability and changes brought about by climate change are challenges faced by urban and regional centres alike. New developments often don't match local expectations or respect the principles for the preservation of historic urban centres. Local and national governments would benefit from more data to support better decision-making and a framework through which to involve citizens more in participatory policy-making

Pressingly, governments and administrations of all sizes must face up to the challenge of climate control and sustainable tourism. Europe is the most visited tourism region in the world, and in the EU, tourism contributes 10% to EU GDP and creates jobs for 26 million people, through its direct, indirect and induced effects in the economy[39]. TM presents the tools and opportunity for the development of smart approaches to tourism that can guide sustainable access to heritage sites[40] and collections, including the

[36] https://op.europa.eu/en/publication-detail/-/publication/f094a641-30dd-11e9-8d04-01aa75ed71a1/language-en/format-PDF/source-86826299

[37] https://ec.europa.eu/education/policies/european-policy-cooperation/education-jobs-and-growth_en

[38] https://rockproject.eu/news-details/210

[39] UNWTO (2018). European Union Tourism Trends: European Union Tourism Trends | World Tourism Organization

[40] This has knock-on environmental benefits - http://blogs.encatc.org/culturalheritagecountsforeurope//wp-content/uploads/2015/06/CHCfE_REPORT_ExecutiveSummary_v2.pdf pg 28

redevelopment of existing heritage sites and the protection of tangible or intangible heritage for future generations.

The simulation capabilities of the TM Mirror World will also support and strengthen the climate-resilience of European cities through the prevention of catastrophe (e.g. by capitalising on locally-responsive climate defence strategies, also noted in Target 13.1_Climate & disaster resilience in the 2030 SDGs[41]) and rebuilding and maintenance of historic built environments affected by natural calamities (e.g. after floods, fire). There is social value in the ability of culturally-responsive smart products to help local residents adapt to new contexts after climate events.

> *The challenges of our time need modern governance, that is, more cooperation between all policy areas. SSH-research plays an important role in facilitating this exchange between research policy and sectoral policies.*
>
> Heinz Fassmann, Austrian Federal Minister of Education, Science and Research[42]

Furthermore, TM will promote and enable the digital preservation of both tangible and intangible conservation, aligning with ongoing efforts to protect at-risk cultural heritage (e.g. from conflict or environmental factors). This supports the Culture|2030 indicator of Climate and Resilience, one of the four pillars identified[43].

Even further on the citizen-level side of the SDGs, TM will support inclusion and participation in policy-making, in the development of knowledge and skills[44] and in the creation of tools and products that will help contribute to a more just and inclusive society for all. The Big Data of the Past can be used to deliver more diverse creative products and customised services that are locally responsive, driven by societal issues and cater to diverse social groups and people with different cognitive and physical abilities. This also meets another one of the priorities in the European Framework for Action on Cultural Heritage[45].

Indicators of innovation impact

Time frame	Outcome	Indicator
Short-term	Increased prominence and accessibility (efficient and meaningful extraction) of the big data of the past	Number of API-calls by GLAM institutions for Time Machine's indexing services (using a unique API key)
Medium-term	More accurate modelling, predictions and pluralistic and inclusive responses to social challenges in policy-making	Increase of 'simulation' used as a tag on research articles over time

[41] https://unesdoc.unesco.org/ark:/48223/pf0000371562, pg 35

[42] https://www.fteval.at/content/home/journal/aktuelles/19_07_2019_ausgabe_48/Journal48_WEB_V2.pdf

[43] https://unesdoc.unesco.org/ark:/48223/pf0000371562

[44] https://unesdoc.unesco.org/ark:/48223/pf0000371562

[45] https://op.europa.eu/en/publication-detail/-/publication/5a9c3144-80f1-11e9-9f05-01aa75ed71a1/language-en/format-PDF/source-101251729

Medium-term	Strengthened climate-resilience of European cities: prevention, rebuilding and maintenance of historic built environments affected by natural calamities (e.g. floods, fire)	Comparative cost- and time-effectiveness of restoration after natural disasters
Long-term	Broadened and deepened public sector digital transformation	Integration of big data of the past in e-government infrastructure (e.g. digital twins)

5.4 Social Impact

Social impact describes a state in which activities lead to stakeholders and/or wider society being affected and changed in a beneficial fashion. Assessing social impact requires the measurement of 'the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions'[46].

Time Machine's social impact is potentially vast, triggered directly with European citizens who have access to the Big Data of the Past, or indirectly through the policy-makers, platforms, products and services that will exploit it for the greater good.

EU citizens feel more connected to their past and assured of their identity in a pluralistic Europe

Cultural heritage is recognised as a tool for social cohesion[47]. Increased citizen engagement with the Big Data of the Past - in informal or formal learning settings - will lead to an increased sustainability acceptance of the wider social and economic value of the GLAM sector.

Access to Cultural Heritage and Big Data of the Past is likely to foster 'a sense of shared ownership and belonging among citizens across Europe'[48], with the result that EU citizens feel more connected to their past and assured of their identity in a pluralistic Europe. This has the potential long-term effect of increased citizen participation in cultural heritage[49].

TM interactive environments will not only offer unprecedented access to the records of our shared past, it will also promote active engagement with that heritage. The massive increase of available data available for use in educational platforms, learning resources and teacher training[50] can lead to scenarios where formal educational settings teach subjects informed by exhaustive access to linked historical data.

> *"AI is only just starting to change the educational ecosystem and as yet it has not necessitated that all educational stakeholders engage with AI and its implications for education"*
>
> *Dr Carmel Kent, European EdTech Network[51]*

[46] Vanclay, 2003, in Tanner (2012) Measuring the Impact of Digital Resources: The Balanced Value Impact Model
[47] http://blogs.encatc.org/culturalheritagecountsforeurope//wp-content/uploads/2015/06/CHCfE_REPORT_ExecutiveSummary_v2.pdf
[48] http://www.europanostra.org/wp-content/uploads/2018/03/cultural-heritage-key-resource-EU-future-cohesion-policy.pdf
[49] https://ec.europa.eu/eurostat/statistics-explained/index.php/Culture_statistics_-_cultural_participation
[50] Teacher training has been identified as a critical dependency in developing childrens' digital skills - Commentary: The rise of the digital economy – and how education may be transformed
[51] https://eetn.eu/knowledge/detail/Evidence-Summary--Artificial-Intelligence-in-education

New interdisciplinary methods developed across the traditional scientific domains make use of the advances in AI developed through TMO programmes, producing new modelling capabilities in SSH and new simulation capabilities in most of the scientific and educational domains. In turn, this leads to offering more depth to educational curricula, sharpening the critical thinking of learners and contributing to informed decision-making at the level of policy-making and delivery.

The insights that will be available through the increased scale of SSH research and legitimacy of quantitative research approaches will challenge divisive rhetoric and provide new perspectives on our globalising societies. The adoption of pluralistic and inclusive narratives around contested (e.g. colonial) cultural heritage will make learning an on-going and inclusive process that will bind generations and different social groups and raise awareness of the connections between cultures and histories.

Europe's citizens are digitally literate critical thinkers

Data skills will be part of the standard history curriculum, allowing pupils and educators to gain new insights into their learning through advanced simulation tools. Pupils will be empowered to challenge traditional theories and contested histories.

Engaging in open science and research – and being inspired by new insights available – has the potential to encourage a new generation of lifelong learners, who maintain their data skills in their professional careers and personal interests. This contributes to several of the core competencies identified by the European Commission for lifelong learners[52].

This will be facilitated by the development of increasingly user-centred services in the GLAM sector and in tourism, made possible through TM's tools and insights. And taking the experience economy to new levels through unobtrusive and highly customized user experiences that are open to all.

TM will make accessible the data, insights and tools that can catalyse a transformational increase in citizen science, as well as supporting better data (analysis and interpretation) skills of the wider population. It will support young people and lifelong learners to exploit their natural intellectual potential in their professions, education and hobbies and create connections through TMO partnership platforms between citizens and SSHs. At the same time, it will stimulate increased social value for the Big Data of the Past and cultural heritage as preserved by GLAMs.

Data driven journalism

Fake news and misinformation are undermining trust in the media and posing a threat to democratic societies. TM data and resources empowers journalists to create radically new methods for tackling misinformation in the media. Archives can provide trusted content and context needed to tackle misinformation but are not accessible in ways that make it easy for journalists to include in their works.

TM provides tools for journalists to create data-driven stories and enables citizens and journalists to validate the trustworthiness of data and stories in the media. Journalists will make use of TM data to create trusted and engaging stories that attract readership and support their business goals.

[52] https://ec.europa.eu/education/education-in-the-eu/council-recommendation-on-key-competences-for-lifelong-learning_en

A rise in citizen science feeds into citizen journalism and professional journalism, making possible new objective and evidence-based insights and knowledge that can be shared widely. We expect that fact-checking sources will use TM infrastructures and also benefit from SSH insights in their work. Connecting with the journalism sub-sector of the creative industries opens up the potential for the wide dissemination of new insights on European history, present and future, as well as increasing the reliability of the media overall.

Indicators of social impact

Time frame	Outcome	Indicator
Short-term	Creation of more diverse creative products and services that are driven by societal issues and cater to diverse social groups, people with different cognitive and physical abilities	Number (and variety) of content platforms that facilitate access to TM data
Medium-term	Increased general participation in cultural heritage activities with both tangible and intangible heritage	Cultural participation rates (Eurobarometer)
Long-term	EU citizens feel more connected to their past and assured of their identity in a pluralistic Europe	TM users suggest that this activity helps them feel more connected to Europe/European identity
Long-term	Reduced risks of misinformation and increased trust in the media due to mechanisms for data validation and contextualisation	Use of big data of the past as source content by journalists via platforms like https://eufactcheck.eu/, https://www.ejta.eu/ and other platforms (number of collaboration agreements and usage statistics)

Annex A: Definitions – Abbreviations

A.1 Definitions

4D Simulator	One of three TM Simulation Engines. The 4D Simulator manages a continuous spatiotemporal simulation of all possible pasts and futures that are compatible with the data. The 4D Simulator includes a multiscale hierarchical architecture for dividing space and time into discrete volumes with a unique identifier: a simulation engine for producing new datasets based on the information stored. Each possible spatiotemporal multiscale simulation corresponds to a **multidimensional representation** in the 4D computing infrastructure. When a sufficient spatiotemporal density of data is reached, it can produce a 3D representation of the place at a chosen moment in European history. In navigating the representation space, one can also navigate in alternative past and future simulations. **Uncertainty and incoherence are managed at each stage of the process and directly associated with the corresponding reconstructions of the past and the future.**
Big Data of the Past	A huge distributed digital information system mapping social, cultural and geographical evolution. A key objective of Time Machine is that such a system brings together dense, interoperable, standardised (linked data, preferably open) and localised (marked up with spatial-temporal information) social, cultural and geographical heritage resources.
Communities	Group of users, self-organised by territorial or transversal interests, offering various voluntary works and favours to the partners (annotation, digitisation, bibliographic research, development), according to the standards in place. These communities can elect a representative.
Digital Content Processor	Automatic process extracting information from documents (images, video, sound, etc.). Level 1 Digital Content Processor labels mentions of entities. Level 2 Digital Content Processor labels relations between entities. The Digital Content Processor of Level 3 labels rules. Each process is fully traceable and reversible. The results of the processing constitute the core dataset of the Big Data of the Past and are integrated in the TM Data Graph.
Large-Scale Inference engine	One of three TM Simulation Engines. The Large-Scale Inference Engine is capable of inferring the consequences of chaining any information in the database. This permits users to induce new logical consequences of existing data. The Engine is used to shape and to assess the coherence of the 4D simulations based on human-understandable concepts and constraints. Its origin lies in more traditional logic-based AI technology, which has been slightly overlooked since the recent success of the deep learning architecture, but that can, nevertheless, play a key role in an initiative like TM.
Local Time Machine (LTM)	Zone of higher "rebuilding the past activities" density. Constituted of a group of local partners and communities bound by a common territorial focus and a declaration of intent, which respect both graphical and values charters. Any institution that meets eligible criteria can integrate a Local Time Machine. The declaration of intent is reviewed on an annual basis (time for new partners to integrate the TM).

Project with Time Machine label (PWTML)	Project respecting the Technical Charter, of which tasks are documented - modelled within the Time Machine graph. All the partners of a PWTML must have signed the declaration of intent of the related Local Time Machine.
Technical Charter	The Technical Charter defines the Time Machines Rules, Recommendations, Metrics and Official software. The document is revised periodically. The Technical Charter should contain information about infrastructure standards required within any Project with Time Machine Label.
Time Machine Box	Servers that allow partners to store their documents and metadata and to integrate the Time Machine Network easily and be appropriately documented in the Time Machine Graph. The Time Machine Box is part of the Time Machine Official Components.
Time Machine Data Graph	Formal representation of knowledge extracted by human or automatic process, represented with semantic web technology.
Time Machine Index	The TM index is a global system indexing different type of objects: e.g. documents, iconography, 3D geometries. It gathers all information regarding documents and their contents and could be used as a basis for other search engine infrastructures (it allows backups).
Time Machine Infrastructure Alliance	Coalition of TM's partners regrouping in-kind donators for infrastructure components (server's space and computing power).
Time Machine Mirror World	One of the API of the Time Machine using the processing of the three TM Simulation Engines to produce a continuous representation model that can be accessed as an information stratum overlaying the real world.
Time Machine Network	Set of all the partners actually interacting in the Time Machine. Each member of the Time Machine Network must have signed the Value and Technical Charter.
Time Machine Official Components	Pieces of software (e.g. Time Machine Box) that help partners conforming to the Time Machine rules seeing as they are directly embedded in the software.
Time Machine Operation Graph	Formal representation of the past, on-going and future operations of the partners in the Time Machine Network and the data pipelines.
Time Machine Organisation	Association regrouping the Time Machine Partners, active or not. Not all may have signed the Values and Technical Charters.
Time Machine Recommendations	Recommendations on technology which are not obligatory at this stage for the development of the Time Machine (e.g. choice of a particular IIIF image server).
Time Machine Request for Comments	Main document for the progressive design of the Time Machine infrastructures, standards, recommendations and rules, inspired by the process used for 50 years for the development of Internet Technology, today administrated by the Internet Engineering Task Force (IETF) as part of Internet Society (ISOC).
Time Machine Rules	Standards and rules that need to be followed to be acceptable in the Time Machine Network and become a Time Machine operator. Any entities not following these rules are removed.
Time Machine Standard Contracts	Set of standard contracts to facilitate the interaction between Time Machine partners.
Time Machine Standard Metrics	Measures helping partners of the Time Machine Network coordinate with one another to compare performance, not only for quotes of services, but also for research performances, etc.

Time Machine Super Computing Architecture and Simulation Engines	TM Super Computing Architecture composed of distributed computing resources from the TM Network provided by the TM Infrastructure Alliance. On this distributed architecture, different typologies of computing processes can run. For instance, Digital Content Processors are intrinsically easier to run in parallel, whereas Simulation engines, which allow users to generate possible pasts and futures from the TM Data Graph need for more specific computing architecture.
Universal Representation Engine	One of three TM Simulation Engines. The Universal Representation Engine manages a multidimensional representation space resulting from the integration of the pattern of extremely diverse types of digital cultural artefacts (text, images, videos, 3D), and permitting new types of data generation based on transmodal pattern understanding. In such a space, the surface structure of any complex cultural artefact, landscape or situation is seen as a point in a multidimensional vector space. On this basis, it could generate a statue or a building, produce a piece of music or a painting, based only on its description, geographical origins and age.
Values Charter	Charter developed in conformity to the principle of openness in EU law.

A.2 Abbreviations

AI	Artificial Intelligence
CH	Cultural Heritage
CSA	Coordination and Support Action
EC	European Commission
ERIC	European Research Infrastructure Consortium (Legal entity for Research Infrastructures)
FAIR	Findable – Accessible – Interoperable – Reusable
GA	General Assembly
GLAM	Galleries, Libraries, Archives and Museums
HE	Horizon Europe (The 9th Framework Programme for Research and Innovation of the EC)
ICT	Information and Communication Technologies
KPI	Key Performance Indicator
LSRI	Large Scale Research Initiative
LTM	Local Time Machine
PWTML	Project with Time Machine Label
RFC	Requests for Comments
SSH	Social Sciences and Humanities
TM	Time Machine
TMO	Time Machine Organisation
WP	Work Package

Annex B: Roadmap for TM Operation – the RFCs

B.1 The RFC Tree table

The table below presents the RFC tree, specifying for each one:

- the phase/ subphase
- the year planned for its development
- the type
- the title
- a description
- the dependencies with other RFCs.

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2020 - Frameworks	2020	Framework	RFC on RFC	To ensure the open development and evaluation of the Time Machine Operation, a process inspired by the Request for Comments (RFC) publication mechanism for negotiation the standards and protocols will be established. Standard themselves may come and go, but the open way of establishing them and negotiating them should persist.	
2020-2022 Bootstrapping	2020 - Frameworks	2020	Framework	RFC on RFC Editorial committee	In order to bootstrap the process, a small group will be created, the TM RFC committee. This RFC defines the process for this election and renewal rules	RFC on RFC
2020-2022 Bootstrapping	2020 - Frameworks	2020	Framework	RFC on Publication Platform	It will be crucial to decide on the technology and platform for managing the publication process of RFC. White-labelled version of existing publication platform may be considered.	RFC on RFC
2020-2022 Bootstrapping	2020 - Frameworks	2020	Framework	RFC on Technical Charter	The goal of the Charter is to guarantee a first level of standardisation for data and processes, in order to remain light and useable by the most, the charter also encourages the use of universal and open interfaces and references that do not need central coordination	
2020-2022 Bootstrapping	2020 - Frameworks	2020	Framework	RFC on Vision Mission and Values Charter	In order to protect overarching purpose, fundamental values and ethical principles, a common Charter will be created. Its duty will be to protect the core of the TM and sustain its future. Becoming a TM network member implies to ratify the Vision, mission and values Charter	

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2020 - Frameworks	2020	Framework	RFC on Intellectual property rights and licenses	Defining licenses to preserve intellectual property rights (regulating data acquisition, sharing and publishing) and sustain the interoperability and accessibility of the TM. The proposed solutions could be based on the Creative Commons copyright licenses and should be further developed with the help of cultural-heritage network (e.g. Europeana), used to tackle such issues and already proposing solutions. Means of monitoring the openness process of data should also be taken into concern.	RFC on Technical Charter, RFC on Vision Mission and Value Charter
2020-2022 Bootstrapping	2020 - Frameworks	2020	Framework	RFC on Training	Complying with the TM Rules and Recommendations and the legal settings, using the TM components and understanding TM infrastructures, will require specific trainings. A proper set of documentation, tutorials, videos, online courses will be offered o the partners. This RFC will set the general rules for building training materials. These principles will be later used by other more specific RFC on training	RFC on Intellectual property rights and licenses

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2020 - Frameworks	2020	LTM	RFC on LTM	As the TM infrastructures are currently on a construction phase, there isn't any common rule or recommendation followed by the partners of existent LTM or PWTML initiatives. Once values and technical requirements settled, they are meant to be the basic structure of the TM networks and play an essential part in the development of the TM Operation and Data Graphs. As technical means are due to evolve over time, those rules and recommendations will be flexible enough to allow future modifications. In order to guarantee a smooth development of the LTM, a perimeter will be clearly settled for both LTM and PWTML. An LTM must be geographically rooted and PWTML contribute to the space-time density' expansion of that same geographical location (Key concepts and global overview – Local Time Machines). Those first assumptions will be tested and further discussed. The main task of the RFC, once the definition settled, will focus on designing means to map those operation and routines within the TM network in order to ensure activities monitoring at all-time and build related guidance (as described below in Specific offices proposals).	RFC on Technical Charter, RFC on Vision Mission and Value Charter

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2020 - Frameworks	2020	LTM	RFC on LTM Value Scale	The proposed LTM's value scale (Key concepts and global overview – Local Time Machines), based on density criteria, will be discussed and its relevance and organisation further developed. Value scale concerning PWTMLs will be created based on the already defined bricks and other criteria need to be proposed in order to foster the development of PWTMLs (e.g. collaboration, cooperation metrics). As some of the measure will relate to qualitative process, a dedicated TM RFC on collaboration indicators, will focus on creating a suitable metrics system. The labelling system might require a third-party certification to assess its efficiency and respect.	RFC on LTM
2020-2022 Bootstrapping	2020 - Frameworks	2020	LTM	RFC on LTM Training	Specific RFC rooted on the general principle established by RFC on training but adapted to the framework developed in the RFC on LTM.	RFC on LTM, RFC on Training
2020-2022 Bootstrapping	2020 - Frameworks	2020	Digitisation	RFC on Definition of typologies of digitisation interventions	A typology of digitisation interventions will be established, separating a. collections that can be moved and processed in digital hubs (large, non-fragile collections), collections or objects that need local intervention (e.g. very fragile document, statues, buildings), b. process that can be performed by volunteers using mobile technology (e.g. scanning campaign across cities, on-the-fly digitisation in reading rooms), processes that can be performed using robots and drones, etc.	

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2020 - Frameworks	2020	Digitisation	RFC on standardisation and homologation	Definition of the terms and contracts enabling digitisation partners to become part of the Time Machine network.	RFC on Definition of typologies of digitisation interventions
2020-2022 Bootstrapping	2020 - Frameworks	2020	Digitisation	RFC on Digitisation Priorities and Data Selection	A Data selection model based on the identification of performance criterion, will help partners focus on those aspects and take according decisions. The National Information Standards Organisation (NISO) also proposed a Framework for guidance for Building Good Digital Collections. Example of performance criterion: Significance of Content to Internal Stakeholders (degree to which a collection, once digitised supports the immediate and long-term research and teaching needs of the institution), Significance of Content to External Stakeholders (a highly successful digital collection is of interest to researchers and users outside of the university), Uniqueness (many unique institutional resources such as original photographs, archival materials, grey literature such as university technical reports and conference proceedings remain to be digitised), Exposure (degree to which the digital collection garners the institution positive recognition and press and assesses the potential for the digital availability of the collection to result in grants and other funding). This Digitation recommandation will also be in line with the LTM coordinated strategy for digitisation.	RFC on Definition of typologies of digitisation interventions

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2020 - Frameworks	2020	Infrastructure	RFC on Open Hardware	Definition of the open hardware strategy for Time Machine including licensing terms, catalogues,	RFC on Definition of typologies of digitisation interventions
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on data lifecycle	The data lifecycle within the TM starts with the concept of documents and data selection. The goal is to help partners select proper documents or collections to be processed by the TM pipelines and then the data within the documents. The data selection is closely related to the LTM or PWTML's perimeters (see LTM/Framework) and should be stated prior to any projects launch. Criteria such as intellectual property rights, obtaining copyright permissions, digitisations, OCR processing or metadata creation costs are also to be taken into concern. Extending the resulti of the RFC of Digitisaiton Priorities and Dataselection, the RFC will aso details Data acquisition, Data sharing and Data publishing	RFC on LTM, RFC on Digitisation Priorities / Data Selection
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on Operation Graph	Definition of the format of the operation graph describing the operation currently pursuded in the TM consoritum, as monitored by the TMO. It includes both automatic processes and human interventions.	RFC on data lifecycle

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on TM Data Graph	The Time Machine Data Graph contains all the information modelled in the Time Machine. The graph is constructed both manually and automatically through the processing of the Digital Content Processor. The Graph is intrinsically composed of two subparts: (1) The bright graph composed of information that have been manually mapped and integrated with other large database or used in a publication. This information is integrated with the current sum of digital human knowledge. It can be considered actual. (2) The dark graph composed of information extracted automatically from (massive) documentation which has been used so far apart as individual historic items. It can be considered virtual.	RFC on data lifecycle
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC for TM APIs	Algorithms and software integrated into the Time Machine need to be able to communicate with each other. Thus, a definition of joint APIs is required. It is likely that TM Services are built on top of REST interfaces. In order to match TM's needs these will have to be adapted towards the need of large-scale machine learning. A probable addition is the option to provide gradient information of a specific module that is integrated using the API, for example. This way remote services can also be integrated into large-scale training processes.	RFC on Operation Graph

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC for classification and planning of languages to address	Defintion of the multilingual strategy of the TM. This RFC has impact on the exploitation platforms.The TM will handle documents in multiple European languages and dialects. Some of them might be more complicated to address than others due to pre-existing tools for modern variants or availability of materials. A working plan of NLP tools development should be conceived by taking the materials, the locations of the LTMs and the Digitisation Hubs, and the features of the languages into consideration.	RFC on TM Data Graph
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on Annotation	Definition of the annotation protocols used for the document of TM Data Graph. This RFC will be used by exploitation platforms	RFC on TM Data Graph
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on Digital Content Processor Development and Testing	Digital Content Processor are Automatic processes for extracting information from documents (images, video, sound, etc.). the following pipeline may be envisioned. (1) Development of a DCP in dedicated “Sandbox” (a place where trial and errors can be made without compromising the entire functioning of the Time Machine architecture). Training will be done on existing labelled documents. (2) Submission of the DCP to the Time Machine Organisation dedicated service. (3) After some benchmark and assessment of performances acceptation or rejection of the DCP. The DCP becomes a TM Official Component.	RFC on General Standards for the Super Computing Architecture , RFC on TM API

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on Digital Content Processor (DCP) of Level 1	Digital Content Processor are Automatic processes for extracting information from documents (images, video, sound, etc.). Digital Content Processor of Level 1 just label mentions of entities. Each processing is fully traceable and reversible. The results of the processing constitute the core dataset of the Big Data of the Past and are integrated in the TM Data Graph. The document should define: a. The technical condition for implementing DCP that can be inserted in the Time Machine Operation Graph. b. The requirement for hosting DCP in an TM Super Computing Infrastructure. The process by which DCP are developed, tested, labelled, published and puts in operations	RFC of Data Graph, RFC on Digital Content Processor Development and Testing
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on Digital Content Processor (DCP) of Level 2	Digital Content Processor are Automatic processes for extracting information from documents (images, video, sound, etc.). Digital Content Processor of Level 2 label relations between entities. Each processing is fully traceable and reversible. The results of the processing constitute the core dataset of the Big Data of the Past and are integrated in the TM Data Graph. The document should define: a. The technical condition for implementing DCP that can be inserted in the Time Machine Operation Graph. b. The requirement for hosting DCP in an TM Super Computing Infrastructure. The process by which DCP are developed, tested, labelled, published and puts in operations	RFC on Digital Content Processor (DCP) of Level 1

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Data	RFC on Digital Content Processor (DCP) of Level 3	Digital Content Processor are Automatic processes for extracting information from documents (images, video, sound, etc.). Digital Content Processor of Level 3 label Rules. Each processing is fully traceable and reversible. The results of the processing constitute the core dataset of the Big Data of the Past and are integrated in the TM Data Graph. The document should define: a. The technical condition for implementing DCP that can be inserted in the Time Machine Operation Graph. b. The requirement for hosting DCP in an TM Super Computing Infrastructure. The process by which DCP are developed, tested, labelled, published and puts in operations	RFC on Digital Content Processor (DCP) of Level 2
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Infrastructure	RFC on Synergy and interaction in EU Research Infrastructure	The TM digitisation network will build upon existing EU Research Infrastructures (DARIAH, CLARIN) and infrastructures providing access to CH (Europeana, Archive Portal Europe, etc.). TM will introduce new processing pipelines for transforming and integrating CH data in such infrastructures.	

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Infrastructure	RFC on General Standards for the Super Computing Architecture	This document will define the general rules that the TM Network partners have to follow to integrate their computing resources in the TM Super Computing Architecture and the routing processes managing the data pipelines. This document will particularly define : a. The software and hardware standards that the computing resources will follow across the entire distributed Super Computing Architecture. b. The routing protocols of the TM Operation Graphs. c. The processes for naming and renewing the administrators of the administrators. d. The role of the TMO for managing of the infrastructure.	RFC on Operation Graph, RFC on Data Graph, RFC on Synergy and interaction in EU Research Infrastructure
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Infrastructure	RFC on Time Machine Box	Also meant to cover storage needs for data, the Box should help partners involved in a data acquisition, sharing or publishing process to conform to the metadata specifications and delivery – harvesting protocols as stated by the data model. One of its goal is to smooth and contribute to the automatization of the digitisation process (offering for instance a way of monitoring the digitisation tasks). This hardware is part of the Time Machine Official Components. The RFC will define how the production of the Time Machine Box should be manage in the long run	RFC on Operation Graph

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2021	Digitisation	RFC Digitisation Hubs	Definition of functionning and business model fo the Digitsation Hubs. In order for the Digitisation Hubs to be implemented, standards in terms of resolution, file formats, and metadata during acquisition need to be defined beforehand (RFC on Technical Charts). These must be consensual and simple, in order to be easily implemented and to fit into existing practices. The RFC also needs to evaluate relevant technologies and recommend affordable technology that does not damage the objects, providing the best possible results at the same time. We aim to distribute cheap technology on a large scale using e.g. open design hardware. More costly and dedicated scan methods such as scan robots and tomographic methods should be available in dedicated specialized centres spread across the European Union such that their services are available to a maximum number of users. The objective of achieving cheap and wide-spread digitisation should be a priority in this RFC.	RFC on Open Hardware, RFC on Time Machine Box
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC for named entity recognition	This RFC defines named entity recognition in older European languages and variants. The results of the tagging of entities will feed the Dark Data Graph with new information.	RFC for classification and planning of languages to address , RFC on Digital Content Processor (DCP) of Level 1

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on Text Recognition and Processing Pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on Structured document pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on map and cadaster Processing pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on Audio Processing Pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on Video Procesing pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on music score pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on Photographic processing pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3
2020-2022 Bootstrapping	2021-2022-Pipelines	2022	Data	RFC on Photogrammetric pipeline	This RFC defines the general architecture for this particular kind of media. It needs to be aligned with the LTM central services.	RFC on Digital Content Processor (DCP) of Level 1 2 3
2023-2025 Scaling	2023 - Synchronization	2023	Framework	RFC on Enhancing Collaboration	Investigating how to supports partnerships across networks members of the Time Machine (e.g. Europeana, Icarus) or external cultural-heritage networks, and what means would be a suitable answer. The reflexion should focus on different aspects: how to enhance collaboration internally and externally both at the level of the LTM and the TMO (e.g. with other LTM or partner's networks), how to enhance best-practices exchanges, share of content and collaboration with already existing cultural-heritage networks and associations	RFC on LTM

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2023 - Synchronization	2023	LTM	RFC on Franchise System	A franchise model clarifying financial relations between LTM and TMO's services will be put in place, according to the financial needs and costs of the technical and coordination infrastructures of the TM. The franchise system is meant to be evolving, as the network will grow along with its reputation in the public's eye, and the LTM's financial benefit generated. This franchise system is meant to be complementary to the one established for the TMO partners. To enter an LTM an institution should at least become a member of the TMO. One of the subtasks of this RFC is also to assess and further design the role of the TMO as a "Finance, Economic, Intelligence and Watch services office	RFC on LTM
2023-2025 Scaling	2023 - Synchronization	2023	LTM	RFC on Solidarity	How to select, align and finance the "redocumentation" project, for potential projects compatible with TM goals but left on a stand-by stage for a while, will be the main tasks of this RFC. What would it take (training, formation) to ensure the project scalability	RFC on LTM
2023-2025 Scaling	2023 - Synchronization	2023	LTM	RFC on Top-Down initiatives	Defining what local and national measures might contribute to the creation of LTMs	RFC on LTM

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2023 - Synchronization	2023	Infrastructure	RFC on Distributed Storage	The TM distributed storage system will be aimed at offering an alternative solution to current HTTP based storage. Although in a first phase, most document and data will be stored on specific servers accessible through standard protocol (e.g. images on IIIF servers), the aim of the project is to develop a storage solution that would have the following objective: (1) Giving access to high volume of data with high efficiency, (2) Optimising storage to store more data, (3) Implementing long-term preservation of data, preventing accidental or deliberate data deletion and keeping a fully versioned history of the data stored, (4) Guarantying authenticity of the data stored and preventing the inclusion of fake sources.	RFC on Data Graph, RFC on Operation Graph, RFC on Synergy and interaction in EU Research Infrastructure, RFC on Time Machine Box

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2023 - Synchronization	2023	Infrastructure	RFC on Distributed storage system for Public Data	This document will define the infrastructure principle for a decentralized solution of public datasets based on Creative Commons licences like CC-0, CC-BY, CC-BY-NC and the Europeana rights declarations. Storage will be done on the resources shared by the partners of the TM infrastructure alliance. A distributed system like IPFS (Interplanetary File System) and the work done by the IPFS Consortium for persistence of IPFS object may be a good starting point. Such kind of file system do not identity a resource by its location but by a unique identification number. Routing algorithms optimise through P2P algorithm the most efficient ways to bring the data to the visualization or computing processes. This also speed up process when the host is a region with low connectivity. Redundancy and long-term resilience can be guaranteed. This means that the system can be designed to make in practice undeletable any public data content that it starts to store, making it hard to censor content. For this reason, it is especially well adapted for public data associated with creative common licenses. Systems like IPFS also give the possibility for each node of the network to choose the categories of data they accept to replicate. This gives some flexibility in the negotiation of common strategy by the Time Machine Infrastructure Alliance. For ensuring the authenticity of the data stored, a blockchain type solution could be the solution. The interaction between the distributed file	RFC on Distributed Storage

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
					system and the authentication solution will be defined by the RFC.	

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2023 - Synchronization	2023	Infrastructure	RFC on Distributed Storage system for Private Data	Private datasets could be stored either (1) - In specific layer of the distributed storage system provided reliable cryptographic and authentication systems are in place, (2) - In “fenced” location otherwise offered by partners of the Time Machine Network as storage solution. In both cases, the RFC should define how such closed dataset could use the services of the Time Machine infrastructure and under which condition	RFC on Distributed Storage
2023-2025 Scaling	2023 - Synchronization	2023	Digitisation	RFC on on-demand digitisation	This RFC defines the process for on-demand digitisation enabling any user to ask for the digitisation of a specific document. A alignment of the archival description system is necessary.	RFC on Data Graph, RFC on Operation
2023-2025 Scaling	2023 - Synchronization	2023	Digitisation	RFC on Global optimization of digitisation process	Defiintion of the strategy for optimizing the digitisation processes. The objective of this RFC is among others to avoir digitisation of redondant printed material through a synchronization of all the digitisation initiatives.	REFC on Digitisation Priorities, RFC on on-demand digitisation, RFC on distributed storage for Public Data, RFC on Synergy and interaction in EU Research Infrastructure,

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2023 - Synchronization	2023	Data	RFC for orthographic normalisation	This RFC defines the orthographic normalisation of older European language variants. The results will improve the search functionality of the databases	RFC for classification and planning of languages to address
2023-2025 Scaling	2023 - Synchronization	2023	Data	RFC on Content Filtering	Content filtering may be necessary to control the exposure of users of the Time Machine services to unsolicited content. Finding the right technology to allow such a control without giving the possibly of abusive censorship operation will be the challenge of this RFC.	RFC on Vision Mission and Values Charter
2023-2025 Scaling	2024-2025 Engines	2024	Framework	RFC on Knowledge transfer	Investigating how to support achievements and knowledge transfer inside the TM network. Ensuring a global research collaboration at a European scale. There are rare examples of large-scale research data management models, dealing with similar complexity level as the TM, however some guidelines can be found such as: “Guidance Document Presenting a Framework for Discipline-specific Research Data Management” (Science Europe, January 2018), “Practical Guide to the International Alignment of Research Data Management” (Science Europe, November 2018).	RFC on Enhancing Collaboration

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2024-2025 Engines	2024	LTM	RFC on Smart Cluster	Defining what would be the rules to be followed by the future smart clusters (for instance compliance with LTM rules and recommendations), what means will ensure the creation of such a space for creativity, support inter-disciplinary exchanges, political involvement and jobs creation, what relations could be built between the participants of the smart clusters and the partners of the LTM, how to monitor, evaluate and revise or update the process.	RFC on LTM
2023-2025 Scaling	2024-2025 Engines	2024	LTM	RFC on Collaboration indicators	This RFC defines Key Perforamnce indicators to evaluate locally and globally the level of collaboration amont the TM partners. It also develops "Affinity maps" to suggest possible future colloboration.	RFC on Enhancing Collaboration

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2024-2025 Engines	2024	Data	RFC on Large-Scale Inference Engine	The Large-Scale Inference Engine is capable of inferring the consequences of chaining any information in the database. This permits to induce new logical consequences of existing data. The Large-Scale Inference Engine is used to shape and to assess the coherence of the 4D simulations based on human-understandable concepts and constraints. Its origin derives from more traditional logic-based AI technology, slightly overlooked since the recent success of the deep learning architecture, that can, nevertheless, play a key role in an initiative like TM. The document will specify the various kinds of rules that the Large-Scale Inference Engine can process including - Rules extracted from documents by DCP, - Implicit Rules made explicit - Rules (statistical or not) induced from the data. The document should define - the process by which rules are submitted, tested and integrated in the engine, - the processes for managing conflicting rules or results from various rules. The document will also motivate implementation solution in relation with existing deployed systems like Wolfram Alpha or IBM Watson and standards like OWL, SKOS.	RFC on Digital Content Processor (DCP) of Level 3

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2024-2025 Engines	2024	Data	RFC on the 4D Grid	Through a hierarchical division of space (3D) and time, the system organises a multi-resolution 4D grid which serves as a general spatiotemporal index. Each “cube” in the grid indexes all the information relevant for these particular spatiotemporal elements. It offers an efficient perspective for organising the large datasets and performing collective curation through manual and automatic processes. Each element of the grid will also be potentially labelled according to other various multidimensional criteria, some of them being AI-based descriptors (e.g. descriptors for architectural style detection in images).	RFC on Data Graph
2023-2025 Scaling	2024-2025 Engines	2024	Data	RFC on 4D Simulations	The 4D grid is sparse as many places/times in the world that are not directly associated with existent archival data. A central research challenge is to develop AI-systems capable of extending the information of the data grid in space and time through continuous extrapolation and interpolation, and developing new ways of visualizing which part of the content is anchored in sourced data, simulated or unknown. Extensions of current deep-learning generative methods, originally developed for 2D imaging, can be envisioned to deal with the richness of the 4D datasets. Many 4D simulations can be associated with the same 4D grid and one central challenge is to manage this multiplicity of worlds and their specific resolutions level for various services of the Time Machine (e.g. entertainment, policy planning).	RFC on the 4D Grid

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2024-2025 Engines	2024	Data	RFC TM tools for history research	To engage researchers in social sciences and humanities is to productively use the Big Data of the Past, and the TM can offer researchers a series of tools that facilitate analyses. These tools will be enhanced by the Digital Content Processor and the Simulation Engines, which will enable scholars to work with historical data in an unprecedented way.	RFC on 4D Simulations, RFC on Large-Scale Inference Engine
2023-2025 Scaling	2024-2025 Engines	2024	Digitisation	RFC on New Scanning Technology	Cutting-edge technologies, such as automatic scanning machines with low human supervision, scanning robots and solutions for scanning films and books without the need to unroll/open them, should be considered and fostered by the TM. A specific scheme to incentivize these technologies will be created. The goal is to reach an appropriate mix of dedicated specialized scanning centres and at the development of mobile special use hardware, e.g. mobile CT scanners that are mounted on trucks.	RFC on Open Hardware, RFC on Digitisation Hubs

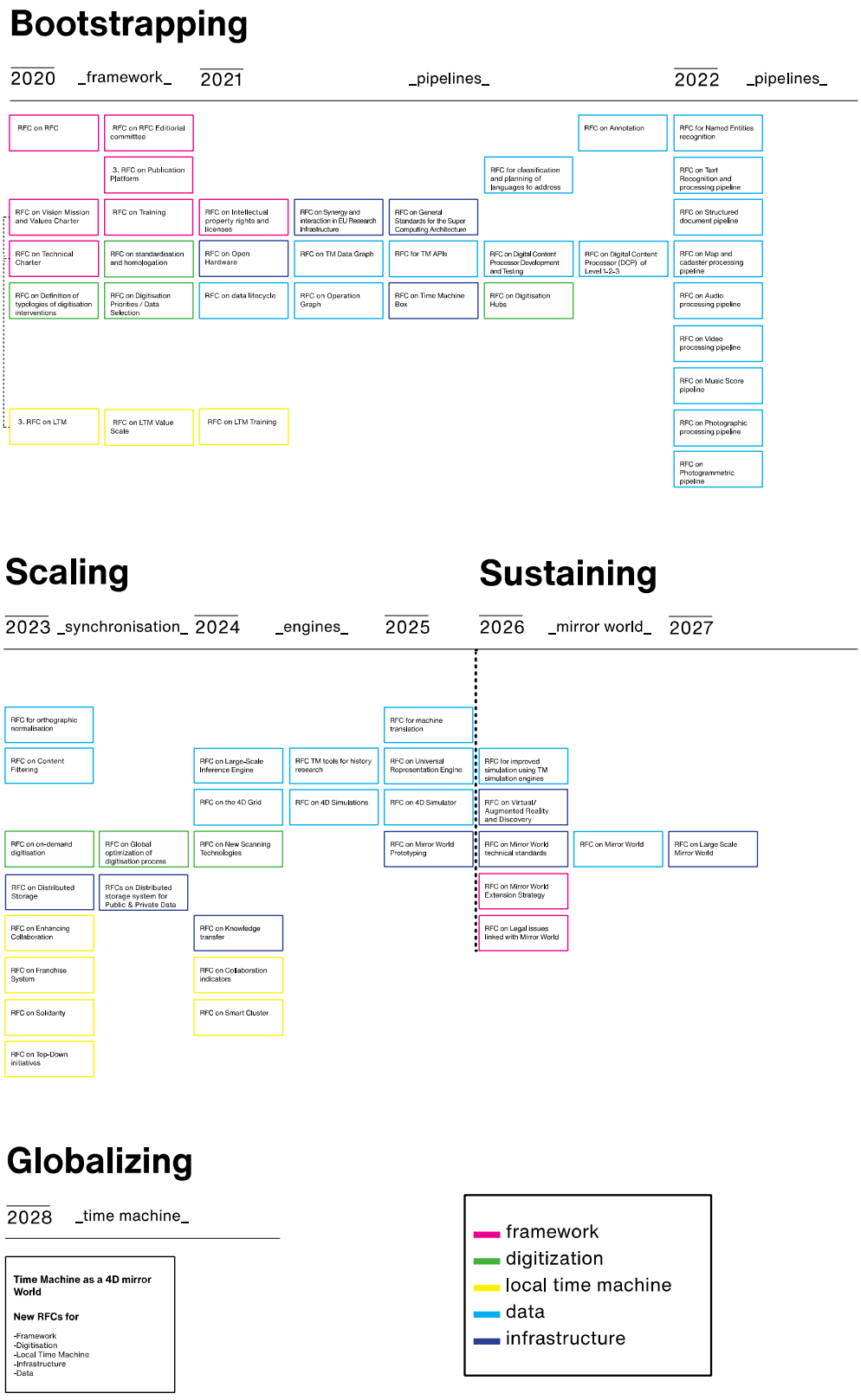
Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2024-2025 Engines	2025	Data	RFC on 4D Simulator	The 4D Simulator manages a continuous spatiotemporal simulation of all possible pasts and futures that are compatible with the data. the 4D Simulator includes a multiscale hierarchical architecture for dividing space and time into discrete volumes with a unique identifier: a simulation engine for producing new datasets based on the information stored. Each possible spatiotemporal multiscale simulation corresponds to a multidimensional representation in the 4D computing infrastructure. When sufficient spatiotemporal density of data is reached, it can produce a 3D representation of the place at a chosen moment in European history. In navigating the representation space, one can also navigate in alternative past and future simulations. Uncertainty and incoherence are managed at each stage of the process and directly associated with the corresponding reconstructions of the past and the future. The document should specify the interaction of the 4D simulator with the rest of the architecture answering questions like: - How can an entity of the TM Data Graph be associated to a particular element of the 4D Grid, - How can 4D simulations be run and cached for future use, - How can the system be used directly in exploitation platform	RFC on the 4D simulations

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2024-2025 Engines	2025	Data	RFC on Universal Representation Engine	The Universal Representation Engine manages a multidimensional representation space resulting from the integration of the pattern of extremely diverse types of digital cultural artefacts (text, images, videos, 3D and time), and permitting new types of data generation based on transmodal pattern understanding. In such a space, the surface structure of any complex cultural artefact, landscape or situation is seen as a point in a multidimensional vector space. On this basis, it could generate a statue or a building, produce a piece of music or a painting, based only on its description, geographical origins and age. The document will specify the integration of the URE in the global architecture, outlining for example how a give node in the TM Data Graph can be associated with a parametric representation space.	RFC for TM APIs
2023-2025 Scaling	2024-2025 Engines	2025	Data	RFC for Machine Translation	Definition of the architecture for multilinguisal diachronic machine translation. Existing algorithms for machine translation will be adapted to older language variants of European languages . This will densifiy the Data Graph and give more input to the Large Scale Inference Engine.	RFC on Named Enty Recognition, RFC on Orthographic Normalisation, RFC on Large-Scale Inference Engine

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2023-2025 Scaling	2024-2025 Engines	2025	Infrastructure	RFC on Mirror World Prototyping	Definition of the implementation strategy for first working protoype of Mirror World using the TM engines. This first prototype is likey to be developed on the most advanced LTM. This RFC will define how to safely experiment with this technology.	RFC on 4D Simulator, RFC on Universal Representation Engine, RFC on Large-Scale Inference Engine
2026-2028 Sustaining	2026-2027 Mirror World	2026	Framework	RFC on Legal issues linked with Mirror World	Mirror Worlds are linked with specifc legal issues which needs to be addressed specifcally. This concerns in particular privacy, confidentiality.	RFC on Mirror World Prototyping
2026-2028 Sustaining	2026-2027 Mirror World	2026	Framework	RFC on Mirror World Extension Strategy	The Mirror World extension strategy takes into account all the technical and legal choices defined by the RFC of the Scaling period in order to address the extension of the Mirror World covering at a larger, mostly European, scale.	RFC on Mirror World Prototyping
2026-2028 Sustaining	2026-2027 Mirror World	2026	Infrastructure	RFC on Mirror World technical standards	This RFC defines the specifc technical standards needed for the Mirror World extension, based on the experience developped with the Mirror World prototype	RFC on Mirror World Prototyping
2026-2028 Sustaining	2026-2027 Mirror World	2026	Infrastructure	RFC on Virtual/Augmented Reality and Discovery	Definition the standards that should be adopted in order to enable the development of Virtual/Augmented Reality services and Discovery module on top of the TM Data Graph.	RFC on Mirror World Prototyping

Phase	Subphase	Planned year	Type	Title	Description	Dependencies
2026-2028 Sustaining	2026-2027 Mirror World	2026	Data	RFC on 4D Mirror World	This RFC defines how the Mirror World can be continously synchronized with the TM Data Graph, enabling the direct access and manipulation of 4D data.	RFC on Mirror World Prototyping
2026-2028 Sustaining	2026-2027 Mirror World	2026	Data	RFC for improved simulation using TM simulation engines	Researchers will be able to use the TM simulation engines to perform simulations studies, without having to rely on external models and tools. The simulation engines have the capacity to improve the performance and the reach of computational simulations for historical research	RFC on 4D Simulator
2026-2028 Sustaining	2026-2027 Mirror World	2027	Infrastructure	RFC on Large Scale Mirror World	This RFC consolidates the vision, strategy and framework conditions for the development of a World Wide Mirror World	RFC on Mirror World Extension Strategy, RFC on Legal issues linked with Mirror World, RFC on Mirror World technical requirement
2028-2030 Globalizing	2028-2030 Global Time Machine	2028-2030		…	… New RFC defines for Framework, Data, Infrastructure and Digitisation program of the Time Machine as a 4D mirror World	

B.2 The RFC Tree development scheme



Annex C: Time Machine Use Cases

C.1 Education

Written by: Emillie de Keulenaar & Julia Noordegraaf (University of Amsterdam)

Title	Using XR applications to teach secondary school students about the Holocaust
User group	As of now, users include educators (e.g., tour guides, schoolteachers); secondary and higher education students; historians; employees of the memorial site; and tourists. After expansion, the augmented reality Time Machine app could include a broader user base with no specific profile, such as users interested in the history of World War 2, concentration camps and/or with a more general interest in software for historical reference.
Core problem	• We are entering a post-witness era characterised by a return of explicit hostility against European Jewish populations and their memory of the Holocaust. • Like many concentration camps across Europe, Bergen-Belsen was demolished at the time of its liberation. The lack of physical evidence of the camp complicates the continued remembrance of the experiences of Bergen-Belsen victims and survivors. • The fact that many memorial sites have been destroyed may fuel the revisionist idea that the Holocaust did not occur - or occurred to a far lesser scale than claimed. • In the context of a growth in populist rhetoric, “establishment” accounts of history have been popularly shunned as deceptive and monolithic. While this criticism may be ideological at source, it may also be due to a radical change in the way citizens consume history through different media. A factor in the return of revisionist accounts of the Holocaust in public political discourse - as well as the loss of witness accounts of concentration camps - could indeed be the growing gap between personal access to history (through, e.g., media, reference and social media platforms) versus access through various institutions, be it schools, museums, or “mainstream media”.
Opportunity	At present, the Future Memory Foundation’s VR app allows Bergen-Belsen visitors to visualise demolished structures and recontextualise documentation of the camp left behind by victims, survivors and archives. The app contains an interface with three tabs and two modalities. The three tabs each contain two modules, which are maps and 3D models of the camp in 1944 (pre-liberation), 1945 (post or during liberation) and 2019 (present day), respectively.

	As a student navigates in the camp, he or she is able to consult three historical maps and corresponding 3D modelled architectural structures. Photographs, drawings, testimonies, and other documents are distributed across the visualisations in their designated places, and visitors may access them through the app when they are a few meters close-by from a document's original (or referred) location. The Time Machine can expand on the Future Memory Foundation's app for education purposes in the following ways (among others): • **Introducing students to critical historical inquiry**. As users, students can use XR history apps for their own reference. They can use available documentation and 3D models to orient themselves around a historical site and inquire about past circumstances and their implications in contemporary history. • **Giving students a "thick" experience of history and historical sites**, on par with current uses of map applications. Current map applications such as Google Maps use linked and user-generated data, such as photos, reviews, tags and other items to situate themselves around a given place. Likewise, a Time Machine XR app can link and map available primary and secondary sources of a given place for students to browse on and off-site. • **Affording students with a comparative experience of historical sites.** A Time Machine VR app could "stack up" various cartographic layers of a given site for students to explore and compare. A comparative perspective can give students with the tools necessary to make inferences about chronology, space, activities and other contingent phenomena. • **Further transpiring the contested nature of historical memories for critical historical study.** Memories linked to the Second World War are notoriously relative to myriads of historical perspectives. The addition of historical sources to datasets for the Foundation to process would allow it to design interfaces that showcase a multiplicity of perspectives while still being transparent about the provenance of the data and carefully managing the possible conflicts between such perspectives.
Persona	Secondary school teacher educating a class of teenagers about the Holocaust in the present and foreseeable future.
Summary (specific and attainable)	The Time Machine aims to build upon the Future Memory Foundation's Bergen-Belsen (and other) XR applications for school students of history to explore the history of the Holocaust with features attuned to the complexity and multi-perspectivity of this historical period.
Scenario	In the foreseeable future, history teachers will need adequate instruments to keep a not-so-distant past (such as the Holocaust) from falling into oblivion. XR applications can tap into contemporary modes of consumption of historical information and bridge a dangerous (and

growing) gap between learning history through new media and existing "top-down" forms of teaching the subject.

Whether in class or in memorial sites, history teachers would be able to invite their students to use an XR application of Holocaust sites to train critical historical skills and inform themselves about historical events. There are four features that, like the Foundation's app, a Time Machine XR application could introduce to this scenario.

5.4.1.1.1 (1) Historical context

Though a Time Machine XR app can allow students to access historical information off site, if they are in a guided tour, they may use the app as a "deep map" to orient themselves around a memorial and situate historical documentation in relation to their specific (geolocated) context. For example: as they walk around the site, students may pass through a spot where, according to a given document, a few prisoners were roll-called to a point of exhaustion by SS soldiers. This document may highlight one specific testimony of one rollcall, and a student may consult it when reaching the specific point where they occurred. A student may consult other documentation adjacent or related to this specific event when walking close-by, such as a document stating the number and name of prisoners before and after rollcalls and assess how deadly this activity may have been (evidently, in combination with other activities).

5.4.1.1.2 (2) Thick history

5.4.1.1.3 A Time Machine XR application may be a case in point of how students, much like users of city maps (e.g., Google Maps), may navigate a space with the support of documents linked to it. The result is an experience of "thicker" history: when standing on a site, students may have a combination of virtual and present access to the plethora of objects that have come to constitute that site's past. The idea of "thick history" relates to Bodenheimer et al.'s concept of "deep maps" (2015), which makes the case for interfaces to combine convenience (e.g., Google Maps combines all relevant information in one interface) with complexity (e.g. a remodelled Commander's house a Westerbork may include various witness perspectives one a single interface).

5.4.1.1.4 (3) Comparative or "stack" history

5.4.1.1.5 Another important feature of a possible Time Machine XR application for education is giving students affordances for comparative perspective of historical sites. Students can, for example, compare Bergen-Belsen from what it is today, when in the site, to what it was like in the 15th of April 1944 or the year after

	(the date of its liberation). Besides congregating multiple objects linked to that site, this application could stack a multiplicity of versions of that place across time. The 4D Research Lab of the University of Amsterdam (as well as the Foundation's own VR installation in the National Holocaust Museum in Amsterdam) both make use of this feature in more depth, in that they allow users to zoom in and out of various layers or "stacks" of a site's history in varying detail. 5.4.1.1.6 (4) Student agency A Time Machine XR app would offer students users the ability to consult a variety of sources of their choice outside of the more static and curated selection of texts available in a sites' permanent exhibition. A student can bookmark, compare and consult documents from several locations at a given site. They can thus engage in their own, personal (documentation-supported) reconstruction of history. By the end of a visit, they may discuss their findings, inferences and doubts among themselves and with their teacher, thereby engaging in genuine and critical historical inquiry.
Needed from Time Machine Pillar 1	• **Linking data from all users** (institutes, historians, witnesses, memorial sites) who are offering documentation about a given site by, e.g., extracting all their metadata and storing them in one specific place; • **Centralising other memorial sites within a single app.** The Foundation's app is limited to the Bergen-Belsen alone and does not include other nearby camps as of yet. The Time Machine could provide a general platform for all camps to be included in the Foundation app. This would allow visitors to explore a memorial site on a broader comparative basis with other sites and its respective documentation. The Time Machine could also take the Foundation app as a template for user navigation in other memorial sites. • **Connecting more data points.** Unite several data centres across Europe. Each of these can contain other information linked to other memorials from the Second World War. With linked data, it should be possible to data points among related datasets and draw new inferences from them. • **Considerable computing power to:** maintain the back and front-end of the Foundation app; link documentation to locations; integrate GPS capacities; and maintain storage for online access;
Needed from Time Machine Pillar 2	• Manage a consortium of members with additional data to feed into the Foundation app; • Manage copyright access; • Integrate Local Time Machine with memorial sites (if applicable);

	• Manage and if possible standardise the user interface (e.g., accessibility features) between Local Time Machines and memorial sites;
Needed from Time Machine Pillar 3	• Managing cooperation with education professionals and education certifying bodies in these fields. • Applying pilot projects in a select number of institutions from a representative sample of the European education landscape, including primary and secondary schools. Via its Community Interfaces (Pillar 2) the Time Machine will allow us to also test the use of TM in informal learning. Pilot projects will consist in experimenting and monitoring the uses of Time Machine components, including historical data, training in analysing big data of the past, accompanying analytical software and training in using and developing Time Machine interfaces for big data of the past.
Needed from Time Machine Pillar 4	• Support community management for this domain; • Ensure that the data meets scholarly standards for trustworthiness; • Ensure that the Foundation app includes features for scholarship and education (e.g., documentation, annotation, etc.); • Ensure that the Foundation app has integration with popularly accessed platforms (e.g., Wikipedia, Google, etc.); • Implement editorial policies for user interfaces.

C.2 GLAM

Written by: Paul Sommersguter (Austrian National Library)

Title	Museums as Smart Spaces
User group	GLAM Visitor / Tourist
Core problem	Traditionally, exhibitions on display in museums do not necessarily provide the possibility to adapt to users' needs and their resources like time available or existing knowledge. One main reason for this is the lack of data.
Summary (specific and attainable)	Users can experience different versions of the same exhibition. This is achieved by an accompanying app that makes use of Time Machine APIs to access Time Machine services and data. Users can choose their preferred context, e. g. • their time resources ("I have limited time"), • knowledge about a topic ("I am familiar with the basics"), • level of desired detail ("I just need an overview"), • their mood and emotional state, • or even different versions programmed by curators (for controversial topics). As a consequence, the app creates tailor-made pathways through an exhibition and thus creates unique narratives. A visitor's experience, when fed back to the Time Machine knowledge graph, could be saved for future reference and influence other exhibitions.
Opportunity	• Re-think GLAMs as exhibition spaces • Time Machine as a driver for linked cultural heritage data at GLAMs • Lower barriers between subsectors of GLAM • Improve accessibility and openness of (digitized) cultural heritage by automated translations of descriptions • Provide meaningful and unobtrusive AR experiences for select artifacts • Provide a possibility for feedback and enrichment on the fly
Persona	Olivia, 39, a tourist from Bucharest, visiting a museum of modern arts in central Berlin, on display is American pop art of the 20th century.
Scenario	Olivia enters the museum. To her surprise, the museum presents a label at the entrance that a particular app is supported. This app aims to enrich her experience at the museum according to her preferences. Moreover, the app lets her even co-curate the exhibition. (She's already used the app in other museums that support the app and is familiar with it. She rarely uses audio guides because of their clumsiness.) Upon entering the museum, she opens the app and chooses her preferred language (Romanian) and sets her available time to a minimum (she has to catch a train in two hours). The app shows the exhibition's highlights according to the curators on an interactive floor

	plan. Because it's a rainy November day outside, she's only in the mood for brighter, more colorful works. Now, the app creates a pathway through the museum that tries to meet her expectations and presents it on an interactive floor plan. The app takes her current location into account. Step by step, it leads her to the next work on the generated pathway. The app seamlessly integrates into the experience. When Olivia stops interacting with it, the app goes quieter and returns to providing essential information only. A colorful portrait by Andy Warhol depicting Goethe catches Olivia's attention. She consults the app, dives deep into the background information of the painting in her native language. Through the app, she finds out that there currently is a special Warhol exhibition on display in her hometown Bucharest (this museum is also participating in Time Machine). She's curious about what other exhibition goers say about the painting and listens to some comments in Romanian. On the fly, she tells the app that she likes the painting's vibrant colors. She is aware that other institutions could use her annotation (in the form of a comment) elsewhere. Her contribution feeds back into the Time Machine knowledge graph. *Experimental and playful addition:* Next, she walks to a space that lets her control the lights in the room illuminating paintings. Through the app, she can browse the large linked data set that exists for all of the artifacts on display. The app lets Olivia select certain metadata tags and properties of the paintings. At first, she's interested in paintings that were created pre-1989 and selects the corresponding tag in the app. All of the works not meeting this criterion appear less illuminated in the room. Then, she only wants to highlight the paintings that were painted by female artists. Again, she uses the app to alter the light situation. With Time Machine data and accurately implemented smart spaces, Olivia can query the room.
Needed from Time Machine Pillar 1	• Artifacts (here: analog artifacts on display in museums) need a unique identifier. • Linked-data-standards. • Rich metadata for heterogeneous objects. • Automated translations.
Needed from Time Machine Pillar 2	This is a special case where a tailor-made app to interact with Time Machine data needs to be developed. Therefore, standardized access to Time Machine APIs (both data contribution and data use) is necessary.
Needed from Time Machine Pillar 4	Rights management of user contributions. Editorial policy for user contributions.

C.3 Creative Industries

Written by Johan Oomen & Rasa Bocyte (NISV)

Title	Big data of the past for data-driven journalism
User group	Journalists
Core problem	Fake news and misinformation are undermining trust in the media and posing a threat to democratic societies
Summary (specific and attainable)	TM data and resources empowers journalists to create new methods for tackling misinformation in the media: • Provide tools for journalists to create data-driven stories • Enable citizens and journalists to validate the trustworthiness of data and stories in the media
Opportunities with Time Machine	• Archives can provide trusted content and context needed to tackle misinformation • Journalists can make use of TM data to create trusted and engaging stories that attract readership and support their business goals • Through TM, journalists have access to state-of-the art technologies to explore data as well as build new tools • TMO connects journalists to a European network of academic, research and cultural heritage organisations as well as well as other European media organisations • Local Time Machines act as living labs for networking, collaboration and experimentation
Persona	Claudia is a senior journalist working for an international news agency in Utrecht, NL. She is leading a team who are investigating the spread of fake news and misinformation in the media and exploring different ways to tackle it. They want to develop tools and methods that enable journalists and citizens to: • Perform research on big data coming from different sources • Analyse, visualise and query data on a granular level to find new trends and patterns • Verify authenticity of various content (e.g. deep fakes) • Trace data sources and their use Claudia's team has decided to work on the following: **[1] a YouTube channel that reports on misinformation in the media** **[2] storytelling template that enables journalists to create online articles supported by in-depth analysis of data** **[3] novel digital tools for data verification and bias** **[4] a series of bootcamps and training sessions for professionals in the media industry**

	[5] educational tools for citizens on fake news detection and digital literacy
Scenario	**[1] Exploring and reusing Time Machine data.** For videos on their YouTube channel, Claudia's team wants to use various segments of archival footage, photographs, audio recordings, etc. They need an interface that allows them to discover, explore, access and reuse this footage. On the TM platform, Claudia can use a generous interface and advanced search functionalities to search for video content on a shot/scene level to find specific segments. She can perform search either by entering text or uploading an image/audio file to find matches - e.g. upload a photo of an unidentified person and find footage where this person appears; type in a place name and find the exact segments in video/audio files where it is mentioned in various languages. TM platform provides clear rights statements and offers Claudia flexible mechanisms for the reuse of content protected by copyright. For example, if her team is interested in using only a couple of seconds from a video, they can use a pay-per-use model that allows them to acquire rights to a specific segment rather than paying a substantial fee for the use of the whole file. **[2] Integration and use of Time Machine resources on external platforms.** Claudia's team wants to create an embeddable web template that enables journalists to analyse various data and present it in online articles. The template would allow users to combine, compare and visualise historical Time Machine data together with data available on other online platforms, and make sure that it can be easily traced to its source and contextualised. Claudia can analyse and export data from the Time Machine platform and add it to the template or access the data via an API to create interactive graphs in the template. The template links back to the exact search results used by the author so that everyone would be able to replicate the analysis. The template is connected to the Time Machine platform, so it is possible to annotate any object in the online article (text, image, video, sound, etc.) - when the object is selected, a small popup window would open with contextual information and display relevant Time Machine resources (e.g. if a street name is mentioned, the popup window would show a 3D reconstruction of it and allow users to browse its representation through time). All TM data would have a fingerprint therefore it would be possible to see how the same resources where used in other contexts (e.g. other news articles, research papers, etc.).

	[3] Use Case Development with Local Time Machines. To develop tools for data verification, Claudia's team reaches out to their Local Time Machine in Utrecht with a specific use case. This connects them to researchers working at Utrecht LTM. Building on the state-of-the-art technologies available at TMO, they work together to develop open source tools that support Claudia's use case and that are available for the use by TMO and other media organisations. Big heterogeneous data provided by the TM members is used to test and improve the tools. **[4] Connecting and scaling up through the TM network.** Claudia's team wants to conduct a series of bootcamps and training sessions that bring European media professionals together to discuss ethical, political and technological concerns and develop toolkits and standards for the media industry. Through the Utrecht LTM, Claudia's team connects to research and cultural heritage organisations who are able to provide their expertise and resources and collaborate in experimentation with new ideas. **[5] Crossovers and collaborations with other exploitation areas**. TM helps Claudia's team to equip citizens with skills and tools to identify and fight misinformation. They team up with educators who are developing learning courses for online platform with TM resources. Together, they prepare a course on digital literacy and misinformation detection.
Needed from Time Machine Pillar 1	• A single interface for exploring all TM data that supports granular queries for multimodal data - sentiment analysis, multilingual search, multimodal search and visualisation, search by image, object detection, video hyperlinking (area 2.4) • Fingerprinting
Needed from Time Machine Pillar 2	• Processing of distributed multimedia data sources • Storage of persistent identifiers • Easy and standardised integration of TM services/tools/resources with external platforms • LTMs need to act as incubators that enable stakeholders to develop use case, connect then with other TMO partners and provide an environment for testing and developing novel services
Needed from Time Machine Pillar 3	Suggestions to be discussed with WP4 leaders: • A platform to build and connect stakeholder groups and communities, enable exchange of expertise? • An observatory to monitor and measure the impact of exploitation that showcases the potential of TM to stakeholders and highlights framework conditions that need to be addressed?
Needed from Time Machine Pillar 4	• Negotiate licenses for use by 3rd party platforms • Outreach to commercial platforms to ensure compatibility and integration of resources

	• Build strong connections to the commercial sector and service providers

Annex D: Measuring TMO's impact

This section consists of recommendations on an Impact Assessment and evaluation approach. We propose how this could be implemented within the broader delivery of each Pillar's activity. It is based upon good practices in impact assessment at the time of writing, and on the presentation of the Pillars and plans for ongoing management of the operation through TMO presented in the Deliverable 8.5.

The four steps to Impact Assessment within TMO (see Diagram 1) will be presented in this section;

- First discussed is how evaluative approaches across the Pillars will be aligned in order to embed evaluation and Impact Assessment thinking throughout TMO. Also discussed is how impact assessment will be managed within the TMO structure.
- Secondly, process evaluation is recommended on a yearly basis to monitor delivery by TMO and LTM.
- Thirdly, and noting the complexity and sheer scale of activity of TMO, an Impact Assessment and Evaluation Research Agenda should set research priorities relating to the exploitation areas. A theory-based approach would be appropriate to develop these research priorities through the formulation of case-study based impact assessments, benefitting from the recent emergence and rigour of this methodological approach.
- Finally, an aggregate Impact Assessment will be completed every five years, analysing and interpreting all of the gathered data.

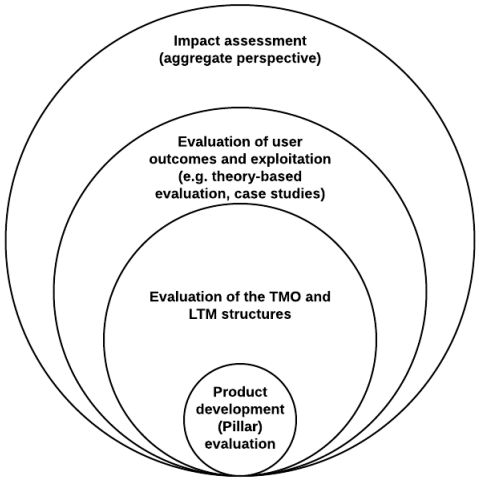


Figure G-1: the four Impact Assessment steps for TMO

D.1 Aligning impact assessment across the Pillars

Impact assessment across the TMO

This deliverable has had the input of the wider TMO management team and WP leaders. As a result, and through the mechanisms outlined in this section, Impact Assessment will be embedded into the wider TMO structure.

In the current structure, Impact Assessment would be managed by the Business Development unit, and in future, by the proposed Business Development and Strategy Unit. An additional lead for this will be identified within TMO's structure or wider partnership to lead and, or support the embedding of impact assessment thinking.

Impact assessment across the Pillars

The building of the Time Machine requires consolidation of efforts from all the pillars that will bring their multidisciplinary and cross-sectoral expertise to drive the innovation throughout the 10-year roadmap period and beyond. Time Machine will adopt a Two-Speed Methodology which will drive research and innovation through two parallel tracks: (1) the fast speed, cyclical development of capabilities driven by specific use cases and business needs from various exploitation areas and (2) state of the art development of foundational components and infrastructures at the core of the TM at a steady speed over the 10-year roadmap period. To complement the iterative Research and Innovation development approaches in Pillars 1 and 2 (iterative tech development processes), we recommended that a similarly iterative evaluation framework that will embed monitoring, evaluation and learning at the heart of TMO during and after this period.

To harness TM's complexity, learning from a developmental evaluation approach seems particularly suitable. This is described as being 'particularly suited to innovation, radical program re-design, replication, complex issues, crises'. This flexibility feels appropriate for TM and it is not new to the research partners. This model follows iterative product development evaluation cycles already in place (i.e. the fast speed, cyclical development of capabilities driven by specific use cases and business needs from various exploitation areas), and Europeana Foundation's Impact Framework takes a similar approach of asking the right evaluation and impact assessment questions at the right times, beginning at the project planning stages.

In essence, it will ensure that learning captured through any evaluation is embedded back into the structure in order to improve processes and outcomes. It provides flexibility to the evaluation logic throughout the development of the Time Machine, and guides monitoring and data collection - as well as reporting - throughout the initiative. This approach reflects the numerous stages of TM's development and delivery (taking a similar research and development approach), as well as the activity taking place under each pillar and the different moments at which each exploitation area will most benefit from the functionality offered by TM infrastructure and the Mirror World.

D.2 Process evaluation of LTMs and TMO

Process evaluation (focussing on the intended inputs, activities and outputs) will be completed to evaluate the core infrastructures (TMO and LTMs). We suggest that this should take place annually. This reflects our desire to demonstrate accountability to funders and stakeholders. An action model (or theory of action) approach will run parallel to the Theory of Change and will help assess the quality of the intervention (a sample assessment framework is referenced further on). This will assess to what extent the project has delivered what it was designed to do, and support the evaluation of what happens when there is a deviation or roadblock.

Developing TMO Key Performance Indicators

KPIs and/or targets will be developed at the project inception, informed by the creation of a baseline and the requirements of funders, and also evaluated annually. KPIs will be developed to measure the progress of the TM against its Research and Innovation objectives set out in the project roadmap. These will be formed at the project outset, the point at which it will be possible to create a baseline against which to measure delivery. To note, KPIs differ from outcomes (the focus of an Impact Assessment), that is, changes

experienced by stakeholders. KPIs involve the setting of targets over time or by a time frame (e.g. yearly, or before 2030). They are likely to inform and be part of reporting to funders. In the Annex F we outline a suggested framework in which a set of KPIs can be developed. The KPIs also inform the reporting of outputs in the overall Impact Assessment.

D.3 The creation of an Impact Assessment and Evaluation Research Agenda

Noting the scale of TM's activities and potential impact, a degree of prioritisation is necessary. Considering the lack of research into data-led innovation processes and social and economic change, TMO could significantly contribute to this gap in knowledge. For example, specific cases could include: the interaction of SSH researchers with the TMO leading to new insights; exposure to new SSH insights leading to more effective evidence-based policy.

A suggested methodological approach is Theory Based Impact Evaluation (and potentially - if resources and skills allow - a process tracing approach). This field of impact evaluation has emerged in the last five years to the benefit of rigour and demonstrating causality in qualitative impact assessment. It is important for our approach, as it relies on the development of case studies or use cases (through which we can explore TMO's impact for the exploitation areas). The methodology is an extension of the Europeana Foundation Change Pathway approach and focuses on the exploration of causal links within a concrete case(s). Doing so will allow learning to be gathered over time about how TMO activities benefit the intended beneficiaries (here understood as the exploitation areas and the general public).

The approach allows the question of 'how (or how not) did the intervention work?'. This is of primary importance in the demonstration of causality (important both on an evidential level and also to funders). It does not answer the question 'to what extent did the intervention create a change?'. The latter question will also be considered as part of these plans, benefitting from the data collection opportunities outlined below.

D.4 Five-yearly aggregate Impact Assessment

Bringing together the relevant data collected through the steps above, TMO will publish a five-yearly Impact Assessment. This will include, for example, the periodic review of externally published statistics (e.g. Eurobarometer) but it will not be possible to make causal inferences between TMO activity and these statistics.

D.5 Supporting recommendations

Underpinning strategic development with a theory of change (ToC) for TMO

The developmental evaluation approach aligns with and complements the approach used by Europeana Foundation's Impact Framework. In 2017, Europeana Foundation published the Impact Playbook, an intuitive and now well-tested method to design impact in the cultural heritage sector. This approach develops a logic model framework (known in the Europeana Impact Framework as a Change Pathway) that works particularly well with project-orientated activity.

Europeana has recently been testing the Playbook methodology with regards to how they describe and measure organisational-level impact in Europeana Foundation. They have found that they need to extend the approach, to develop an organizational Theory of Change. Based on this experience, this approach is also followed with TMO.

It allows us to effectively visually describe the steps, assumptions, dependencies and impact that we expect Time Machine to have in all of the exploitation areas and for society and the economy. Importantly, a ToC can help map out broader ecosystems in which change occurs and in which multiple partners play a role.

- It visually describes complexity and maps dependencies in a way that is not possible in a Change Pathway.
- **It has helped us draw out the connections between Time Machine's activity and the economic and social impact we expect it to create.**

These connections in this preliminary ToC will continue to be developed further and causality examined in detail in the individual research proposed as part of the Impact Assessment and Evaluation Research Agenda. This will be informed by a possible follow-up detailed evidence review that would interrogate existing literature on each of the causal pathways identified in the ToC.

A preliminary Outcomes framework

Having mapped the outcomes TMO could create as a result of its activities, indicators were developed by the Working Group to identify what data could be collected to understand the impact of TMO activities. These indicators will form the basis of an ongoing monitoring and evaluation approach. They complement but do not replace KPIs. An initial outcomes framework (still a working document) has been developed by the Pillar 3 working group and complements these recommendations.

Methods to promote causality

A Theory-based evaluation approach (proposed above) will help to demonstrate causal links between TMO activity and outcomes for the beneficiaries (exploitation areas, case studies). A mixed methods approach to measuring the impact of TMO is appropriate. Reporting outputs or KPIs would tell an insufficient story of the transformative power of the new insights provided by empowered SSH and their use. Such a quantitative-only approach would lack the nuance to understand how the core stakeholders of scholarship and education benefit from the data and opportunities unlocked through TM.

While the proposed approach involves qualitative data collection on a relatively small scale (case-study), this can more rigorously represent the diversity of impact that will be generated.

Demonstrating causality for the impact created by TMO will be challenging. The outcomes framework above, however, attempts to mitigate this by capturing a range of short- and long-term outcomes that could help to show to what extent TMO has delivered against its objectives. Similarly, an openness to a mix-methods approach - in which population-level data and analytics could be reviewed in combination with qualitative case studies, interviews and questionnaires - will help the project investigate causality at a sample level.

It should be noted that this approach requires dedicated time and investment and should be fully costed at an early project stage.

Data collection opportunities

Timeframe	Data collection opportunity
Annual process evaluation	• Evaluation of TMO (self-reporting according to an agreed template) • Evaluation of LTMs (self-reporting according to an agreed template, documenting yearly activity) • Review of Pillar activities
Ongoing monitoring	• Survey of TM users (periodically, e.g. quarterly) • Survey of partners (e.g. satisfaction, case study creation) • Analysis of user engagement with the tool (e.g. API calls, number of visits) (monthly, or continually via a dashboard) • Questionnaire at partnership or LTM registration • Annual LTM and TMO member surveys
Ad hoc	• External data, document and research review (e.g. Eurobarometer, Enumerate) • Development of discrete impact assessment approaches and related data collection plans
Five-yearly impact assessments	• Aggregation of evaluation data • Summary of external data review • Economic perspective as well as social value

This data collection plan reflects the dependencies between different parties acting to deliver TM, whether this is at the level of LTMs members or strategic or exploitation partners. Similarly, it highlights the multiple data points available (that is, where data can be collected).