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

Deliverable D8.4
Time Machine LSRI Strategic Guidelines

Preamble:

This deliverable is part of a structured set of outputs produced and built upon during the 12-month TM CSA project. As such, the content contained within was further refined, synthesised and improved throughout the project and in particular when combined with material from other deliverables during the production of the full D8.5 TM LSRI Strategy and Implementation Proposal. Please be advised that the most up-to-date version of any information found in this document will be found in D8.5, where it can also be viewed in proper context as part of the entire TM LSRI proposal.

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 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 of 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 for 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, giving birth to a digital information “overlay” over the physical world, a “mirror-world”, as an up-to-date model of the world as it is, as it was and as it will be. So, time will be a “palpable” fourth dimension, since it will be very easy to go back to the past, at any location, reverting to a previous version kept in the log, but also 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 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.

The basic 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.

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.

[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 Network is organised as an 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 Time Machine Organisation 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. In the course of time, LTMs pass through different maturity phases. Each maturity phase permits to envision specific exploitation strategies. A series of events taking the form of LTM Academy events 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, core architectural choices for the Time Machine components.

The plan

Time Machine proposes an integrated programme with concrete objectives to be reached in 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 the 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 counts more than 500 European institutions from 34 countries, including close to 200 top research institutes, a huge representation – more than 100 organisations - from galleries, libraries, archives and museums (GLAM), as well as leading large enterprises, innovative SMEs, institutional bodies and strong civil society organisations.

Time Machine will stand as a community of communities to foster the relations not only between itself and digital cultural heritage stakeholders, but also among the related stakeholders themselves. Mechanisms for an intensified interaction are envisaged to foster the European Research Area in Digital Cultural Heritage and to strengthen the impact of TM at 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 already 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 that maximise socioeconomic impact.

In order to ensure the long-term sustainability of the initiative, the TM partners decided to create 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 partnership network and presently counts 400 members, showing that the large majority (80%) of the TM network partners commit to support the implementation of the Time Machine roadmap.

TMO will make the transition from the organisation environment set up during the current conception phase to one that covers the specific needs and work flows of a much broader ecosystem that implements 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.

In this set-up stage, the key objective is to secure the 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 the Time Machine 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 promoting 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.

Concrete and momentous outcomes and benefits are targeted in the following dimensions:

- A strong boost in EU competitiveness in AI and ICT:
    - An AI trained on Big Data of the Past will offer a strong competitive advantage for Europe in the global AI race.
    - Disruptive technologies in machine vision, linguistic and knowledge systems, multimodal (4D) simulation, HPC and long-term data storage will strengthen the competitive position of EU industry in these fields.
- New disruptive business models in key economic sectors:

    - Cultural Heritage is a unique asset for European businesses. Time Machine will act as an economic motor for new services and products, impacting key sectors of European economy (ICT, creative industries and tourism).
    - Time Machine will develop a paradigm to follow for cities that wish to make a creative use of their historical past.
- A transformational impact on Social Sciences and Humanities (SSH):
    - With Time Machine, SSH will be able to apply their lines of inquiry to large amounts of data, and to analyse the data across language borders, over administrative and collection divisions, allowing new interpretative models that can smoothly transition between the micro-analysis of single artefacts and the large-scale complex networks of European history and culture.
- Moreover, Time Machine will:
    - Be a driver of open (and citizen) science, as well as open (public) access to public resources.
    - Provide a constant flux of knowledge that will have a profound effect on education, encouraging reflection on long trends and sharpening critical thinking.
    - Render education for Europeans more accessible, interactive and diversified.
    - Develop new or updated legislation or guidelines in the field of AI, including ethical norms and ethical standards in areas such as access to and re-use of digital data, harmonised rules on data-sharing arrangements, especially in business-to-business and business-to-government situations, as well as clarified concepts in data ownership.
    - Create new jobs for digital and traditional humanists and social scientists, while offering clear opportunities for talented humanities graduates with increased digital skills, by demonstrating the benefits of the new profession “Digital Humanities expert”.
- Having confirmed itself as one of the pioneers, Europe will make meaningful contributions to the foundation and use of the mirror-world, in line with its values and ethics.

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. In the resulting crisis of authority that affects journalism, academia and politics, many people do not trust anymore the information received from these institutions.

These unprecedented transformations create a vital need for Europe to restore and intensify its engagement with its past as a means of facilitating an evidence-based dialogue between diverse historical memories, 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, 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 pursed by Time Machine is that 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 for the general public, with a significant common denominator: contributing to informed decision-making from everyday life to academic, professional and political matters.

This report summarises the key findings of a pan-European action to elaborate 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 500 organisations, comprising leading research institutions, most prestigious European cultural heritage associations, large enterprises and innovative SMEs, influential business and civil society associations, and international and national institutional bodies.

Following this introduction, the document is organised as follows:

- The second part, 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 part, research and Innovation plan, the focus is on the breakthroughs that Time Machine will bring in science, technology and innovation, starting from an extensive analysis of the state-of the-art and presenting the methodological approach and time frame of the targeted achievements.

- In the fourth part, implementation plan, a governance scheme is proposed that will enable the current organisational structure to evolve into the one responding to the requirements of a LSRI, by building synergies and exploiting funding opportunities from different sources; the main barriers and risks are examined in this context.
- 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 professions, services and products, transforming and leveraging the 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 representing the funnel 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 at enlarging the stem of this funnel, firstly, by developing the technology and infrastructure for conducting massive digitisation and processing of cultural heritage sources (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).

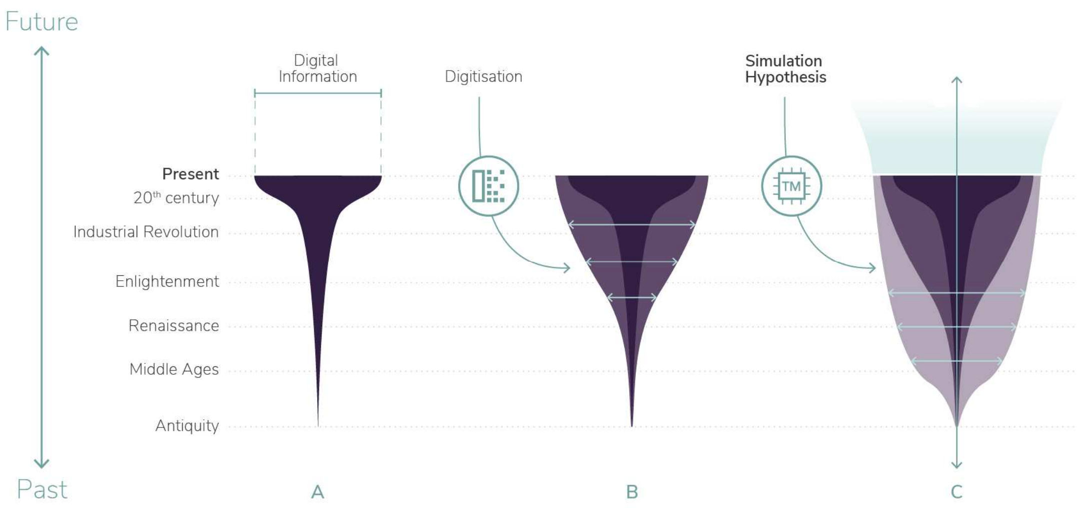

Figure 2-1: Creating the Big Data of the Past: (A) Current situation. (B) Extension based on digitisation and processing of new sources. (C) Extension based on simulation.

The conversion of billions of historical documents, large collections from museums, other geo-historical datasets, but also 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 inaugurates an era of open access to sources, making past and ongoing research open science, 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 designs 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. After the creation of the web that digitised information and knowledge and the social media that digitised people and characteristics of human behaviour, a third technology platform is being created, digitising 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 subject 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 that can be anticipated about the 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. Time Machine is today the most advanced concrete proposal to build the first version of a European mirror-world.

Like the other two platforms, 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 (open standards, interoperability). With Time Machine, while it will have a powerful tool to strengthen its cohesion and sense of belonging, Europe has, moreover, an opportunity to impose its own terms against the multinational technology giants that will fight for dominating 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

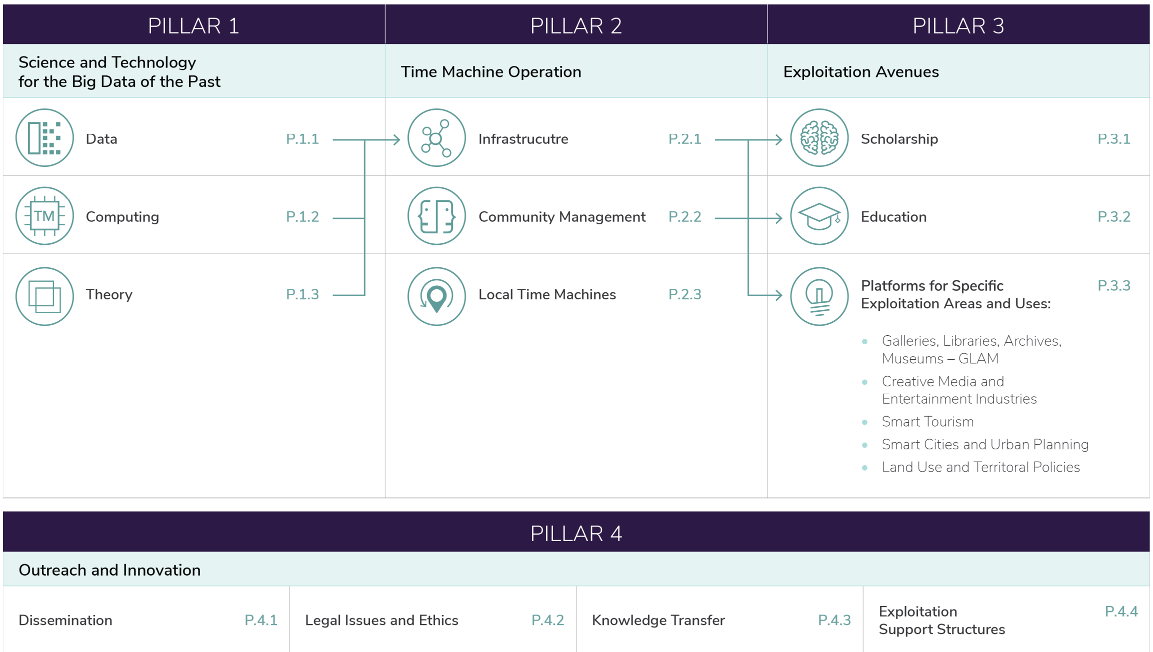

Figure 2-2: Time Machine Pillars & Thematic Areas

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 in the course of the LRSI. The main areas explored cover:

- Dissemination
- Policy, legal issues & 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 follow 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, 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

- **Accessibility** - TM RFC are freely accessible, free of charge.
- **Openness** - Anybody can write a TM RFC.
- **Identification** - Each TM RFC, once published, has a unique ID and no changes are allowed after publication. Any important changes result in a subsequent TM RFC. For this reason, some TM RFCs could be tagged as obsolete.
- **Incrementalism** - Each TM RFC should be useful for its own right and act as a building block to others. Each TM RFC must be aimed as a contribution, extension or revision of the TM infrastructure.
- **Standardisation and linguistic diversity** - TM RFCs should aim to make use of standardised terms to improve the clarity level of its recommendation but can be written in any language. Once published they should be translated in a maximum number of language.
- **Scope** - TM RFCs are designed contribution and implementation solutions solving practical problems. TM RFC are not research papers and may not necessarily contain experimental evidence.
- **Self-defining process** - Like for the development of the Internet, TM RFC could be the main process for establishing TM Rules, TM Recommendations, TM Standard Metrics but also the processes and roles for managing TM RFCs themselves

Time Machine Organisation

The whole governance is conceived around the **Time Machine Organisation (TMO)** that sets the global rules for all operations related to the initiative, including the 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 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 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, like the one developed by Europeana.

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 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, connected with one another. This progressive decomposition and refinement needs to be seen not as a mere automatic process but as a collective negotiation.

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

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

Each intervention, either algorithmic or human, will be fully traceable and reversible. The results of the processing 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:

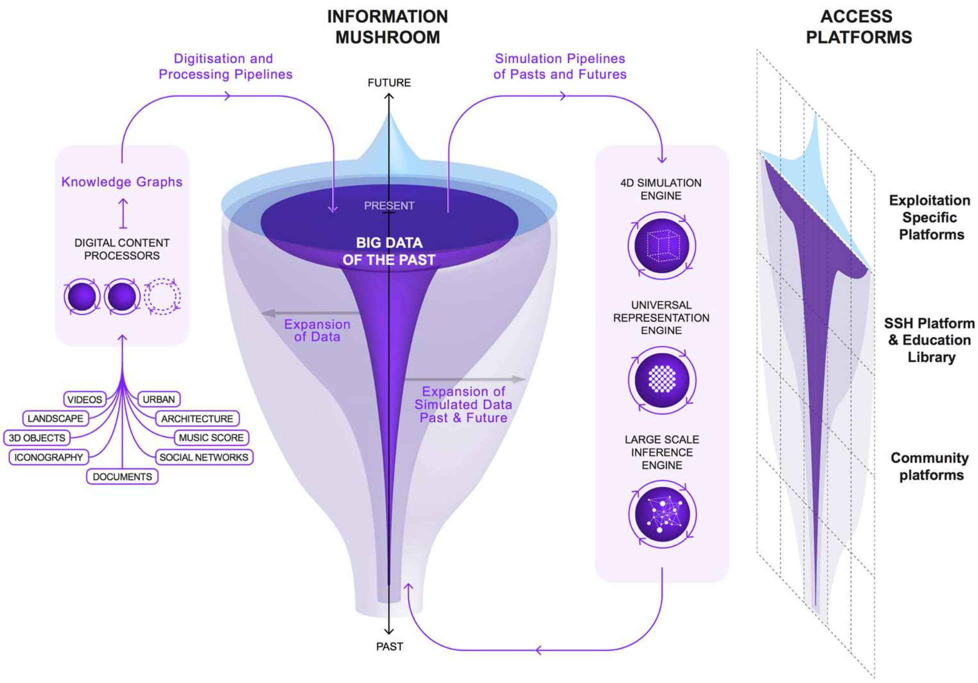


Figure 2-3: TM Digital Content Processor and the three simulation engines

- 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 permitting 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 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.

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 to indefinitely extend the availability of the digitised content of TM.

Local Time Machines

The Time Machine Network is organised as an unlimited amount of **Local Time Machines** (LTMs). Each LTM is anchored in the space of a city or a region, around which various partnerships can form, aiming to transform it into a zone with a higher *density of "rebuilding the-past activities*". The TMO provides help in their launch and growth. The governance scheme for Local Time Machines and their overall interaction with the TMO will be elaborated as a series of RFCs.

In 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 permits to envision specific exploitation strategies. Each LTM will implement *Projects with Time Machine Label (PWTML)* that aim to increase its density of rebuilding the past activities. Once funding is secured by the partners with, when needed, the help of the TMO, partners of a Local Time Machine can decide to gather around a common goal and create and finance a new PWTML. A series of events taking the form of LTM Academy events (one 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 permitting to create 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 other urban infrastructure. As the city's structure and shape continuously change in time, the city's digital twin is necessary a 4D model, schematically represented in Figure 2-4.

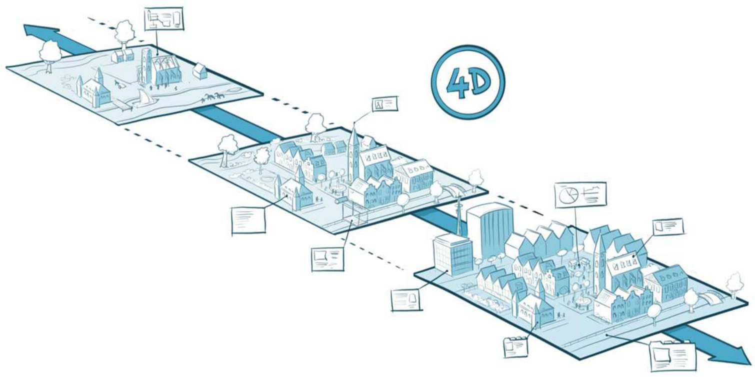


Figure 2-4: 4D model of a city's digital twin ***(CC-BY-SA Europeana/JAM visual thinking)***

In the Time Machine approach, each Local Time Machine ambitions to build a dense database of spatiotemporal information laying the foundation of a 4D model. The Time Machine Organisation 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 to the Local Time Machine.

To develop the various exploitation platforms, Time Machine 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 always denser Big Data of the Past (Figure 2-5).

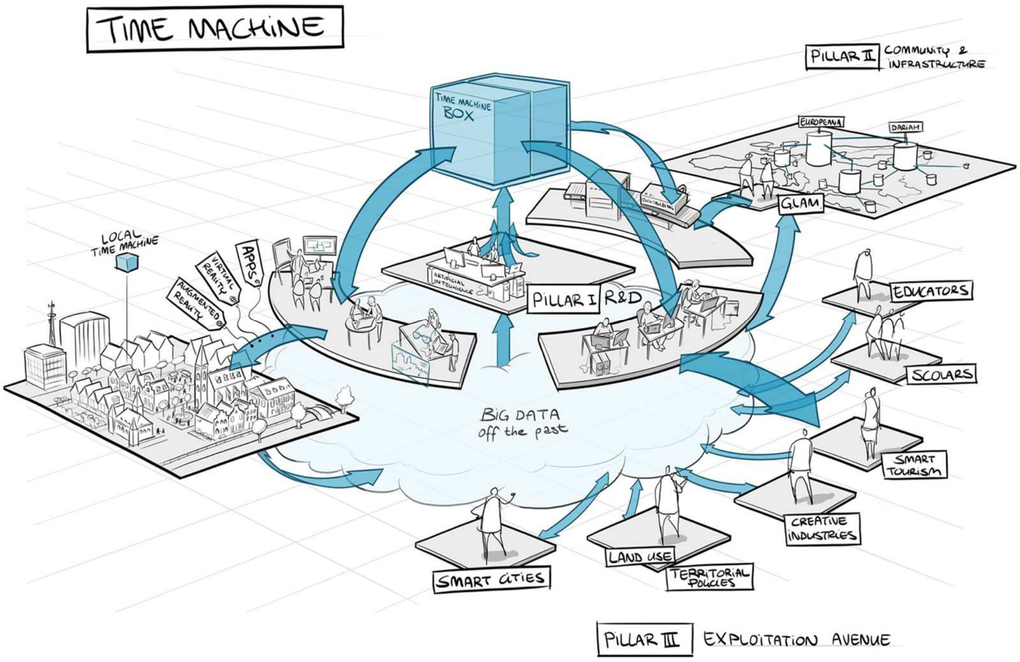


Figure 2-5: The TM overall concept ***(CC-BY-SA Europeana/JAM visual thinking)***

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, like tomographic approaches for scanning documents without opening them, and innovative data storage solutions, including early experimenting with DNA storage.
2. Automation of mark-up – the boundaries of knowledge modelling (layered annotations, temporal and geographical characterisation) are pushed, harnessing all the 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 Time Machine engines shown in Figure 2-3 enable to control and density the dataset of information extracted from patrimonial sources, enabling scientists and other stakeholders in the SSH and cultural heritage fields to envisage new methodological approaches in different fields of research.
5. Experience – To develop the various exploitation platforms, Time Machine 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. In this way, it was possible to identify and analyse the areas in science and technology which can be expected to be most relevant for the science and technology advances in 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 the Time Machine infrastructure, targeted communities of users and the LTMs.

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

- 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 the 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 the LTMs, the aim was to 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. Emphasis was also given to recording the approaches and achievements of current local TM 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 Time Machine, including structures for the organisation / coordination of action(s) 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 make it available to researchers and other users in the various associated domains/disciplines, while Time Machine 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 base line 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 managed education environments, including teaching and studying practices; (d) tools designed to extend education skills, including critical and analytical thinking, by way of, e.g., analytical tools.

The specific exploitation avenues and uses were chosen based on criteria related to the 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 relation.
- **Creative industries**: the capacity of creating and mobilising people imagination is key for our future to reach a vision aligned with our values.
- **Smart tourism**: a specific domain where technology and demand readiness are at good levels and Time Machine has a huge 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. Cities concentrate most human activities and 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 a context of climate change.

In each case, the baseline analysis aimed at determining the key aspects that could be relevant to innovative business models: stakeholders, technology and demand readiness, as well as needs in terms of new tools and processes to be developed from the TM processing and simulation infrastructure.

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 with the big data of the past. Each of these targeted achievements involves work in particular areas of expertise according to the taxonomy for Science and Technology developed during the state-of-the-art analysis (Box 2-1). The order of relevance of these areas of expertise for each specific goal has been specified in the pillar 1 roadmap (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 needs 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 emergency for endangered objects; and (b) guidelines and standards to follow regarding formats and protocols to store and query data, 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 scan technologies, such as scan robots and tomographic methods.
- 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. Also, connection to long-term storage, e.g. DNA storage and selection of the most important data to be stored in such archives.

Computing and AI

Generic methods will be developed to explore, connect, 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 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 described in Box 2-3 above.
- 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 scores recognition, developed using material of the Time Machine Graph.

SSH

Explanatory models of historical evidence opening the way for new, plausible narratives, radically transforming the manner in which SSH engage with and interface 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 call for papers. The implementation strategy for this framework rely on tools that facilitate and enhance scientific analysis, like 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 Time Machine engines to perform simulations 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 Time Machine infrastructure and the management principles and processes for an ecosystem of Time Machine contributors and users extending across Europe.

Infrastructure

Specifications will be developed for the Time Machine hardware and computing infrastructure that will define the research challenges to be addressed in pillar 1. The research results will then be used to design and develop:

- A network of digitisation hubs on a European scale, managed by a peer-to-peer platform in charge of managing optimising digitisation strategies at European level, also tasked with the development of generic solutions for archiving, directly documenting the digitisation processes, and swiftly 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 partners.
- The distributed super computing infrastructure for processing big data of the past as described in Box 2-3, equipped with specially designed content and discovery interfaces for accessing the Time Machine Data Graph for all intended uses and applications.

Community Management

Work deals with the organised interaction of TM with scholars, developers, cultural heritage professionals, service providers and citizens. A system of platforms will connect Time Machine with such external communities that will benefit from and can provide input in various forms to the TM, so the aim is 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 the Time Machine communities.

- Develop interfaces facilitating connection of TM infrastructure with those of existing communities.[5]
- Design and implement transparent mechanisms for tracking community involvement and reporting on community contributions, through metrics on individual participation and overall impact on the Time Machine Data Graph.

Local Time Machines

The thematic area is related to the governance scheme of the Local Time Machine network and by extension to the overall governance scheme of the TMO. So, this thematic area constitutes the core of the Time Machine 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 Local Time Machines, 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 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 members' 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).

Pillar 3: Exploitation avenues

Pillar 3 is designed to leverage the societal and economic impact of Time Machine. 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, 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. The new methods of analysis will open the way to a better understanding of the complex systems that characterise our present-day digitizing and globalizing cultures and societies and, thus, provide a basis for developing more meaningful solutions for the future.

Because of its integrated approach that combines digitisation, interpretation & data gathering and management, as well as methodological innovation, the Time Machine infrastructure will drastically speed up advances in the state of the art in 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 that 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).

[5] 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.

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 subsequently are 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.

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 swift availability of many facts on a single subject, as well as on epistemological and methodological issues and critical analysis.

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 Time Machine will enrich teaching material associated to SSH, the sciences, health and practical technologies.

Time Machine'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'[6]. From that perspective, it makes sense to design an infrastructure that provides direct access to the Time Machine 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, the 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 visualise big data of the past, including the simulation of those pasts using advanced visualisation techniques, including 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.

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.

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

Time Machine will boost, aid and accelerate many developments that are already underway in GLAM and introduce completely new transformative effects in four areas dealing with (digital) collection(s):

- 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. Time Machine 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 so 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: Time Machine will enable institutions to provide richer and more diverse experiences for their users, both in a physical, augmented, and virtual setting: multimodal interfaces and feedback mechanisms will give ground-breaking multisensory experiences, that are elegant, authentic, nuanced, unobtrusive, and customisable according to the user's requirements. A relevant use case is presented in Annex B2 for an accompanying application making use of Time Machine APIs that enables GLAM users to experience different versions of the same exhibition in a way that suits their specific needs, for example, the time one disposes for a GLAM visit.
- Collection Linking, Reuse & Remix: (a) through the adoption of automated data linkage based on customisable parameters, disparate data storages 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 Time Machine'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.

Creative Industries

The European creative industries contribute 6.8% of GDP and 6.5% of employment in the EU[7], at the same time offering a strong potential for stimulating innovation in other sectors with a competitive edge, such as tourism, education and advertising. Time Machine will introduce scientific and technological breakthroughs that will significantly impact the production cycle of the creative, media and entertainment industries, through interventions to the creative value chain as the ones below:

- 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 also 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 and tackling misinformation in the media, 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 findable, 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 and visualisations and possibilities to query granular properties of digital objects 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

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

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 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. Time Machine 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.

Smart 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.[8] To face strong competition from other world regions, Europe largely invests 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, Time Machine 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 to offer products and services that are enhanced by Time Machine technologies that boost touristic demand based on cultural heritage.
- Innovative clusters working with LTMs to create a sustainable ecosystem of smart tourism.
- Increased awareness and respect toward cultural heritage destinations through TM narratives.
- Economic sustainability of destinations, locations and institutions (e.g. GLAM) through the Time Machine smart tourism model.

Smart cities, urban planning, land use & territorial policies

The aim is to use Time Machine technologies to achieve more inclusive societies as well as 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 environment dynamics, identifying what are the 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 learn to use data and state of the art knowledge. The main targets are described below.

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

- Integrated, inter-connected information systems for cities and lands, across time, space and scales, across administrations, across authorities and citizens, that supports not only browsing but also queries. We target intensified and more relevant (smart) information exchange in smart cities with new data sources, including exchange with other 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 cities or lands information systems (Time machine projects) that integrate into a wider framework, whatever a city or rural territory or country resources (in terms of funds but also expertise and communities), including in emerging countries, and available also for transversal themes (e.g. Glaciers Time Machine, Wetlands Time Machine, etc.).
- User-centred retrieval of facts and data in Europe history (other cities, other territories) to favour exchange and mutualisation as a bottom up process to find solutions to sustainable development challenges, that may complete existing a top-down process using the state or using the European Commission. Users also need meaningful documentation of uncertainties and hypotheses.
- Recommendations for decision makers to support their planning and design solutions: suggesting connections, presenting situations from the past that are related to the present-day experience of specific localities and phenomena 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, e.g., managing tourism, water management, social cohesion, and share data and solutions.
- Enhanced scienceS-policy interface as well as scienceS-stakeholders interface either in cities or in land management in general: to connect stakeholders who seek a longitudinal perspective on a present-day problem with the relevant scientific communities to sample history and space and design training data set with regards to a given issue, apply machine learning method, trained on these samples from the past, and using Time Machine Knowledge graph to make recommendations on his 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 citizen 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 background and perspectives, considering data available to associate trustable dashboards to the policies.

Pillar 4: Outreach and Innovation

Pillar 4 will contribute to creating enabling conditions for the dissemination and promotion of Time Machine and the uptake of the results and other outputs produced during and beyond the life time of the initiative.

- The **dissemination** strategy of Pillar 4 aims at building awareness of the goals and achievements of Time Machine, but also at securing the engagement of all stakeholders, including academic institutions (curricula in Digital Humanities, publications), policy makers and public research funding institutions (strategic research agendas, innovation support measures in cultural heritage, organisations involved with the management of patrimony (fully integrated platforms for crowdsourcing and citizen science), the private sector (new business paradigms), and the general public (targeted communication actions), in the actions related to the operation of TM and the exploitation of its achievements. More specifically targeted achievements could be described as follows:

  - Communication Structure for TM is sustained: composed of Central, National and Stakeholder Communication Hubs.
  - Relevant stakeholder groups are reached, continuously identified and profiled by proper stakeholder monitoring mechanisms
  - Periodic evaluation guidelines and mechanisms are settled to produce novel, fir for purpose and relevant dissemination tools and actions
  - Stakeholder specific dissemination and communication actions are implemented through tailored strategies and workflows (innovative formats will be enabled).
  - A sustained brand strategy is developed and implemented which is supported with widely adopted key messages across Time Machine Community
  - Tailored dissemination materials are continuously produced and used for targeted stakeholder communication

- **Policy, legal issues and ethics** related actions will analyse EU and Member State-related policies, legal aspects and ethical issues referring to cultural heritage and, in particular, its protection, preservation and use for developing societal and economic benefits. The objective is to identify the policy, legal or ethical matters related to the scientific and technological goals of Pillars 1, 2 and 3, and to take action to address these. Related actions will be to support the work of the TM members. Moreover, the TM experts, through participation in relevant committees, thematic workshops and events, will promote demand-side innovation to policy setting initiatives and legal bodies in the EU and that will enhance the development of cultural heritage. Thus, the targeted achievements could be described as follows:
  - Providing an analysis of and ways to address policy, legal and ethics-related issues that have impact on and could be influenced by TM objectives and activities
  - Establishing a helpdesk as a body of knowledge and support on the policy, legal and ethical issues and conditions for TM members and TM stakeholders
  - Proposing policy, legal, ethical guidelines, toolkit and recommendations for digitisation of cultural heritage both for internal and external use
- TM`s capability to generate IP and manage it across TM members, target sectors and actors needs an agile knowledge transfer framework. **Knowledge Transfer** actions are based on the principle of enabling effective and purposeful interactions among TM stakeholders, namely between ICT and SSH scientists, researchers specialising in different disciplines, and professionals of the CH, as well as among other scientists, private sector professionals, decision-makers and the general public. Dedicated actions will be planned to design, operate and monitor IP, data and knowledge management. A Knowledge Transfer Action Plan will be developed with aim to exploit the results of knowledge graph as the central technology structure of the TM. This action plan will set frameworks for:
  - the data produced, gathered, curated through TM
  - knowledge and information exchange processes among TM members
  - managing the ownership of TM results with regards to existing and new IP
  - managing the ownership of resources for possible exploitation areas
  - managing the commercial exploitation of results, as described below.
- **Exploitation support structures** will be designed to facilitate the exploitation of results acquired by Time Machine through different routes, including (a) shaping and creating markets for new services and products, (b) further research and follow-up research and innovation projects to address socioeconomic challenges, (c) informing related policies, and (d) skills enhancement. Targeted achievements are as follows:
  - Enabling exploitation structures and methods to support the use of technology and infrastructure for conducting massive digitisation and processing of CH sources
  - Underpinning the “game changer” nature of TM through exploitation channels for the targeted fundamental breakthroughs in Artificial Intelligence, Robotics and ICT
  - Leveraging the use of the results of the TM for addressing the grand scientific and technological challenges at hand
  - Converting the research results into actual innovation platforms servicing new sectors and markets in promising application areas.

3.3 Methodological approach

Time Machine Requests for Comments (RFC) will be used as the main methodological process for establishing rules, recommendations and core architectural choices for the Time Machine components. The TM RFCs will be freely accessible publications, identified with a unique ID. To bootstrap the **publication process**, the initial publication pipeline will go through the following stages

a) Submission of RFC text and figures
b) Handling by RFC editors naming RFC reviewers.
c) Open Review Process
d) Attribution of TIME RFC ID and a DOI publication with names of reviewers disclosed and possible additional comments by them.
e) Translation in several other languages.

The TM RFCs will be accompanied by a set of fundamental research questions that need to be clarified by scientific project work, for example user studies required to prepare the development of a RFC. In this category, call for papers and conferences will also enhance the communication and help clarify the goals and assess the progress in different areas.

Once individual RFCs are developed, the roadmap will be implemented via a modular design covering a 10-year period, in which various **calls-for-proposal** will attract bottom-up research proposals targeting specific milestones in a pre-specified time-frame. The draft roadmaps for pillars 1-3 have developed lists of RFCs and research topics leading to the targeted achievements discussed above.

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 for the potential users, which offers strong incentives for their participation in the design of solutions and their commitment in applying them. As examples, 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 Time Machine. The resulting implementation plan can be outlined as follows:

- Initially, pillar 2 sets out the specifications on how to develop the basic concepts, in a way that respects the main idea of the Time Machine: creating a distributed digital information system mapping the European social, cultural and geographical evolution that can be used by a number of communities to create momentous social and economic impact.
- 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.
- Reaching consensus on the science and technology options to follow and to ensure the open development and evaluation of work, the RFC process that was used for the development of the Internet protocol will be adapted to the needs of Time Machine

- Pillar 2 designs the physical and management infrastructure and undertakes the Time Machine operation according to the results of the designing process. Operation also includes overseeing the development of and providing support to the Local Time Machines (LTMs).
- Pillar 3 brings together communities that work on exploitation avenues in three thematic areas: two of them refer to scholarship and education and target at demonstrating the benefits of new approaches in scientific methods and in learning; the third thematic area comprises important sectors of activity for the EU, for which the Time Machine is expected to introduce new approaches and transformative business and cultural models: GLAM, creative industries, smart tourism, as well as smart cities, urban planning, land use & territorial policies.
- Pillar 4 will implement a dissemination programme for researchers, innovators and decision makers, address legal and regulatory issues related with the implementation of the TM actions, develop framework conditions for knowledge transfer and support the valorisation of TM's innovation output.

3.4 Overview of expected scientific and technological progress

An overview of the scientific and technological advances that are targeted by Time Machine are shown in Table 3-1.

Table 3-1: 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 – P4.4 Dissemination, legal & regulatory, knowledge & data management, exploitation support	Critical mass needed to boost the impact of cultural heritage for technological, social and economic fields	TM will streamline research and innovation in the area of cultural heritage across Europe, by creating a vibrant ecosystem of researchers, innovators, and decision makers committed to the Time Machine strategic agenda. TM will keep this strength for building inter-sectoral and inter-disciplinary linkages at European and international levels. Dedicated structures provide efficient support for legal and regulatory aspects, knowledge and data management, as well as actual use of TM results in different applications of socio-economic relevance.

3.5 Milestones and time plan

The development of Time Machine is foreseen in four phases: bootstrapping, scaling, sustaining and globalising.

- 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 Time Machine 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 SSH 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 Time Machine (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 with the extension to non-European archives and patrimony, while sustaining the European densification (Pillars 1,2,3).

The timeline for the accomplishment of the milestones in the course of the next 10 years has been developed considering the requirements of each of them and can be found in Tables 3-2 to 3-5 below.

Table 3-2: Milestones and time plan for Pillar 1

Thematic Area / Milestones	Time										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
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 priorities of objects to digitise											
RFC on models and formats											
Computing and Artificial Intelligence											
1. Annotation Interface											
User studies of current annotation platforms											
RFC on interface for annotation											
Annotation interface implementation											
2. User Interface											
User studies of current platforms for historical data											
RFC User Interface											
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											

Thematic Area / Milestones	Time										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
RFC for Large-Scale Inference Engine											
RFC for 4D Simulator											
RFC for Universal Representation Engine											
6. Automatic Text Recognition											
RFC on Text Recognition (1)											
RFC on Text Recognition (2)											
7. Automatic Graphic Document Recognition											
RFC for music scores recognition											
RFC for map 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 3-3: Milestones and time plan for Pillar 2 – (a) overall time plan; (b) RFC planning for 2020-23; (c) Milestones for 2020-23

(a) Overall time plan

Thematic Area / Milestones	Time										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Infrastructure											
1. Core Technical Infrastructure											
Development of 30 RFCs (details in part b below)											
TM search engine prototype											
TM digital hubs											
Assessment and Evaluation											
2. Deployment											
TM 4D Mirror World											
Operation and scale of TM pipelines and engines											
3. Fill sustainability of infrastructure											
4. Globalisation of infrastructure											
Community Management											
1. Growth and consolidation											
Professional communities within TMO											
TM communities for individuals											
2. New communities											
Development based on Mirror World services											
3. Consolidation											
Communities beyond early adopters											
4. Internationalisation											
Communities beyond Europe											
Local Time Machines (LTMs)											
1. Bootstrapping and coordination											
Consolidation of 10+ LTMs											
On-boarding of new LTMs											
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 for 2020-23

RFC Planning	2020	2021	2022	2023
RFC on RFC	x			
RFC on LTM/Framework	x			
RFC on Value Scale	x			
RFC on Definition of typologies	x			
RFC on Standardisation and homologation	x			
RFC on Open Hardware	x			
RFC on General Standards for the Super Computing Architecture	x			
RFC on Technical Charter	x			
RFC on data lifecycle	x			
RFC on Intellectual property rights and licenses	x			
RFC on Vision Mission and Values Charter	x			
RFC on Time Machine Box	x			
RFC on Franchise System		x		
RFC on Synergy and interaction in EU Research Infrastructure		x		
RFC on Training		x		
RFC on Distributed storage system for Public Data		x		
RFC on Distributed Storage system for Private Data		x		
RFC on Content Filtering		x		
RFC on on-demand digitisation		x		
RFC on Global optimization of digitisation process		x		
RFC on Digital Content Processor (DCP)		x		
RFC on TM Data Graph			x	
RFC on Large-Scale Inference Engine			x	
RFC on 4D Simulator			x	
RFC on Universal Representation Engine			x	
RFC on Virtual/Augmented Reality and Discovery			x	
RFC on Solidarity				x
RFC on Enhancing Collaboration				x
RFC on Knowledge transfer				x
RFC on Top-Down initiatives				x
RFC on Smart Cluster				x
RFC on Collaboration indicators				x

(c) Milestones for 2020-23

Milestones	2020	2021	2022	2023
RFC Coordination: Each identified RFC have been assigned a specific coordinator by the RFC Committee.	x			
(1) Close of the TM RFC on LTM/Framework (e.g. typologies and routines, perimeter). (2) Labelling system: definition. Close of the TM RFC on Value scale systems. V1 of the value scale systems for both LTM and PWTML. (3) Close of the TM RFC on Time Machine Box. Prototype V1.	x			
TM's Rules and Recommendations - Time Machine Box development: Close of the TM RFC on Time Machine Box. Prototype V1.	x			
Close of the documentation and trainings phase for the implementation of the framework, including welcome guide, starter kit, LTM and PWTML's forms.	x			
TM's Rules and Recommendations and Legal settings: models: Close of TM RFC on Vision Mission and Values Charter, TM RFC on Technical Charter, TM RFC on data lifecycle, TM RFC on intellectual property rights and licenses, and contractual documents phase. V1 of the respective documents.	x			
TM's Rules and Recommendations: Time Machine Box, assessment. End of the evaluation of the technologies. When needed, new RFC.		x		
TM's Rules and Recommendations and Legal settings: roll- out. Close of the test phase for implementation with a representative percent of the TM partners aligning with its processes and prerequisites and making feedback to the development team.		x		
Labelling system: assessment End of the evaluation of the system. When needed, new RFC.		x		
Financial system: definition. Close of the TM RFC on Franchise system, franchise V1. And close of the TM RFC on Training.		x		
TM's Rules and Recommendations and legal settings: adaptation. According to the result of the roll- out phase: Data selection Model, Data acquisition Model, Data Sharing Model, Vision Mission and Values Charter, Technical Charter, contractual documents, decision on opening a new RFC.		x		
Financial system assessment: End of the evaluation of the system. When needed, new RFC.			x	
Standardisation of the TM network. Launch of the first 10 LTM officially complying with the TM's Framework and TM's Rules and Recommendations and Legal settings, advertisement and tracking on the TM's Operation Graph and on the TM' networks landing pages (use of the proper labels).			x	
Standardisation of the PWTMLs. Launch of the first 10 PWTMLs officially complying with the TM's Framework and TM's Rules and Recommendations and Legal settings, advertisement and tracking on the TM's Operation Graph and on the TM networks landing pages (use of the proper labels), payment of the proper franchise fee.			x	
Alignment: All TM partners now comply with TM's Rules and Recommendations and Legal settings (comprises alignment of previous initiatives).				x
TM Cooperation: Close of the TM RFC on Solidarity, TM RFC on Enhancing collaboration, TM RFC on Knowledge transfer, TM RFC on Top-Down initiatives, TM RFC on Smart Cluster. V1 of the respective models.				x
Community - Density growth. Close of the assessment of the network's growth performances in terms of partners actively involved within the TM, number of LTMs and PWTMLs launched and density of “rebuilding the past activities” in a geographical area. Definition of supportive top-down initiatives or new RFCs.				x

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

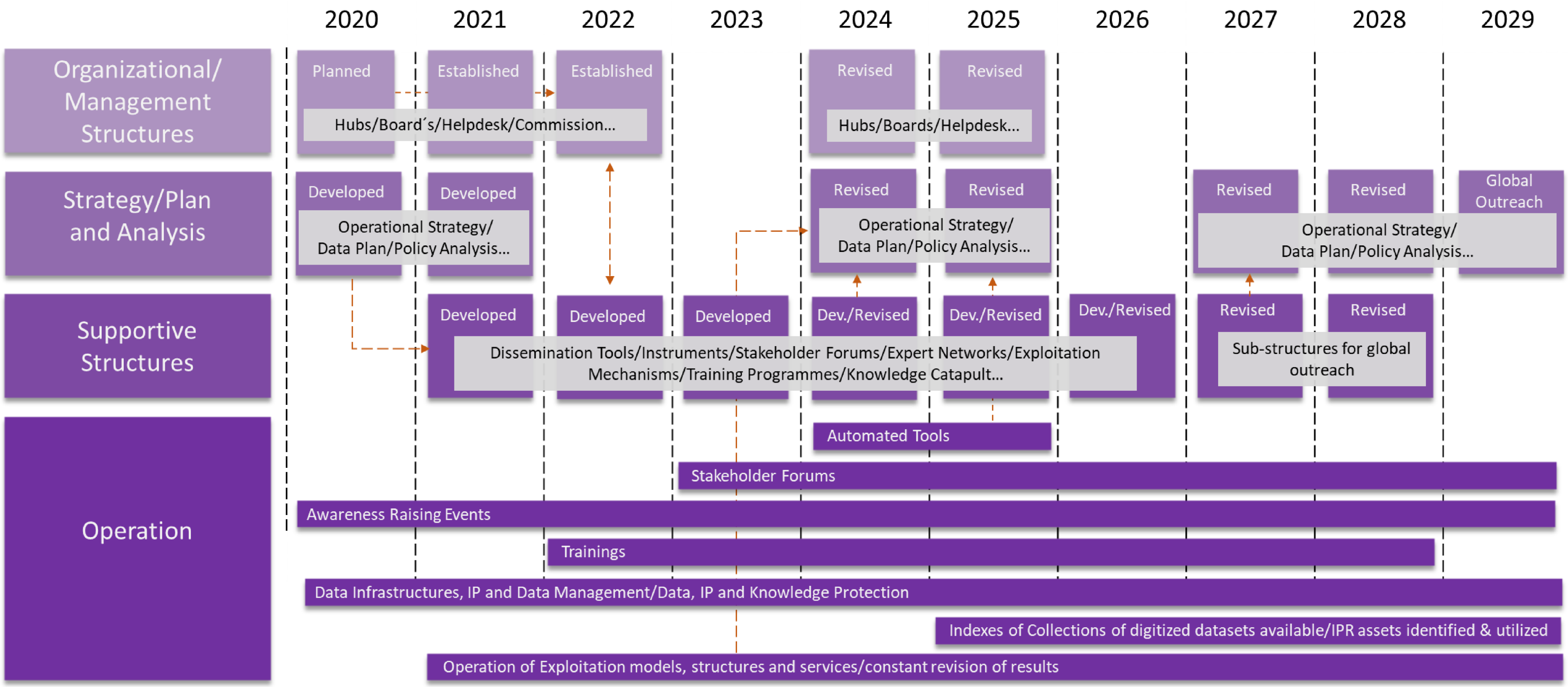
Exploitation avenue / Milestones	Time										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Scholarship											
1. Collaboration and strategy											
Collaboration planning											
Outreach strategy											
2. Use cases											
Use cases defined											
Use cases executed											
3. Proof of concept											
Best practices & training material											
Concertation across TM Pillars											
4. Open calls for proposals											
Open call for scalable SSH research with TM Data Graph											
Concertation across TM Pillars											
Open call for SSH research with TM box components											
Concertation across TM Pillars											
5. Impact											
Monitoring impact of scalable SSH research											
Education											
1. Collaboration and strategy											
Collaboration planning											
Requirement analysis											
Sustainability - Curriculum update process											
2. Pilot studies											
Pilots: (a) 2 usage types in primary education; (b) digital learning all levels											
Demonstrators											
Concertation across TM Pillars											
Pilots: (a) 3 usage types in primary education; (b) 2 usage types in higher & informal											
Improvement of demonstrators											
Concertation across TM Pillars											
3. Implementation											
TM software for education											

Exploitation avenue / Milestones	Time										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
4. Sustaining											
Customer satisfaction											
Rollout of TM for education											
GLAM											
1. Vision and Strategy											
Strategy task force											
User stories and use cases											
2. Experimentation and exploration											
Selection criteria											
Selection process concluded											
Test scenarios refined											
Pilot actions launched											
Impact analysis of pilot actions											
3. Generalisation and sustainability											
First model from Experimentation/Exploration											
Sustainability plan											
Large scale roll-out initiated											
4. Collaboration and outreach											
First cooperation initiated											
Creative industries											
1. Collaboration and outreach											
Hub infrastructure established											
Outreach strategy developed											
2. Use cases											
User stories created											
Concertation across TM Pillars											
3. Incubation											
Launch incubation activities											
4. Support Mechanisms											
Launch and operation of monitoring observatory											
Licensing hubs											
clinics with content co-designed with end-users											
5. Sustainability											

Exploitation avenue / Milestones	Time										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Large-scale roll-out of incubation activities											
Smart Tourism											
1. Definition of strategy											
Pilot region defined											
Local 3S and LTM smart tourism cluster established											
2. Elaboration of scenarios											
Strengths/weaknesses of local tourism											
Cultural heritage prioritised narrative refined											
3. Proof of concept											
Local creative industries hub											
Launch of the pilot technology-driven products and services											
4. Sustainability											
Testing products and services with infomediaries											
Customer satisfaction											
5. Impact											
Building smart tourism model											
Smart cities, urban planning, land use and territorial policies											
1. Vision and Strategy											
Thematic TM committee established											
Thematic TM Roadmaps developed											
2. Experimentation and exploration											
Definition of use cases											
Challenge platform											
Knowledge graph associated to samples of reference specified, version 0											
Collaborative platform, and one regulation and related datasets referenced on it											
Sandbox for European Culture Information System connected to LTM											
Prototype of TM Land Use debating platform											
3. Collaboration and outreach											
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											
Prototyped connections existing Smart City and Land Use portals with LTMs											
Second call for TM land-use digitisation proposals											

Exploitation avenue / Milestones	Time										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
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. Sustainability											
Master programme promoted to students											
Implementation of INSPIRE historical data and UN GGIM with TM protocols											
Survey to detect references of related work											
Implementation											
Yearly Open Calls											

Table 3-5: Milestones and time plan for Pillar 4



4 Implementation plan

4.1 Time Machine Governance

The two-stage approach

Time Machine benefits from an already existing governance structure, the Time Machine Organisation (TMO). The TMO idea started being developed already at the CSA preparation phase and matured over the following months, enabling to launch TMO as an Association under Austrian law in 2019.

TMO will undertake to initiate Time Machine, by securing the resources for starting the implementation of the LSRI, so one 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 target is for this process to reach a 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.
- A combination of the above.

In such a case, a new structure, the future TMO, 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.

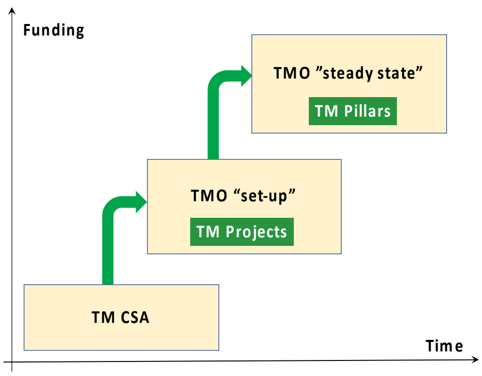


Figure 4-1: From the TM CSA to the future TMO governance scheme

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 like the EC.	A new TMO structure has to be developed to cope with the requirements of a LSRI.
B. Financial support has to be found in regular calls around dedicated sub-projects, which places a strong accent 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 have to obtain the necessary resources through EC or national calls.	A combination of the current and future structures has to be elaborated at a time when TMO will be in position to make a close assessment of the long-term funding opportunities.

A decision on the way to go should be taken when detailed plans are available for the implementation of HE and other programmes of the next programming period (2021-27) enabling the TMO to assess the degree to which these could support the Time Machine agenda. An appropriate time for such decision would then be the last half of the second semester of 2020.

The current TMO

The Management Functions

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

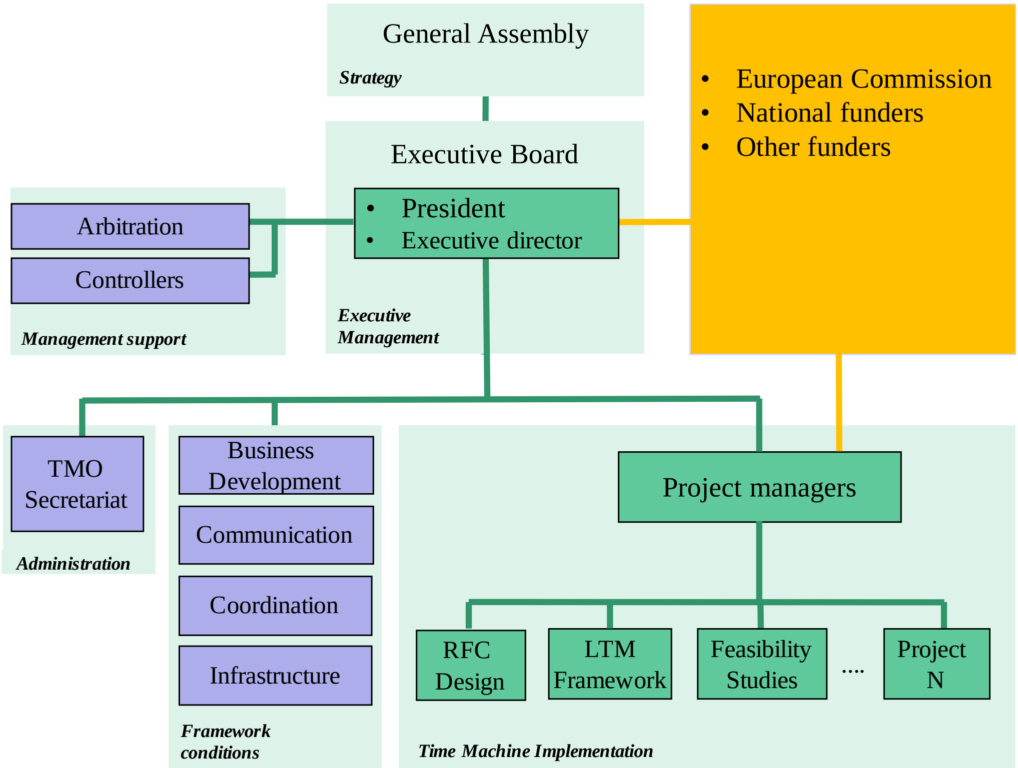


Figure 4-2: Organigram for current TMO

The General Assembly, where all partners of the TMO participate as voting members, is in charge of the 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 daily management and coordination of TMO actions.

The governance scheme comprises also:

- For implementation, management structures tasked with carrying out projects, following the usual pattern of project manager, WP leader and project team, with reporting levels and lines that are depend on the complexity of each project.
- For management support, the functions of arbitration as the highest level to resolve any issues that are escalated to General Assembly, and financial control for the audit of the TMO financial activities.
- For framework conditions (Box 4-1), the organisational units for (a) business development, (b) communication, (c) coordination, and (d) infrastructure.
- For administration, the TMO Secretariat, dealing with administration and finance of the TMO operation, including the management of TMO membership aspects.

Box 4-1: Management functions for framework conditions

Framework conditions refer to actions that enable the Time Machine 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.

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 for 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 is to collect calls and other opportunities from and for all partner institutions. Crucial activities are those involved with following-up the development of the European Partnership ideas and continuous dialogue and interactions with related initiatives.

Communication

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

- Strengthen and expand the TMO membership, by raising understanding of Time Machine and 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 part in the implementation of the Time Machine agenda, these networks will produce substantial communication-multiplier effects across the EU and worldwide.
- Promote Time Machine to the European Commission and other funding institutions, creating favourable conditions for its being financed 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 CSA will continue its operation in close cooperation with the Executive Board.

Coordination

Coordination refers to actions related with:

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

Coordination structures are foreseen in the following thematic areas of Time Machine:

- Science and technology
- Time Machine Infrastructure
- Local Time Machines
- Scholarship and education
- Exploitation areas: GLAM, Creative Industries, Smart Tourism, Smart Specialisation, Spatial Components
- Policy, legal aspects and ethical issues, open data.

Infrastructure

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

- Administrative infrastructure, including resources management platforms and related hardware.
- Communication infrastructure related to platforms for the internal on-line cooperation of TMO teams (e.g. MS Teams).
- Communication infrastructure related to platforms for external actions: managing development of existing websites and the creation new sites for sub-projects / conferences and similar areas.
- Infrastructure for supporting management of projects by TMO and external partners that 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, opportunities follow-up and matching partners in projects.

The Executive director will be in charge of developing this management function in cooperation with the Executive Board and managers that will use the platforms and tools to be developed

Administration

The whole TMO 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 coordinator 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 at different levels.

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

- Appoint, suspend or dismiss the Executive Board
- Decide on strategies for the construction and exploitation of Time Machine results
- Approve the TMO work programme and annual budget
- Accession/termination of new members
- Decisions on changes of TMO status, including winding-up of TMO.

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

- Formulating policies and plans, internal procedures, the global plan and budget, the annual budgets and reports, and for confirming that these 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 with the involvement of the TMO, and the longer-term impact. Also, 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 recommendation for the following reporting period.

The action plan

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

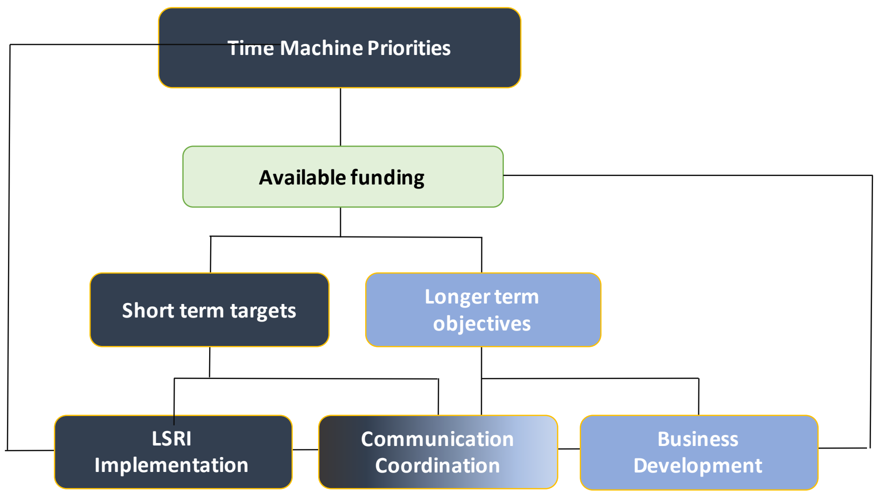


Figure 4-3: Planning process for the current TMO

The starting point for the programming cycle is the Time Machine roadmap that defines the priority objectives to be achieved at 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 for following programming periods
- The Communication and Coordination actions that support implementation in the current period, as well as objectives to be reached in following programming periods
- The Business Development objectives, specifying resources to be secured for the following 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 CSA period are aligned with priority actions identified in the Time Machine roadmap. These can initially include[9]:

- Rules and modalities for the development of RFCs
- Rules for LTM management and coordination
- Designing the use cases with which work on the Scholarship would start
- 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 for the search for and exploitation of opportunities, concentrating on the ones that fit with the above priorities.
- The Communication manager designs and implements tasks for supporting the above priority actions, by targeted actions for relevant funding institutions and key stakeholders. In parallel, the target is also to promote TMO broader objectives, in particular, planning the TM conference 2021.
- The Coordination managers 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 funding has been secured, through a strategic partnership framework with the EC and/or other national / 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 (important) parts of the Time Machine research and innovation agenda presented in Section 3.

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

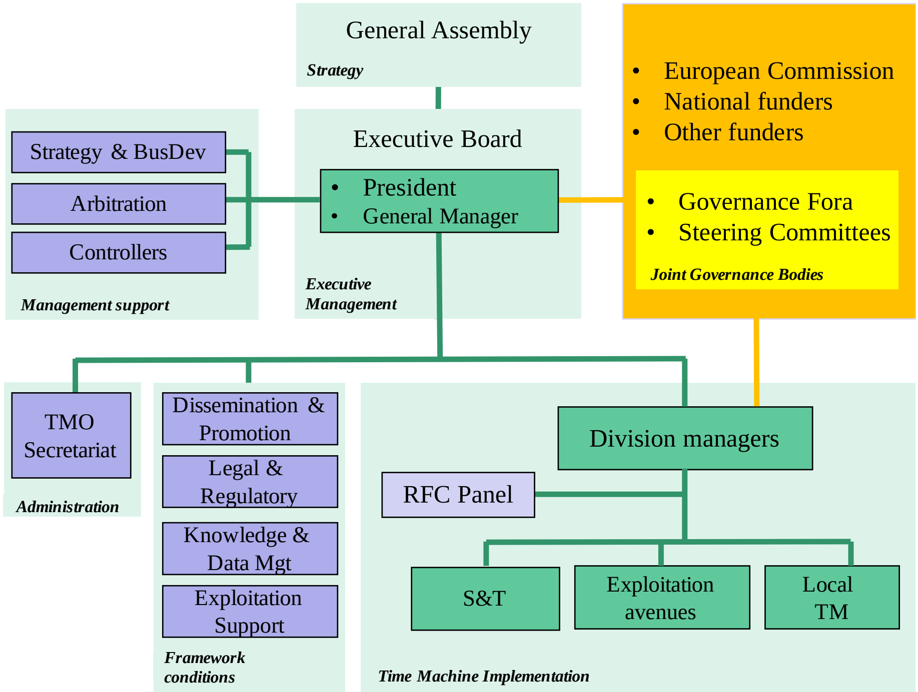


Figure 4-4: Organigram for future TMO

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 aiming to best synchronise activities funded by different entities enabling to maximise 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 Time Machin agenda, forward planning and operational matters to be addressed at this level.

The future TMO has the following organisational units:

- The General Assembly, where all partners participate as voting members, remains the highest decision-making body for 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:
  - o A Strategy and Business Development Unit (SBDU), in charge of elaborating strategic directions and evaluating progress
  - o The Controllers, acting as auditors of the TMO financial activities
  - o The Arbitration panel to resolve any issues that are escalated to the level of the General Assembly.
- At the level of framework conditions:
  - o Dissemination and promotion
  - o Legal and regulatory matters
  - o Knowledge and data management, and
  - o Exploitation support
- The TMO Secretariat deals with administration and finance of the TMO operation.

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 to organise 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 Time Machine, an RFC panel continuously supports the work programming in each division.

<u>Support functions</u>

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 in charge of advising the Executive Board in the different cycles of strategy development, as described below.

Strategy and Business Development

The SBDU is in charge of the annual evaluation. Conclusions of this exercise together with an assessment of the changes in the broader environment of Cultural Heritage are used to re-examine the Time Machine Strategic Agenda and propose changes in 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 (e.g. applications for funding) is coordinated with the Division Managers, who identify the resources that can more efficiently contribute in the preparation of detailed proposals for the new areas of action.

Advisory panels

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

<u>Framework conditions</u>

Dissemination

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

Policy Legal Issues and Ethics

The following structures are envisaged:

- A de-centralized first level support helpdesk, co-operated with extant service providers as libraries / associations etc. (First level support)
- Central legal hub who operates and coordinates the first level support, and assigns tasks to 3rd level of support and commissions. (Second level support)
- Network of legal experts / consultants on a national, domain-specific level to answer, investigate specific issues (Third level support)

- Commission for Law and Ethics: Frequently meeting commissions for strategic decisions and supervision

Knowledge Transfer

An IP Management Hub will be settled and principles and workflows will be handled in the IP Management Plan. This Plan will be developed to set guidelines and principles for the process from IP creation to exploitation. It will deal with IP Management in three strands as IP Commercialization, IP Asset Management and IP Protection Plan. This Plan will aim at assessing the innovation potential and capacity of IP.

Exploitation

An Exploitation Advisory Board will coordinate and align exploitation strategy and efforts of the TMO including LTMs. The Board will ensure proper implementation of the strategy and its continuous adaption to changing needs of TMO and its target markets/sectors/avenues for exploitation.

The Exploitation Hub of TMO 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 supporting all forms of exploitation of Time Machine outputs and outcomes with sound advice and hands-on assistance as required by experienced professionals engaged to cover the different thematic areas of Time Machine.

4.2 TM ecosystem and synergies with existing/planned initiatives

The Time Machine partnership network comprises more than 500 organisations from 34 countries (as of December 2019), including associate 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 enterprises – that will contribute to the actual implementation of the 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...)
- 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 the Time Machine sustainability potential comes from the fact that more than 80% of these organisations have agreed to be part of the TMO, this providing active support for the continuation of the initiative.

Time Machine aims to stand as a community of communities to foster the relations not only between itself and digital cultural heritage stakeholders, but also among the related stakeholders themselves. Mechanisms for an intensified interaction are envisaged to foster the European Research Area in Digital Cultural Heritage and to strengthen the impact of TM at 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 topped up for bringing 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 with 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)
- 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, as the ones described below.

- TM initiated a survey to understand the regional, national and European level schemes concerning cultural heritage related research and innovation including policies, funding programmes, projects, initiatives, skills, future trends and actors. The survey results provide a basis upon which TM will configure its exploitation support structures and initiatives to top up existing measures.
- The state of the art with regards to complementary initiatives and projects are analysed in two strands. Best practices of large scale European research and innovation initiatives are analysed such as current running FET-Flagships. Moreover, the projects in similar and complementary themes of TM initiative are analysed with respect to their achievements. This is to set a relevant background to offer actions those would top up existing efforts for greater impact and to better position and structure TM to build tailored linkages.
- It is aimed to inform and enable international and European associations about technologies available to support their requirements for digital transformation and organizational change as well as to incorporating their perspectives and competencies in the TM development process and to leverage synergies in the fields tackled by TM. In this respect and framed by the TM principles and values 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 find out complementarities/synergies and to develop joint actions towards common goals where needed.
    - Enabling a joint membership option that will allow members of partnering organisations to jointly register as a member of the TM organization
- TM plans to disseminate into training programmes and events. Training programmes for researchers, GLAM professionals and PhD students will be developed and maintained. Partnering mechanisms with educational programs and events will be developed. These mechanisms will be developed through providing an overview about all school, student and vocational training programs of relevance for the TM as well as mechanisms to place “own” topics in syllabuses as well as events.
- Recommendations and support for legal initiatives concerning digitisation of cultural heritage will be provided. It is aimed to propose a legislative and regulative framework to lead authorities and TM community and provide consultancy for translating the delivered content to EU wide practices and framework conditions with regards to digitisation of cultural heritage.

4.3 Funding

The required extensive, long-term and sustained effort to reach the Time Machine 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 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 should receive half of its funding from Horizon Europe and the other half from other sources. The TM partners have, therefore, examined the different forms of funding from the very start. 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).

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						
SSH	x	x	x					
Pillar 2								
Infrastructure					x			x
Community Mgt					x	x		
LTM						x	x	x
Pillar 3								
Scholarship		x					x	
Education		x		x			x	x
Exploitation areas&uses								
GLAM		x	x		x	x	x	x
Creative industries		x	x		x	x	x	x
Smart tourism		x	x		x	x	x	x
Smart cities-related areas		x	x		x	x	x	x

Most activities of TM pillar 1 and 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, Time Machine 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 other critical technologies, Time Machine 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 give a strong boost to SSH topics across pillar III of HE.

Time Machine is particularly relevant to the Digital Europe programme broad area dealing with ensuring the wide use of digital technologies across economy and society that 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 Time Machine agenda will also have synergies with other broad areas, including supercomputing, AI, and advanced digital skills.

The Time Machine approach offers concrete methodologies and tools in line with the objectives of the Creative Europe successor programme. In this respect, Time Machine 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 development of local Time Machines, as well as actions related to:

- Developing the TM infrastructure,
- Applications related to LTMs, as well as the exploitation avenues and uses considered in pillar 3.

Moreover, there are opportunities for raising private funding, especially in pillar 2 and pillar 3 actions. Such private investments are expected to be leveraged by specific instruments of the next programming period, including the COSME successor 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 the Time Machine infrastructure, initiatives related to new education programmes, as well as the specific application areas for GLAM, creative industries, smart tourism and smart cities.

Other sources of funding include:

- **Industrial funding and entrepreneurship** to valorise and co-finance the Time Machine. 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** as valorising results in terms of IPR, data or labour force will leverage the outcomes of the TM and therefore add value to the TM projects. The process will be facilitated by incubators or other technology transfer intermediaries that will specialise on the big data of the past and required resources, structures and competencies as well as selection mechanisms. Additionally, innovative formats to support entrepreneurship and research to practice transfer 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 on works related to cultural heritage will be invited to provide direct or indirect support.

5 Impact

5.1 A thorough dialogue with our past

Cultural Heritage is one of Europe's biggest assets. The Council of the EU and the EC place digital preservation and online availability of cultural heritage among the key priorities for the EU and its Member States, and have defined a digitisation plan and quantitative targets to ensure that Europe maintains its world-leading position in culture and creative content, and uses its wealth of cultural material in the best possible way.[10]

However, the digitisation of European cultural heritage represents a formidable challenge, both in terms of cost[11] and in its implementation: the allocation of funding for digitising cultural heritage across the EU is not adequate and there are still many delays associated with non-transparent management approaches and inadequate use of technology.[12]

Another key issue is that only a small number of artefacts in collecting institutions is actually made publicly available, stressing the need for improving access to heritage information using the latest technological progress. More crucially, billions of digital records are useless if they cannot be searched and analysed, while myriads of scanned books, sculptures and other artefacts cannot be used if their content is not indexed in an appropriate manner.

TM will offer new technologies, methods and protocols to address these challenges through mass digitisation campaigns across the whole of Europe, covering also landscapes, cityscapes and architecture, enabling the EU Member States to reach their ambitious objectives for cultural heritage preservation and access. TM will set up coordinated initiatives through public-private partnerships, exploiting additional funding sources, such as the European Structural and Investment Funds (ESIF), with well-specified criteria of efficiency and effectiveness.

5.2 A transformational impact on SSH

SSH accounts for well above 40% of students in European Higher Education.[13] SSH is also the largest European research community, with more than 30% of EU researchers in Higher Education, corresponding to about 500.000 Full Time Equivalent (FTE) positions. The SSH research spending, however, is substantially lower than 30% of the overall research spending, and is often lower than 20% in many countries.[14] The main reason seems to be that research projects in SSH are traditionally more limited in scale and scope compared to the exact sciences. This limitation stems primarily from the lack of easily accessible digital datasets that cover multiple modalities (text, sound, image) indexed using uniform metadata systems. Efficiently exploiting the available datasets as linked open data in SSH still requires a considerable degree of expert domain knowledge, for example in ancient languages, which prevents scholars from answering large-scale research questions.

A crucial leap forward is TM's promise of delivering unified access to Europe's past as linked open data. This will revolutionise the individual researcher's search capabilities, ranging from yielding immensely rich results for simple term queries, to the option of exhaustively tracking individual cultural artefacts through time and space, including texts, paintings, ideas or places. The goal is to scale up the typical scope of SSH studies by a factor of 1,000: if an average project nowadays considers ten artefacts (e.g. manuscripts), TM should allow that same project to consider +10,000 artefacts under the exact same conditions. The TM will thus enable SSH research at an exhaustive scale. Such distant reading and panoramic viewing will radically alter the scaling capabilities of SSH research because multiple information streams will be seamlessly aligned through history.

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[10] COM(2018) 267, A New European Agenda for Culture

[11] The cost of digitising the collections of Europe's museums, archives and libraries, including the audio-visual material they hold, is estimated at circa €100 billion, or €10 billion per annum for a period of ten consecutive years - Poole, N. (2010). The Cost of Digitising Europe's Cultural Heritage. The Collections Trust, https://espace.okfn.org/items/show/223

[12] Nauta, G. J. and van den Heuvel, W. (2015). Survey Report on Digitisation in European Cultural Heritage Institutions. Tech. rep. http://enumeratedataplatform.digibis.com/reports/survey-report-on-digitisation-in-european-cultural-heritage-institutions-2015/detail and Nauta, G. J. and van den Heuvel, W. (2017). Europeana DSI 2 – Access to Digital Resources of European Heritage, Tech rep. http://www.den.nl/art/uploads/files/DSI-2_Deliverable D4_4_Europeana_Report on ENUMERATE Core Survey 4.pdf

[13] https://ec.europa.eu/eurostat/statistics-explained/index.php/Tertiary_education_statistics

[14] ISSC World Social Science Report 2016 http://unesdoc.unesco.org/images/0024/002458/245825e.pdf

Above all, Big Data of the Past enhances our ability to deal with historical information, and in this way, it will drive SSH towards larger problems of world events and institutional development over longer periods of time. The abundance of new data about the past and the development of a new generation of AI will allow new interpretative models to be built on a superior scale. TM will offer the opportunity for researchers in SSH to work hand-in-hand with computer scientists and engineers to develop new models for reinterpreting the dynamics of socio-economic growth and crises on a European and global scale.

Identifying larger patterns, correlations and connections will contribute to important advances in scientific approaches and methodologies that open new frontiers in our capacities for in-depth analysis and informed decision making. TM will, therefore, drastically raise the scale and scope of SSH research, enabling it to effectively contribute to developing strategic answers to major challenges, such as sustainable growth, social welfare, migration and integration of migrants, and safeguarding European democracy.

5.3 A more accessible, interactive and diversified education

Education is a crucial factor for social and economic well-being in Europe and the world. TM will develop new ways of delivering education, especially in SSH, moving away from the traditional approaches of classroom lectures, textbooks and printed materials, and making use of localised and customised sample data at different – and extremely enhanced – levels of detail, enabling learning to be accompanied with new levels of analysis. The interactive environments that will be developed will not only offer unprecedented access to the records of our shared past, it will also promote active engagement with that heritage, which will make learning an on-going and inclusive process that will bind generations and cultures.

In this way, European history will become much more accessible to citizens of all ages and backgrounds, raising awareness of European culture, and consolidating our shared European identities. At the same time, there will be a stronger focus on exploratory learning, encouraging reflection on long trends that have shaped our present. New interdisciplinary methods will also be developed across the traditional scientific domains, making use of the advances in AI, the new modelling capabilities in SSH, and new simulation capabilities in most of the scientific and educational domains, and offering more depth to educational curricula, sharpening the critical thinking of learners, and contributing to informed decision-making at all levels.

5.4 A strong boost in European competitiveness in Big Data, AI and other ICT areas

TM will develop new smart algorithms that can meaningfully extract information and create knowledge from noisy, heterogeneous and complex data at a massive scale, from medieval manuscripts, collections of objects and cultural artefacts, to the recent smartphone and satellite images, and the multimodal content from websites and platforms. Due to this data's inherent complexity, an AI trained on Big Data of the Past will offer a strong competitive advantage for Europeans in the global AI race. The new processing and simulation technologies of TM, combined with its global curation and exploitation platforms, will enable Europe to increase its share of gains from the announced AI revolution.[15] TM will also introduce disruptive technologies in deep reading, linguistic and knowledge systems, multimodal (4D) simulation, HPC and long-term data storage.

Many of the advances developed by TM would require advanced software, an area in which many European companies have world leading roles. TM will further enhance their leadership, through scientific and technological achievements in rapidly growing segments of the global ICT industry. All the core components of the TM infrastructure will be developed as open source software, ensuring that the LSRI creates a legacy of code that can be corrected, reused and adapted for continuous development and deployment already during and after the end of the proposed initiative.

[15] 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?' - https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf.

The simulation capabilities substantially enhanced by TM will have a major impact on all areas of research in science and engineering that use HPC to process large volumes of data, including life and environmental sciences, as well as SSH. These 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.[16] Through Pillars 3 and 4, the TM LSRI will create advanced B2B / B2C services. In this way, TM will have a strong contribution to the competitiveness of European ICT.

TM will develop novel scanning technologies to digitise massive amounts of fragile documents and artefacts, through new types of sensors, robots and automated processes. These will provide rapid scanning solutions in science, industrial archives, public administration, and potentially in services for consumers. Massive increases in demand for scanning services would lead to economies of scale and falling costs, and falling costs would further boost demand. As a result, vast amounts of materials and data from practically unvisited archives would be accessible in digital form, offering a clear opportunity for European start-ups to compete in the growing Document Process Outsourcing (DPO) market, currently dominated by American and Asian players.[17] Possible applications for massive digitisation may include: (a) administrative registries to be used for studying policies, legislation or social norms in different societies and points in time; (b) health archives and records in Europe and beyond: turning these to digital records would enable scientists to perform joint analyses of patient reports, and other vital parameters crucial for developing health policies and health management practices.

5.5 Enhancing key sectors of the European economy

Creative Industries

The European creative industries contribute 6.8% of GDP and 6.5% of employment in the EU[18], 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 introduces disruptive technological solutions which will transform cultural heritage into rich creative assets. Specifically, the following creative industries sectors will benefit from TM:

Gaming and film industries. Due to the inaccessibility and costs of filming in historic locations, the use of detailed 3D reconstruction will become increasingly relevant for film and game makers. Mass-scale digitisation will remove spatial and temporal barriers to CH: using complex 3D models constructed from rich heterogeneous sources, creators will be able to produce immersive, multi-sensorial experiences of historic sites from different periods, and customise them according to their needs. Four-dimensional cinema and virtual reality experiences on large (amusement park) and small (AR/VR headsets) scales will represent a new market for photorealistic 3D models and digitised audio-visual assets.

Design. TM will harness the potential of the European heritage as a resource for creative reuse. Tools developed to analyse complex multimodal digital objects will enable designers to extract individual aesthetic features and concepts and re-appropriate them for new creations, from fashion to architecture. Advanced 3D modelling technologies combined with decentralised storage solutions will present new opportunities for real-time visualisations of objects and enable transnational, remote collaborative design processes. These enhanced engagement possibilities will translate into new avenues for creators to exploit cultural heritage sources as digital capital.

Media. With online video content expected to constitute 82% of all internet traffic by 2019[19], media professionals will continue to develop competitive business models and services that focus on providing seamless user experiences across devices and media types, and increasing the reach of

[16] 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)

[17] Worth US$ 30 billion in 2014, the DPO market is projected to reach a valuation of around US$ 35 billion by 2020 https://www.futuremarketinsights.com/reports/document-outsourcing-services-market

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

[19] https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.html

their content.[20] TM will introduce disruptive high-performance computing and storage technologies for the curation, enrichment and distribution of audio-visual content. Building on these technological innovations and the availability of much richer datasets, media industries will develop smart services of a new level of quality that will close the gap between media content and audiences by offering personalised experiences.

Journalism. The lowered barriers for content creation and distribution via digital platforms has given rise to an unprecedented abundance of data that currently lacks effective verification and curation methods. Moving forward, the industry will rely even more on citizen journalism as well as computational journalism, both of which require knowledge-validation mechanisms to maintain the trust of their audiences.[21] TM will fulfil this need via deep reading tools that can effectively analyse and assess the quality of digital objects. To remain competitive in the changing landscape, media agencies will utilise the distributed processing and simulation infrastructure introduced by the TM to synthesise disparate datasets into facts and narratives that offer new, more transparent and engaging perspectives.

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 contribute to the emerging need to strengthen GLAM by offering these institutions and their collections new ways of exploitation, based on:

- Promotion of innovative services through research, educational and creative activities
- New opportunities in fundraising and brand licensing combined with cost savings associated with rights and reproduction management overhead
- Employment of staff with more mission-critical activities, resulting in more efficient and less costly digitisation functions

The relevance of TM for GLAM is demonstrated by the large number of GLAM organisations in the TM Consortium and associate partners (section 1.3d).

Smart 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.[22] To compete with strong competition from other world regions, Europe intensively invests in smart tourism, i.e., in smart, innovative and inclusive approaches to touristic development, paying particular attention to cultural heritage and creativity. As a resource, TM is uniquely placed to revolutionise smart tourism, through the rich, multi-faceted and comprehensive cultural and historical data and innovative tools that will allow for the creation of endless avenues of experience and exploration, *in situ* or remotely. This will contribute to shaping tourists' behaviour, by attracting them to new locations or repositioning the interest for well-known and mature destinations through virtual pre-visits of cultural heritage sites, for example. It will furthermore help to regulate the tourist flow to "overwhelmed" destinations, through immersive educational and cultural experiences at home.

TM will also help to diversify cultural heritage tourism by creating tailor-made data platforms for each type of tourism: cultural, slow, rural, cruise-based, ethical, sport event-driven, wellness, medical, business, or adventure. By offering a full package (online preparation at home, experience-based visit, post-visit experience with materials gathered on site), the visit will become both educational

[20] Research indicates that between 2018 and 2022, many traditional media industries - television, radio, newspapers - will suffer from stagnation or decline in revenue due to their reliance on out-dated business models, whereas digital platforms that will implement personalised advertising methods and introduce monetised user-centred services can expect a growth of 8.7%. https://www.pwc.com/gx/en/entertainment-media/outlook/perspectives-from-the-global-entertainment-and-media-outlook-2018-2022.pdf

[21] Research demonstrates a waning trust in traditional news media (radio, television, newspapers) due to their assumed expertise and lack of transparency. Increasingly, more credibility is assigned to citizen journalists from social media platforms as they are perceived to have earned the trust of their audiences by being much more personal, accountable and insightful. http://www.journalism2025.com/bundles/svdjui/documents/Scenarios-for-the-future-of-journalism.pdf

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

and experience-driven, enhancing tourist retention of local history and identity, and thus strengthening the sense and understanding of European belonging.

Smart Cities

A Smart City is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies, for the benefit of its inhabitants and businesses. Smart Cities are at present mainly based on the networking of current data from interconnected sensory devices. The exchange of information will be fundamentally intensified by TM by, on the one hand, enriching it with so far unconsidered data, and, on the other hand, through data collections with historical depth.

Object recognition and tracking over time will play a vital role for future city planning. Based on the advanced modelling methods of TM, urban planning will enter a new stage, as it will be possible to find examples of cities that are similar to a city’s present state. In doing so, it will be possible to compare different strategic measures that were undertaken in these other cities to substantiate communal decisions.

The integration of urban information will further enhance risk mitigation in smart cities. Architectural data is essential for preservation, renovation and everyday management of buildings, and can also improve the efficiency of emergency operations or the detection of technical malfunctions. For example, the large-scale provision of architectural layouts and infrastructural aspects facilitates the mapping of infrastructural needs. The inclusion of historical data makes it possible to track urban, land and infrastructure developments such as electricity networks, gas conduits, and drainage systems. The analysis of architectural, urban planning, land use, economic and social data collected over long periods can make it possible to predict the future development of specific areas, and thereby allow for more sustainable and efficient decision-making.

Land use and territorial policies

Europe has the highest proportion in the world (80%) of land used for settlement, production and infrastructure. Population growth and the increase of commercial activities for food, bioenergy and industrial crops contribute to an even higher demand for land and more intense competition between municipal and industrial uses. This excessive pressure negatively affects biodiversity, degrades habitats and raises issues ranging from carbon dioxide emissions to soil sealing, landscape fragmentation and urban heat island effects.

TM offers a long-term perspective for a transition to sustainable land management, based on our common history and with the perspective of the next generation. By increasing the possibilities of in-depth analysis of highly heterogeneous data (aerial and spatial images, land database, soil quality database), TM will develop methods and indicators to objectively monitor the consumption of natural, agricultural or forest areas at all territorial scales. The increased potential of TM in digitising and indexing old data (silver prints, maps, tables, legal texts), will also make it possible to retroactively calculate these indicators, which offers a unique opportunity to analyse the impact of policies on land use over time.

The TM platform for land use will enable a shared framework to compare territorial configurations across space and time, promoting the exchange of knowledge and experience between similar territories. It will also strengthen the science-policy interface, enabling land-use stakeholders in particular to simulate the effects of transposing European legislation into national and local levels.

5.6 The international dimension

Time Machine comes at a time where culture occupies a central role in the UN 2030 Agenda for Sustainable Development. For the first time, the international development agenda refers to culture within the framework of Sustainable Development Goals related to education, sustainable cities, food security, the environment, economic growth, sustainable consumption and production patterns, peaceful and inclusive societies. A strong opportunity exists to develop synergies with UNESCO's programme, through UNESCO’s Culture Conventions on the safeguarding and promotion of cultural and natural heritage, and the cultural and creative industries, as well as joint programmes with other UN Agencies for the implementation of the 2030 Agenda for Sustainable Development.

Europe has a leading role in the digitisation of culture. TM will strengthen this role at a time where this field gains momentum in Asia and the USA. Furthermore, TM will increase the scientific reputation of EU institutions in Digital Humanities and SSH, opening the way to launch or reinforce international collaboration. Opportunities will be exploited for initiatives for world Cultural Heritage in cooperation with UNESCO, the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and leading institutions and stakeholders from other parts of the world.

Time Machine is designed as an open platform based on a set of standards, pipelines, interaction rules and best practices. Therefore, an interaction with community projects, such as Wikimedia, Open Knowledge Foundation, Open Street Map, The Web Archive or the World Monuments Fund is important. The Time Machine community would enrich the landscape of networks by contributing an original European and Cultural Heritage centred perspective.

Accordingly, interaction with standardisation bodies, such as the European Committee for Standardisation or policy makers like the Council of Europe, are of relevance in order to ensuring both, quality of prospective input in the TM as well as sustainability of TM outcomes.

Local Time Machines can be created all over the world provided they are following the platform principles. Based on existing contacts, collaboration will be sought with UNESCO's Memory of the World Program and UNI-MED, in order to devise strategies for disseminating technology, expertise and support for Local Time Machines outside the European area. Outcomes and communities created within focused networks like the Virtual Multimodal Museum network and its follow-up initiatives will also be considered as input to attract and involve stakeholders from these regions.

Annex A: Definitions – Abbreviations

Definitions

4D Simulator	One of 3 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 3 TM Simulation Engines. 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 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	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 should contain information about infrastructure standards required within any project with the Time Machine label. The Technical Charter defines the Time Machines Rules, Recommendations, Metrics and Official software. The document is revised periodically.

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 3 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 out.
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 3 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.

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: Time Machine Use Cases

B.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	As of now, 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. (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). (2) Thick history 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). (3) Comparative or "stack" history 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. (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.

B.2 GLAM

Written by: Paul Sommersguter (Austrian National Library)

<table>
<tr><td>Title</td><td>Museums as Smart Spaces</td></tr>
<tr><td>User group</td><td>GLAM Visitor / Tourist</td></tr>
<tr><td>Core problem</td><td>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.</td></tr>
<tr><td>Summary (specific and attainable)</td><td>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.</td></tr>
<tr><td>Opportunity</td><td>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</td></tr>
<tr><td>Persona</td><td>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.</td></tr>
<tr><td>Scenario</td><td>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</td></tr>
</table>

	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.

B.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