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Cognitive revival

Modernising historical and heritage cities through emerging technologies

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01 Introduction

Our historical cities embody a rich legacy of tangible and intangible heritage, encompassing built form, art, and culture inherited from the past.

While these cities and their heritage neighbourhoods offer a wealth of benefits, their preservation and development presents unique challenges. Amidst rapid urbanisation, it has become critical for heritage cities to embrace modernisation, while conserving their unique identity, promoting culture, and enhancing assets for the local population and visitors.

Strategic collaboration among city development authorities, governments, conservation departments, citizen groups, and international organisations is essential to preserve the identity of heritage cities. Successfully integrating cultural preservation with economic development, sustainability, and the use of emerging technologies is fundamental.

Moreover, heritage cities should continue to adopt strategies that balance the preservation of heritage with improving livability for residents, protecting citizens' rights, and adapting to the dynamic urban landscape. This holistic approach ensures that heritage cities remain relevant and resilient while honouring their historical foundations.

In this thought leadership, we explore the core principles guiding the transformation of heritage cities, identifying key factors and enablers driving their modernisation. Drawing insights from use cases, we uncover valuable lessons and unfold the framework, looking at the opportunities, considerations, and implications of the cognitive revival of historic cities.

02 The past can drive the future

Evolution and significance

Heritage assets offer numerous benefits to cities, contributing to their economic, social, and cultural importance. Cities with a rich heritage represent the legacy of tangible and intangible elements of cultural elements passed down through generations. From an economic perspective, this attracts cultural tourism, and stimulates local economies

However, these cities also continuously face challenges posed by natural disasters, climate change and rapid tourism growth. Rising population, urban expansion, increasing demands on infrastructure, regulatory limitations, and considerations around retaining cultural identity pose additional challenges that are unique to these locales.

Retrofitting historic districts with modern amenities, infrastructure, and state-of-art technology, while preserving their unique cultural and historical character, makes them more desirable places to visit, live, work, and invest – creating an optimum balance of modernisation efforts and historical integrity.[1]

London and Prague exemplify cities that preserve history while modernizing. London evolved from Georgian townhouses to Victorian neighborhoods and, by the 20th century, iconic skyscrapers, balancing heritage with urban growth. Prague, with its medieval architecture, preserved its charm through political shifts, blending history with select modernization by 2000.

Recently, both cities embraced sustainable innovations. London has implemented green rooftops, eco-friendly housing, and smart traffic systems. Prague leverages 3D replica of the city, merging heritage with sustainable, smart urban planning.

In recent years, countries in the Middle East have taken up the modernisation of historic and heritage cities as a crucial component of their cultural preservation and development strategies. Saudi Arabia's Vision 2030, which includes the transformation of some of its historic cities into major cultural destinations, and the UAE's use of digital tools for the preservation of cultural artefacts[2], exemplify the region's commitment to leveraging innovation to safeguard heritage while creating future opportunities.

Cities such as Diriyah, Jeddah, Lusail, AlUla, AlFaihidi district (in Dubai) and Muscat are collaborating with organisations like UNESCO and the Arab Regional Centre for World Heritage on initiatives that blend their rich heritage with modernisation. Diriyah and AlUla are at the heart of Saudi Vision 2030, which includes a remit to transform heritage cities into cultural hubs[3], while Jeddah has been actively working towards enhancing its historical districts with technology-driven solutions. Meanwhile, in Qatar, Lusail is developing as a smart city with cultural preservation at its core[4]. Cities in the UAE, Oman, and Bahrain are also incorporating digital tools and smart solutions in transforming their historical neighbourhoods.

[1] What are the benefits of urban heritage conservation for your community? (n.d.). linkedin. https://www.linkedin.com/advice/3/what-benefits-urban-heritage-conservation-your-community#:~:text=Urban%20heritage%20conservation%20can%20boost,and%20products%20related%20to%20heritage

[2] https://www.emerald.com/insight/content/doi/10.1108/LHTN-02-2024-0032/full/html

[3] https://www.pwc.com/m1/en/media-centre/articles/redefining-cultural-and-heritage-conservation-in-the-middle-east.html

[4] Exploring Qatar's Smart City Initiatives. (2024, August 28). Landvault. Retrieved October 22, 2024, from https://landvault.io/blog/qatar-smart-cities

While historical cities and heritage neighbourhoods make efforts to become future-ready, they face several challenges

Threat to cultural identity

Continuous rise in population of historic towns can encroach on heritage neighbourhoods, disrupting the unique architectural heritage, threatening the cultural identity and creating tension between development and preservation efforts.[5]

Population growth and resident-visitor ratio:

A continuous influx of visitors and overcrowding can burden the infrastructure and increase the pressure on open spaces & civic amentities.[6]

Limitations in delivering an ultimate experience:

With growing demand, the strained public services can compromise the overall experience for residents and visitors.[6]

Microclimatic conditions and environmental challenges:

Microclimatic variations, such as temperature fluctuations and humidity levels, and local environmental factors, like pollution and biological growth, contribute to accelerating the wear-and-tear of historical structures.[5]

Natural disasters and civil conflicts:

Natural disasters pose a significant threat to the structural integrity of heritage cities – ancient buildings may be less robust or too old to repair using modern equipment. Conflicts driven by geopolitical tensions can endanger physical structures and threaten the cultural fabric of communities.[5]

Policies and urban regulations:

While stringent zoning, building codes, and conservation guidelines help in keeping a check on urban sprawl, they also draw limitations on various infrastructure development initiatives.[7]

Financing and funding:

Competition with faster growing cities and modernisation projects prioritised for tangible return on investment can sometimes see historical cities struggle to secure funding for conservation-focused initiatives.[5]

Availability and authenticity of historical data and designs:

Heritage cities often have difficulty accessing and managing historical records, such as architectural drawings and preservation details of old buildings. They also face challenges in maintaining architectural authenticity within the city's neo-urban designs.[8]

Our historic cities and heritage neighbourhoods face various challenges but remain a testament to our rich past, a reflection of our society today and our aspirations for tomorrow.

[5] Assessment of urbanisation impact on cultural heritage based on a risk-based cumulative impact assessment method - Heritage Science. (2023, August 21). Heritage Science. Retrieved October 22, 2024, from https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-023-01024-0

[6] Travel without leaving a trace – how to tackle overtourism | The UNESCO Courier. (2024, August 14). The UNESCO Courier. Retrieved October 22, 2024, from https://courier.unesco.org/en/articles/travel-without-leaving-trace

[7] Smith, K. (n.d.). Heritage Conservation in Rapidly Growing Cities. Department of Architecture, University of Cambridge. file:///C:/Users/vsainani002/Downloads/24_Heritage%20Conservation%20in%20Rapidly%20Growing%20Cities%20(1).pdf

[8] Practices and challenges of cultural heritage conservation in historical and religious heritage sites: evidence from North Shoa Zone, Amhara Region, Ethiopia - Heritage Science. (2022, October 27). Heritage Science. Retrieved October 22, 2024, from https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-022-00802-6

03 Unfolding cognitive revival

A trinity of phases — past, present, and future

Exploring the journey of a heritage city is like diving into a story told through the lens of the past, present, and future. For the past, the focus is on preserving history, exploring structures, artefacts, and documented cultural practices. In the present, the story shifts to conserving, restoring, and preserving. For the future, the narrative shifts to adaptive reuse and the evolution of heritage sites, where the integration of cognitive technologies becomes a powerful tool for preservation and innovation From intelligent preservation systems to virtual heritage tours, technology enhances the city's attraction and transforms it into a cutting-edge, more livable contender compared to its skyscraping competitors.[9]

[9] Toschi, I., Borghini, S., & Margherita, A. (2017). The role of digital technologies in the preservation of cultural heritage. ResearchGate. Retrieved October 23, 2024 from https://www.researchgate.net/publication/317757322_The_Role_of_Digital_Technologies_in_the_Preservation_of_Cultural_Heritage

Factors driving tech-powered transformation

In the ever-evolving landscape of historical cities, the drive for technological transformation arises from a shared vision of growth, focusing on resource optimisation, advanced infrastructure, improved quality of life, and economic development. There are various factors that drive cities to rely on tech-powered transformation to safeguard their unique heritage and unlock the potential at the core of our rich heritage:

Enhancing quality of life
Leveraging technology improves residents' quality of life by enhancing accessibility and effectiveness of public services.

Preserving cultural identity
Digital archives, LiDAR, virtual twins, and interactive exhibits contribute to conservation of historical artefacts and designs

Economic growth
Fostering innovation, supporting MSMEs related to traditional art, culture and handicraft through e-commerce, and attracting new businesses

Top-tier infrastructure
Technological advancements are essential for top-tier infrastructure in heritage cities, enhancing attractiveness.

Sustainable urban planning
Empowering sustainable urban planning through smart technologies aids the preservation of historical and cultural identities.

Resource optimisation
Smart technologies optimise resource management in heritage cities, promoting economic viability, sustainability, and efficiency.[10]

Tourism
Integrating immersive experiences through AR, VR and twins can help attract as well as promote virtual-physical balance in tourism

Community wellbeing
Embedding citizen engagement platforms, digital feedback systems, and smart city applications can improve responsiveness to community needs.

Green heritage
Prioritising zero carbon footprint technologies, including renewable energy sources and smart waste management, helps keep heritage sites sustainable.

Regulatory evolution
Technological integration leads to efficient implementation and monitoring of compliance with regulations.

Adaptive reuse
Technological adoption can help repurpose the assets, while monitoring their physical conditions.

[10] ESRI. (2012). Cultural heritage management and GIS in Petra, Jordan. ArcNews. Retrieved October 23, 2024 from https://www.esri.com/news/arcnews/summer12articles/cultural-heritage-management-and-gis-in-petra-jordan.html

Cognitive revival stack

In the journey towards transforming a historic city, it is important to consider the needs of stakeholders and the technological capabilities of the implementing authority. Unlocking the potential of our cities and making them future-ready is a delicate process that requires a comprehensive approach to navigate the potential complexities faced by city leaders and their advisors. Cognitive technologies have emerged as a means of addressing these challenges, helping with various components that form the value chain of the city developments and redevelopments.[11]

This approach helps create a human-centred, technology-powered framework that includes the voices of people – stakeholders and users – as well as services for these people. Platforms and solutions are designed to deliver these services effectively, supported by various technological enablers. By stacking the key elements into layers, we ensure a holistic approach that places stakeholder benefit and their role in decision making at the heart of the transformation, while leveraging cutting-edge technology to enhance delivery and engagement.

This integration is crucial for creating adaptive, responsive urban environments that respect historical heritage while meeting modern needs. The cognitive revival stack exemplifies the commitment to harmonising the old with the new, ensuring a balanced, forward-thinking approach to urban development.

[11] BIM Plus. (n.d.). New York's Navy Yard adopts digital twin to become greener. BIM Plus. Retrieved October 23, 2024 from https://www.bimplus.co.uk/new-yorks-navy-yard-adopts-digital-twin-to-become-greener/

Non-exhaustive

The revival stack

To rejuvenate and preserve our historical cityscape through cutting-edge technology, fostering a resilient, vibrant heritage that bridges our rich past with a sustainable, cognitive future

The Voices

Tourists and Visitors	Community Champions (Citizen Groups & Communities)	Preservation Advocates (Historical Societies & Researchers)	Investors and Funding Agencies (Private, Public and International Agencies)	Preservation Authorities (Conservation Office)
Local Political Leaders	Custodians of Urban Development (City Government)	Architecture & Heritage Enthusiasts (Architects & Private Individuals)	Tourism and Culture Ambassadors (Tourism Boards & Entities)	

Heritage Services/ Mandates

Preservation and Conservation	Adaptive Reuse & Revitalization	Sustainable Urban Development	Smart Infrastructure & Connectivity	Building and Facilities Management	Heritage Tourism
Municipal Services	Cultural Events and Festivals	Community Engagement	Resilience & Risk Management	Research, Development and Innovation	Document & Archiving

Platforms

Metaverse	Geospatial (GIS)	Governance, Risk & Compliance	City OS	Integrated Tourism
Building Management System	Centralized Command & Control	Construction & Conservation Works	Archival & Documentation Platform	Community Engagement Platform

Technologies

Geographic Information System	LiDAR	Building Information Modeling	3D Scanning & Printing
IoT and Edge Compute	Digital Twin	Artificial Intelligence	Mixed Reality

Enablers

Robust Organizational Framework	Policy Framework	Governance	Public Awareness & Participation	Collaboration & Partnerships	Financial Requirements

Voices of revival – Key players in the transformation journey

Key players in our transformation journey include citizens, residents, and visitors – as well as producers, including decision-makers, funding providers, city managers, technical experts, and architects. Various stakeholders play important roles in the development, redevelopment, and revival of our cities. Although not an exhaustive list, here are some key stakeholders expected to make a significant contribution to the cognitive revitalisation of historic cities and neighbourhoods.

Tourists and visitors

Vital to heritage cities as they generate revenue that supports conservation efforts and local economies. Help in raising awareness of the cultural identity

Preservation advocates

Contribute academically to preservation, researching and advocating for protection of historical sites.

Preservation authorities/agencies

Implement policies and strategies for structural integrity and endurance of historical landmarks.

Urban development custodians

Balance modern development with safeguarding historical assets through urban planning and policies.

Tourism and culture ambassadors

Promote heritage cities as unique destinations, showcasing cultural richness.

Community champions

Includes citizens and residents who bring vibrancy through cultural engagement and fostering local pride.

Investors and funding agencies

Provide necessary financial support to preserve, restore, and adapt historical sites sustainably Foster economic growth, tourism, and cultural preservation

Local political leaders:

Influence policy decisions to balance cultural heritage and contemporary needs.

Architecture & heritage enthusiasts:

Ensure functionality and innovation in heritage conservation while respecting historical significance in such structures.

04 Technologies powering sustainable revival

Adoption of development-oriented, human-centric technologies can enhance livability and alleviate pressure on heritage assets by supporting the planning, optimizing resource use, ensuring operational efficiency, and promoting innovative use cases. The incorporation of digital and technology across the lifecycle of a heritage city or neighborhood from **preservation and conservation** to **adaptive reuse and planning** to **tourism** to a continuous **research and development.**[12] Key technologies in current applications include**:**

- **Geospatial technologies**
- **IoT**
- **Light Detection and Ranging (LiDAR)-enabled drones**
- **Digital twins**
- **Building Information Modelling (BIM)**
- **Artificial Intelligence (AI) and Machine Learning (ML)**
- **3D scanning and printing**
- **AR and VR**

[12] Akenza. (n.d.). How IoT can aid in the conservation of built heritage. Akenza. Retrieved 23 October, 2024 from https://akenza.io/blog/how-iot-can-aid-in-the-conservation-of-built-heritage

Some of the use cases that demonstrate how emerging technologies can be leveraged across the lifecycle of revival of heritage cities:

Heritage city services	Preservation and conservation	Adaptive reuse and urban revitalisation[13]	Heritage tourism	Research and development
Technologies				
Geospatial technologies	**Cultural heritage mapping:** Use geospatial technologies to create accurate digital maps of heritage sites. World heritage cities in Uzbekistan are using Geographic Information System (GIS) technology to develop a database that contributes to the understanding of the outstanding heritage value of these cities while also aiding the development of preservation strategies.	**Zoning and planning:** Geospatial data assists in urban planning by identifying suitable areas for adaptive reuse projects. Kyoto in Japan uses geospatial technologies for urban planning and zoning to balance modern development with the preservation of its traditional neighbourhoods, supporting adaptive reuse projects.	**Interactive maps and tours:** Using geospatial technologies to create interactive maps or virtual tours for the public, educating residents and visitors. For Egypt's pyramids, geospatial data has facilitated the creation of virtual tours, allowing people from around the world to explore the pyramids without physically visiting the site. This not only increases accessibility but also raises awareness.	**Spatial analysis:** Geospatial technologies support research efforts by examining spatial patterns and trends in heritage cities, furthering understanding of the evolution of urban landscapes. In Petra, Jordan, GIS is providing the framework for an automated monitoring system that will be used to detect changes in conditions that, left unchecked, would ultimately destroy irreplaceable archaeological remains.
LiDAR	**Change detection:** Implement LiDAR-based change detection to identify any alterations or damages to heritage structures over time. In Granada, Spain, LiDAR is used for detailed mapping and monitoring of the Tajos landscape, aiding conservation and restoration efforts.	**Site analysis:** Use LiDAR for detailed site analysis, supporting architects and developers in the adaptive reuse of heritage structures. Around Machu Picchu, Peru, LiDAR technology helps in mapping and studying the terraced landscape, supporting sustainable tourism planning.[15]	**Virtual tours:** LiDAR scans are used to create immersive virtual tours of heritage sites, allowing tourists to explore landmarks. On the Caribbean island of Curaçao, LiDAR technology is being used to create a virtual scan of a hospital for tour purposes.	**Topographic mapping:** Using LiDAR for precise topographic mapping, providing detailed elevation information. In Angkor Wat, Cambodia, aerial LiDAR surveys revealed a canal network and ancient urban sprawl, providing insights into environmental management and urban planning of Khmer civilisation.
BIM (1/2)	**Condition assessment:** BIM allows for real-time monitoring of structural and material conditions, helping identify areas needing immediate attention.[16]	**Energy efficiency optimisation:** BIM can help integrate modern technologies for energy efficiency without compromising historical integrity.	**Augmented reality guides:** BIM models are used to create augmented reality guides for tourists, allowing the visualisation of historical buildings.	**Material analysis:** BIM can assist in the analysis of the historical materials used.

[13] DS-A. (n.d.). The concept of adaptive reuse: Transforming old buildings for new purposes. DS-A. Retrieved October 27, 2024 from https://ds-a.co.uk/the-concept-of-adaptive-reuse-transforming-old-buildings-for-new-purposes/
[14] ESRI. (2012). Cultural heritage management and GIS in Petra, Jordan. ArcNews. Retrieved 27 October, 2024 from https://www.esri.com/news/arcnews/summer12articles/cultural-heritage-management-and-gis-in-petra-jordan.html
[15] Valverde, F., García, A., & Seoane, P. (2021). Survey of a Peruvian archaeological site using LiDAR and photogrammetry: A contribution to the study of the Chachapoya. ResearchGate. Retrieved 23 October, 2024 from https://www.researchgate.net/publication/354530360_Survey_of_a_Peruvian_Archaeological_Site_Using_LiDAR_and_Photogrammetry_A_Contribution_to_the_Study_of_the_Chachapoya

Heritage city services

Technologies

BIM (2/2)

Preservation and conservation	Adaptive reuse and urban revitalisation[13]	Heritage tourism	Research and development
In the dungeons of Tetuán, Morocco, the application of BIM resulted in both the study of a historical building and its subsequent preservation by pathological parametric study of the buildings (as-damaged model) and a specific information database for each architectural element.	In Kyoto, Japan, building systems are incorporated in the adaptive reuse of traditional machiya townhouses, experimenting to balance modern comforts and energy saving with historical authenticity of the residence.	Florence, Italy, uses BIM to create digital models of its museums and galleries, providing immersive virtual tours and exhibits for people to experience from anywhere.[17]	In Piracicaba, Brazil, a knowledge-based digital built heritage model of the city's Central Mill was created.

3D scanning and printing[18]

Mock-ups:	Physical prototyping:	Tactile experiences:	Archival database:
Create 3D-printed mock-ups for restoration planning, allowing conservationists to visualise and test different approaches.	Utilise 3D printing to prototype modern additions to heritage structures, allowing stakeholders to assess the visual impact prior to construction.	3D-printed replicas of architectural elements allow tourists to experience tactile interactions with historical structures.	3D scanning may be used to create accurate replicas of heritage artefacts and structures for archival purposes.
The Great Buddha of Kamakura in Japan utilised laser scanning and 3D printing techniques to replicate and replace damaged parts of the statue.	In Piraeus Museum, Greece, ancient artefacts were digitised and 3D-printed tactile replicas were produced from recycled Polylactic Acid (PLA) material, providing a multisensory experience.	The British Museum in London uses 3D-printed replicas for educational purposes, allowing hands-on interaction with historically significant artefacts without damaging the originals.	In Palmyra, Syria, experts used 3D scanning to create accurate digital replicas of destroyed monuments, with the scans also serving as virtual archives.

IoT

Structural health monitoring:	Connected heritage spaces:	Interactive exhibits:	Data collection:
Deploying IoT sensors enables real-time structural health monitoring of heritage buildings.	IoT can be used to create a network of connected heritage spaces.	IoT-enabled exhibits provide visitors with interactive experiences, such as touchscreen displays that offer information about historical sites and artefacts.	IoT devices collect real-time data on visitor flow and behaviour, providing researchers and destination managers with insights into tourist preferences.[19]
In Rome, Italy, IoT sensors are monitoring the stability of the Ponte Vecchio Bridge and its nearby land. The sensors track ground movements and soil structure, providing real-time data that allows for a quick reaction in the event of a structural shift.	In Rome, IoT sensors such as wireless accelerometers, tiltmeters, and probes were used around heritage districts including the Colosseum to seamlessly integrate and construct the Rome metro and protect historical architecture from damage.	In Prague, Czech Republic, IoT devices are used at the LEGO museum, which hosts replicas of heritage structures made of LEGO, providing interactive exhibits and audio guides that enhance visitors' understanding of its history.	In Hoi An, Vietnam, IoT sensors integrated with mobile functions and geotags are being used to track tourists and collect and document cultural heritage.

[17] Google Arts & Culture. (n.d.). A virtual holiday to Florence. Google Arts & Culture. Retrieved October 27, 2024 from https://artsandculture.google.com/story/a-virtual-holiday-to-florence/YwWxaFvyCQYDQA?hl=en
[18] Utilities One. (n.d.). Reviving tradition: 3D printing and the preservation of historic buildings. Utilities One. Retrieved October 27, 2024 from https://utilitiesone.com/reviving-tradition-3d-printing-and-the-preservation-of-historic-buildings
[19] Akenza. (n.d.). How IoT can aid in the conservation of built heritage. Akenza. Retrieved October 23, 2024 from https://akenza.io/blog/how-iot-can-aid-in-the-conservation-of-built-heritage

Heritage city services

Preservation and conservation

Adaptive reuse and urban revitalisation[13]

Heritage tourism

Research and development

Technologies

Digital twins

Virtual preservation:

Digital twins create virtual replicas of heritage sites, allowing conservationists to monitor and simulate the impact of environmental factors on historical structures.

The Getty Conservation Institute created digital twins of ancient cave paintings, aiding in identifying areas in need of restoration.[20]

Virtual prototyping:

Digital twins simulate proposed urban revitalisation projects, allowing to visualise and assess the impact on heritage buildings. Twins also contribute significantly to investor attraction

The redevelopment of the Brooklyn Navy Yard used the creation of a digital twin, aiding in the adaptive reuse of historic naval buildings for modern industries and becoming greener.[21]

Virtual tours:

Digital twins enable immersive virtual tours of heritage cities, providing tourists with an interactive experience of historical landmarks.

Singapore created digital twins of its heritage precincts, offering virtual experiences and interactive tours that highlight the area's cultural heritage.[22]

Predictive Modelling:

Digital twins support predictive modelling of urban development scenarios, helping researchers understand the long-term implications on heritage conservation.

Rotterdam in the Netherlands has built a digital twin model to evaluate and improve the city's ability to withstand change using information on the city's infrastructure, population, land use, and data on climate-related risks.

AI and ML[23]

Real-time monitoring analytics:

Use AI for real-time monitoring analytics to identify changes in the condition of heritage structures.

The National Archives of the UK utilises AI algorithms to identify and preserve deteriorating paper documents, ensuring the longevity of historical records.

Cognitive planning models:

Employ AI for cognitive planning models to simulate the long-term effects of urban planning decisions on heritage.

Amsterdam's Canal District applies AI algorithms for predictive modelling in urban planning, balancing growth while respecting its historical character.

Personalised experiences:

AI-powered recommendation systems provide tourists with personalised suggestions for heritage sites and activities based on their preferences.

Florence uses AI and ML to analyse visitor data and preferences, personalising museum experiences and tour recommendations to enhance tourists' engagement.

Data analysis:

ML algorithms analyse large datasets, such as historical documents and archaeological records, to extract valuable insights for heritage research.

The British Library uses AI to digitise and categorise historical manuscripts.[24]

AR and VR[25]

Virtual restoration Simulations:

Use VR for virtual restoration simulations, allowing conservationists to test and refine restoration strategies.

The Metropolitan Museum of Art in New York utilises AR to provide virtual replicas of artworks that visitors can access through an in-app map to guide them to artworks around the museum.

Interactive planning:

Utilise VR for interactive planning sessions, allowing stakeholders to visualise adaptive reuse projects.

The St. Nicholas Cathedral in Sremski Karlovci, Serbia utilises a highly detailed 3D virtual model in VR to assess and plan any adjustments needed to be made.

Virtual heritage tours:

Offer virtual heritage tours using VR to provide immersive experiences of historical sites.

The Petra Museum in Archaeological Park in Jordan utilises VR to digitally preserve architecture, art, and history, offering visitors a virtual glimpse into the city's ancient past.

Virtual reconstructions:

Mixed reality technologies facilitate the creation of virtual reconstructions of historical landscapes and structures for research purposes.

Rome offers mixed reality experiences at its archaeological sites and museums, allowing researchers to visualise historical reconstructions and interpretive exhibits that enhance immersion.

[20] Kantaros, Antreas. "Three-Dimensional Printing and 3D Scanning: Emerging Technologies Exhibiting High Potential in the Field of Cultural Heritage." MDPI, https://www.mdpi.com/2076-3417/13/8/4777. Accessed 27 October 2024.
[21] BIM Plus. (n.d.). New York's Navy Yard adopts digital twin to become greener. BIM Plus. Retrieved 27 October, 2024 from https://www.bimplus.co.uk/new-yorks-navy-yard-adopts-digital-twin-to-become-greener/
[22] Infra Global. (n.d.). Singapore's digital twin: From science fiction to hi-tech reality. Infra Global. Retrieved October 27, 2024 from https://infra.global/singapores-digital-twin-from-science-fiction-to-hi-tech-reality/
[23] Toschi, I., Borghini, S., & Margherita, A. (2017). The role of digital technologies in the preservation of cultural heritage. ResearchGate. Retrieved October 27, 2024 from https://www.researchgate.net/publication/317757322_The_Role_of_Digital_Technologies_in_the_Preservation_of_Cultural_Heritage
[24] Revolutionizing Library Cataloging with Artificial Intelligence (AI). (2023, December 4). LinkedIn. Retrieved October 27, 2024, from https://www.linkedin.com/pulse/revolutionizing-library-cataloging-artificial-intelligence-ai-cover
[25] Google Arts & Culture. (n.d.). A virtual holiday to Florence. Google Arts & Culture. Retrieved October 27, 2024 from https://artsandculture.google.com/story/a-virtual-holiday-to-florence/YwWxaFvyCQYDQA?hl=en

While the technologies and use cases mentioned above are key to transformation of historical cities and heritage neighborhoods across key phases, there are many other solutions that, once integrated, enable additional applications that may be common to aspects of life in any cognitive city:

Smart security:

Smart security systems, utilising technologies such as blockchain, facial recognition, and smart cameras, bolster security within heritage sites. Facial recognition ensures secure access, while smart cameras provide real-time monitoring.[26]

Smart crowd management:

Integrating IoT sensors and AI analytics, smart crowd management systems can mitigate visitor congestion, a major challenge in heritage cities, by dynamically managing entry flows and guiding visitors to less crowded areas in real time.

Micro-environment monitoring:

Micro-environment monitoring uses drones, IoT sensors, digital twins, and 3D modelling to protect heritage structures from environmental damage. Real-time data collection enables proactive conservation efforts, mitigating environmental impacts and ensuring long-term preservation.[28]

Smart energy and infrastructure management:

Smart energy and infrastructure management, utilising technologies like smart grids and Building Management Systems (BMS), optimise energy usage and maintenance while preserving historical authenticity. Minimising disruption during installation ensures heritage site preservation.[32]

Ultra-reliable low-latency networks:

Robust connectivity between numerous sensors and digital end points through ultra-low latency communication systems can facilitate several advanced use cases and reduce the response and synchronisation time to near zero. [33]

Smart regulations:

Smart regulations, enabled by LiDAR, GIS, drones, digital twins, BIM, and 3D photogrammetry, ensure compliance with preservation standards in heritage areas. Streamlined permit processes and data-driven analysis uphold regulatory objectives while preserving historical landscapes.[34] [35]

… and there are **futuristic use cases** to be enabled by **cognitive technologies** that have the potential to transform the approach to the heritage revival. Some of these are, but not limited to:

Generative AI for restoration:

Generative AI can analyze architectural styles, materials, and historical data to aid in the restoration of heritage assets. This will be valuable for damaged structures where original architecture needs to be digitally reconstructed before restoration.

Virtual replicas (digital twin and metaverse):

By creating a digital replica of a heritage city or specific structures, cities can simulate different restoration approaches, assess climate impact, and plan preservation efforts more accurately. Virtual replicas also allow people to explore these environments digitally. This approach also preserves the physical sites by reducing visitor traffic.

[26] Sorino, C., Galiano-Garrigos, A., & Garcia-Soriano, L. (2019). The policies and process of preserving the historical and heritage buildings in Dubai City: Case study of historical district. WIT Transactions on the Built Environment, 191, 65-75. Retrieved October 27, 2024 from https://rua.ua.es/dspace/bitstream/10045/100134/1/2019_Sorino_etal_WITTransBuiltEnviron.pdf
[27] Infra Global. (n.d.). Singapore's digital twin: From science fiction to hi-tech reality. Infra Global. Retrieved October 27, 2024 from https://infra.global/singapores-digital-twin-from-science-fiction-to-hi-tech-reality/
[28] Akenza. (n.d.). How IoT can aid in the conservation of built heritage. Akenza. Retrieved 23 October, 2024 from https://akenza.io/blog/how-iot-can-aid-in-the-conservation-of-built-heritage
[29] Columbia University. (2021). Utilizing digital twin technology to optimize city traffic. Columbia Data Science Institute. Retrieved October 27, 2024 from https://datascience.columbia.edu/news/2021/utilizing-digital-twin-technology-to-optimize-city-traffic/
[30] Wang, Z., Liu, X., & Zhang, Y. (2024). Digital twin-based traffic management for smart cities: Leveraging IoT, sensors, and real-time data analytics. Sensors, 24(5), 1665. Retrieved October 27, 2024 from https://doi.org/10.3390/s24051665
[31] Wang, Z., Liu, X., & Zhang, Y. (2024). Digital twin-based traffic management for smart cities: Leveraging IoT, sensors, and real-time data analytics. Sensors, 24(5), 1665. Retrieved October 27, 2024 from https://doi.org/10.3390/s24051665

05 Fundamentals for revival of historic cities and heritage neighbourhoods

The revival journey for historic cities is driven by key enablers, considerations, and implications spanning social, ethical, technological, and governance aspects.[14]

Enablers

01
Organisational framework

Defining roles and communication ensures efficient execution of heritage initiatives.[37]

02
Policy framework

Providing a structured approach with clear conservation goals.[38]

03
Governance

A clear decision-making and oversight system ensures transparency, accountability, and effective management.

04
Public awareness and capacity building

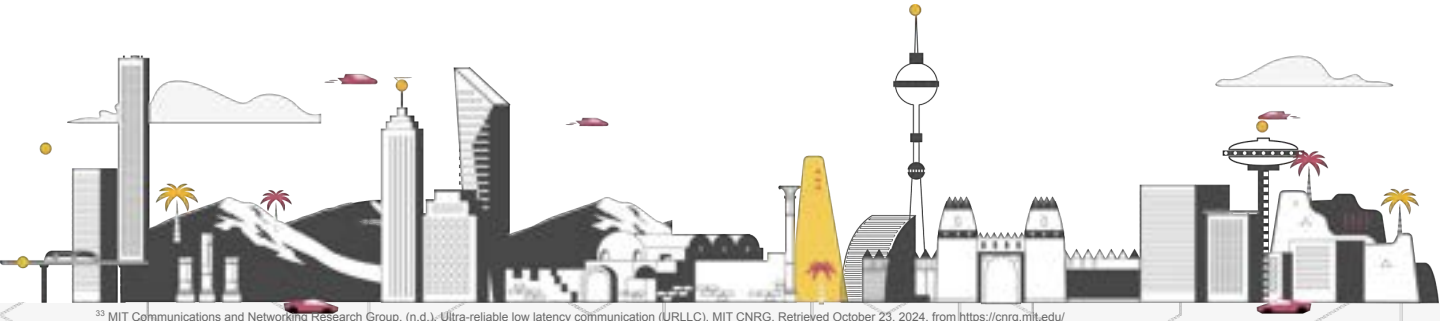
Raising awareness and enhancing skills for individuals and organisations to address challenges.

05
Collaboration and partnerships

Leveraging shared resources, expertise, and support for heritage initiatives.

06
Financial consideration and investor attraction

Aiding successful execution through partnerships, grants, or sustainable models. Attracting investors for growth, and establishing a mechanism for the socio-economic benefits



[33] MIT Communications and Networking Research Group. (n.d.). Ultra-reliable low latency communication (URLLC). MIT CNRG. Retrieved October 23, 2024, from https://cnrg.mit.edu/
[34] LiDAR Magazine. (2021, September 9). Using drone LiDAR and photogrammetry to create a digital twin. LiDAR Magazine. Retrieved October 27, 2024 from https://lidarmag.com/2021/09/09/using-drone-lidar-and-photogrammetry-to-create-a-digital-twin/
[35] LiDAR Magazine. (2024, July 10). Point cloud to BIM: Transforming legacy buildings into digital assets. LiDAR Magazine. Retrieved October 27, 2024, from https://lidarmag.com/2024/07/10/point-cloud-to-bim-transforming-legacy-buildings-into-digital-assets/
[36] Wang, Y. (2018). Heritage conservation in rapidly growing cities: A case study of the challenges and strategies in China. Diva Portal. Retrieved 27 October, 2024 from https://www.diva-portal.org/smash/get/diva2:1224014/FULLTEXT01.pdf
[37] Zhang, T., Huang, B., & Jiang, H. (2022). Participatory governance and sustainable heritage management: Case studies from urban development projects. Frontiers in Sustainable Cities, 4, Article 777708. Retrieved October 27, 2024 from https://doi.org/10.3389/frsc.2022.777708
[38] Zhang, T., Huang, B., & Jiang, H. (2022). Participatory governance and sustainable heritage management: Case studies from urban development projects. Frontiers in Sustainable Cities, 4, Article 777708.

Considerations and implications

01 **Community engagement and benefits sharing**

Prioritise community engagement by organising cultural events to boost local engagement.

02 **Balancing development vs cultural identity**

Alignment with international standards, adherence to UNESCO guidelines, and making efforts towards retaining the cultural identity while urban redevlopment.[39]

03 **Regulations**

Understanding site-specific regulations and buffer zone regulations for seamless heritage preservation and sustainable development.

04 **Collaborative governance**

Ensure successful transformation through collaborative governance involving municipalities, conservation offices, and non-profit organisations. Understand various organisations' roles and leverage their collective strength.

05 **Different degrees of heritage**

Differentiate between the different degrees of heritage and their significance, prioritising sustainable reuse of buildings for environmental sustainability.

06 **Resident-visitor balance**

Prevent overtourism through a balanced influx of visitors and prevent gentrification.

07 **Interconnected city platforms**

Integration helps realise the full potential of cognitive revival.

08 **Data privacy**

Collection and use of data can raise significant privacy concerns.

09 **Ethical AI**

Prioritise ethics in AI to address algorithmic bias and ensure transparency and accountability.

10 **Transparency**

Transparency in algorithms and accountability for outcomes is critical.

[39] Riveiro, B., & Solla, M. (2023). Heritage Building Information Modeling (HBIM): Overview and critical challenges. Multimodal Technologies and Interaction, 6(2), 38. https://doi.org/10.3390/mti6020038

06 Forging the path forward

Historic cities and heritage neighbourhoods face several challenges. Yet, these very challenges present opportunities for innovation and collaboration. Within these settings, Various stakeholders play pivotal roles as innovators and enablers, shaping and redefining the identities of these locales.

This tech-powered transformation is fueled by the cognitive revival stack, a collaborative framework that can be a guiding light for historic cities and heritage neighbourhoods that are on their journey to becoming smart and cognitive. It offers an exciting opportunity for innovation.

The human-centric, tech-powered transformation of historic cities into smart living spaces is a dynamic interplay between tradition and innovation, envisioning a future that honours historical roots while aligning with future needs. At the heart of this transformation is the identification and prioritisation of various use cases enabled by emerging technologies such as digital twins, AI, mixed reality, IoT, natural language processing, generative AI, and blockchain, among others.

Bridging these technologies and applications together on a unified cognitive platform provides numerous benefits, allowing for seamless data exchange and enhanced interoperability among various technological systems. These technologies act as catalysts for smarter, more adaptive, and culturally sensitive urban development. In doing so, they foster global awareness, education, and appreciation of cultural heritage.

A robust organisational framework, supportive regulations, governance, community participation, partnerships, and sustainable financing are all vital in shaping the resilient and vibrant identities of our heritage cities. **This transformation honours their historical roots while preparing them for the future.**

What's next?

Develop the overall heritage city aspirations and KPIs

Define a strategy with clear vision and aspirations that align with the city's cultural identity and future needs. Establish Key Performance Indicators (KPIs) to measure progress in preservation, sustainability, and community engagement, ensuring accountability and alignment with the cognitive revival journey.

Analyze the existing services and address the gaps

Conduct a comprehensive analysis of current services related to heritage preservation, tourism, and community amenities. Identify gaps in service delivery and infrastructure, prioritizing upgrades and integrations with emerging technologies to enhance efficiency, accessibility, and the cultural experience.

Identify and build international and local partnerships

Forge collaborations with global heritage organizations, technology providers, local stakeholders and other voices to pool inputs and resources. Partnerships can bring innovative solutions, funding, and best practices, helping heritage cities achieve both global standards and local development goals.

Nurture community engagement to reinstate the balance between cultural identity preservation and development

Involve local communities actively in decision-making to ensure their cultural identity and values are respected in the revival process. Create platforms for dialogue, workshops, and cultural programs that encourage residents to participate in preserving their heritage while embracing responsible development.

Support the research and innovation on preservation, restoration

Invest in research and technological innovation to advance sustainable methods of preserving and restoring heritage assets. By supporting studies and pilot projects, and setting-up living labs, cities can explore new materials, techniques, and technologies that enhance restoration quality and resilience against environmental and urban challenges.

Contact us:

Rajat Chowdhary
Partner, Technology Consulting
rajat.c.chowdhary@pwc.com
https://www.linkedin.com/in/rajatchowdhary/

Hazem Galal
Global Cities and Local Government Leader and Global Smart Mobility Co-Leader
hazem.galal@pwc.com
https://www.linkedin.com/in/hazemgalal/.

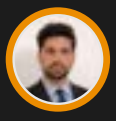
Kaveh Vessali
Partner, Digital Services
kaveh.vessali@pwc.com
https://www.linkedin.com/in/kaveh-vessali-0b3229/

Varun Paul
Partner, Digital Transformation - Cities
varun.p.paul@pwc.com
https://www.linkedin.com/in/paulvarun/

Gaurav Jaisinghania
Associate Director, Cities Technology
gaurav.jaisinghani@pwc.com
https://www.linkedin.com/in/iamgauravjaisinghania/.

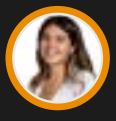
Contributors

Geoff Rich
Subject Expert - Heritage Technology (UK)
https://www.linkedin.com/in/geoff-rich

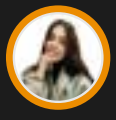


Azaan Bin Adnan Khan
Senior Associate, Consulting
https://www.linkedin.com/in/azaank

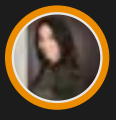
Yukti Sajnani
Associate, Consulting
https://www.linkedin.com/in/yukti-sajnani-ab860179



Jana Ahmed Makled
Associate, Consulting
https://www.linkedin.com/in/jana-makled-26ab931a5



Gaelle Stephan
Architect and Cultural Heritage Expert
https://www.linkedin.com/in/gaellestephan/



Yosra Maatallah
Architect and Cultural Heritage Specialist
https://www.linkedin.com/in/yosra-maatallah-architect/

07 Other references

01 Brusaporci, S., & Maiezza, P. (2021). Smart Architectural and Urban Heritage: An Applied Reflection. *Heritage*, *4*(3), 2044–2053. https://doi.org/10.3390/heritage4030116

02 Carmen, del, Molinero-Sánchez, J. G., Concepción Rodríguez-Moreno, Gómez-Blanco, A. J., & Reinoso-Gordo, J. F. (2024). High Resolution 3D Model of Heritage Landscapes Using UAS LiDAR: The Tajos de Alhama de Granada, Spain. *Land*, *13*(1), 75–75. https://doi.org/10.3390/land13010075

03 COE. (2014). *Understanding the Impact of Digitisation on Culture*. Culture and Cultural Heritage. https://www.coe.int/en/web/culture-and-heritage/culture-and-digitisation

04 Dezen-Kempter, E., Cogima, C., Vieira De Paiva, P., Antonio, M., & De Carvalho, G. (2018). *BIM for Heritage Documentation An ontology-based approach*. https://papers.cumincad.org/data/works/att/ecaade2018_295.pdf

05 enas. (2023, February 26). *The Petra Museum*. Flow Travel Jordan. https://flowtraveljo.com/the-petra-museum/

06 *Heritage scanning in Curacao with mobile LiDAR*. (n.d.). Www.faro.com. https://www.faro.com/en/Resource-Library/Case-Study/Scanning-a-hospital-with-the-ZEB-Horizon

07 Howarth, C. (2023, July 28). *World Heritage Sites face unprecedented challenges from climate change, study suggests*. Phys.org. https://phys.org/news/2023-07-world-heritage-sites-unprecedented-climate.html#google_vignette

08 Iba, C., & Hokoi, S. (2022). Traditional Town Houses in Kyoto, Japan: Present and Future. *Energies*, *15*(5), 1913. https://doi.org/10.3390/en15051913

09 Jasink, A. M., Faralli, C., & Kruklidis, P. (2017). MUSINT II: A Complex Project on a Virtual and Interactive Museum Involving Institutions of Florence, Rome and Heraklion. *Studies in Digital Heritage*, *1*(2), 282–297. https://doi.org/10.14434/sdh.v1i2.23192

10 Kantaros, A., Soulis, E., & Alysandratou, E. (2023, August 22). *Digitization of Ancient Artefacts and Fabrication of Sustainable 3D-Printed Replicas for Intended Use by Visitors with Disabilities: The Case of Piraeus Archaeological Museum*. Ssrn.com. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4551766

11 Liu, Y. (2022). Application of Digital Technology in Intangible Cultural Heritage Protection. *Mobile Information Systems*, *2022*, 1–8. https://doi.org/10.1155/2022/7471121

12 Menegaldo, M., Livieri, A., Isigonis, P., Pizzol, L., Tyrolt, A., Zabeo, A., Semenzin, E., & Marcomini, A. (2023). Environmental and economic sustainability in cultural heritage preventive conservation: LCA and LCC of innovative nanotechnology-based products. *Cleaner Environmental Systems*, *9*, 100124. https://doi.org/10.1016/j.cesys.2023.100124

13 Nilson, T., & Thorell, K. (2018). *Cultural Heritage Preservation: The Past, the Present and the Future*. https://www.diva-portal.org/smash/get/diva2:1224014/FULLTEXT01.pdf

07 Other references

14 Obradović, M., Vasiljević, I., Đurić, I., Kićanović, J., Stojaković, V., & Obradović, R. (2020). Virtual Reality Models Based on Photogrammetric Surveys—A Case Study of the Iconostasis of the Serbian Orthodox Cathedral Church of Saint Nicholas in Sremski Karlovci (Serbia). Applied Sciences, 10(8), 2743. https://doi.org/10.3390/app10082743

15 Otero, J. (2021). Heritage Conservation Future: Where We Stand, Challenges Ahead, and a Paradigm Shift. Global Challenges, 6(1), 2100084. https://doi.org/10.1002/gch2.202100084

16 Pietroni, E., Menconero, S., Botti, C., & Ghedini, F. (2023). e-Archeo: A Pilot National Project to Valorize Italian Archaeological Parks through Digital and Virtual Reality Technologies. Applied System Innovation, 6(2), 38. https://doi.org/10.3390/asi6020038

17 Pintossi, N., D. Ikiz Kaya, Pieter van Wesemael, & A. Pereira Roders. (2023). Challenges of cultural heritage adaptive reuse: A stakeholders-based comparative study in three European cities. Habitat International, 136, 102807–102807. https://doi.org/10.1016/j.habitatint.2023.102807

18 Science Gov. (n.d.). world heritage cities: Topics by Science.gov. Www.science.gov. https://www.science.gov/topicpages/w/world+heritage+cities

19 SmartGuide. (2023, July 31). The implementation of digital audio guides for indoor and outdoor expositions. Smart-Guide.org; SmartGuide. https://blog.smart-guide.org/en/smartguide-digital-audio-guide-for-indoor-and-outdoor-expositions

20 Sorino, G., Manfredi, C., & Jiménez-Delgado, A. (2019). BIM METHODOLOGY APPLIED TO ARCHITECTURAL HERITAGE PRESERVATION: CASE STUDY OF THE MEDINA AND DUNGEONS OF TETUÁN, MOROCCO. WIT Transactions on the Built Environment. https://doi.org/10.2495/bim190141

21 Tuong Tri Nguyen, Hwang, D., & Jung, J. J. (2017). Using Geotagged Resources on Social Media for Cultural Tourism: A Case Study on Cultural Heritage Tourism. Springer EBooks, 64–72. https://doi.org/10.1007/978-3-319-58967-1_8

22 Wakamatsu, K., Matsuoka, M., & Hasegawa, K. (2006). GIS-based nationwide hazard zoning using the Japan Engineering Geomorphologic Classification Map. GIS-BASED NATIONWIDE HAZARD ZONING USING the JAPAN ENGINEERING GEOMORPHOLOGIC CLASSIFICATION MAP , 16. https://www.researchgate.net/publication/242370857_GIS-based_nationwide_hazard_zoning_using_the_Japan_Engineering_Geomorphologic_Classification_Map

23 Weareunity. (2023, August 29). Adaptive Reuse in Architecture | Design Studio Architects. DSA. https://ds-a.co.uk/the-concept-of-adaptive-reuse-transforming-old-buildings-for-new-purposes/

24 Why the City of Amsterdam developed its own crowd monitoring technology. (2021, October 5). ITU Hub. https://www.itu.int/hub/2021/10/why-the-city-of-amsterdam-developed-its-own-crowd-monitoring-technology/

At PwC Middle East, we are strongly committed to providing national ministries, royal commissions, city development authorities, destination management offices, and international organisations with strategic advisory services required to progress their cognitive journeys and deploy human-led, tech-powered solutions.

We deliver tailored services across the development stages of city transformation, including assessing technological capabilities, creating digital transformation roadmaps, designing emerging technology ecosystems and platform architecture, drafting RFPs, evaluating suppliers, thereby ensuring a seamless launch of a cognitive revival.