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Lessons from Al-Madinah Al-Munawwarah, City Transformation Initiatives, Development, and Transformation: An Urban Retrofitting Perspective

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Abstract: ***This research examines the complex nature of urban reconstruction in a city marked, by its sacred and radial urban structure, with its great recurrent strain, from millions of pilgrims, Al-Madinah Al-Munawwarah. With the urgency of current sustainable advancement and accelerated growth, the study highlights the serious ordeal, of merging material and abstract heritage preservations. This work is carefully modelled, via the Historic Urban Landscape (HUL) concept and the Human Smart City (HSC) framework. It utilizes a qualitative case study method, that moves the systematic perspective, from citizen experience and cultural integrity to technological efficiency. Strongly supported by Saudi Vision 2030, and under the Smart Madinah Program, the city reflects a strong governance strategy, that positively combine HSC technology and HUL susceptibility. Major results show, specifically in infrastructure, neighborhood upgrades and smart mobility, that change solutions, focus on strengthening the city's spiritual and social ecosystem, above technological deployment. Through presentation of three main transferable lessons; the paper ends, stressing the necessity for adaptable, resilience-based governance, to enhance enduring, systematic integration, and the great importance, of elevating place-identity, for other religious and historical mega-cities, that encounter same challenges around the world.***

Keywords: Mega-city Governance, Human Smart City, Urban Retrofitting, Historic Urban Landscape.

1. Introduction

Marked by an ancient, radial, urban frame, created around the heart of the Prophet Mosque, is Al-Madinah Al-Munawwarah. Standing as one of the world's most epochal religious and cultural centers (Nassar, 2017).

In the last three decades, although, historic and reverent, the physical structure, experiences enormous pressure, from rapid population shifts, particularly, an exceedingly high demographic and a huge convergence of international visitors. Portrayed in earlier frameworks, the historical approach, mainly strengthened the radial designs, with ring roads; this is currently viewed as inadequate, to explore the complex nature of modern city sustainability requirements.

A complicated and delicate change is what this urban advancement requires. In Al-Madinah, the setbacks exist, in merging the abstract and practical preservation of its heritage, with the urgency of current sustainable direction. Urban planners are increasingly exploring two great models, in addressing this duality: the national advancement towards a Smart, Sustainable, and Human-Centred City (Ahmed, 2025), and the Historic Urban Landscape (HUL) approach, that decrees incorporation of the wider regional context, with historical sites, to promote sustainable development (UNESCO, 2011); to reconcile with the goals of Saudi Vision 2030. The

city's governance, infrastructure and quality of life, form the initiatives focus of central reconstruction.

This paper analyzes the transformation initiatives undertaken in Al-Madinah Al-Munawwarah through an urban retrofitting lens. By examining the methodology, current achievements, and strategic frameworks (such as the Smart Madinah Program and the Human Smart City model), the study seeks to articulate the crucial balance between cultural preservation and technological integration. The findings will then be used to derive actionable lessons and recommendations for other globally significant religious, historical, and rapidly developing mega-cities facing similar urban dilemmas.

2. Literature Review and Conceptual Framework

2.1 Historical Contexts in Defining Urban Retrofitting

the systematic process of changing and modernizing earlier urban areas, governance and infrastructures, to connect current issues of functionality, sustainability, and resilience (Droege, 2011). Retrofitting is marked by its constraints, unlike 'greenfield' development, operating within established spatial boundaries and respecting existing urban morphology (Nassar, 2017). This explication bears more weight, in historical areas, such as Al-Madinah. Demanding that the city's historic features or the integrity of its radial structures, should not be compromised by transformational works. Consequently, the reconstruction of Al-Madinah, consists incorporation of sustainable urban elements (Smart City), enhanced Information and Communication Technology (ICT) solutions, into the city's layers of historical (HUL). This guarantees, that technological upgrades, rather than replace, prior cultural ecosystem, aid to enhance them.

The Historic Urban Landscape (HUL) Approach

From viewing heritage sites, as remote monuments, to regarding them as merged units, of a bigger city structure, the conservation of historic urban centers, requires a radical change. As declared by UNESCO in 2011, this technique is computed in the Historic Urban Landscape (HUL) framework, promotes sustainable development, through fully evaluating the social, concrete and abstract values, of heritage areas (Bandarin & van Oers, 2012). For a city, such as Al-Madinah, whose identity is connected intrinsically, to the historical urban thread, that encompasses it and its Prophet Mosque; the HUL model is pivotal.

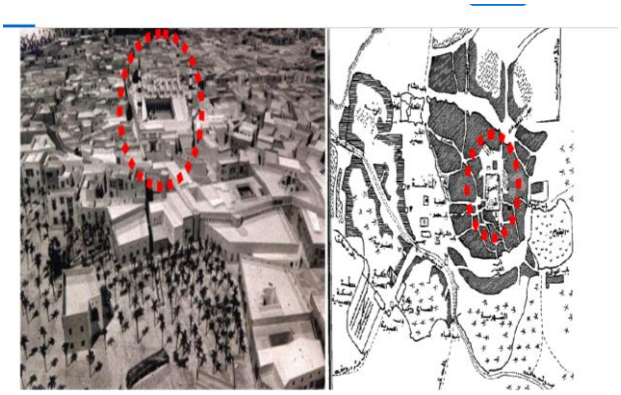

Figure 1: The old city frame of Al-Madinah Almunawarah: The Prophet Mosque prior and after the expansion, showing the old radial street network.

The pressure in this process; the historical direction of design in Al-Madinah (such as the Grand Tunis case mentioned in the initial background) reflects, initial 20th-century projects, such as the Valensi project (1920), positioned to avoid separating the authentic structure of Medina, although eventually turned down, for fear of transforming the living city into an "unanimated museum." In contrast, proposals which aimed to viciously transform the urban morphology; like opening big urban streets, via the historic centre, were dismissed, because of the danger, of changing the city's existent identity and originality. A core HUL belief, underlie these historic rejections: respect the entrenched radial street network, and the sensitive coordination between sanctity and function, and. interventions must be strategic,

Across physical structures, to consist the wider regional spaces and the historical transformation of the city, the HUL framework advances the boundary of preservation. The HUL approach views the Medina's heritage through its socio-economic function as a magnet for residents and visitors, as well as its architecture, cultural practices and the spatial relationships created over centuries. Any modern urban reconstruction technique, must adopt the HUL perspective, to guarantee, that development design, whether linked to vicinity, mobility, infrastructure, strengthens, rather than dilute the city's unique historical and religious character.

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2.2 Smart City Terminologies and Models

Moving from early replications, with a focus on mainly digital facilities, to encompassing models, which are more coordinated, the 'smart city' framework has advanced greatly. At first, Knowledge and Digital City emphasized Information and Communication Technology (ICT) investment, as well as knowledge creation (Caragliu et al., 2011). The Resilient City and Eco City, initiated infrastructural and environmental sustainability concerns. Via technology, the modern Smart City designs, tries to connect these aspects, usually, leading to a model, controlled by solutions that are complex (Ahmed, 2025).

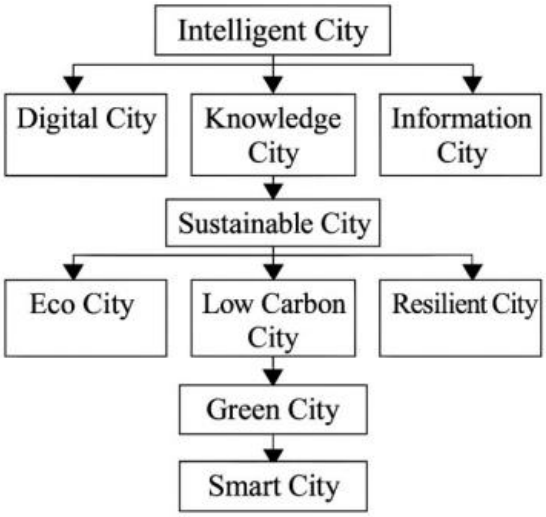

Figure 2: Conceptual Evolution of City Models: From Digital/Knowledge City (Intelligent City) to Smart City.
Source: Ahmed, 2025

A technologically-driven model, is inadequate, for cities, affluent in religious and cultural values, such as Al-Madinah. The choice of the Human Smart City (HSC) model, has been directed, by this necessity. With a focus on social equity, human-centred design, citizen participation and cultural preservation, the HSC moves the emphasis, from technology effectiveness, to improve the quality of life. Coordinating with the values, of the Historic city Landscape method, this belief guarantees, that smart technologies are exploited to enhance, the spiritual and cultural ecosystem, rather than compromise them.

2.3 Smart City Dimensions

In the ideal model of the Human Smart City, to efficiently measure and elevate the results, of Al-Madinah's transformation, a thorough set of standards must be applied. The exploration of the city's sustainability and smartness is classified, over six inter-connected standards: Smart Economy, Smart Living, Smart Mobility, Smart Governance, Smart Environment and Smart People (Giffinger et al., 2007). These aspects best offer the strong base, for assessing the city's reconstruction efforts, from sustainable transport (Mobility) to digital service delivery (Governance) and historical site control (Environment/Living).

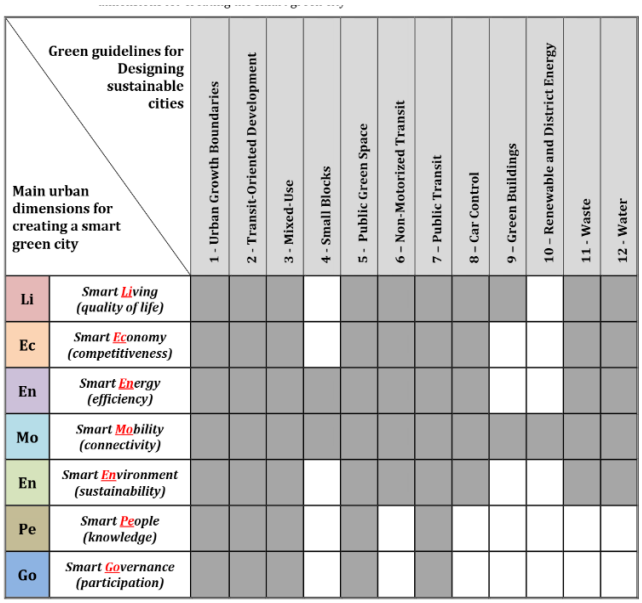

Figure 3: Display of the inter-related parts (Smart Living, Economy, Mobility, Environment, People, and Governance), and their link to sustainable city guidelines.
Smart City Correlation Matrix
Source: Usama A. Nassar (2017)

Outlined in the investigative template, are the interdependence and equivalence of these six aspects, specifically, the great connect between human experience and technology.

3. Methodology and Case Study Context

serving as a case study and occupying a special worldwide stance, is Al Madinah, naturally growing around the Prophet's Mosque, anchored in its radial urban morphology and spiritual importance. Although managing enormous operational and population stress, this historical structure supports

current plans that must closely follow Historic Urban Landscape (HUL) beliefs. In addition to the massive annual flow, of millions of pilgrims, the city's consistent human growth, exerts great, recurring pressure on all base services and facilities (Nassar, 2017). Not yielding cultural integrity, is the primary drive, of the progressive transfiguration towards a Smart and Human-Centred City, which is necessary for modernization.

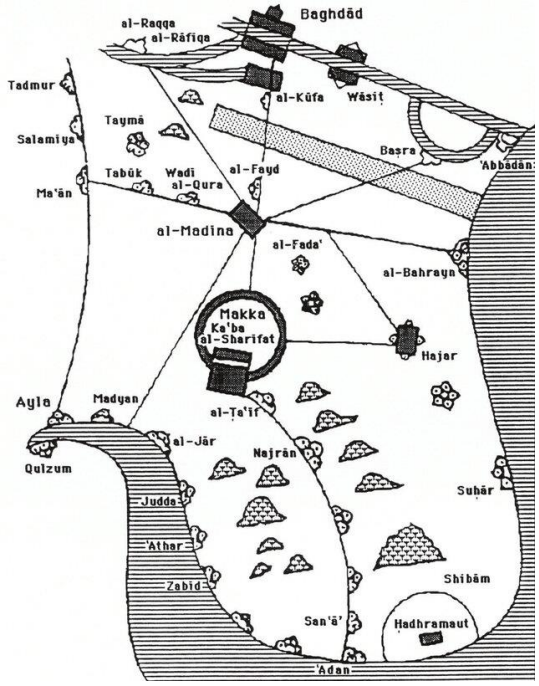

Figure 4: Medina in its regional context according to the Al-Balkhī school of land mapping in Baghdad, tenth century

Source: Whitcomb, 1998.

This research synthesizes data via numerous secondary sources, to examine the initiatives of change and utilizes a qualitative case study method. Official city master plans, technical reports, related to the Smart Madinah Program and systematic documentation, from authorities, relating to Saudi Vision 2030, form the core data. Guiding the assessment of the systematic relationship and success of Al-Madinah's reconstruction stance against international sustainable development model, is the empirical framework, set in Section 2, where HUL principles are incorporated with the Human Smart City Dimensions (Table 2) (Nassar, 2017; Ahmed, 2025).

4. Transformation Initiatives and Achievements

4.1 Strategic Vision and Governance

The transformation of Al-Madinah Al-Munawwarah is systematically rooted in the Kingdom's national development blueprint, Saudi Vision 2030 and not a lone planning exercise (Kingdom of Saudi Arabia, 2016). For visitors and residents, this vision directs a highly enhanced quality-of-life, for development of sustainable, economic diversification, technology-driven cities. Functioning as the core governance tool, for urban reconstruction, Al-Madinah's efforts are formalized, via the Smart Madinah Program, which directly interprets the national vision, into practical, city-specific initiatives, coordinating the city's technological integration and the preservation of the city's the city's specific religious and cultural stance. The development of cross-sectoral collaboration platforms, that allow varied private and government bodies to rally efforts over the six aspects of the Human Smart City model (Governance, Mobility, Living, Environment, People, and Economy), is central to this governance structure.

4.2 Implementation Pillars

To manage the complex nature of urban reconstruction, in a historical space, the Smart Madinah Program is built across multiple implementation pillars, created to represent the main functional areas, where facility and technological elevation are being merged, into the existing urban fabric:

1. Transport & Mobility: Deploys smart mobility solutions, to manage the recurrent congestion caused by pilgrims and residents, improving public transit. Focuses on improving existent radial and ring-road networks.
2. Ancient Neighborhoods (Urban/Reconstruction Design): To upgrade living standards, without yielding the area's historical originality or social construct. Centering on special facility enhancement and urban design solutions, within its historical core
3. Logistics, Business and Industry: Through enabling technology-driven businesses and creating smart logistics hubs, that relates with the "Smart Economy" concepts. Pursues the diversification of the city's economy, beyond pilgrimage services.
4. Agriculture and Environment: To safeguard the city's natural context, involves using

smart sensors, for management of resource (water, energy) and sustainable practices coordination.

5. Tourism, Healthcare and Wellbeing: Via digitized cultural data, provides location-aware services and explores digital tools, to proffer easy to access smart healthcare and enhance the pilgrim/visitor experience.

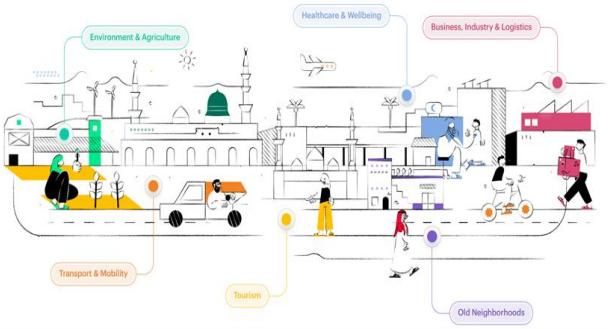

Figure 5: Illustrating major functional areas, for urban reconstruction; implementation Pillars of the Smart Madinah Program (Transport & Mobility, Old Neighborhoods, Environment & Agriculture, etc.).

4.3 Achievements and Impact

In explicating concrete results in the reconstruction exercise, important achievements have been observed on these implementation pillars. Initiatives have rapidly increased digital awareness and public service delivery, as regards Smart Governance and Smart People, to upgrade engagement, between the citizens government. Smart Mobility success consists, sending real time traffic management and Intelligent Transport System (ITS), specifically in proximity to the Prophet Mosque, to enhance movement. For sustainable and human-centred growth, serious, reconstruction works in the historical areas, were premised on boosting public areas and utility tools, to relate the Historic Urban Landscape (HUL) requirements with the physical change. Rather than as an end in itself, the achievements all reflect a commitment to the Human Smart City model. Using technology as a means to achieve spiritual, environmental and cultural sustainability (Al-Thani & Hassan, 2020).

5. Lessons for Other Religious and Mega Cities

For other rapidly advancing big cities around the world, experiencing the same strain; population, technology and heritage, the urban transfiguration experience of Al-Madinah Al-Munawwarah, provides three great, transferable lessons. In its double commitment, to the Human Smart City (HSC) framework and Historic Urban Landscape (HUL) approach, lays the breakthrough of the Smart Madinah Program.

5.1 Reconciling Tradition and Technology: Prioritizing "Place" over "Platform"

The lesson learned, is that in religious, historical cities, the preservation of place-identity, must be primary to technology incorporation. Al-Madinah highlights, that rather than disrupt, the spiritual and cultural ecosystem, smart city technologies (ICT systems for mobility and governance) are best when they are modelled to reinforce the biosphere. This is achievable, through adopting the HUL principle: perceiving the city as a transformed landscape, that encompass concrete and abstract cultural values, rather than as a series of structures to be modernized. This implicates for other cities:

I. ICT Contextualization: Smart facilities must not simply be taken as off-the-shelf interventions; they should be created to solve specific urban issues (pilgrim flow management near the Prophet Mosque).
II. Minimal Intrusion: To manage the original urban morphology, heritage cores reconstruction, should be based on covert infrastructural improvements (smart utility grids, underground services), rather than fostering, high-tech physical structures, that are new.

5.2 The Centrality of the Human Element: Adopting the Human Smart City Model

A needed corrective for technology-centred smart city shifts, is offered by the Al-Madinah's pivot, towards the Human Smart City (HSC) model (Ahmed, 2025) provides. The experience highlights that when projects focus on the spiritual, economic and social balance of the visitors and inhabitants, sustained transfiguration is possible.

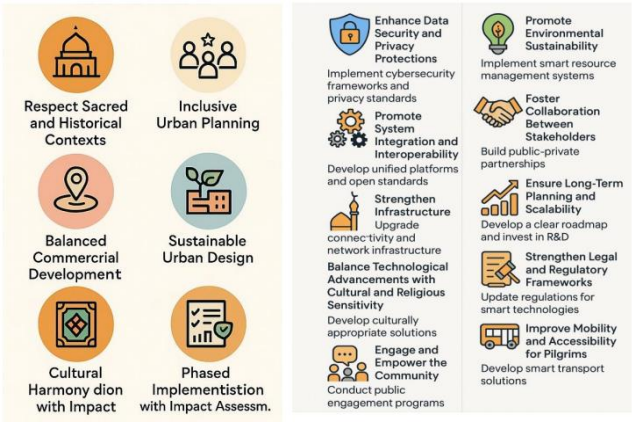

Figure 6: Recommended model for Medina as a Human Smart City, stressing honor for spiritual context and encompassing urban planning.
Source: Ahmed, 2025

The HSC framework guarantees, that technological investment directly interprets to improvements in cultural experience, quality of life and social equity. For other cities, this implicates these major practices:

1. Encompassing City Planning: Transformation efforts should ensure, that urban planning decisions are encompassing; must respect sacred contexts and cultural diversity, as well as improve the experience of all city users; tourists, pilgrims and residents.
2. Citizen-Centred Statistics: Advancement should be measured, in addition to efficiency statistics or data connectivity, by human-centred reflectors, like pilgrimage satisfaction the vitality of local cultural economies and digital awareness rates, among residents.

5.3 Scalability and Governance: Strengthening Adaptive Frameworks

A planning and governance framework, that can match quick, recurrent adaptation, is necessitated by the enormous practical stress, via annual visitors. The need for centred, well-funded techniques, that endure long planning horizons, is emphasized by the governance model, set by the Smart Madinah Program and its coordination, with Saudi Vision 2030.

1. Enduring Systematic Relevance: The political will and economic balance needed to execute difficult, multi-decade reconstruction works, is provided by the merging, with a national or regional long-term vision (Vision 2030).
2. Flexible City Frameworks: Specifically in safety, transport and utilities, the city must plan for unusual situations, through deployment of scalable, resilient and responsive facilities (Meerow et al., 2016), to ensure, the system can function effectively, for the resident demographic, while possessing, excess capacity, for peak pilgrim periods. For any city, that acts as a periodic mega-hub, this is a crucial lesson.

6. Conclusion

In evaluating its coordination with the Historic Urban Landscape (HUL) concept, and the Human Smart City framework (HSC), this work, via the analytical optics of city transfiguration, investigates the urban transformation of Al-Madinah Al-Munawwarah. The results indicate, that while concurrently managing the severe functional stress, raised by quick demographic advancement and huge pilgrim inflow, Al-Madinah's strategy, smoothly negotiates the difficult duality of safeguarding its honored, historic identity (the radial urban form and cultural heritage). The major advancement, handled through the Smart Madinah Program, and strongly supported, by the Saudi Vision 2030, reveal that technology, specifically in the susceptible reconstruction of old neighborhoods, mobility and public services, is used as an enhancing tool, to improve the human experience. For mega-cities with rooted religious or cultural importance, the case study corroborated, that the future of sustainable development, is based on using a human-centred framework, that stresses the originality of place, over technological platform.

Specifically, Al-Madinah case study, provides a great addition to works on city reconstruction, at the link of smart city development and heritage conservation. In a huge, working religious space, with the ever changing, technology-driven HSC model, it offers a rare, thriving example of incorporating the prescribed model of the HUL approach. Nevertheless, this research, proffers an objective model for different mega-cities, around the world; religious or otherwise, which are marked by a deep, recurrent population pressure, compact, historical base, a quick advancing periphery; exhibiting how to exactly utilize national

systematic visions, to manage indigenous and culturally complex, city change, in addition to guaranteeing, the resilience and scalability of urban structures.

7. Recommendations and Area for Further Studies

7.1 Recommendations for Practice/ Policy

These suggestions are offered, for policymakers and city planners, in contexts that are same, premised on the lessons got, through the Al-Madinah transformation initiatives:

8. Direct HUL-First Planning: To ensure all solutions (in addition to technological ones) upgrade the concrete and abstract heritage, projects that relates the historical core, should be specifically evaluated through the HUL framework.
9. Advance Facilities that are Resilience-Focused: Investment in smart, scalable, facilities (smart utility networks and public safety systems) modelled to manage the severe discrepancy between peak visitors loads and resident population.
10. Integrated Human-centred Statistics: From financial or technological statistics (broadband speed), move practical observation to Human Smart City exhibitors (social equity in service delivery, resident engagement and pilgrim satisfaction)

7.2 Future Research

Although, this research investigates the systematic planning and initial achievements, of the reconstruction attempts, in order to assess the enduring impact, further studies should be premised on longitudinal studies:

11. Assessment of Socio-Cultural Impact: In the reconstructed, old vicinity, an informative evaluation of how the urban designs and new smart technologies impact the daily life and social integration of long-term residents.
12. Comparative City Analysis: A study comparing and contrasting, the Al-Madinah HSC framework with the smart city methods, of different holy cities (Makkah, Rome or Jerusalem), in order to separate universal principles, for handling religious city centers.
13. Statistics of Economic Diversification: As stipulated by Saudi Vision 2030; assessing the efficiency of the 'Smart Economy' structure, in achieving reduced dependence on pilgrimage revenues and enduring sustainable economic diversification.

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