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URBAN DEVELOPMENT IN ARID REGIONS: A COMPARATIVE STUDY OF MASDAR CITY AND THE NEW TOWN OF HASSI MESSAOU

Abstract: Rapid urbanization worldwide poses significant challenges in creating resilient urban environments, particularly in arid regions. This study examines the development of sustainable urban environments in desert climates through a comparative analysis of two distinct cities: Masdar City in the United Arab Emirates and the New Town of Hassi Messaoud in Algeria. Masdar City represents a high-tech, globally oriented model that integrates advanced technologies, renewable energy, and innovative urban planning to achieve a zero-carbon urban hub. In contrast, the New Town of Hassi Messaoud adopts a regionally focused, socially inclusive approach, emphasizing thermal comfort, cultural identity, and the relocation of populations at risk due to industrial activities. By analysing their urban planning, economic strategies, social dynamics, and environmental sustainability, this study highlights the unique opportunities and challenges of desert urbanization. Key findings reveal that Masdar City excels in technological innovation and renewable energy integration but faces gaps in social infrastructure, while Hassi Messaoud prioritizes social equity and traditional design but encounters challenges in energy efficiency and funding limitations. The study underscores the importance of balancing technological advancements with social inclusivity, integrating traditional and modern practices, and adopting adaptive, holistic approaches to urban development. Lessons learned from these case studies provide valuable insights for future urbanization and climate strategies, particularly in arid regions, emphasizing the need for equitable, resilient, and sustainable cities capable of addressing the interconnected challenges of rapid urbanization and climate change.

Keywords: cities, climate change, economy, environment, social aspect

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Introduction

The world is experiencing rapid urbanization and population growth (Gu, 2019; Nour el Houda & Marwa, 2020), particularly in large cities. This trend often leads to urban expansion and the creation of new cities to accommodate the increasing number of urban dwellers. However, when urban growth is not accompanied by well-planned infrastructure, public policies, and socio-environmental considerations, it can result in adverse consequences, including environmental degradation (Chatti & Majeed, 2022).

To address these challenges, cities must align their infrastructure development with environmental, economic, and social sustainability principles. In this context, the concept of new sustainable cities has emerged as a strategic response to multiple urban issues, such as preserving historic urban centres, reducing population density in existing cities, and optimizing the use of natural resources to enhance quality of life (Dijkstra et al., 2021).

In contemporary urban planning, smart and sustainable cities have gained significant prominence. While interconnected, these two models differ in their approaches: smart cities prioritize technological integration and digital innovation, whereas sustainable cities emphasize environmental conservation, resource efficiency, and social well-being (Shmelev & Shmeleva, 2025). Their implementation is shaped by regional resources, socio-economic dynamics, and climatic conditions. Desert regions, in particular, offer unique opportunities for testing innovative urban solutions due to their distinct challenges and potential for renewable energy.

Deserts cover approximately one-third of the Earth's land surface, with a total area of around 46 million square kilometres. Prominent deserts include the Sahara in Africa, the Arabian Desert in the Middle East, the Gobi Desert in Asia, and the Sonoran Desert in North America (Osborne et al., 2020; Salem, 1989). Despite their vastness, these regions pose significant challenges due to harsh climates and limited direct access to resources. Nevertheless, approximately 2.1 billion people currently reside in deserts or drylands, underscoring the pressing need for effective and sustainable urban solutions in these areas (Osborne et al., 2020). These areas, particularly arid and desert regions, have become focal points for new urban development projects, yet they are also widely recognized as among the most vulnerable ecosystems to the impacts of global climate change (Lioubimtseva, 2004). In this paper, the study examines two such urban developments: in the United Arab Emirates (UAE), and the New Twon of Hassi Messaoud in Algeria.

Background

Deserts have historically been considered inhospitable for urban development due to their extreme climates, limited water resources, and sparse vegetation. However, global climate change and the loss of wetlands have made these regions increasingly attractive for urbanization (Junk et al., 2013). Moreover, their vast expanses and renewable energy potential offer significant opportunities for sustainable urban planning (Benasla et al., 2024).

On the other hand, in the context of climate change, these areas face several critical challenges. Some are linked to poorly adapted urban design and infrastructure, which can lead to urban heat island effects, increased temperatures, higher evaporation rates, and reduced outdoor thermal comfort. Other challenges stem from the continued impact of climate change itself. Research has shown that arid and semi-arid regions are particularly

sensitive to global climate shifts, with high evaporation rates that often exceed precipitation, rising temperatures, intensifying heatwaves, thermal stress, and increasing energy demand (Golden, 2004; Khourchid et al., 2023; Portnov & Paz, 2008).

Examples of successful desert cities, such as the Mزاب Valley in Algeria and the Bahariya Oasis in Egypt, demonstrate how vernacular architecture and traditional planning principles can harmonize with arid environments to create resilient urban settlements that have supported vibrant social life for centuries. These cities not only showcase prestigious urban and architectural designs adapted to desert conditions but also provide valuable lessons on achieving a high socioeconomic quality of life while maintaining harmony with the environment (Ahmed Shabaan Samra, 2022; Bouchair, 2004; Gherraz et al., 2023).

Modern cities like Masdar City and proposed projects such as Neom in Saudi Arabia reflect a growing focus on integrating advanced technology and sustainability into desert urbanization (Cano-Suñén & Castejón, 2024; Madakam & Bhawsar, 2020).

Similarly, initiatives like the new city of South Sabah Al-Ahmad in Kuwait demonstrate the expanding trend of constructing urban centres in desert regions (FOSTER+PARTNERS, 2017). Many Gulf nations are actively investing in sustainable urban projects, leveraging their robust economies to adapt to the harsh desert climate and promote forward-thinking urban development.

While deserts present numerous challenges to sustainable urbanization, such as high temperatures, limited water supplies, and fragile ecosystems, they also offer unique opportunities. These include harnessing solar and wind energy, promoting sustainable tourism, and pioneering innovative urban designs that prioritize conservation and social equity (Benasla et al., 2024). Lessons from existing desert settlements, including adaptations in architecture, urban design, and planning strategies, can guide the development of new urban areas and the restructuring of existing ones to address the challenges posed by climate change (Daoudi et al., 2019).

Among the emerging urban projects in desert environments, Masdar City, a high-tech sustainable development in the United Arab Emirates (UAE), and the New City of Hassi Messaoud in Algeria, a planned urban expansion in a developing nation, represent two distinct approaches to sustainable urban development. This paper examines two desert urban developments, comparing their urban, architectural, economic, social, and environmental strategies. Through this analysis, the study explores the distinct challenges and opportunities of urban growth in arid regions. By synthesizing the findings, it identifies critical lessons to inform sustainable and resilient urban planning in desert environments.

Method

This study adopts a structured and comparative approach to analyse the urban trajectories of Masdar City and the New Town of Hassi Messaoud. An initial overview presents the historical, geographical, and planning contexts of both cities. This is followed by a comparative analysis structured around key factors, including climatic conditions, spatial and planning strategies, economic frameworks, social dynamics, and environmental policies. The analysis is primarily based on an extensive literature review of academic publications, technical reports, and official documents. The final discussion and conclusion synthesize the findings in relation to the broader discourse on emerging urban models.

This methodology is widely used in literature-based research in urban studies, especially for analysing spatial structures, environmental challenges, and socio-economic shifts (Abubakar & Alshammari, 2023; Durkin, 2018; Van Noorloos & Kloosterboer, 2018). It enables a comparative, cross-contextual understanding of urban models through selected analytical dimensions derived from existing documentation. Previous studies have applied similar approaches to examine urban responses to climate change, including strategies for heat mitigation, compact urban form, and climate-responsive planning (Hui et al., 2023; Wamsler et al., 2013). This method supports the synthesis of existing knowledge and highlights cross-contextual insights into the evolving relationship between cities and their challenges.

However, the study has limitations that should be noted. It relies on early-stage data and planning documents, limiting its ability to assess long-term sustainability. Issues of equity and inclusion, such as access to housing and services for marginalized groups, are not deeply explored, despite their relevance to Hassi Messaoud's goals. The focus on technological solutions, particularly in Masdar City, may overlook the potential of low-tech, community-driven approaches. Additionally, broader regional impacts, such as effects on ecosystems and local communities, are not fully considered.

Overview of the two cities

Masdar city

Abu Dhabi, the capital of the United Arab Emirates (UAE), has historically relied heavily on its abundant oil and gas reserves to sustain its economy. According to the CIA Country Report (2008), the UAE ranks as the world's 11th largest oil producer, with approximately 40% of its national output derived from oil and gas production (Marful, 2010). However, with concerns over the eventual depletion of these reserves and the potential economic and political challenges exacerbated by regional instability, Abu Dhabi has proactively pursued urban development as part of its long-term economic diversification strategy.

To address these challenges and prepare for a post-petroleum future, Abu Dhabi launched several ambitious urban projects, most notably Masdar City (Cugurullo, 2016a, 2016b). Conceived under the leadership of Foster and Partners, Masdar City was initiated in 2006 as a model for sustainable urban living, envisioned as a master-planned, zero-carbon community. The project represents a strategic shift towards renewable energy and clean technology, aligning with Abu Dhabi's broader vision for economic and environmental sustainability (FOSTER+PARTNERS, 2017).

Masdar City serves as a flagship initiative within the global eco-city movement, attracting international attention and setting new benchmarks in urban planning and environmental stewardship. The project has profound implications for the future of sustainable urban development, providing valuable insights for architects, planners, and policymakers worldwide.

A key aspect of Masdar City's vision is its function as an innovation hub for renewable energy and clean technology. The city attracts both established corporations and emerging startups, providing a conducive environment for research, development, and the testing of advanced green technologies. It acts as a living laboratory, allowing companies to experiment with and showcase their innovations in a real-world urban context (D'Eramo, 2021).

Additionally, Masdar City serves as a permanent exhibition space for green technology, offering a platform for businesses to present their products and solutions to a global audience. This positioning enhances its appeal as a leading destination for investment and collaboration in the renewable energy and clean tech industries.

The New Town of Hassi Messaoud

Hassi Messaoud, historically an industrial hub dominated by oil production, has undergone significant transformation due to the Algerian government's efforts to establish a permanent urban population in the Sahara region. The administrative zoning reforms of 1984 reclassified Hassi Messaoud from an industrial centre to a town with a growing residential population. This shift led to the planning of the New Town of Hassi Messaoud, located approximately 70 kilometres from the existing town (Ghosn & El Jazairy, 2014; Lamis, 2023).

The creation of the New Town of Hassi Messaoud was formally announced by decree on September 18, 2006, as part of the implementation of Law No. 04-20 (December 25, 2004) on risk prevention and disaster management. The project aimed to tackle two major challenges; mitigating risks posed by proximity to oil and gas installations, ensuring the safety of the population; accommodating anticipated urban and economic expansion in response to future mining and industrial developments (The Minister of Housing, 2023).

Aligned with Algeria's National Spatial Planning Scheme 2025 (SNAT 2025), the development of the new city follows four core principles; sustainability of resources; territorial rebalancing; social and spatial equity; enhancing regional attractiveness and competitiveness (The Ministry of Finance, 2023).

The designated site for the new city is Block 445, an area selected for its strategic importance. Despite being the wealthiest municipality in Algeria, with an average annual budget exceeding 5 billion Algerian Dinars, Hassi Messaoud has not witnessed the rapid urban development seen in other oil-rich regions, such as Texas, the UAE, or Kuwait. The project aims to accommodate at least 80,000 inhabitants, along with essential infrastructure, but has experienced significant delays (Mahammedi, 2023).

Hassi Messaoud, as Algeria's largest oil field, has witnessed substantial urban sprawl due to growing demand for housing and employment in the hydrocarbon sector. However, the New Town of Hassi Messaoud is primarily a social and regional development project rather than a purely economic one. Its purpose is to foster balanced territorial development and reduce dependency on oil-driven urbanization.

Unlike Masdar City, which was spearheaded by the private sector and international investment, the New Town of Hassi Messaoud remains a public sector-led initiative, overseen by Algeria's Ministry of Energy and Mines, with Groupement DONGMYEONG as the primary project executor (Haraoui & Rouidjali, 2020; Nour el Houda & Marwa, 2020).

Geographical and climatic features

Masdar city

Masdar City is located in Abu Dhabi, United Arab Emirates, approximately 17 km east-southeast of Abu Dhabi city centre (Figure 1), at coordinates 24.4261°N latitude and 54.6140°E longitude. The city sits at an altitude of 12 meters within a flat desert landscape characterized by sandy terrain and sparse vegetation. Figure 2 illustrates the subsurface

profile of the region. Covering an area of approximately 6 square kilometres, Masdar City is strategically positioned near Abu Dhabi International Airport, one of the busiest airports in the Middle East, ensuring seamless connectivity for both domestic and international travellers. Its proximity to major road networks and various transportation options further enhances its accessibility (DB-city, 2023b; Zhu et al., 2012).

Masdar City experiences a hot desert climate, categorized as BWh in the Köppen-Geiger system (Kottek et al., 2006). Average summer temperatures often exceed 40°C, while winter months remain relatively mild, ranging between 14°C and 24°C. The annual temperature variation reaches approximately 15.9°C, highlighting a moderate seasonal shift. Precipitation is scarce, with an average annual total of approximately 42 millimeters, and is largely concentrated in the winter season. January tends to be the wettest month, averaging 1.73 rainy days, whereas June is typically the driest, with nearly no precipitation, averaging only 0.03 rainy days. The total difference in precipitation between the driest and wettest months is minimal, at about 11 mm. Relative humidity peaks in December at around 64%, while the lowest levels are observed in May, dropping to 49.44%. The city benefits from abundant solar exposure throughout the year, receiving an estimated 3,838 hours of sunlight annually, or about 126.14 hours per month. This high level of insolation is integral to Masdar City's clean energy ambitions and urban sustainability model (Climate-Data.org, 2023; Ibrahim, 2016).



Fig. 1. Geographical situation of Masdar city and the new Town of Hassi Messaoud (Source: Google map and Author).

The new town of Hassi Messaoud

The new town of Hassi Messaoud is located in the Oued El Maraa region, within the province of Hassi Messaoud, in the wilaya of Ouargla, Algeria. The site is strategically positioned, equidistant from the towns of Ouargla, Touggourt, and the existing town of Hassi Messaoud, approximately 80 km from each. It lies about 86 km southeast of Ouargla, the wilaya's capital, and 900 km southeast of Algiers (Figure 1), with coordinates 32.35°N latitude and 5.86°E longitude (HADDADI, 2014). The terrain of the new town is generally flat, with an elevation of around 120 meters. While it lacks wadis, the site features dunes extending from the northeast to the southwest, with those in the northeast being higher (Figure 2). The town spans approximately 4,483 hectares (DB-city, 2023a). Its strategic location along the RN03 national road enhances transport and connectivity. Additionally, the presence of airports in both Ouargla and Hassi Messaoud improves accessibility to and from the region (Bounekhla & Merghit, 2020).

A distinctive feature of the region is its water abundance, with several aquifers supplying drinking water, including the Mio-Pliocene aquifer, the Senonian aquifer (composed of limestone), and the Albian aquifer (composed of sandy clay).

Hassi Messaoud has a desert climate with extreme aridity, classified as BWh under the Köppen-Geiger system (Kottke et al., 2006). The average annual temperature is approximately 22.9°C, with significant temperature variability throughout the year. January is the coldest month, averaging 11.3°C, while July is the hottest, reaching 35.2°C. Precipitation is extremely scarce, with an average annual total of 34 mm, depending on the source. Rainfall is primarily concentrated in the cooler months, with January marking the most significant period, reaching up to 7 mm. Monthly rainfall remains minimal during the rest of the year, with June and July being the driest months. Relative humidity shows seasonal variation, peaking at 57.10% in December and dropping to a low of 16.83% in July. The region receives high solar exposure, with approximately 3,948 hours of sunshine annually, averaging 129.74 hours per month (Climate-Data.org, 2023; Guessoum & Benmir, 2021).

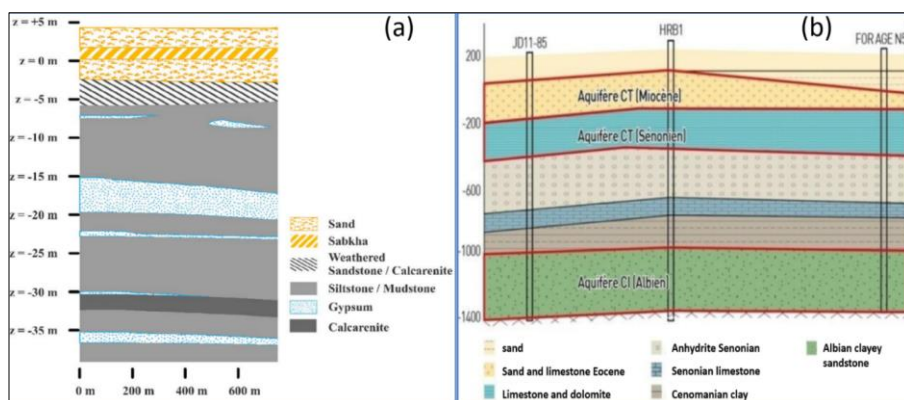


Fig. 2. Subsurface profile of Masdar city (a) and the new Town of Hassi Messaoud (b). (Source: Costa et al., 2018; Nour el Houda & Marwa, 2020).

Urban planning specificity

Masdar city

Masdar City integrates traditional urban planning principles with advanced technological innovations (Figure 3). The city's design features two compact checkered plans incorporating a diagonal grid, marked by a sinuous line representing the Light Rail Transport (LRT) system. Additionally, two Green Linear Parks, along with blue spaces, span the city, leveraging land-sea breeze interactions to enhance natural ventilation. Inspired by traditional Arab-Saharan cities, Masdar City adopts a compact layout with high-density yet low-height buildings (4-5 stories), narrow streets, and natural shading (FOSTER+PARTNERS, 2019; Griffiths & Sovacool, 2020; Ibrahim, 2016; Tang, 2010). The population density is 140 people per hectare, encouraging a sense of community (Lau, 2012).

To address the challenging desert conditions, urban planners strategically oriented the urban grain in a Northeast-Southwest diagonal grid. This orientation maximizes shading in the streetscape, creating cool public spaces that provide respite from daytime heating. The narrow streets replicate the shading conditions found in traditional Arabic cities such as Aleppo, Syria, where thermal comfort has been a priority for centuries (Tang, 2010).

Emphasizing sustainability and environmental protection, Masdar City is surrounded by green spaces and conceptualized with the principles of a walled city. This design acts as a protective barrier against desert sand and grit carried by the winds, contributing to the city's resilience. Furthermore, the city is elevated on a 7-meter podium, strategically separating transportation from pedestrian movement. This feature, reminiscent of "plinths" in historic Arabic cities like Shibam, Yemen, enhances functionality, mobility, and flood protection (Tang, 2010).

The development of Masdar City follows a phased approach, with the urban layout divided into two sectors connected by a linear park. The master plan's high flexibility allows it to benefit from emerging technologies and adapt based on lessons learned during the initial phases. Anticipating future expansion, the city aims to prevent urban sprawl, a common challenge in contemporary urban planning (FOSTER+PARTNERS, 2019). The residential sector occupies the largest portion of the city (62%), surrounding the urban core, while the city centre is dedicated to institutional buildings and offices.

Sustainability is a key aspect of Masdar City's planning. The land surrounding the city is designated for wind and photovoltaic farms, research fields, and plantations. The urban design incorporates traditional strategies used by Arab city builders, focusing on thermal comfort and settlement security in an arid desert environment (Ibrahim, 2016).

Mobility

Masdar City is the world's first planned car-free city, featuring an advanced mobility infrastructure with multiple sustainable transportation options, including walking, biking, personal rapid transit (PRT), group rapid transit (GRT), bus/light rapid transit, and metro systems. The city is connected to surrounding areas through a Light Rail Transit System (LRT), while its narrow, shaded streets promote pedestrian walkability and biking for shorter trips (Menichetti & Vuren, 2012; RAVEEN KUMAR MAGHELAL, 2022). The PRT system utilizes electric pod cars, covering trips up to 200 meters, with approximately 85 to 100 stations generating around 135,000 daily trips (Marful, 2010). Masdar City's electric

mobility strategy prioritizes safety and environmental sustainability, reinforcing its commitment to eco-conscious urban development.

Building design

The master plan of Masdar City integrates traditional Arab urban planning strategies with innovative building designs. Architects have adopted a hybrid approach that combines passive design strategies with active technological solutions to optimize well-being, energy efficiency, and security at the architectural level (Hassan et al., 2016).

Building orientation is meticulously planned to maximize shading on the streets, reducing heat accumulation and creating a cooling effect on adjacent structures. Facades are adorned with glazed reinforced concrete panels covered with highly insulated surfaces wrapped in aluminium foil. The incorporation of projecting oriel windows, crafted from sustainable reinforced vitrified concrete and featuring contemporary moucharabieh, harmonizes with the Saharan context, creating a sustainable yet visually captivating architectural expression. Natural roof lights are strategically positioned to diffuse direct sunlight, ensuring energy-efficient illumination while providing additional surface area for photovoltaic systems to harness solar energy (FOSTER+PARTNERS, 2019, 2021; Ibrahim, 2016).

Furthermore, construction emphasizes the use of environmentally friendly and cost-effective materials such as wood, low-carbon concrete, aluminium, and superior thermal wall insulation, surpassing industry benchmarks to enhance energy efficiency and reduce environmental impact. The high-performance double-glazed system with low-emissivity timber frames incorporates operable windows strategically positioned to optimize natural ventilation, ensuring a comfortable indoor environment while minimizing reliance on artificial cooling systems (Ibrahim, 2016).

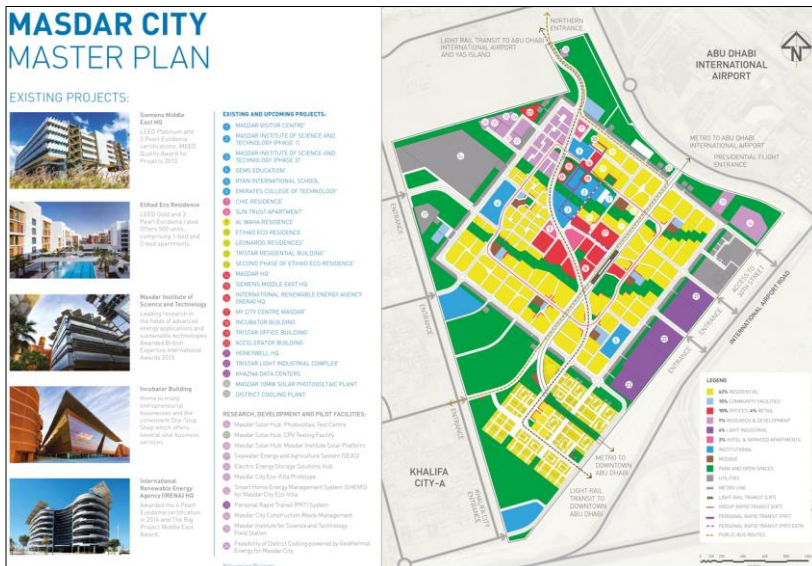


Fig. 3. Master plan of Masdar City (Masdar, 2018).

The new town of Hassi Messaoud

The new Town of Hassi Messaoud integrates modern urban planning principles with traditional Saharan urbanism (Figure 4). Designed as an oasis-like settlement, the city prioritizes thermal comfort through compact urban planning and climate-responsive design. Its high-density layout and integration of green spaces reduce heat accumulation by minimizing exposed surfaces. Shaded areas are strategically positioned to mitigate solar radiation, enhancing outdoor comfort. The city is divided into two primary zones: a residential area and a logistics area, separated by three kilometres. The logistics zone is designated for industrial and energy-related activities, relocated from the existing city of Hassi Messaoud (Haraoui & Rouidjali, 2020).

The urban design follows an octagonal city plan, with four distinct neighbourhoods, each subdivided into two adjacent units. These neighbourhoods are framed by administrative, commercial, and socio-cultural infrastructure. At the centre of this urban fabric is a core hub, featuring a central mosque, a large promenade, commercial spaces, recreational parks, and tourism infrastructure. Pedestrian walkways and arcades shield public spaces from excessive solar exposure, reinforcing climate adaptability (Haraoui & Rouidjali, 2020; Nour el Houda & Marwa, 2020).

Planned for approximately 80,000 residents, the city serves as a strategic development hub for regional urban growth. The structural plan follows a radio-concentric model, optimizing connectivity between commercial districts and residential neighbourhoods. The design encourages walkability, cycling, and public transport, with public facilities strategically positioned based on population distribution and accessibility (Haraoui & Rouidjali, 2020; Mahammedi, 2023).



Fig. 4. 3D model of the new town of Hassi Messaoud and its infrastructure
(Source: Evnh, 2010 & Author)

Covering a total land area of 404,480 hectares, the new Town is divided into four distinct zones. The urbanized area and planned development boundary cover 2,044 hectares, while 1,161 hectares are reserved for future expansion. Additionally, 313 hectares are designated as a protective boundary, and 965 hectares are allocated to the logistics zone (Figure 5). The logistics zone primarily serves to relocate industrial and energy-related activities from the existing city of Hassi Messaoud to this new site (Haraoui & Rouidjali, 2020).

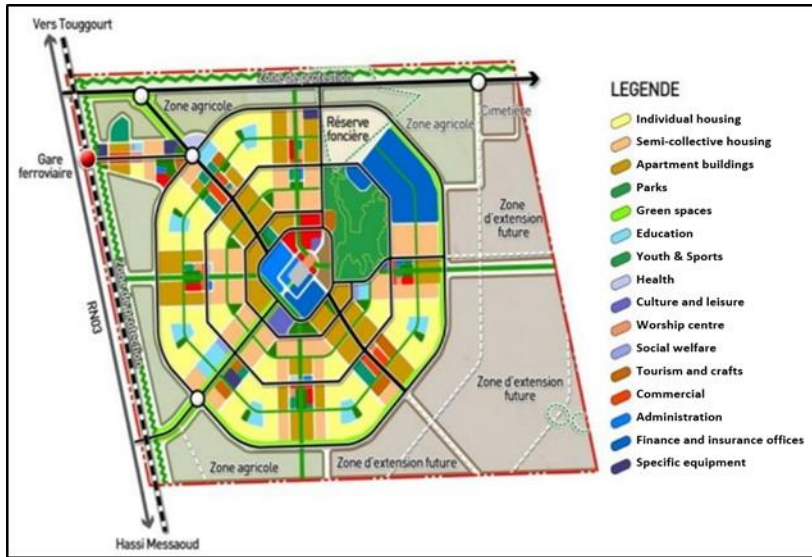


Fig. 5. Land use plan of new town of Hassi Messaoud (Nour el Houda & Marwa, 2020).

Mobility

The urban design of the new town emphasizes a multimodal mobility system, prioritizing public transportation while integrating pedestrian-friendly and cycling infrastructure alongside vehicular routes (Figure 6). A structured and secure bus network will form the backbone of the transportation system, featuring a primary route and a secondary loop that encircles the town. Complementing this, green axes will incorporate dedicated pedestrian and cycling paths, ensuring seamless connectivity and promoting soft mobility flows. Central to the mobility strategy is a hierarchical framework that defines pedestrian travel distances and access to local amenities. This system is designed to scale cohesively from individual neighbourhood units to the broader city level, enhancing walkability and accessibility across the urban fabric. To strengthen regional connectivity, a railway line currently under construction, it will link Touggourt to both the new and existing towns of Hassi Messaoud. This rail connection will also serve the logistics zone, improving transportation efficiency and reducing reliance on road-based freight movement (Haraoui & Rouidjali, 2020, 2020; Mostafa, 2023).

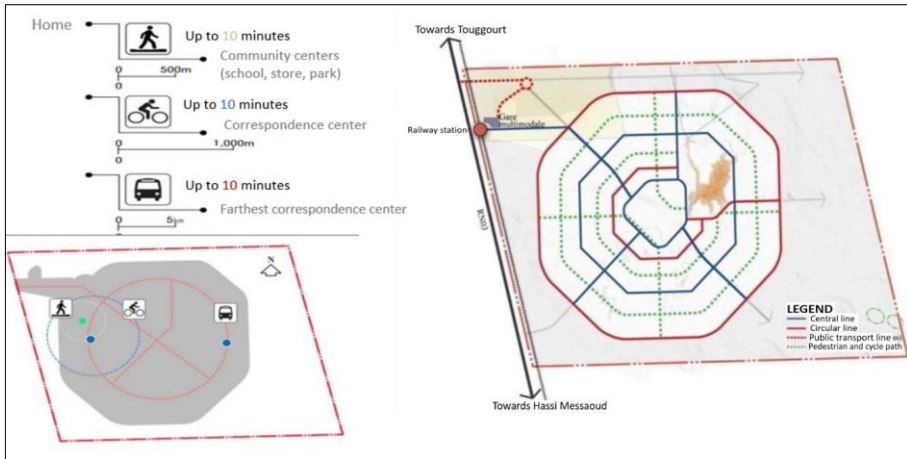


Fig. 6. Transport and Traffic Network Organization in the New Town of Hassi Messaoud (Bounekhla & Merghit, 2020)

Building design

The architecture of the new town of Hassi Messaoud is rooted in Saharan bioclimatic principles, emphasizing sustainability and cultural heritage. At the core of the urban-architectural design is the concept of the interior courtyard, inspired by the traditional "wast el dar" (centre of the house). This concept is applied across various scales of development, creating a cohesive and culturally resonant built environment. Construction companies have incorporated environmentally friendly materials alongside conventional ones such as wood, concrete, brick, stone, and iron, as well as standard insulators. To improve thermal performance, building units are oriented at a 45° angle to the north, providing an additional three hours of sun protection daily compared to traditional north-south or east-west orientations. Passive cooling strategies, including natural ventilation, are integrated into the design to reduce reliance on mechanical systems. The architectural style reflects southern Arab heritage, with façades featuring traditional elements such as arches, claustra (decorative screens), and small openings. Buildings are designed with flat roofs, while individual houses are crowned with domes, further emphasizing the region's cultural identity (Haraoui & Rouidjali, 2020).

Economic aspect

Masdar city

Masdar City represents a groundbreaking initiative by Abu Dhabi to prioritise urbanisation while transitioning towards a post-petroleum economy based on clean, renewable energies (Cugurullo, 2016b). The city's focus on developing urban technologies and alternative energy sources aims to preserve political and economic stability in the region. With the anticipation that its oil reserves can sustain the local economy until the end of the twenty-first century, Abu Dhabi's commitment to the Masdar City project exemplifies a proactive approach towards economic diversification and sustainable practises (Cugurullo, 2016a). Despite a reduction in financial support, the significant seed capital contribution from the Abu Dhabi government (US\$15 billion) and the involvement of stakeholders like Consensus

Business Group, Credit Suisse, and Siemens Venture Capital underscore the collaborative efforts to make Masdar City a global hub for renewable energy and clean technology companies (Centre for Public Impact, 2018; Grey, 2018). The creation of over 70,000 jobs within the city's premises showcases its potential to stimulate economic growth while promoting sustainable employment opportunities for the local community (Hendro Prabowo & Mahargyantari P. Dewi, 2017).

Masdar City's dedication to renewable energy projects is evident in its ambitious goal of achieving 100 GW of renewable energy capacity by 2030. The city explores diverse sources of renewable energy, including wind, solar technologies, and green hydrogen production. By embracing circular economy principles, Masdar City actively engages in initiatives such as Catalyst, a sustainable technology accelerator, to support innovative startups and organisations working on sustainable technologies in various sectors (Masdar, 2022). This approach fosters a dynamic ecosystem for green finance, underpinned by stringent Environmental, Social, and Governance (ESG) standards, positioning Masdar City as a major investor and driver of the global energy transition. The city's recent achievements in collaborating with other countries on renewable energy projects indicate a promising and determined effort to contribute to the global shift towards sustainable energy solutions. Notably, the successful closure of the financial deal on the largest wind farm in Uzbekistan and the initiation of partnerships with the Government of Azerbaijan on integrated offshore wind and green hydrogen projects showcase the city's relentless commitment to advancing renewable energy on an international scale (Griffiths & Sovacool, 2020; Masdar, 2022).

The new town of Hassi Messaoud

The Hassi Messaoud region occupies a central position as Algeria's main oil exploration centre. The town itself is relatively new, established in the heart of the oil field and home to major oil extraction and refining facilities. In 2012, the commune of Hassi Messaoud was the richest in Algeria, with resources reaching 8 billion dinars (Benhaddya et al., 2016; Bouzouaid & Benabbas, 2020; Halla, 2018). The project to create the new city aims to establish a dynamic hub to support the sustainable economic and social development of the south of the country, mainly the oil zone, and focused on the development of the energy sector. This initiative is fuelled by the prospect of growth in mining activities and the need to maintain a balance with the existing town. The cost of building the new town, to be borne by the Algerian government, is estimated at 371 million dollars. Complementing neighbouring towns, the new town is expected to play a significant role in regional economic development, with the creation of almost 40,000 jobs. The aim is to improve the living conditions of local workers, thereby enhancing their productivity and well-being, while taking into account the environmental challenges associated with the oil industry (Lamis, 2023).

Social aspect

Masdar city

Masdar City, with its emphasis on social interaction and lifestyle, displays an appealing social element, contributing to an acceptable profile for this feature. The city's master plan highlights a social dynamic, including parks, open spaces, cultural, religious, educational, and healthcare structures, as well as activities that encourage high levels of social participation and interaction. Masdar actively engages with the local community through a variety of outreach programmes, events, and initiatives, encouraging public engagement and awareness in

sustainable practises. These initiatives allow citizens to contribute to the growth of the city and build a sense of ownership and involvement in shaping its social fabric (Masdar, 2022). However, some researchers argue that the current reality in the city falls short of achieving an affordable social aspect and quality of life (Cugurullo, 2016b; Nicolai Ouroussoff, 2010). During the first phase of construction, Masdar City prioritised technological infrastructure, economic development, and environmental sustainability over the construction of residential and other buildings related to social needs. As a result, Masdar City has become renowned worldwide as a technological hub for renewable energy and clean technology companies. This focus on technology has led to a gap in the social aspect of the city, affecting mobility as public transport receives less importance than personal transportation. Additionally, only a small percentage (10%) of the city's plan is allocated for community facilities. Despite these challenges, Masdar City's population is set to welcome more population, with the current population reaching 4000 residents (Masdar 2022).

In the realm of education, Masdar City hosts the Masdar Institute of Science and Technology, offering advanced degree programs and attracting students from over seven countries. Starting from nurturing young minds in nurseries to hosting the world's first AI research-based university, the city provides a comprehensive educational framework (Henrie, 2015; Randeree & Ahmed, 2019; Yigitcanlar et al., 2019)

Another aspect of concern is the perceived preferential allocation of housing and job opportunities within the city. It is believed that access to housing and employment is predominantly reserved for individuals who share common interests with city executives, including students and professionals. This approach might inadvertently lead to a lack of diversity in the community and raise questions about equitable access to resources and opportunities for all residents. To offset some of these challenges, Masdar City has introduced various commercial activities aimed at enhancing the quality of life for its residents (Grey, 2018; Nicolai Ouroussoff, 2010)

The new town of Hassi Messaoud

The new Town project, which envisages the construction of housing for at least 90,000 inhabitants, together with all necessary infrastructure, responds to a particular social context and the severity of the arid environment of the region, combined with the industrial risks associated with local oil exploration (The Minister of Housing, 2023). The new town of Hassi Messaoud is designed primarily as a response to the social needs of the regional population. Urban planning is closely aligned with the needs of the local society, encompassing a large part of the city for the construction of housing of various typologies. In addition, the city offers a wide range of infrastructure, including green spaces, sports facilities, cultural, religious, educational, and health facilities. The Algerian Government has announced that the city will serve as a new urban development centre in southeastern Algeria, allowing the relocation of the existing city and providing a solution to populations exposed to geological and environmental risks resulting from intensive oil exploration activity (Lamis, 2023).

The social aspect of the city is also reflected in its architecture, which draws inspiration from the intimacy of the ancient Saharan cities and the traditions of the Saharan population. With regard to education, the city offers free educational opportunities for the entire regional population, covering the first three cycles up to university. Additionally, as in all Algerian cities, the government will provide free healthcare and medication in the new town of Hassi Messaoud, ensuring accessible medical services for all residents (Haraoui &

Rouidjali, 2020). This approach reinforces the inclusive and socially oriented character of the new town of Hassi Messaoud.

Environmental aspect

Masdar city

In Masdar City, the environmental aspect takes centre stage as a pioneering model of sustainable urban development. The city is designed to benefit maximally from the natural environment by being conducive and friendly to it. The city is designed to prioritise environmental stewardship, aiming to minimise its ecological footprint while maximising resource efficiency. Embracing clean and renewable energy sources, smart infrastructure, and innovative sustainable technologies, Masdar City serves as a global showcase for environmentally conscious urban planning and is one of the world's most sustainable urban communities—a low-carbon development that pioneers the UAE's ambitions to achieve net-zero by 2050 (Masdar, 2022).

City power is generated by a 10 MW solar PV plant and rooftop solar panels (Masdar 2022). In addition to solar installations on most rooftops, 20 MW of wind turbines will be constructed outside the city's perimeter (Madichie, 2011). The city's thermal and concentrated solar power systems are also implemented (Gil et al., 2016).

The city's infrastructure is designed to maximise energy efficiency and minimise environmental impact. Buildings incorporate green building principles, including advanced insulation, efficient lighting, and smart energy management systems (Maghelal et al., 2022).

The city employs advanced waste management methods to reduce its reliance on landfills. This method entails categorising waste for efficient treatment. Bio-waste is composted and used to improve agricultural land and plants outside the city. Recyclable elements are properly processed, and the remaining waste is used in a waste-to-energy plant. Furthermore, during construction, a strong emphasis is placed on recycling and reusing materials such as steel, concrete, and wood (Manghnani & Bajaj, 2014).

Masdar City has implemented water conservation measures, including solar-powered desalination facilities for freshwater needs and recycling up to 80% of the water used. Greywater is used for irrigating agricultural land, and a separation and recycling system manages grey and black water, promoting sustainable water management (Tang, 2010).

Masdar City prioritises green infrastructure by incorporating green spaces in linear parks and around buildings, creating a pleasant micro-climate through vegetation that enhances residents' well-being and improves air quality. In alignment with its commitment to environmental preservation, the city also promotes sustainable mobility options, such as an autonomous and electrified public transport system, which reduces emissions and fosters eco-friendly commuting (FOSTER+PARTNERS, 2019; Tang, 2010).

The new town of Hassi Messaoud

The planning of the new town of Hassi Messaoud is a response to ecological problems for the citizens and workers of the region and the industrial risks that exist in the region, mainly in the oil-producing region of the old town of Hassi Messaoud (Farid, 2011). The design given to the city is rationally integrated with the environment, mainly the climate. While

the materials used in construction are not very environmentally friendly, given the lack of use of local materials. This results in buildings that are less energy efficient (Lamis, 2023).

From an energy planning point of view, the new town includes a solar power plant and a wind farm on the outskirts of the town, but given the town's energy needs and the renewable energy portion, this only covers a portion of the town's energy consumption, mainly for air conditioning in buildings, while other energy sources will be fossil fuels. The town relies, and will continue to rely during both its construction and operation, on a significant share of non-renewable energy. This includes the installation of electricity generators and high-voltage power lines, with the country's electricity supply primarily derived from non-renewable sources such as natural gas (Evnh, 2010; The Minister of Housing, 2023; The Ministry of Finance, 2023).

A number of necessary infrastructure projects have been carried out, including the collection of drinking water from deep wells (1,700 m deep), and its treatment at the demineralisation plant located to the north of the site, then stored at the water towers, of which there are 4 for the town and 3 for the ZAL, and distribution, as well as the collection and treatment of wastewater at the peripheral treatment plant for reuse as irrigation water for the peripheral green strips. In the same context, in order to avoid flooding, the use of water management by accumulation in low-lying areas, in addition to the collection network, specific infrastructure integrated into the urban plan enables optimum management of rainwater in public spaces and its use for watering and/or irrigation (Haraoui & Rouidjali, 2020; Nour el Houda & Marwa, 2020).

For waste treatment, the city uses the traditional method of separate collection at the resource and then collection by vehicle to the waste treatment plant, which recycles almost 20% and the remaining 80% is household and similar waste. Green infrastructure in the city also takes a primordial place regarding the climate conditions, a peripheral green strip develops over a length of 6 km and a width of 500 m protects the city against hot winds and minimizes risks of silting in its environment. These green spaces are unified by corridors and greenways that integrate cycle paths, footpaths and public transport routes. These green axes are created as a meshed network that includes aquatic spaces forming the blue network ((Haraoui & Rouidjali, 2020; Medjahed, 2018).

Discussion

The study of Masdar City and the New Town of Hassi Messaoud provides a rich foundation for understanding the complexities of the new urban development in desert environments. While both cities offer innovative solutions to the challenges of rapid urbanization and climate adaptation, they also reveal critical gaps and areas for improvement.

Masdar City exemplifies a high-tech, sustainable urban model that integrates advanced technologies with traditional Arab urban planning principles. Its compact, high-density layout, narrow shaded streets, and orientation to maximize natural cooling reflect a deep understanding of desert climates. The city's phased development and flexibility in adapting to emerging technologies demonstrate a forward-thinking approach to urban planning. In contrast, the New Town of Hassi Messaoud adopts a more traditional Saharan urban morphology, emphasizing thermal comfort and social cohesion through its compact, oasis-like design. While Masdar City prioritizes global innovation and technological integration,

Hassi Messaoud focuses on regional equity and the relocation of populations at risk due to industrial activities.

Economically, Masdar City is a flagship project for Abu Dhabi's transition to a post-petroleum economy, leveraging renewable energy and clean technology to attract global investment. Its economic model is built on diversification, job creation, and the establishment of a hub for green technology. Conversely, the New Town of Hassi Messaoud is driven by Algeria's need to balance economic growth in the oil sector with social and environmental sustainability. While Masdar City benefits from substantial financial backing and international collaboration, Hassi Messaoud faces challenges related to funding and implementation delays, highlighting the disparities between developed and developing nations in executing large-scale urban projects.

Socially, Masdar City's initial focus on technological and economic development has led to a gap in social infrastructure, with limited community facilities and housing opportunities. However, its educational institutions, such as the Masdar Institute of Science and Technology, contribute to its role as a global knowledge hub. In contrast, the New Town of Hassi Messaoud is designed with a strong social focus, providing housing, educational facilities, and cultural infrastructure to improve the quality of life for its residents. Its architecture and urban design draw inspiration from traditional Saharan cities, fostering a sense of cultural identity and community.

Both cities prioritize environmental sustainability, albeit through different approaches. Masdar City is a global leader in renewable energy, utilizing solar and wind power, advanced waste management systems, and water conservation technologies. Its commitment to achieving net-zero carbon emissions sets a benchmark for sustainable urban development. Hassi Messaoud, while incorporating renewable energy sources like solar and wind, faces challenges in achieving energy efficiency due to the use of conventional construction materials. However, its green infrastructure, water management systems, and waste treatment facilities demonstrate a commitment to mitigating environmental risks associated with industrial activities.

Many lessons can be learned from these two new urban developments in arid climates. The design and implementation of cities in desert environments, as demonstrated by Masdar City and Hassi Messaoud, provide a strong foundation for developing more resilient urban areas. Both cities showcase the importance of adapting to climate challenges through traditional urban and architectural principles, which can serve as valuable references for the renovation or construction of future urban projects. The integration of technology and renewable energy, combined with passive design strategies, offers a balanced approach that can lead to more comfortable and sustainable urban environments. Masdar City highlights the potential of cutting-edge technologies to address environmental challenges, while Hassi Messaoud emphasizes the significance of traditional design principles for thermal comfort and cultural identity. Future urban developments should aim to harmonize these approaches, leveraging advanced technologies where appropriate while preserving local knowledge and practices. Additionally, Hassi Messaoud's focus on social infrastructure and community well-being underscores the importance of equitable urban development, ensuring that affordable housing, inclusive public spaces, and access to education and healthcare are prioritized. Masdar City's phased development and adaptability to emerging technologies also offer valuable insights, suggesting that urban plans should incorporate flexibility to address future challenges and opportunities. Both cities emphasize

the critical role of renewable energy, particularly solar power, in desert environments, advocating for decentralized energy systems, energy-efficient buildings, and innovative storage solutions. Sustainable water and waste management systems, as seen in both cities, are equally vital, with a focus on advanced desalination, recycling, and waste-to-energy technologies, alongside water conservation and circular economy principles. Finally, the incorporation of green infrastructure, such as linear parks and green corridors, demonstrates the importance of nature-based solutions for mitigating urban heat islands, improving air quality, and enhancing biodiversity. These lessons collectively highlight the need for a holistic approach to urban development, blending tradition and innovation, equity and sustainability, to create resilient cities capable of thriving in arid climates.

Conclusion

The comparative analysis of Masdar City and the New Town of Hassi Messaoud reveals valuable insights into the development of sustainable urban environments in desert regions. Masdar City represents a technologically advanced, globally oriented model that leverages innovation and renewable energy to address the challenges of urbanization. Its success lies in its ability to attract international investment and serve as a hub for clean technology. However, its limited focus on social infrastructure highlights the need for a more balanced approach to urban development.

On the other hand, the New Town of Hassi Messaoud embodies a regionally focused, socially inclusive model that prioritizes the well-being of its residents and the mitigation of industrial risks. While it faces challenges related to funding and energy efficiency, its emphasis on cultural identity and community cohesion offers important lessons for sustainable urban planning in developing nations.

Both cities underscore the importance of integrating environmental, economic, and social pillars in urban development. Masdar City's technological innovations and Hassi Messaoud's social and cultural focus provide complementary approaches to addressing the challenges of urbanization in arid regions. Future research should explore the long-term impacts of these models, particularly in terms of their scalability and adaptability to other desert environments. By learning from these case studies, policymakers and urban planners can develop more holistic strategies for creating sustainable cities that balance technological advancement, economic growth, and social equity.

Conflicts of Interest: The authors declare no conflict of interest.

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