AMERICAN UNIVERSITY OF BEIRUT

A CLIMATE-RESPONSIVE MODEL FOR TRANSIT ORIENTED DEVELOPMENTS: THE CASE STUDY OF AL-SUFFOUH SUBURB, DUBAI

by
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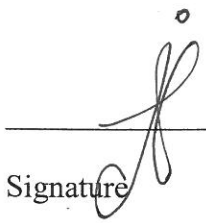

8th May 2015

Signature Date

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AN ABSTRACT OF THE THESIS OF

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Title: A Climate-Responsive Model for Transit Oriented Developments: The Case Study of Al-Suffouh Suburb, Dubai

As an approach to the sustainable development of automobile-oriented suburbs, the concept of Transit Oriented Development (TOD) has been promoted mainly in the United States and Europe in an attempt to re-focus suburban sprawl and reduce regional ecological footprints. However current TOD research and case studies are mostly confined to temperate-climatic zones with limited applicability to the Middle Eastern gulf countries like the Emirate of Dubai with its tropical desert climate. This thesis is an attempt to bridge this gap by proposing an alternative climate-responsive TOD model taking into consideration the three tenets of sustainability: economic vitality, social diversity and environmental integrity. The model and its design toolkit are articulated around the five generic dimensions of urban design i.e. identity, infrastructure, ecology, public space and private development. They are applied to the development of a TOD master plan for the Nakheel Metro Station in Al Suffouh- one of the oldest suburbs in Dubai's sprawling urban region. The master plan and design scheme are aimed at retrofitting existing urban form through a set of diversified land uses and the re-articulation of pedestrian and vehicular networks, public open spaces, block morphologies and building typologies.

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CHAPTER ONE

INTRODUCTION

A. Introduction

Promoted as a tool of sustainable development in sprawling suburbs, Transit-oriented development model (TOD) has been implemented in the United States, Europe, Asia and Australia. TOD is used to retrofit auto-oriented development, re-focus urban growth in sprawling urban regions and adopt a more dense compact urban form; thus reducing urban regions' ecological footprint.

This study investigates how TODs can be applied in cities of the Arab world, particularly in the Emirate of Dubai to retrofit suburban districts into sustainable developments.

Current research in designing and planning transit-oriented development (TOD) deals partially with issues of urban design and sustainability in temperate climates. Its limits applicability is to the Gulf cities of the Arab world. As a result, the study proposes a comprehensive toolkit structured around the three pillars of sustainable development. The urban design tools are grouped in five generic dimensions of urban design i.e. Identity, Infrastructure, Ecology, Public Space and Private Development (Saliba 2015). The toolkit establishes a specific climate-responsive TOD model.

Both model and toolkit are applied to conceptualize a transit-oriented development master plan around Nakheel Metro Station in Al Suffouh, one of the oldest suburbs in Dubai's sprawling urban region. This chapter gives an overview on the study

context, frames the research questions as a response to the gaps in current TOD research and explains the methodology to answer them.

B. Urbanization and Urban Sprawl

The rapid urbanization of cities results in the expansion of their surface area using the available land to build low-density single use districts. Urban sprawl is the result of this rapid urbanization characterized by auto-oriented leapfrog patterns of development that lacks possibilities of public open space. (Seoule D., 2006).The developments resulting of urban sprawl limit transit mobility choices for its dwellers (Crane, 2001).

Researchers highlighted the ills of this pattern of urbanization (Burchell, et al., 2002). Social and economic polarization increases in urban regions affected by urban sprawl. (Seoule D., 2006). Extensive researches also cover the environmental cost of urban sprawl. Sprawling suburbs disburse large tracts of land, reduce agricultural lands, and increase the depletion of natural resources and Carbon emissions. The body of this research is particularly interested in linking the global strive to limit climate change to the adoption of more sustainable urban forms on the local level (Bart, 2009). Particularly, the current research tackles the health risks resulting from the car-dependent lifestyle. Auto-oriented developments are linked to an alarming rise in obesity, diabetes and chronic diseases for its residents. Moreover, living in car-dependent environments limits social interaction and causes depressive disorders (Frumkin, Frank, & Jackson, 2004).

1. Dubai - An example of Urban Sprawl in the Arab World

Dubai witnessed one of the highest rates of urbanization in the last two decades. It has expanded from a small city center in the last century to a sprawling urban region (Nassar, Blackburn, & Whyatt, 2012).Since the end of the last decade, Dubai developed footprint has grown 400% (equal to 1287 km^2). Dubai urbanization followed Sheikh Zayed highway, a regional road corridor connecting Dubai to different emirates (Alawadi, 2011). For the past three decades, emerging forms of urbanism in a context of optimized fluid networks and maximized opportunities for global investments were tested in Dubai (ElSheshtawy, 2004).The resulting townscape is suffering from suburban sprawl. Dubai cityscape (viewed from plane) reads as an expanding field traversed by highway corridors and transit lines connecting heterotypic patches of residential communities, industrial and business enclaves, theme parks, and reclaimed islands. Similar to global metropolises such as Los Angeles and Beijing, large scale development and complex infrastructure have replaced buildings and in-between spaces as constituents of urban form.

Dubai urban sprawl causes an increase of car dependence as a result of auto-oriented large scale development. In fact, Dubai has one of the highest car ownership rates in the world. Based on a 2007 study released by the Roads and Transport Authority (RTA), Dubai car ownership rate is 541 cars per 1,000 population, higher than cities like: New York State (currently at 444 cars per 1,000 population), London (345 cars per 1,000 population) and Singapore (111 cars per 1,000 population). Dubai is expected to reach 5.3 million registered cars (Shariff, 2014). Car dependence in Dubai is further worsened due to the lack of walkable environment responding to its tropical

desert climate e.g. Dubai temperatures reach 50 degrees in summer and humidity can rise to 75%.

On September 9, 2009, Roads and Transport Authority (RTA) launched Dubai Metro to encourage Dubai residents to adopt a more sustainable transport modality (RTA, 2014). The Red Line of the Dubai Metro stretches over 52 km and connects 29 stations. ; Dubai Metro line runs parallel to Sheikh Zayed Road, Dubai's urban growth corridor. Since its launch, Dubai metro ridership increased from 60,000 passengers in 2009 to 500,000 in 2014 (RTA, 2014). However, public transport in Dubai still accounts only for 6% of total transport trips. Hence, Dubai represents an example of urban sprawl in the Gulf countries of the Arab world and presents an opportunity to test and propose an alternative model of sustainable urban development.

Figure 1.1. Dubai Urban Sprawl.

2. Retrofitting Suburbs through Transit Oriented Development

In order to address the issues resulting from urban sprawl, Transit-oriented development model (TOD) is proposed as an alternative development tool. It is based on articulating densities near transit as a proven method to reverse car dependence and sprawl (Kenworthy and Laube 1999). It increases the livability in suburbs and encourages employees, residents and visitors to choose from an array of transport choices including transit, cycling, walking or going by bus. Transit-oriented development (TOD) improves the experience of the "first mile" and "last mile" e.g. before and after getting into the transit system (Williamson, 2013).

Transit Oriented Developments are linked to the current debate of climate change, put forward as a sustainable development tool for suburbs. TODs promote compact urban form, diverse uses and connected public realm. The latter is proved to foster wellbeing and health in suburbs, contribute to their livability, and increase their economic values (Wheeler, 2013; Sohn, Moudon, & Lee, 2012; Dunham-Jones & Williamson, 2009; Calthrope & Fulltrom P., 2001).

3. Potential of TOD in Dubai

Transit-oriented development (TOD) could be used to retrofit Dubai's expanding suburbs focusing their growth around the current Dubai Metro and Dubai Tram stations. Nakheel metro station, located in Al Suffouh suburb, is one of the Dubai Metro Red Line stations; its ridership numbers is only 2.7 million trips annually compared to an average of 7 million trips for other stations, despite being surrounded by diverse land use (Dubai Statistics Center, 2014). The low ridership of the station, despite its important constituents, makes it a tactical site for transit-oriented development (TOD).

C. Issues and Thesis Approach

The current gaps in transit-oriented development (TOD) research limit its applicability as an urban design tool in Dubai. First, Current TOD literature links its benefits to the sustainability of its host city or region. However, it does not provide a specific set of tools to design TOD principles (Density, Diversity and Design) in accordance to the three pillars of sustainable development: environmental integrity, social diversity and economic vitality.

Second, the current literature on the urban design aspects of TOD is fragmented. Different sources mention different aspects of urban design, limiting its role to the design of public realm. A more comprehensive set of design principles and tools would better address the complexities of retrofitting existing suburbs.

Third, the current literature on transit-oriented development (TOD) is limited to temperate climate; specific design criteria for urban form, public realm design and walkability in hot climate conditions such as Dubai's are seldom mentioned.

As such, TOD generic model needs to be re-adjusted to retrofit Dubai's existing suburban districts and addresses the sustainability challenges posed by its urban sprawl.

D. Research Question

This study attempts to answer the questions below:

How can we design transit-oriented development (TOD) as a sustainable development tool for retrofitting suburbs in hot and humid climates?

What are the urban design tools specific to transit-oriented development (TOD) which enhance the economic vitality, social diversity of their host suburban districts?

What are the climate responsive urban design strategies for hot and humid climates? How do they impact the current TOD generic model?

E. Objectives

First, the study proposes a comprehensive toolkit which includes a set of urban design objectives distributed into: Identity, Infrastructure, Ecology, and Public Space and Private Development (Saliba, 2015). The impact of these objectives on sustainability is classified according to the three aspects of sustainable development: Economic vitality, Social diversity and Environmental integrity. Second, the study re-designs the alternative climate-responsive model based on climate-responsive design strategies in hot and humid climates. Third, the study tests the applicability of the new TOD model and toolkit across three scales-on city scale (Dubai),on District scale (Al Suffouh) and site scale (Nakheel Metro Station immediate area).

F. Significance

Transit is slowly gaining momentum in the Middle Eastern Gulf countries as an alternative transport mode. Consequently, this research increases awareness about urban designers' important role as focal design agents for planning stations and influence metropolitan transportation strategies. Such engagement would reframe the concept of stations as centers of thriving walkable, mixed-use and climate responsive neighborhoods rather than a financial burden on public authorities and developers.

Dubai urbanization is extensively researched by urban planners, urban geographers and urban anthropologists-qualifying its problems. This study stems from a

pro-active stand on the role of urban design in proposing pragmatic strategies for re-integrating and re-connecting Dubai's existing urban footprint.

Public policy on transport in GCC is gaining prominence. The outputs of the research could be a blueprint for GCC municipalities and governments to formulate policies regarding Transit-oriented development (TOD) around metro stations. It could be used as the basis for policy documents such as transit-oriented development (TOD) design guidelines advocating an alternative urban form for other gulf cities whose post-oil urbanization transformed into urban sprawl.

G. Methodology

In order to answer the research question, the study follows a process divided into two parts – a theoretical study and its application as illustrated in Figure 1.2.

The theoretical study starts with introducing the TOD model and its current application. Then, it proceeds in tackling three gaps identified in TOD literature: urban design, climate responsiveness and sustainability.

First, the three TOD general principles of Density, Diversity and Walkability provides the structure to reflect on urban design of TOD, resulting in specific urban design tools to retrofit existing suburbs. An additional fourth general principle i.e. Time, is proposed in this study. It addresses the process of designing resilient urban forms.

Second, a review of climate responsive design literature on natural ventilation, shading and greening design provides walkability guidelines and tools for lowering ambient temperature of urban spaces in hot and humid climate due to its absence from current TOD literature. The findings of these two analysis tracks reveal the inadequacy of the current generic TOD model for tropical desert climate and trigger its re-

assessment. Therefore an alternative model and a specific toolkit are proposed in order to guide comprehensive design interventions in the Gulf Cities of the Arab World

The toolkit also includes the lessons learned from five award-wining international TOD analyzing their urban design aspects in relation to their stated sustainability strategies

Dubai, Al Suffouh suburb and Nakheel metro station plots are respectively selected to test the model and toolkit application on city scale, district scale and site scale.

On city scale, Dubai's urbanization is critically diagnosed as demonstrating the effects of urban sprawl and its negative impacts on the city's sustainability. Graphical materials such as photos, maps as well as textual materials are used to demonstrate how Dubai's urban sprawl followed Sheikh Zayed highway as an urban growth corridor. So, a proposal is made to retrofit Dubai's current urban growth corridor into a regional TOD transit corridor as an attempt to reverse its sprawl.

On District scale, the analysis of Al Suffouh suburb current situation points out the issues of urban design and sustainability. Site visits and the city's various smart applications[1] provide the necessary data in order to map the underlying issues. A visual survey of the site, in addition to reviewing academic and non-academic research on the site area further clarifies the core causes of these issues. The latter provides the main objectives for a proposed urban design strategy for the selected study area in Al Suffouh suburb; which integrated its different constituents into two transit oriented developments centered respectively around Nakheel Metro Station and Dubai Media City Tram Station.

[1] Smart Applications are electronic information portals created by Dubai Government through its smart city initiatives covering different aspects of city management.

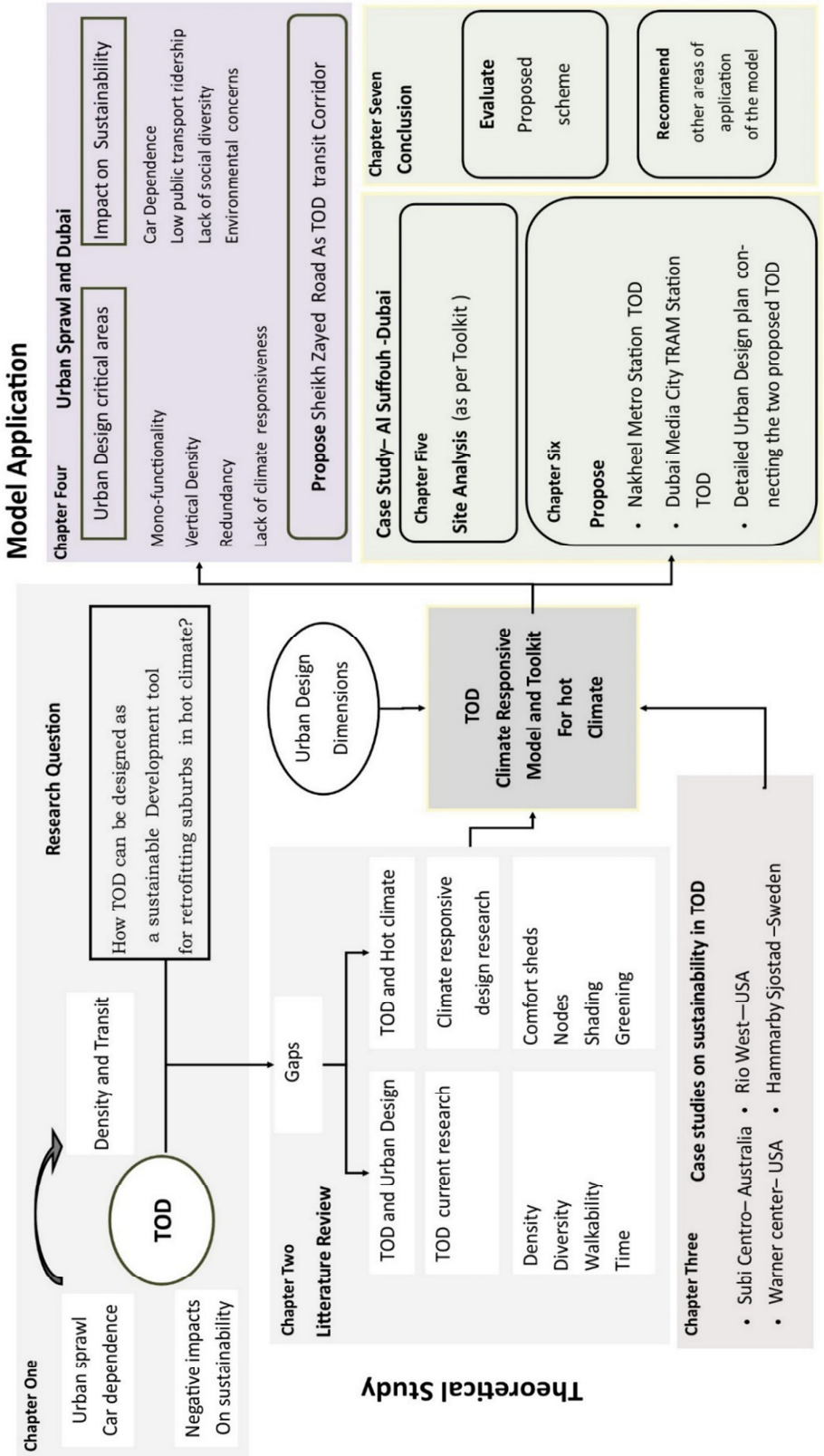
On site scale, areas surrounding Nakheel Metro Station were re-designed following the principles set out in the model and toolkit. The application of the toolkit and model ended with an evaluation on their effectiveness and applicability. Additional applications and areas of research are recommended to further refine them.

H. Thesis Content and Structure

The report structure reflects its methodology (see Figure 1.2). Chapter two structure reflects the two gaps in current TOD Literature. It is divided into three parts: a comprehensive overview of the current main principles of transit-oriented development (TOD), a summary of the design strategies of climate responsive TOD in hot climate, synthesis of the above into an alternative climate-responsive TOD model for hot climate and tabulation of the corresponding urban design tools.

Chapter three refined the toolkit through incorporating lessons learned from the urban design strategies of five case studies in TOD and sustainability. Chapter four proposes the application of the climate responsive TOD model on a city scale to address the impacts of Dubai's urban sprawl.

Figure 1.2. Methodology Diagram.



Chapter five presents a detailed assessment of the study area in Al Suffouh analyzing it identity, vehicular and pedestrian circulation, its open spaces network and diagnosing its current sustainability situation. Chapter six is a setting out of the TOD urban design strategy applying the TOD climate responsive model on a district level. A detailed design proposes for the civic spaces and mixed use area around the transit station in Chapter six demonstrates how the toolkit is applied on a site level.

Chapter six ends with an evaluation of the application of the model and toolkit. Chapter seven concludes with recommending further areas of research and potential improvement areas to inform subsequent applications and areas of research.

CHAPTER TWO

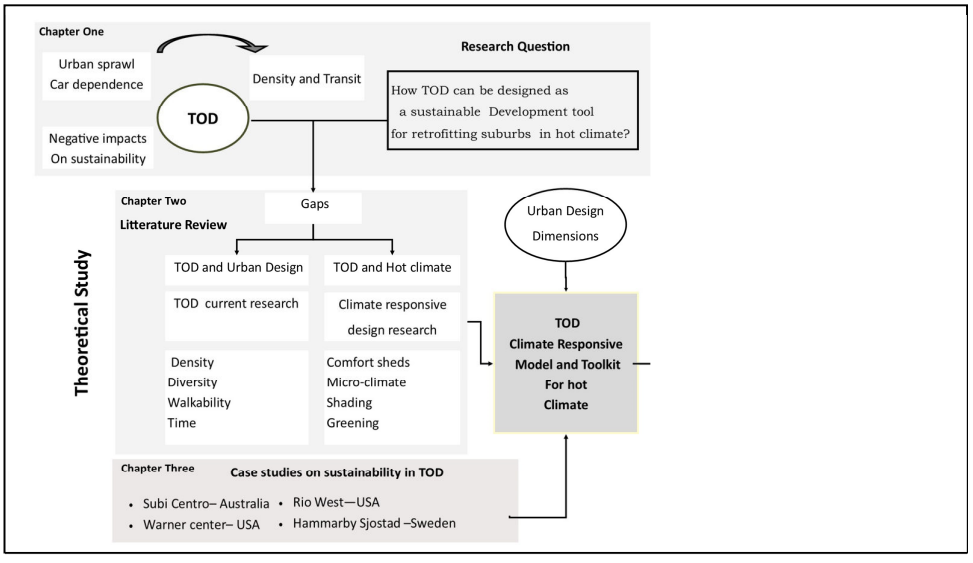
TOWARDS AN ALTERNATIVE TRANSIT-ORIENTED DEVELOPMENT MODEL

A. Introduction

Current literature emphasizes that densifying suburban districts around transit stations reduces car dependence and controls sprawl. These articulated densities took the form of Transit-Oriented Development (TOD) retrofitting suburbs into dense, mixed-use and walkable community .However; current literature on TOD does not expand on the urban design tools which impact TOD's sustainability. Moreover, the environmental sustainability of TOD conceived for suburban districts in hot and humid climate is handicapped by the limitations of the generic TOD model to temperate climate.

As such, this chapter reviews TOD and climate responsive research in order to address current gaps and propose an alternative climate responsive TOD model for hot climate, structured as per the process outlined in Figure 2.1.

Figure 2.1. Chapter two Road Map - synthesis of current Literature into an alternative TOD Model.



B. Transit-Oriented Development and Urban Design

Peter Calthrope (1993) proposed "Transit Oriented Developments"(TOD) as centres physically articulated on critical points along transit served corridors.

Figure 2.2. Transit Oriented Development Diagram – adapted from Calthrope (1993).

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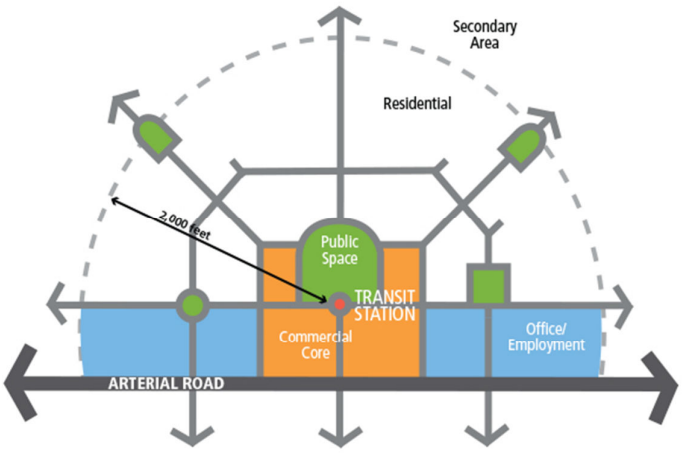


As Figure 2.2 shows, commercial and employment areas are built on the edge of the arterial road and around a major civic space serving a transit station. Streets radiate from the transit station to residential areas. A network of public spaces and streets are planned so that the maximum walking distance to transit does not exceed 2000 feet – 600m (distance between half-mile and one quarter of a mile) i.e. the development radius established in transportation research to analyse and study transit ridership numbers (Cervero, 2002).

The nomenclature given to this alternative development model clarifies its foundation as planning approach that integrates transport and land use plans for a specific site using urban design to transform it into a place. Transit-oriented developments emerged as a name after a conversation between Robert Cervero - an expert on transit and transportation - and Peter Calthrope, a regional planner. Calthrope

had developed "pedestrian pockets", a compact sustainable community concept of housing units surrounding green public spaces. Cervero was researching with his Berkeley team the importance of intensifying uses around transit to increase ridership. Their discussion focused on the role of urbanism in building sustainable communities; they were discussing adequate land-use densities that could be outlined in suburban development guidelines for the cities of Sacramento and Portland in order to encourage light rail ridership. After their meeting, Calthrope renamed and transformed "Pedestrian pockets" into "Transit-Oriented Development" - used for the first time in 1991 in a New York article discussing it as "the next evolutionary stage in American suburb"(Carlton 2007).

Lately, Transit-oriented developments are discussed as tools that embody the principles of sustainable development. In fact, TOD model is considered as a key planning paradigm aiming at a more sustainable efficient urban form. In introducing TOD's best practises, Ditmarr and Ohland (2004) described the positive impacts of TOD as including the provision of a higher quality of life for residents, reducing transportation costs ,reducing environmental impact and being an alternative to traffic congestion.

Literature on transit-oriented development explained mostly its land use planning aspects (Arrington & Cervero, 2008).During a recent study on Asian cities, TOD is defined as a planning technique that results into an environmentally friendly development (Sung and Oh 2011).Peter Calthrope (1993) explained TOD role as a planning tool on the regional level generating employment and providing additional housing stocks, transforming them into destinations (Calthrope , 2010).

Figure 2.3. Transit-oriented development and Sustainability; Emphasis on Planning and Land Use Tools - source: Calgary TOD guidelines manual (2010) - one of 50 TOD manuals that have been published since 1991.

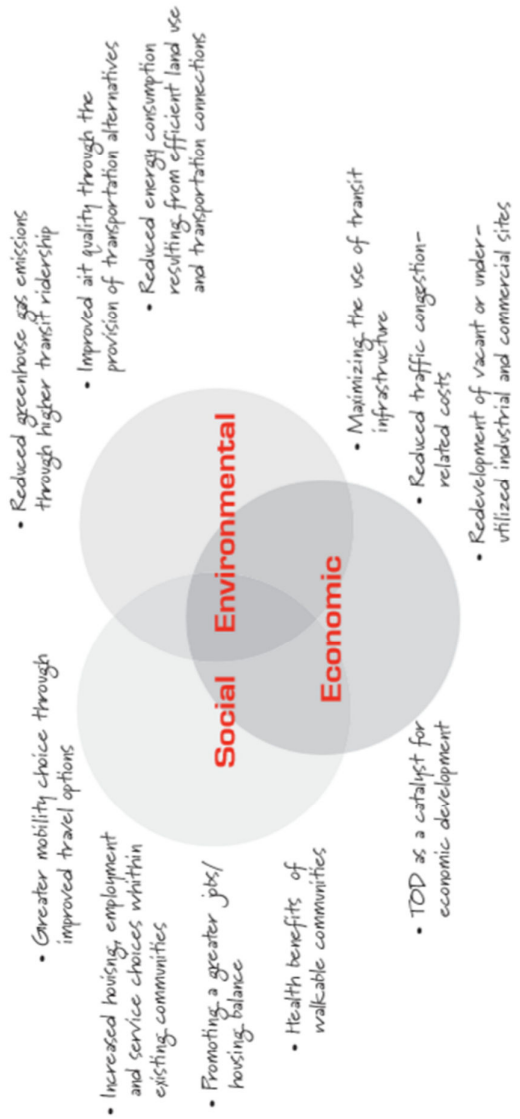
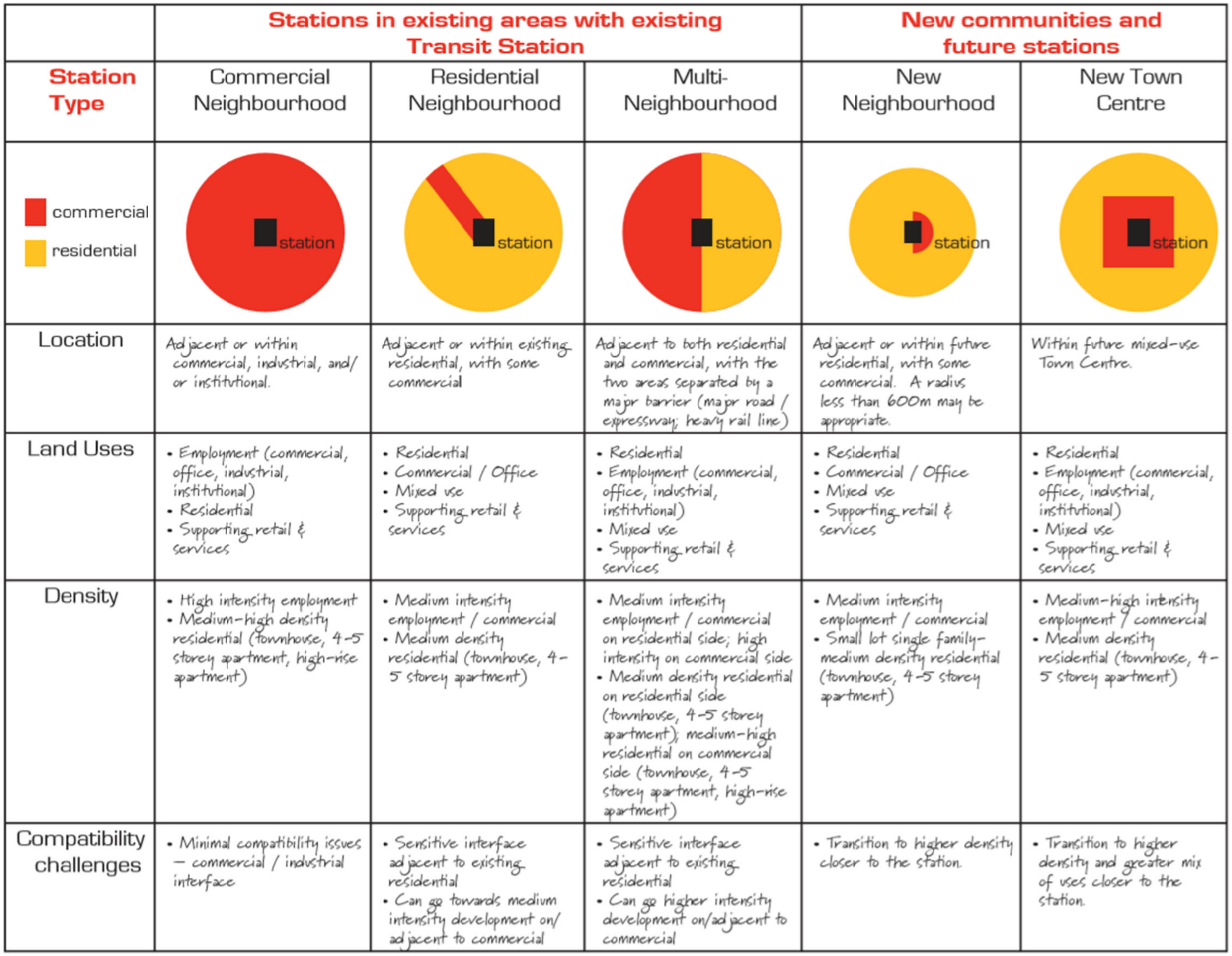


Figure 2.4. Examples of Transit-Oriented Development Classifications Emphasizing on Land Use and Planning Tools- source: 2004 Calgary TOD Guidelines.



	Stations in existing areas with existing Transit Station			New communities and future stations	
Station Type	Commercial Neighbourhood	Residential Neighbourhood	Multi-Neighbourhood	New Neighbourhood	New Town Centre
commercial / residential	station	station	station	station	station
Location	Adjacent or within commercial, industrial, and/ or institutional.	Adjacent or within existing residential, with some commercial	Adjacent to both residential and commercial, with the two areas separated by a major barrier (major road / expressway; heavy rail line)	Adjacent or within future residential, with some commercial. A radius less than 600m may be appropriate.	Within future mixed-use Town Centre.
Land Uses	• Employment (commercial, office, industrial, institutional) • Residential • Supporting retail & services	• Residential • Commercial / Office • Mixed use • Supporting retail & services	• Residential • Employment (commercial, office, industrial, institutional) • Mixed use • Supporting retail & services	• Residential • Commercial / Office • Mixed use • Supporting retail & services	• Residential • Employment (commercial, office, industrial, institutional) • Mixed use • Supporting retail & services
Density	• High intensity employment • Medium-high density residential (townhouse, 4-5 storey apartment, high-rise apartment)	• Medium intensity employment / commercial • Medium density residential (townhouse, 4-5 storey apartment)	• Medium intensity employment / commercial on residential side; high intensity on commercial side • Medium density residential on residential side (townhouse, 4-5 storey apartment); medium-high residential on commercial side (townhouse, 4-5 storey apartment, high-rise apartment)	• Medium intensity employment / commercial • Small lot single family-medium density residential (townhouse, 4-5 storey apartment)	• Medium-high intensity employment / commercial • Medium density residential (townhouse, 4-5 storey apartment)
Compatibility challenges	• Minimal compatibility issues — commercial / industrial interface	• Sensitive interface adjacent to existing residential • Can go towards medium intensity development on/ adjacent to commercial	• Sensitive interface adjacent to existing residential • Can go higher intensity development on/adjacent to commercial	• Transition to higher density closer to the station.	• Transition to higher density and greater mix of uses closer to the station.

1. In Search of a TOD Urban Design Framework

Current studies note that urban design is important in enhancing the quality of suburban space in TOD through fully integrating urban form around transit nodes. Developments in which urban space is not fully integrated with the transit node are labelled "Transit-Adjacent Development"(Tumlin & alt., 2003).

Cervero (2002) recognised design as an integral and essential principle of TOD based on comprehensive studies on successful transit-oriented developments[1] (Cervero, Ferrell, & Murphy, 2002; Cervero R., 2004).However, most studies list under 'Urban Design' the criteria for designing the public realm design and softening the impact of dense urban form on people experiences. Additional urban design tools would render TOD model more adapt to tackle the complex issues of re-integrating the fragmented and undefined urban spaces of existing suburbs. As such, TODs need to adopt a holistic urban design frame.

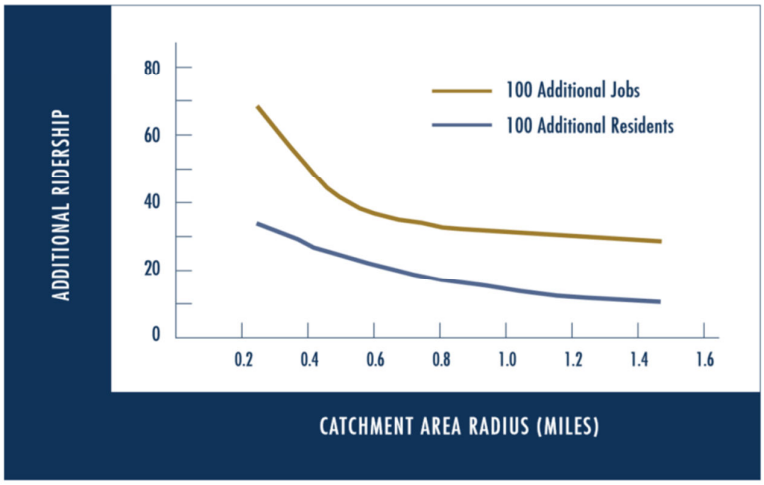
This section identifies these comprehensive tools of urban design which are necessary deducted from the three principles of TOD – Density, Diversity, and Design while recommending the addition of Time as a fourth principle (Calthorpe 1993;Seigman 2003;Ditmarr and Ohland 2004;Ewing and Cervero 2010).

2. Density

Transit-oriented development accommodates different densities that vary according to their regional context whether it is an urban, a peri-urban or suburban. Densification spreads over a catchment area of one quarter to half a mile radius (400 m to 800 m). Calthrope (1993) model mentions 2000 feet – approximately 600 m as median radius (figure 2.5).A recent study reviewed the half-mile development radius used by transportation and planning agencies to forecast ridership and assign densities

policies of TOD (Gueraa, Cervero, & Tischker, 2012). The half mile (800 m) roughly corresponds to the distance covered by ten minute walk in a temperate climate city (assuming 5 km per hour as average pedestrian speed). Regression analysis is run on 1500 high capacity transit stations in 21 cities in the United States. The study adopts an abstract radial catchment area rather than actual distances based on roads' networks, usually referred to as ped-sheds (an analysis tool used for calculating distance covered by pedestrians to reach a transit station). Regardless of the transit frequency, bus connections and the relative location of the station in the city, the study confirms that ridership maintains the same average for the development radius range (200m -1000m). For one quarter-mile catchment areas, every additional 100 residents added 34 trips to ridership estimates in comparison to 69 trips for adding 100 jobs. For half –mile catchment areas, every additional 100 residents add 25 trips to ridership estimates in comparison to 42 trips for adding 100 jobs. As such, the study recommends concentrating offices and retail uses within the quarter mile and plan housing for the half mile radial catchment area.

Figure 2.5. Ridership and catchment area radius - Source (Guerra & alt. (2012).



Densification as the main principle in planning TOD has been successfully used in retrofitting existing low dense suburban business parks to a more compact urban form (Booth & Leonard, 2002;Calthrope P. , 2010;Dunham-Jones & Williamson, 2009 ;Ditmarr and Ohland, 2004). These work destinations are low dense, clustered and single-use districts near freeway interchanges due to zoning restrictions. The additional densities as stipulated in the TOD model are used integrate them with transit adding footfall to their retail spaces and in particular, increased the value of their spaces (Booth & Leonard, 2002).

Figure 2.6. Densities for an urban TOD - source: Calthrope (1993).

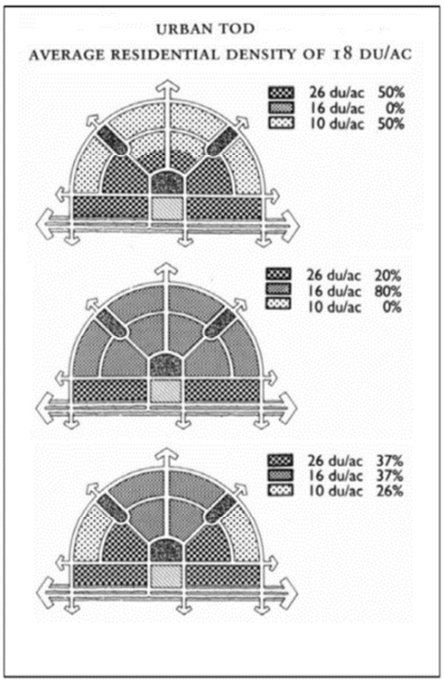
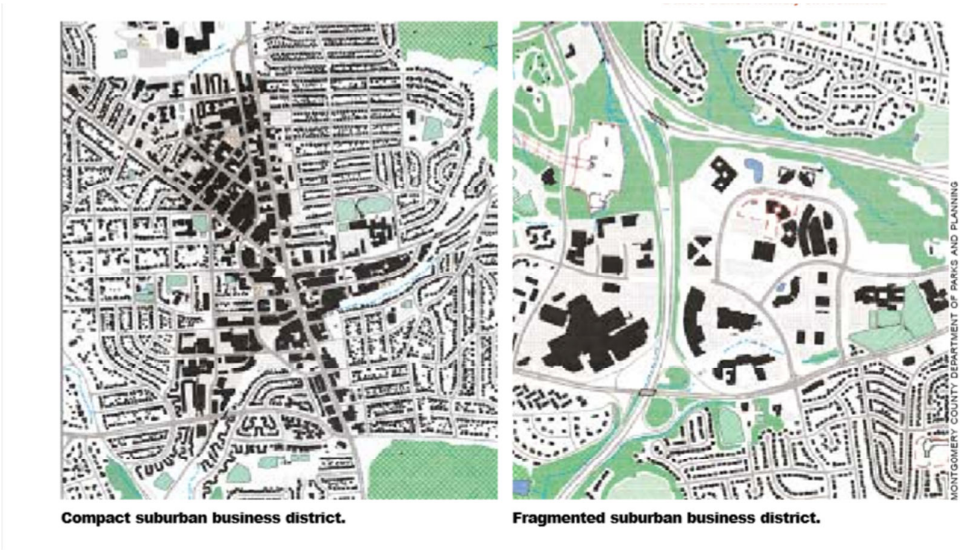


Figure 2.7. TOD and suburban business park - source (Booth & Leonard, 2002).



The implications of density on the urban design aspects of TOD and its sustainability are detailed below. In order to reinforce the identity of TOD while achieving acceptable densities within the 400m radius, the urban form of the TOD needs to be centred around the transit node .The compactness of the urban from is due to the limitation on its development radius – 400 to 800m . Densities will increase gradually from edge to centre, thus creating an urban form that can be linear or nodal depending on site constraints (Cervero, Ferrell, & Murphy, 2002).

Densities proposed in TOD need to be clearly structured in order to maintain legibility. The urban structure provides the backbone on which the different nodes of uses and activities are distributed within the overall catchment radius area. Nodes' legibility within dense environments contributes to the distinctiveness of dense urban form and thus reinforces the identity of TOD's. Lynch (1960) considers nodes as spaces

that people usually relate to, especially if they need to change uses or modes of transport such as crossing a street or performing a particular activity. He particularly emphasizes nodes as a tool to structure the image of the urban space, mentally in how it is perceived and physically in how it is experienced (Lynch 1960).

Research on density linked the resulting intensification of use to the economic viability of the project. First, higher vertical and horizontal intensification of use increases site activities; and thus increases the demand on different services such as retail, education, health and daily needs. Construction costs of infrastructure provision are lessened due to economies of scale and cost sharing such as basement car parking construction. In particular, operational costs such as community maintenance fees due to its distribution among multiple users are significantly lessened. Land value increases depending on density allowance and transit proximity (Calthrope, 2010). Public agencies, local councils and developers depend on this value increase in order to cover development and construction costs (American Planning Association, 2006).Density encourages positive interaction between residents and improves the viability and access to shared community services, providing the necessary population concentration for its sustenance (Dempsey & Bramley, 2012).

In conclusion, Transit-Oriented Development uses are concentrated around rail and bus stations within a radius ranging from 200 till 800 m. Studies show the importance of concentrating offices within 200m and residential beyond 200m. Density, regardless of the use, diffuses as we go farther from the station. Thus, a clear structure - whether radial or linear - punctuated by activities and using nodes will enhance TOD identity and legibility. Density is an essential driver of the economic vitality of TOD in suburban setting.

3. Diversity

Densifying low dense suburban environments enables the intensification of uses and activities. This intensification needs to be paired with a diversification of uses and groups in order to increase transit ridership. Current studies have identified empirical evidence on the mixity of uses conducive to increasing transit ridership. Community Diversity in TOD is equally important (Suzuki, Cervero and Luchi 2013;Fainstein 2005 ;Talen 2006). The current literature refers to specific design criteria, planning and public policy tools in order to provide diverse spaces for multiple social groupings of different races, ethnicities, genders, ages, occupations, and households; and preserves it during the development process. This section lists the urban design tools to achieve diversity of uses and of social groups.

a. Use Diversity

Mixing uses in TOD increase the number of passengers taking transit especially if mixing is intense at transit stations surrounding urban spaces.

First, people drive less when they can meet most of their daily needs in nearby places to their residence. At suburban business centres, the availability of community services, restaurants and other uses reduces the need of employees to drive for their breaks or errands. Mixing use in suburban developments increases transit usage by an average of 3.5 percent compared to mono-functional suburban business campus (Cervero, Ferrell & Murphy ,2002). In addition, mixing use encourages ‘bi-directional flow’- an important factor included in modelling transit. As each use becomes both an origin for a journey and a destination for another, people choose more to walk or cycle on their way (Cervero 1996;Bernick and Cervero 1997;Ceverro 1998).

Different Studies for TOD listed retail co-location with residential and office use as an important factor of increasing transit ridership. This co-location facilitates trip chaining – combining more than one destination in each trip (for example, by going to the hardware store and the grocery store on the way home from work, rather than making a separate trip for each of these destinations). Mixing housing and office use next to transit node encourages both residents and office workers to use transit and thus increase station ridership. For example, in the case of the Silver Spring Metro office complex Centre, situated at 60 m from the Metrorail portal, 52% of workers who lived in Washington, D.C., chose to commute through rail to reach it (Translink,2014).

Transit ridership is particularly sensitive to an increase in commercial use around the transit stations and in the site area. An analysis of different TOD found that locating employment near a rapid transit station increased ridership and decreased auto trips.(Jun ,2008;Chen, Chen, & Barry, 2008;Badoe & Miller, 2000).

The implications of use diversity on the urban design aspects of TOD and their sustainability are detailed below.

Mixing of retail and office use at the core near transit station increase transit ridership and shape the identity of the development. TOD design guideline manuals consistently list commercial uses as preferred at the TOD core consisting of ground-floor retail, offices, restaurants, and consumer services, like bakeries and convenience shops. TOD design guidelines do not specify the type of commercial and retail uses; it depends on the existing development patterns and community needs (Calthorpe 1993;Ewing 1997).

Retail outlets need to be concentrated around the immediate pedestrian pathways leading to the transit node: one can pick up grocery after a long day at work or

meet a friend at a coffee shop before going home. Retail around transit support TOD financially; Chicago's Union Station, the second busiest railroad station in the United States, is surrounded by locally owned businesses. The station's food retailers generated more than $12.5 million in sales, one of the highest retail sales (Cervero R., 2004).

Mixed use in TOD within the suburban setting contributes to social and economic sustainability. First, buildings of different use parking reducing overall parking construction and maintenance expenses, increasing its profitability. Each land use has also different criteria for its infrastructure; road access, water consumption and other systems operate at different peaks in different times of the day and week - thus reducing infrastructure loads and facility sizing. Retail shops and consumer services activate the development on weekends and afternoons; and generate off-peak and weekend trips activating transit stations. As all-day, all-week trip generators to transit, they improve the cost-effectiveness of expensive station construction investments; thus contributing to its economic sustainability (Calthrope, 2010).

Different urban design tools ensure mixed uses in TOD. Mixing in the dense core can be vertical with retail on the ground: commercial in the first three floors and then residential on top. Mixing uses and activities can be horizontal on the block level where a part of the block is residential and another one is commercial. Mixing also can be on a district level different; buildings on the same street corridors might have different uses. Building typologies and block guidelines guide private developers in order to respect intended mix.

TOD literature on diversity does not expand on the types of night activities in ensuring the activation of urban spaces throughout the day and week increasing their livability and financial sustainability. Cultural facilities (such as art galleries),

entertainment venues (such as jazz cafes) or hospitality services (such as furnished apartments or boutique hotels) can animate at night the core in proximity to transit. First, it encourages residents to walk to these venues at night and thus, animates streets and increases safety at night. Regionally, locating them within walking distance from the transit attracts city-wide audience to use it as a mean to access these venues, thus operating stations off-peak hours.

b. Community Diversity

Community diversity is defined as when "people with different demographic, socio-economic, cultural, employment and visitor characteristics live in an inclusive, interactive and harmonious manner."(Queensland, 2010b, p.7)

An extensive literature review on community diversity in TOD, sponsored by the Queensland government in 2010, is one of the few international studies to research diversity in TOD's. [2], the study points out to nine key factors in promoting community diversity based on reviewing multiple international case studies across different continents.(See Table 2.1).

First, the new proposed urban form and land use of the development needs to respect and relate to the existing community hubs. In addition, the new hubs might host shared community services and facilities among diverse residential clusters, increasing social interaction between its residents. The proposed hubs integrate with the transit station encouraging diverse groups to live near transit.

[2] Queensland is the third largest state in Australia attracting migrants and different ethnicities which is similar to Dubai .

Table 2.1. Diverse Groups Living and Working in TOD - Source: Queensland (2010).

Demographically diverse groups	
Age	Children (preschool (0–4 years) middle childhood (5–9) early teens (10–14)
	Young people (15–19)
	Young adults (20–29)
	Mature adults (30–54)
	Empty nesters (typically 55–64)
	Older people (65+)
Household/ family composition	Nuclear families (2 parents with child/children)
	Single-parent families
	Couples
	Large (including extended) families
	Single people (of all ages)
	Group households (unrelated individuals sharing a dwelling)
Other demographic characteristics	Disability
	Gender
	Alternative lifestyle (e.g. eco-villagers)
Socio-economically diverse groups	
	Middle- and high-income groups
	Low-income groups
	Renters
	Homeowners
	Homeless people
	Pensioners and self-funded retirees
Culturally and linguistically diverse groups	
	Established and recent immigrants
	Refugees
	Indigenous (i.e. Aboriginal and Torres Strait Islander) people
	Religious groups
Workforce groups	
	Students
	Key workers
	Temporary workers (seasonal and holiday workers)
	Home workers
	Other workforce groups
	Unemployed workers

Second, diversity of residential units and types is highlighted as one of the main strategies of social diversity. A mixed, diverse housing stock with a variety of housing types, ownership schemes and prices attracts residents from diverse social and economic background. In most of the case studies reviewed, the development incentives preserve the affordability of a part of the housing stock.

Third, the guide specified that the inclusion of facilities for different age groups and disability levels encourages spontaneous and organised social contact. Providing communal spaces and facilities in TOD (such as shared gardens or foyers) motivate different groups to share the same space.

Fourth, building a quality public realm depends on the provision of a network of spaces that promotes more physical activity in TOD; public spaces need to be flexible and versatile. Fifth, different and mixed employment opportunities result from allowing different commercial facilities sizes. The guide noted that social diversity in TOD depends also on selecting site activities which are complementary or supportive to the existing local businesses. The provision of different types of jobs next to the transit station attracts different income groups and sustains the diversity of existing communities.

Sixth, the guide mentions that formal and informal spaces in TOD provide opportunities for different ethnicities and groups to express themselves such as hosting a new cluster of restaurants and shops showcasing traditional ethnic cuisines. Cultural diversity celebrates different interests of the community.

Seventh, retail spaces sizing within TOD needs to support local and small businesses through the provision of an array of shops sizes at different locations.

Financial incentives support retail diversity through discounted rent rates or lease grace period.

Eighth, the guide stressed on the fact that early community engagement in the design process ensures that TOD meets the expectations of the community it is serving. The earlier community engagement was, the more robust the results of such engagement would yield in strengthening community diversity and future-proof it against possible gentrification.

Last, the study concludes that diversity in housing typologies is the most optimum strategy to encourage diversity in communities based on five international TOD award-winning schemes from North America and Australia. Housing diversity attracts mixed-income households and different types of households – families and older people.

The implications of community diversity on the urban design aspects of TOD and its sustainability are detailed below.

First, public spaces network in TOD need to be diverse in types and sizes in order to host various events and programs e.g. celebrating community cultural diversity and promoting social interaction across various groups. The connectivity between the latter and the existing and proposed community spaces is strengthened through providing safe and convenient pedestrian access. Its parks and open spaces accommodate different range of activities such as social activities (e.g. meeting, talking, markets, and community events), recreation activities (e.g. pleasure, exercise, play, sport).

Second, fine grained network animates the streets and is associated with street retail use, supporting local businesses. Specifying minimum and maximum street retail frontage activates streets and thus contributes to their liveability as linear public spaces.

Third, different housing typologies accommodate multiple social groups meeting their needs for a variety of space programs. For example, the addition of small apartments above small offices might be more suitable for start-up owners and young entrepreneurs who will financially benefit of the reduction of transport costs.

Fourth, the provision of community services and facilities such as library, day care centre, health clinic, senior centres supports housing diversity. Different services cater for different social groups. The presence of grocery and convenience stores within walking distance from transit and homes encourages people with fewer means such as low-income families, elderly or university students to relocate for they can walk or use local bus to get there.

In conclusion, mixing uses in proximity to transit station, designing diverse housing typologies, community amenities and public spaces promote use diversity and community diversity which in turn contribute to the sustainability of TOD.

4. Design-Walkability and Public Realm

Current research considers that the provision of a sound pedestrian system connecting a network of civic and public space to the transit station is the central theme of any urban design strategies for TOD (Dittmar and potticha 2004).The current TOD urban design literature mostly lists the design criteria of pedestrian areas contributing to walkability. (Bernick and Cervero 1997; Ewing & Cervero, 2010)

Current TOD planning practice recommends a 400 to 800 meter radius as the pedestrian catchment area for transit service (Translink, 2014 ;Gueraa, Cervero, &

Tischker, 2012).For local stop transit service, a 400-meter pedestrian catchment area is often used, representing a 5-minute walking distance. For rapid transit, an 800-meter pedestrian catchment area to transit is generally used, representing a 10-minute walking distance. An Australian study examines walking patterns across five transit stations in Perth and reveals that 55 per cent of transit passengers walked more than one kilometer away (Ker and Gin 2003).Pikora (2003) attributes people willingness to walk longer distances to reach transit to the design of the pedestrian network.

The specific urban design aspects of designing for walkability in TOD are detailed below.

Public realm Design for TOD is based on ensuring safe and direct access through foot paths, cycle paths, and streets to transit stations and to the surrounding civic spaces (Suzuki, Cervero and Luchi 2013).Public realm network in TOD also depends on the connectivity of the proposed pedestrian and bicycle networks to site uses as points of origins and destinations for daily trips and to the civic spaces surrounding the transit node (loukaitou-Sideris 2004). The continuity of the network supports also a continuous network of sidewalks wide enough to accommodate anticipated levels of pedestrian traffic. Walkable sidewalks need to be safe visible and provide direct access to core commercial areas and transit stops (Carmona, Heath, Oc, & Tiesdell, 2003).

However, the provision of a pedestrian network connected to open spaces network is not sufficient to encourage walkability. Additional urban form and circulation networks tools make sure that public spaces and pedestrian walkways are accessible, well-defined and legible.

First, 'Complete streets' is a tool that contribute to the legibility and accessibility of pedestrian network. It promotes streets that are designed to allow transit, cycling and

walking spaces to run parallel to car circulation. Streets can be retrofitted to more ‘’complete’’ using different tactics such as widening the sidewalks, adding crosswalks and including exclusive lanes for bikes and transit (Iaplante and McCann 2008).

Second, Pedestrian networks legibility is enhanced through the use of fine-grained street patterns. Current studies dismiss the cul-de-sacs and curvilinear streets since they reduce bus ridership and increase their trip length and time (Cervero and Bernick 1997). So, TOD streets adopt a grid pattern proved to increase transit-usage levels increase by 20% (Cervero, 2002; Ewing and Cervero, 2010; Seigman, 2003).Moreover, the frequency of street pedestrian crossings ensure safe, convenient, and frequent pedestrian circulation to the transit station (Rodriguez and joo 2004).The placement of street crossing is tactical;placing street crossings to connect major pedestrian paths on both sides of the road would also increase connectivity across the site, specially if the latter lead further to activity nodes and proposed community hubs.

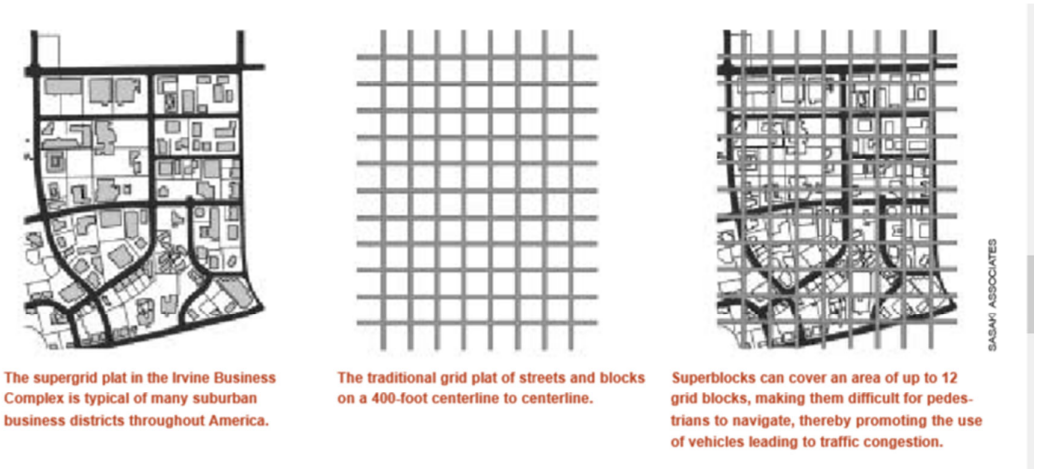
Third, Blocks lengths affect walkability. Different design tools shorten long blocks such as using minimal building setbacks or inserting pedestrian shortcuts. Ped sheds are tools to assess urban blocks length. Figure 2.8 shows how the suburban superblock in Irvine business complex covers about 12 grid blocks –i.e. about 4800 feet (1600 m) – which is 12 times longer than the standard of 400 feet (200 m) ped-shed for walkable neighbourhoods.

Fourth, walkability in TOD depends also on human scale. Breaking down the usual high densities in the commercial core into human scaled spaces encourages pedestrian circulation and enliven streets. Different strategies can be used depending on the nature of a TOD. In city centres, high-rise buildings could be wrapped up with ground-floor retail. Such solution needs to be evaluated in the context of hot and humid

climate. In town centres, midrise buildings could be integrated into a block system that respect the pedestrian walkable distance while allowing efficient building footprints to financially sustain the development. In particular, for suburban districts, streets frontage guidelines can easily guide to favour a pedestrian-friendly side of the office development on the main streets and services as well as parking on the service roads. Planning shared parking and structured parking mitigates the separations typically created by large surface parking (Calthrope 2010). Additional measures reinforce human scale in suburban districts of TOD such as the reduction of parking regulations in buildings within 200 m of transit stations. Reducing parking requirements reduces parking structures on streets and enables more uses and activities to be placed on street level (Booth 1983).

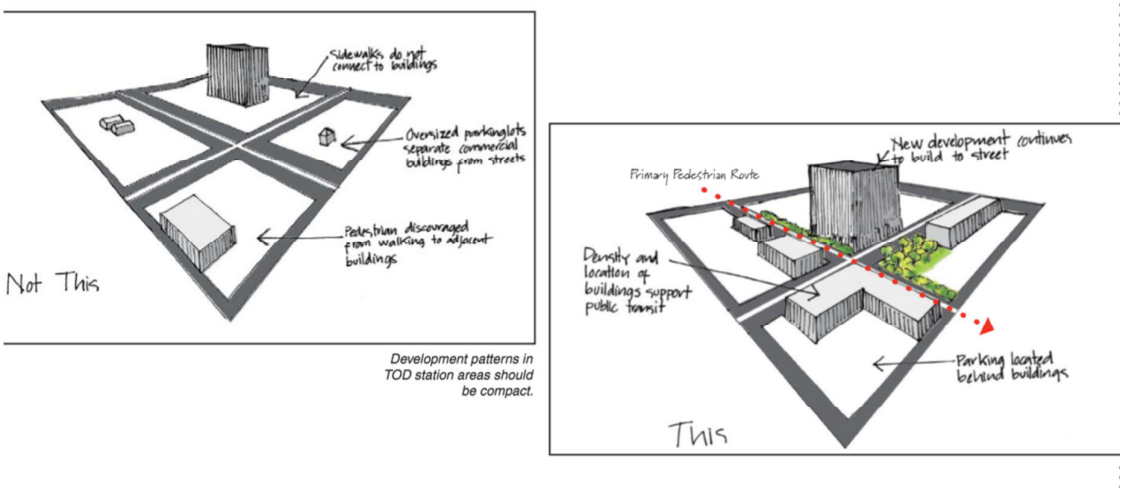
Fifth, Buildings orientation affects enclosure, an important element in creating a comfortable outdoor environment. Buildings oriented to the street coupled with reduced setbacks activate street fronts, provide visual enclosure and thus enhance walkability (Ewing, 2010).

Figure 2.8. Superblocks and Walkability.



In particular, buildings need to frame public spaces increasing their 'positivity'. Public space identity is physically defined by buildings boundaries, plots and the residual space (Bently, 1991). In the absence of concerns for the space between buildings, public space becomes accidental and residual (Trancik, 1986).Its boundaries are not defined and disconnected from the built space - hence they become less walkable. Urban design strategies such as densification and designing a connected web of buildings and streets contribute to "Positive Space" - a public space characterised by a defined and distinctive shape and definite boundaries (Carmona &alt., 2003). Figure 2.9 shows how the positivity of the space increases as it is more enclosed by the vertical and horizontal relationship between the surrounding buildings (Booth 1983).Also, a varied perimeter block buildings with indentations and projections in building facades create sub-spaces that are more intimate and maximize the ‘positivity ‘of public spaces. Dominant volumes maintain a sense of direction within TOD neighbourhoods designed using the perimeter blocks morphology.

Figure 2.9. Positive space as a result of relating buildings to each other and using a dominant volume – Source: Calgary TOD guidelines.



In Conclusion, walkability in TOD demands the placement of major uses within 400m of transit stations. TOD literature has emphasized the provision of sidewalks and an integrated pedestrian network. In addition to designing an integrated pedestrian network, urban design tools such as complete streets, blocks design, Grid Street patterns, building orientation and positive space enhance the legibility of the urban fabric and thus increase walkability.

5. Time

TOD was always linked to the New Urbanism movement camps lead by Andres Duany and Elisabeth Plater-Zyberk from the East Coast of United States and Peter Calthrope on its west coast. DPZ- nickname of husband and wife team Andres Duany and Elizabeth–use the traditional neighbourhood units model inspired by ‘’garden cities’’ and theories of the ‘city beautiful ‘movement in the late nineteenth and early twentieth century . Their design process is based on town planning principles and thus each of their communities – such as seaside –Florida streets, buildings, blocks and green spaces are meticulously controlled through detailed design codes booklets (Katz, Scully, & Bressi, 1994).Peter Calthrope focuses more on researching urbanism as a way to build ecologically-sensitive, pedestrian –friendly spaces. Still, his design solutions rely on ‘’historical precedents’’, criticised for creating a nostalgic townscape and an imagery that is controlled through controls and does not change over time.

Although many studies acknowledge that Transit oriented developments are gradually built, little emphasis was given on their design’s resilience to change how the development of TOD urban form, massing, public space network functioning and programming respond to Time (Jacobson 2008). Ditmar and Postiche (2004; p. 32) call

this “Design for change”; design that is flexible to adapt to changes in programs, built form and surrounding site forces.

In his book on ‘suburban transformations’, Paul Lukez (2007) stated the above concerns and concluded that further experimentation was needed to generate new identities that are unique to site and evolve over time. In the intention of mining suburban narratives to find building typologies that were contemporary yet timeless in their evolution over time, he proposed alternative principles to guide suburban development under Adaptive Design Process:

1- Evolving identity over applied identity
2- Rooted to place over absent to place
3- Historical versus A-historical
4- Temporal versus A-temporal
5- Acquired meaning over marketed meaning
6- Community as Place versus Community as Commodity

These principles allow for the search for the right fit defined in his book as ‘’urban form matched to place or circumstance which can only happens over time’’.Thus, mapping as a process of tracing the different elements of the suburb through time and using urban morphologists tools would lead to a complex understanding of the space features that define its uniqueness and then engaging time to produce a ‘’flexible, adaptable, resilient’’ urban tissue.

It is an alternative approach that uses time as a birthplace for urban form and yet once born, a force that would also shape it. This approach is more moderate in considering suburbs as narrative spaces that are not ‘’foster ‘’ kids of the ‘’illegal ‘’ union of private development and car dependence but as ‘’creations’’ worth of being

acknowledged as having their unique code and origins. Also, the hybrid relationships of uses with forms and spaces might not have historical precedents but might be historical in the sense of its ability to adapt to time.

6. Summary of TOD Urban Design Tools

In this section, the existing TOD literature on density, diversity and design is reviewed and expanded in order to propose a comprehensive set of urban design tools. The below table (Table 2. 2) summarizes this review listing the tools, their benefits and the sustainability pillar they contribute to.

Table 2.2. Summary of Urban Design Tools of TOD.

Principle	Urban Design Tool	Associated benefits	Sustainability
Density (concentration of jobs and dwelling units around transit)	Compact urban form (400-800m) Dense core of Commercial uses around transit station Radial or linear structure with gradual decrease of densities above 200m from transit node Legible structure supporting nodes of uses and activities	Legibility Identity Legibility Identity	Economic Vitality
Diversity (mixed Uses)	Mixing Retail and commercial use within 200 of transit node Structure mixed use areas as nodes Linking retail to major bus routes and pedestrian paths near transit node	Intensification of programs around transit Bi-directional flow from/to transit node Active street fronts Vibrant neighborhoods	Economic Vitality
Diversity (diverse social groups)	Diversity of housing typologies Social infrastructure to support residents needs Diverse types of public spaces (sizes and function) Diverse retail and office typologies	Diversity of Residents profiles Attract low mobility groups and families Social interaction Cultural ethnic expressions through programs and events Multiple sizes of retail and commercial companies Active street fronts	Social Diversity
Walkability and Public realm	Continuous network of green and open public spaces leading to transit stations Complete Streets and Grid fine-grained street patterns Short perimeter dense blocks with buildings oriented to the street buildings facades indentations buildings setback from sidewalk Human scale of urban form on street level	Continuity and Connectivity of open spaces networks Accessibility of transit station to residents, employees and visitors Accessibility enclosure Positive public space Legibility Safety	Environmental Integrity Social Diversity
Time (Design Development through time)	Phasing Flexible, resilient ,adaptable urban tissue Time as shaper of urban form Hybrid uses, forms and spaces	Resilience of proposed TOD Adapt proposed typologies to different site forces Contemporary response to 'new urbanism'	Economic Vitality Environmental Integrity

C. Transit Oriented Development and Hot Climate

Responding to local climate makes TOD more environmentally and financially sustainable. Climate responsive TOD uses passive design strategies to reduce their energy demands, increases their vitality and maintains street and open spaces activities in all seasons. In fact, Calthrope (2010) supported "passive urbanism" that "focuses on ends of city systems not means"(p: 18). It is aligned with reduction of resources use through compactness - the main-objective of transit oriented development. In fact, according to research undertaken by Calthrope (2010), townhouses within communities designed according to passive design methods consume less energy than townhouses that have undergone an environmental technological retrofit such as weathering and greening.

Although TOD model is always presented as environmentally sustainable, their applicability to different climates is rarely addressed. Most transportation and urban planning studies of TOD have been limited to cities in more temperate climates, such as San Francisco, Seattle, and Portland, Oregon (Saelens 2003).General walkability, planning, transportation and neighbourhood design studies rarely analyses the impact of climate on the distance one can walk, cycle or run (Kashef 2010;Ewing, Handy, et al. 2006;O'hare 2006;Saelens, Sallis and Frank 2003;Ash, et al. 2009;Saelens 2003; Besser and Dannenberg 2005).

Limitations to the study of climate considerations of hot and humid climate on density and walkability might be linked to the perception that such climates lead to automobile dependence. Newman and Kenworthy (2000) denounces it as a myth. Actually, gasoline consumption and average annual temperature do not impact transit ridership, taking Barcelona as an example of a dense, transit-oriented city despite its hot

weather during summer. They state that "The use of transit seems to be also related to more than just climate. All our Data show that it depends on how fast transit is relative to cars, how frequently it comes and how easy it is to get to. If low-density planning and high car use are encouraged in a city, it is probably for reasons deeper than lifestyle induced by climate.'(p.234)

As such, this section proposes specific design measures that are responsive to hot and humid climate and proposes an alternative TOD model based on them.

1. Recent Research on Climate-Responsive Design Measure

The generic transit oriented model depends on a catchment radius of 200 to 800 m. O'Hare (2006) questions the usefulness of the half mile radius (400m) of a transit station as a walkability standard since it was only tested in temperate cities.

Devoeu (2011), based on an analysis of thermal comfort in sub-tropical climate, has recommended changing the transit core radius to 240 m as the maximum distance one can walk without being affected by skin wetness, humidity and extreme summer heat conditions. The new distance is termed "comfort shed". Also, O'Hare (2006) recommends other design strategies such as placing sidewalk awnings at 100 to 200 meter intervals along walkways to provide shaded areas for pedestrians. Abbate (2005) proposes a continuous network of deep overhangs and canopies surrounding buildings. In conclusion, most studies recommend that designing TOD in hot and humid climate require a breakdown of the classic 200m walking distance into segments of 70-100m in order to enable comfort during high summer temperatures.

Also, based on the analysis on walkability, these segments ends function might be designed as semi-public spaces that would provide thermal comfort and rest periods between pedestrian trips.

The interaction between climate and TOD is a two-way relationship: climate impacts TOD which in turn creates a "microclimate" or a small area that has different climatic conditions than its surroundings. Studies revealed that urban form heavily influences ambient temperature in microclimate. Urban design tools such as building and street orientation, enclosure ratios and density distribution in TOD promote natural ventilation - lowering both humidity and temperature. Shading through buildings, structures and vegetation heavily influences microclimate of TOD in hot and humid cities (Bekele 2008).

a. Natural Ventilation

Wind-tunnel tests are used on different orientation and placement of buildings in order to determine the optimal urban form to promote air circulation and breezes in urban areas (Bekele, Jones and Rajamani 2008).These recommendations can be adopted as climate responsive urban design criteria for TOD.

The study recommends the orientation of buildings at a 45 degree angle to prevailing winds: Orienting buildings in TOD parallel to prevailing winds puts most buildings not directly facing the incoming winds under "negative pressure", a channelling effect that reduces air circulation around buildings. A 45-degree orientation creates both positive and negative air pressures, allowing breezes to be carried around buildings and promoting circulation at all street levels.

The placement of tall buildings between prevailing winds and the rest of the district needs to be avoided because high-rise towers can block prevailing winds before they move into the area. When placed directly in the line of prevailing winds, tall buildings create air movement on their windward sides while causing decreased air movement on their leeward sides due to a "shielding effect". For TOD, most of the tall

buildings concentrated around the transit node need to be oriented 45 degrees with the direction of prevailing winds.

Using relatively narrow streets in TOD promotes air circulation. The study recommends varying building heights in relation to street widths across the different areas of a district in order to further promote circulation. The gradual increase of spaces between buildings and of heights across the neighbourhood allows more air to flow and consequently cause the dispersion of air pollutants (Goncalves and Duarte 2008).

b. Shading and greening

Vegetation, street trees, narrow streets, north-west oriented buildings, semi-public spaces and structures can lower ambient temperature and provide the necessary shading to conserve walkability in TOD all year/seasons around. The use of passive design strategies for shading provides cooling-island effect which is more environmentally friendly (Goncalves and Duarte 2008; Sun and Chen, 2012; Bowler et al., 2010; Abdullah et al.2011; Chang et al., 2007;Makamuri, et al. 1999)

Lowering ambient temperature is essential in hot summer days to encourage walkability to transit, and consequently increase station ridership in summer. Greening reduces ambient temperature up to 5 degrees Celsius ambient temperature (Sham, 1990; Wong and Yu, 2005; Chang, 2007). Meanwhile, Bowler et al. (2010) also observes that urban greening through short vegetation like shrubs and grass helps as well in reducing ambient temperature through its evaporative mechanism (Abbate ,2005).

Greening through natural vegetation in TOD provides shade as well (luxmoore, jayasinghe and mahendran ,2004;Abbate ,2005;Goncalves and Duarte ,2008).Greening through trees on major pedestrian walkways leading to transit must be placed close together and favour species that limit sun rays to the greatest extent possible while still

allowing for air flow close to the ground (Devoeu 2011).Street trees provide an added benefit of creating visual enclosure, increasing pedestrian network legibility and activity on street level (Ewing 1999). Street trees also contribute to enhancing the quality of the public realm; a factor highly associated with increasing transit ridership in TOD.

However, the extensive use of vegetation such as trees, shrubs and grass increases irrigation water demands which pauses environmental challenges for TOD in desert climates. Thus, the selection of vegetation should consider more native and ecologically restorative types which possess large canopies and are friendly to drought climate. In addition, the uses of native vegetation facilitate the adaptation to local climate and reduce the cost of maintenance - eventually increasing TOD's economic sustainability.

The use of green shading structures in TOD thus reduces energy needs. Façade planting ,green trellis and pergolas attached close to buildings play an important role, as they dissipate heat from building skin and improve microclimate adjacent to buildings (Sandifer,2009).Green shading structures may also become an urban design element reinforcing TOD identity.

In addition to vegetation, the built environment can itself be a source of shading for surrounding open spaces. Buildings framing narrow streets in TOD provide continuous shading to sidewalks provided that existing streets are oriented to the North/South direction. In cases where existing streets could not be oriented to north south direction, various structures such as arcades, awnings, breezeways, canopies, overhangs, and verandas can provide shaded areas in comfort sheds. Building typology and landscape design guidelines in TOD can encourage their use and those of verandas

and arcades as shading spaces, forming a boundary between interior and exterior space as well as creating links between blocks and reinforcing permeability (bajrchaya 2008).

2. Summary of Design Measures for Hot and Humid Climate

Based on the above, a climate responsive TOD for hot climate should respect the below mentioned points:

1- Reduced walking distances as function of 100 m – length found bearable in extreme temperatures and climate conditions
2- Semi-public spaces need to be located at the start and end of walkable segments such as arcades, awnings, breezeways, canopies, overhangs and verandas
3- Climate responsive buildings and urban form that maximize ventilation and shading through defined street frontage guidelines, and while accommodating a variety of ground flow expressions and block typologies favouring perimeter block surrounding courtyards and broken down in response to wind direction
4- Shading open pedestrian network in order to provide thermal comfort as a way to drive walkability
5- Greening that would act as a microclimate element in reducing urban heat – encouraged through urban design guidelines

D. Proposed Alternative TOD Model for Hot Climate

Recent research in Australia emphasized the needs for a place-sensitive climate responsive TOD mode. In fact, Bajrchaya (2008) reviewed major advances in subtropical passive design for five categories (Lifestyle, Public Realm, Architecture, Transport, Landscaping and Sustainability) and established a planning framework to guide a more "Place-sensitive" TOD (bajrchaya 2008). During a recent World Bank

report (2013) on transit and land use integration, cities that did not yet build Transit Oriented Development were encouraged to develop a TOD prototype designed to their specific context.

1. Alternative Climate Responsive TOD Model for hot climate

Based on the above recommendations, the current transit oriented model proposed and applied for American and European context needs to be revised, otherwise it will not be an impactful tool of sustainable development.

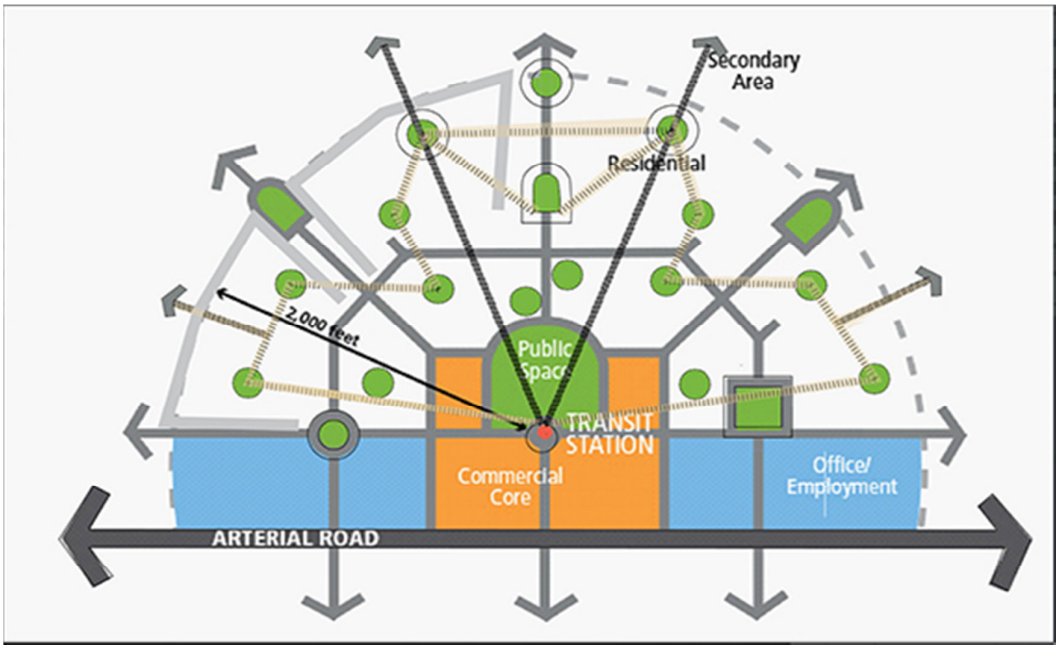
The main changes to the transit oriented model are not the development intensification. In fact, the development radius – as studied in our literature review on density and diversity -has been thoroughly tested in various contexts to build the adequate densities, uses and networks supporting transit ridership and eventually the maintenance of the transit point as a node and as a place (Suzuki, Cervero and Luchi 2013).

However, this study proposes the breaking down of the pedestrian networks covering the development catchment area into manageable segments of 100 m comfort - sheds strategically located at secondary and tertiary nodes of activities. Nodes could take many forms such as shaded patios, semi-public courtyard, indoor public atrium, semi-covered plazas, sunken squares or pocket parks adjacent to a building entry. At particular points, these nodes can be climatic controlled environments that are creatively designed as destination points and distinguished to emphasize important street intersections.

In addition, the alternative model is organised around an interconnected system of open space and courtyard to maximize summer breeze and provide shaded areas.

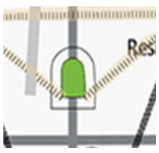
Wind Cooling will also be used through the creation of wind corridors adjacent to high vertical surfaces and horizontal surfaces.[3]

Figure 2.10. The proposed alternative climate responsive TOD model diagram – adapted from Calthrope (1993).

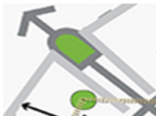


Nodes every 75-120 m :

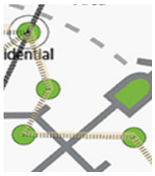
Climate responsive nodes typologies are shaded patios, semi-public courtyard, indoor public atrium, semi-covered plazas, sunken squares or pocket parks adjacent to a building entry, seating areas under awnings, forecourts, arcades,



Gathering spaces every 200m:
Enclosed Squares and courtyards of diverse uses, sizes and functions



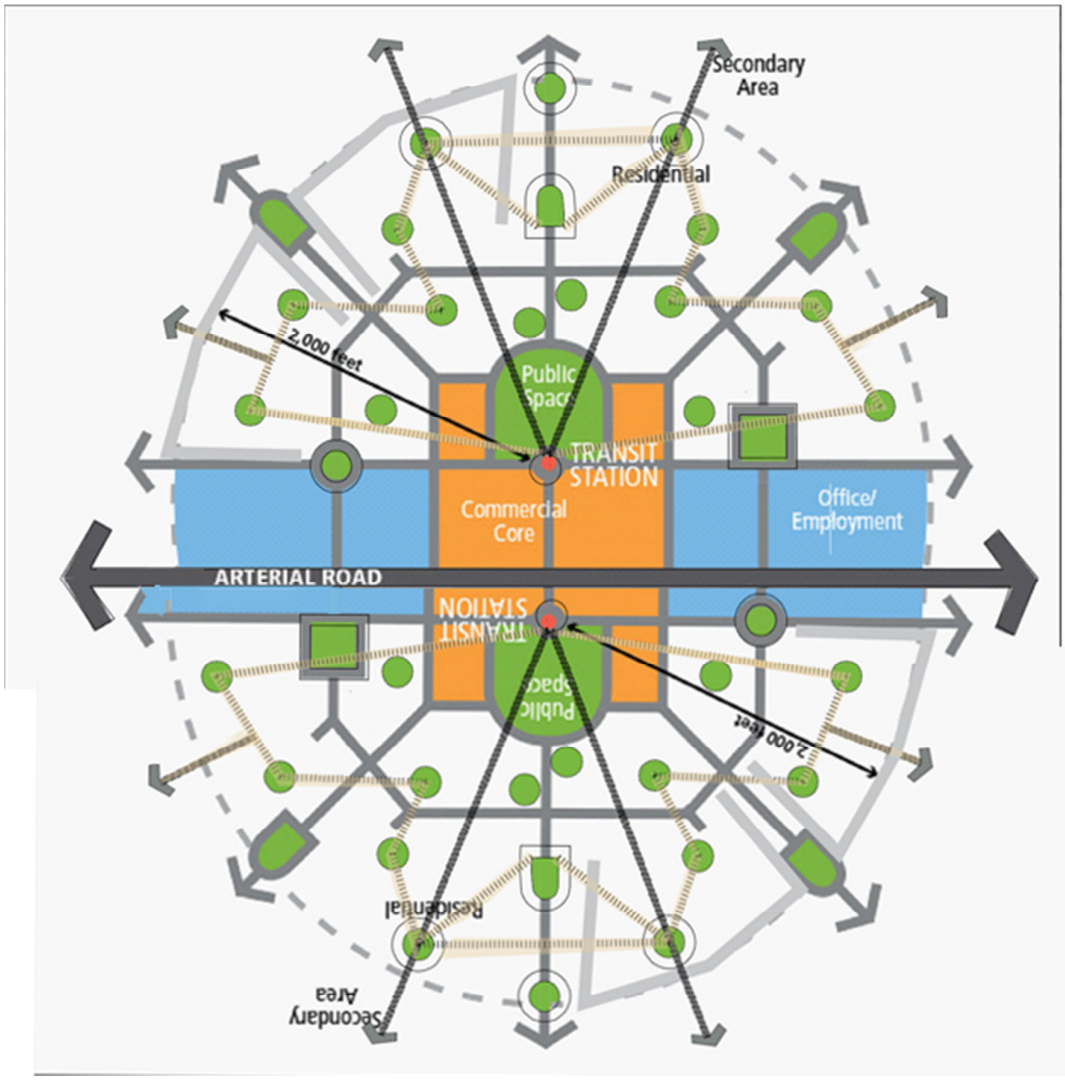
Create wind corridors through enclosure, edging, and passageways:



Main primary shaded pedestrian spine with continuous tree canopies connect nodes and gathering spaces, and converge secondary pedestrian to the transit node
Climate responsive typologies of pedestrian paths are sidewalks of narrow enclosed streets, alleys, streets with continuous tree canopies, linear shade structure, and indoor linear semi-public spaces

[3] See Dubai analysis Chapter – Dubai Urbanisation section

Figure 2.11. TOD proposed diagram for a self-contained development.



2. Toolkit for the Alternative Climate Responsive Transit Oriented Development Model for Hot Climate

The TOD generic universal model is subject to climate realities of the Arab World proposing an alternative TOD model that could be applied to the gulf countries characterised by hot and humid climate.

|The urban design framework used in the study is proposed by Saliba (2015) in his book on urban design in the Arab world. Saliba (2015) describes the diversity that one faces when defining 'Arab world' as an area that needs to reformulate urban design tools in the context of the specificity of each of its contexts. He perceives such diversity as a womb of which emerges "a multiplicity of opportunities for shaping, upgrading, and rebuilding urban form and civic space while subjecting global paradigms to regional and local realities". He proposes to frame these opportunities using five generic dimensions – identity, ecology, infrastructure, public space and private development. Within these five generic dimensions, it is important to note the accessibility to transit is one of the main objectives regarding infrastructure in TOD.

Accessibility remains the main purpose behind Transit oriented development as an infrastructural development. Further breakdowns are proposed in order to geographically position the proposed area of intervention on the urban 'continuum' (inner city, periphery, peri-urban, sub-urban) taking into account the ecological perspective out of which the position originates (market-centred, community-centred, conceptual–based or empirically-based) (Saliba,2015).

Current literature analyses of TOD project document the different planning and policies associated with the environmental sustainability of TOD (Cervero & Sullivan, 2011). However, it does not address the role of urban design in shaping urban form of

TOD that is economically, socially and environmentally sustainable. Based on the research and studies revealed above, the urban design toolkit specifies different urban design tools broken down into three dimensions based on the sustainable development model - economic vitality, social diversity and environmental integrity (Gilbert, et al. 1996).

The toolkit is structured in order to be read horizontally if one needs to strengthen an urban design dimension or vertically if a particular aspect of sustainability needs to be improved. The urban design implications of density in TOD affect mainly their economic sustainability. The extensive research on diversity in TOD guides the tools for social sustainability. The proposed new TOD diagram for hot climates is incorporated in the below urban design principles mainly under the environmental integrity section. For example, if one wants to reinforce identity through TOD, he can use only the tools listed on the toolkit sheet specific to Identity running across the three dimensions' pillars. If an area needs to be made more socially diverse through TOD, the tools listed in the five dimensions sheets under social sustainability would apply.

The Identity sheet focuses on the role of TOD as a prime orientation feature and thus use density, mixity and nodes in order to reinforce legibility and identity at city and district scales. The Infrastructure sheet focuses on the role of TOD as a pole of activity concentration and diffusion, and uses social infrastructure and extensive pedestrian network supported by fine grained urban structure to promote walkability to join social, cultural and commercial facilities**.** The Ecology sheets focuses on the role of TOD as generator of economic activity and uses urban design measures of compact urban form, diverse housing typologies and an extensive green space network linked to transit station in order to refocus growth, enhance social interaction and increase the use of

public transport. The Public space Sheet focuses on the TOD role as a large-scale development and lists urban design elements for public spaces and climate responsive design strategies in order to connect the network of existing streets and places to the transit node. The Private development sheet focuses on the role of TOD as a shaper of the urban form and thus puts forward criteria for phasing, typologies and blocks design.

Table 2.3. Toolkit for climate responsive TOD model.

		Sustainable Development Pillar					
		Economic Vitality		**Social Diversity**		**Environmental Integrity**	
Urban Design Dimension		**Urban design**	**Planning and programs**	**Urban design**	**Planning and programs**	**Urban design**	**Planning and programs**
	Identity	Transit as a point of density Convergence -Mixed use core -high density around transit node -density decrease away from transit node	TOD guidelines Zoning policies and incentives	Mixed use development -transit supportive uses -Mix horizontally and vertically -Mix to be determined according to surrounding and development need	Smart growth policies Zoning encouraging vertical and horizontal mixing of uses Lowering parking requirements for co-located uses Minimum non-residential use percentage in zoning Mixed use city wide studies	Break the 600 m catchment - 100 m segments - node at the origin and end of each segment - accommodate air-conditioned indoor gathering spaces at strategic locations	Research specific to the city on thermal comfort and distance travelled Financial incentives for maintaining the semi-public spaces Awareness campaigns for active lifestyle Architectural study on local heritage space typologies that were adopted to extreme weather conditions
		References Arrington & Cervero(2008)) (Cervero, Ferrell, & Murphy, 2002) (Calthrope, 1993) (Booth & Leonard, 2002)	**Case studies** Warner Center- Los Angeles Hammarby Sjostad Rio Vista West Florida TOD guidelines San Diego TOD guidelines Calgary TOD guidelines Singapore regional transit policy Guangzhou –china	**References** (Dempsey & Bramley, 2012) (Ditmarr & Ohland, 2004) (Cervero, 1996) (Jun, 2008) (Badoe & Miller, 2000) (Suzuki, Cervero, & Luchi, 2013)	**Case studies** Warner Center –Los Angeles Silver Spring , Maryland New city place, west palm beach, Florida Addison Circle Plan, Texas	**References** (Sung & Oh, 2011) (De Veau, 2011) Bowler (2010)	**Case studies** Ho Chi Minh City- China Hammarby Sjostad – Sweden Rio Vista West
	Ecology	**Urban design** compact urban form in a radius of 400 -600 m: building to plot edges vertical densities limited to strategic location	**Planning and programs** Urban growth boundary Land bank established near transit node for future TOD Zoning requirements Set Densities for different land uses that promote compactness	**Urban design** Diverse housing typologies building Social infrastructure to support it Civic uses and institutional services for the community	**Planning and programs** Affordability policies such as discretionary zoning Government assistance programs Participatory Planning Social infrastructure co-location in order to limit land requirements	**Urban design** Green spaces network connect transit to various location Conserve important local ecosystem and habitats	**Planning and programs** Greenways planning City-wide landscape framework City wide public realm guidelines Policy on ecosystem preservation for transportation projects Requirement for environmental impact assessment for TOD
		References (Seigman, 2003) (Guerra, Cervero, & Tischker, 2012) (Cevero, Howard/Stein-Hudson, & Zupan, 1995) (Suzuki, Cervero, & Luchi, 2013) (American Planning Association, 2006) (Dunham-Jones & Williamson, 2009)	**Case studies** Subi Centro Australia Rio Vista West Hammarby Sjostad - Sweden	**References** (Brinckerhoff, Quade, & Douglas, 1995) (Ewing & Florida, 1997) (Ewing, 1999) (Fainstein, 2005) (Ceverro R. , 1998) (Queensland, 2010)	**Case studies** Rio Vista West - San Diego Santa Clara Transit – San Diego Fruitvale , California River District, Portland ,Oregon East Perth, western Australia False Creek North, Vancouver Footscry, Victoria Cleveland ecoVillage , Ohio	**References** (Calthrope, 2010) (loukaitou-Sideris, 2004) (Bajracharya, O'Hare, & Byrne, 2010)	**Case studies** Hammarby Sjostad- Sweden Subi Centro – Australia
	Infrastructure	**Urban design** Plan a retail mixed use area community retail for residential neighborhood concentrate convenience stores around transit node, bus stops and on major pedestrian routes Introduce night time activities to increase transit use off-peak hours	**Planning and programs** Incentives for small retail business Permitting fees reduction for community retail Programming of events in order to attract city-wide population into retail	**Urban design** pedestrian and street network: Safe Convenient Comfortable fine-grained connected to nodes with active street fronts	**Planning and programs** Cycling master plans Community sports events for active lifestyle Integration of the design process between transport, roads and planning agencies Reducing ROW due to infrastructure oversizing	**Urban design** urban structure : fine -grained permeable transit as center enabling wind corridors urban blocks that are human-scaled	**Planning and programs** Intersection frequency guidelines to limit large blocks Zoning discouraging large urban block
		References Tumlin, Millard-Ball, Seigman, & Zucker, 2003	**Case studies** Warner Center- Los Angeles Chicago Union Station TOD San Diego Horton plaza	**References** (Ewing & Cervero, 2010) (Talen, 2006) (Bernick & Cervero, 1997) (Lund, 2006) (Translink, 2014) (Pikora, 2003)	**Case studies** Subi Centro- Australia	**References** (Booth & Leonard, 2002) (Dunham-Jones & Williamson, 2009) (Ditmarr & Ohland, 2004) (Calthrope, 2010) (Ewing R. &., 2010)	**Case studies** Hammarby- Sjostad - Sweden
	Public Space	**Urban design** Major civic place around transit Secondary civic spaces based on 18 hour activity Public space planned as positive space frame by buildings	**Planning and programs** Incentives for business who open off-peak hours Additional development rights in lieu of public space Operation and maintenance of public spaces Participatory planning	**Urban design** Diverse types of open spaces Age: children, elderly Type : residents , employees and visitors Function: Rest, Play, Exercise, Interact	**Planning and programs** Senior citizen public realm guidelines CPTED(Crime Prevention Through Environmental design) policy Financial plan for maintaining and operating the spaces	**Urban design** climate responsive walkability strategies Shading Trees canopies Structures Building orientation Streets enclosure ratios Superstructures Greening: Trees Parks Walkways Urban agriculture	**Planning and programs** City-wide greening strategies Nursery for local trees and plants and a horticultural assessment of the size and impact of their canopies on urban heat Energy consumption tax Carbon footprint policy Plant your own garden scheme
		References (Jacobson & Forsyth, 2008)	**Case studies** Subi Centro Australia	**References** (Jacobson & Forsyth, 2008)	**Case studies** Hammarby Sjostad	**References** (Sandifer, 2009) (Pikora, 2003) (Bajracharya, O'Hare, & Byrne, 2010) (DeVeau, 2011) (Thani Sharifah, Nik Hanita, & Idilfitri, 2012)	**Case studies** Rio Vista west - San Diego
	Private Development	**Urban design** Gradual Intensification of uses over time Development phasing plan Development design Program Priority to public realm improvement around the transit node	**Planning and programs** Real estate gradual asset release Policies against speculative developments Public private partnership	**Urban design** Diverse residential, commercial and retail typologies Flexible to host multiple sizes Encouraging perimeter urban blocks	**Planning and programs** Review of zoning ordinances contributing to typology redundancy Participatory planning – user-driven design schemes	**Urban design** climate responsive urban design guidelines to guide development proposals: provide shaded areas on urban blocks edges Use wind for natural ventilation by orienting corridors to prevailing wind directions	**Planning and programs** Development review process set up for development proposals in accordance to guidelines Integrated design process as requirements for guidelines issuance Environmental modeling of proposed designs Establish a best practices database
		References (Jacobson & Forsyth, 2008) (Ditmarr & Ohland, 2004) (Seigman P. , 2003) (Lukez, 2007) (Katz, Scully, & Bressi, 1994)	**Case studies** Subi-Centro Australia	**References** (Chen, Chen, & Barry, 2008) (Boehmer & Brownson, 2004)	**Case studies** Rio Vista West - San Diego Maritime Square China	**References** (Canepa, 2007) (Bajracharya, O'Hare, & Byrne, 2010) (O'hare, 2006) (Thani Sharifah, Nik Hanita, & Idilfitri, 2012)	**Case studies** SubiCentro – Australia

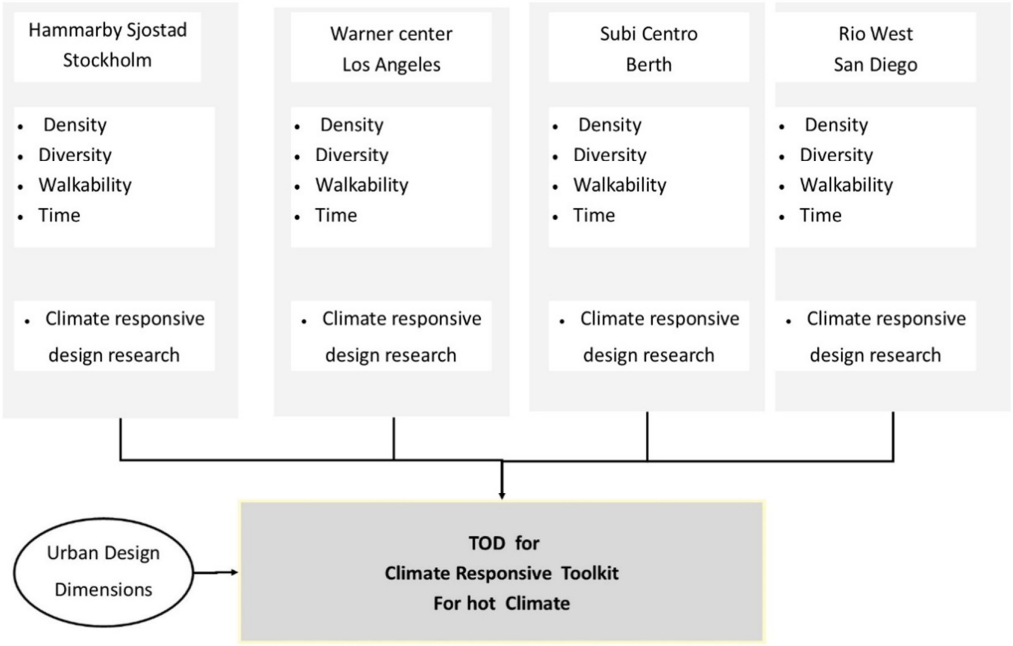
CHAPTER THREE

CASE STUDIES - SUSTAINABILITY AND URBAN DESIGN IN TRANSIT ORIENTED DEVELOPMENTS

A. Introduction

This chapter presents an overview of award – winning TOD projects located in different continents – America, Australia and Europe. The purpose of this chapter is to learn the best practices of urban design employed in these projects to implement the economic, social and environmental objectives of their sustainability strategies. Each section addresses one case study starting with a general description, its sustainability strategy and the urban design tools selected to implement this strategy. The input collected from the case studies is summarized using the toolkit for alternative TOD climate responsive model.

Figure 3.1. Case study analysis methodology.

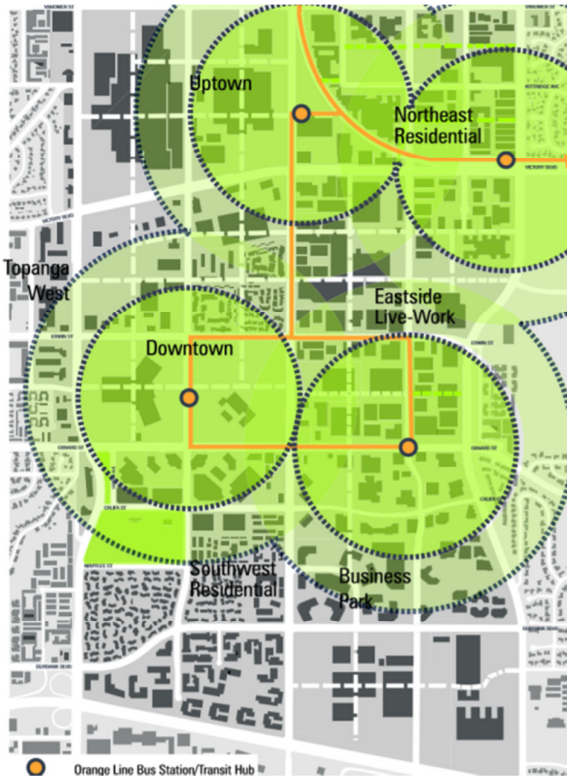


B. Warner Centre- Los Angeles

1. Description

Located in the Eastern San Fernando Valley region of the City of Los Angeles, Warner Center is a suburban employment center characterized by large superblocks defined by bordering arterial streets. During the 1970's, Warner Center started as an employment center attracting employees from the surrounding suburban communities. Over the last two decades, traffic and congestion inhibited its growth. In 2005, the new Orange Line bus rapid transit line opened, including three stations within Warner Center. In 2013, the proposed Warner Center plan 2035 structured it into multiple TOD around the three stations based on connectedness, public transit, job diversity and promotion of innovative businesses.

Figure 3.2. Plan of Warner Centre showing the orange line, proposed transit oriented districts and proposed plan



2. Sustainability

Warner Center adopted different policies to for energy reduction and fixed clear environmental sustainability objectives. Its main sustainability objective was to reduce the Vehicle Kilometers Travelled (VKT) i.e. car trips.[4] Other environmental sustainability measures included building measures such as Leed certification, green roof guidelines, and the adoption of renewable solar energy sources. Socially, the planning framework was set out to attract diverse groups such as young employees, senior citizens, families with teenagers. The urban regeneration strategy focused on diversifying the site economic activities, offering incentives for renewable energy companies and local educational institutions to feed the increasing demand of creative sector jobs (Wikepedia, 2015; BGI, 2015).

Figure 3.3. Summary of Sustainability measure (Warner Center Specific Plan 2013).

Architecture. Green capital of the valley / healthy buildings / innovative architecture, design & public art / model of a sustainable community / integrate solar components.

Natural Environment & Open Space
Access to Calabasas Creek & L.A. River / sustainable lifestyle / native & drought tolerant plants / permeable paving / great park with variety of activities.

[4] VKT or Vehicle Kilometers Travelled is a specific measure used in transportation in order to calculate the distance that a car use to go in and out of the study area

3. Urban Design and TOD

a. Density

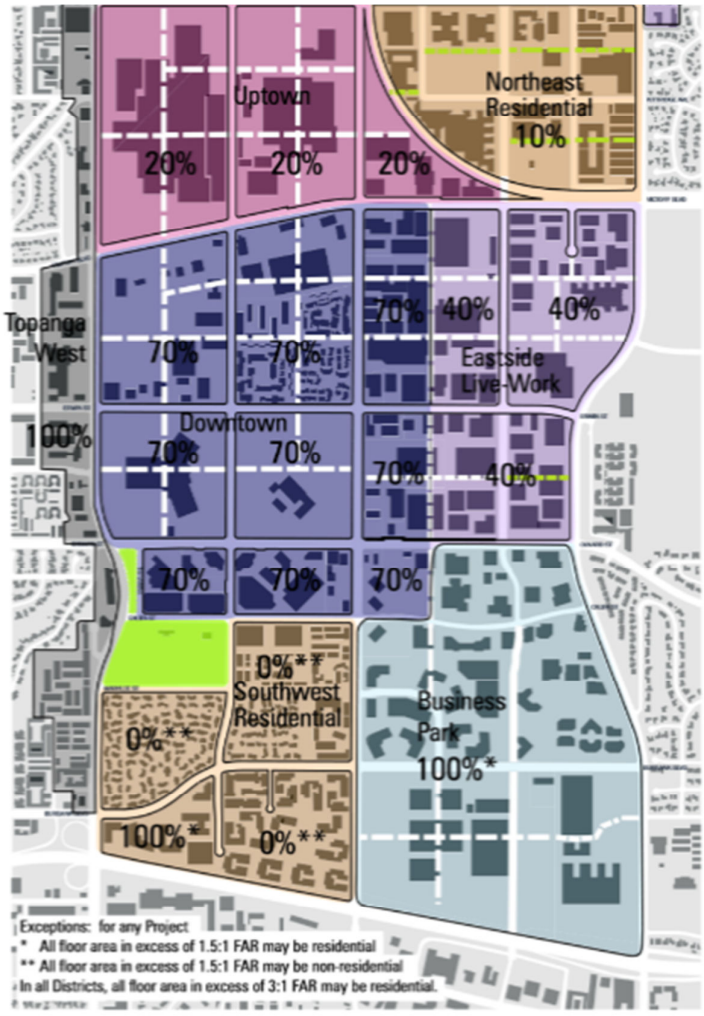
Densities amounting to 32.9 million square feet are planned at walking distance from the nearest transit station. Thus, its urban structure was based on compacting development based on a development radius of 700 m from the nearest transit station. Floor Area Ratio increased to 4.5 to provide sufficient ridership for the transit stations. The developments' proposals which included community or public spaces as per the master plan's assigned list of uses, are given additional built up areas to use on site (Los Angeles City Council , 2009).

b. Diversity

Urban design guidelines specified the typologies sections and street frontage guidelines for vertical mixing of uses. The mono-functionality of the current Warner Center land uses were reversed through levying a minimum non-residential use cap for all plots. Non-residential use included civic uses, retail uses, office uses and cultural amenities (See Figure 3.4).

Community diversity was ensured through maintaining housing affordability. Average unit sizes guidelines were assigned to specific properties within a walking distance from transit station. Additional measures to ensure community diversity included prescribing inclusivity guidelines for the design of green open spaces. Any proposed plan –regardless of its size-need to include active, passive and leisure areas for senior citizens, children, and teenagers.

Figure 3.4. Warner Center Land Use and Street Guidelines.



Walls above the ground floor that step back less than 20' from the ground floor street wall are part of the street wall, as illustrated above.

DISTRICT / NEIGHBORHOOD	MINIMUM PERCENT OF PROJECT FRONTAGE TO BE LINED WITH BUILDING STREET WALL AT BACK OF SETBACK [1]		MINIMUM STREET WALL HEIGHT
	WHERE GROUND FLOOR RETAIL IS REQUIRED	OTHER LOCATIONS	FEET (STORIES) [2]
Uptown	100%	60%	35' (3)
Northeast	100%	50%	35' (3)
Downtown	100%	80%	45' (4)
Eastside	100%	70%	35' (3)
Southwest	NA	50%	35' (3)
Business Park	100%	60%	25' (2)
Topanga West	NA	NA	NA
RIO	100%	70%	35' (3)

1 Setback is as specified in Figure 3-1.

2 Stories are included for information only. The requirement is height measured in feet.

c. Walkability and public realm

Multiple measures mentioned in the master plan report and urban design guidelines encouraged walkability to transit node. 75% of Streets sections were required to be visually and physically accessible making them more active and contributing to lively streets. Pedestrian adapted streets subdivided large auto-oriented blocks in order to increase site permeability.

Entertainment uses guidelines specified the list of permissible uses. Open spaces network was re-designed to include active spaces such as a fitness path and some picnic facilities. Residents from other suburban areas should be attracted to use transit during weekends to benefit from these new facilities.

d. Climate responsive design

The master plan included guidelines for Green roof, and incentivized developers to transform them into public spaces via street level via ramps. Building guidelines specified solar powered shade structure for all surface parking. Public spaces guidelines encouraged the use of drought tolerant landscaping and the provision of trees to shade pedestrian adapted streets and walkways.

In conclusion, the master-planning of Warner Center applied mainly the urban design principles of density and diversity to retrofit its existing auto-oriented form into a more sustainable dense form.

Figure 3.5. Plan and Massing for a Neighborhood Unit in Warner Center showing the network of green spaces and streets- (Warner center specific plan)

C. Hammarby Sjostad – Stockholm

1. Description

Hammarby Sjostad is one of the largest mixed use housing in Stockholm, and is considered a sustainable Neighborhood development model. The plan followed the brown field development principles set out in Istanbul's 1996 Conference for sustainable urban development. It was mentioned in the literature as the largest TOD to date in Stockholm, and a model for green TOD. The development spreads over 25 million square feet with 35,000 people. It has succeeded in getting 80% of residents walk, cycle or use transit for their daily trips, and to go to their offices (Foletta, 2014).

2. Sustainability

The sustainability strategy focused on reducing energy demand, recycling water and providing open spaces. A comprehensive utility model was designed in order to convert waste and wastewater into energy to reduce the overall energy demand for heating in winter. The model combined and connected three systems i.e. the water company system, the electricity and power system and the waste system. As for open spaces, the Master plan sustainability strategy assigned five square meters of courtyards and thirty square meters of parks within three hundred meters of every apartment. In particular, the development targeted an increase of transit share by setting itself a target of 60% of all trips to be done through transit or by foot.

Socially, the city of Stockholm initiated the project to diversify the housing options especially for elderly and families, and to provide sufficient density for local small businesses to thrive.

Economically, the project targeted to generate 5000 jobs and opportunities for flexible offices schemes for startups and young entrepreneurs. The reduced costs of energy and water encouraged more residents to move in thus contributing to the profitability of the project (Fraker, 2013).

Figure 3.6. Hammarby Sjostad - Comprehensive Energy Model.

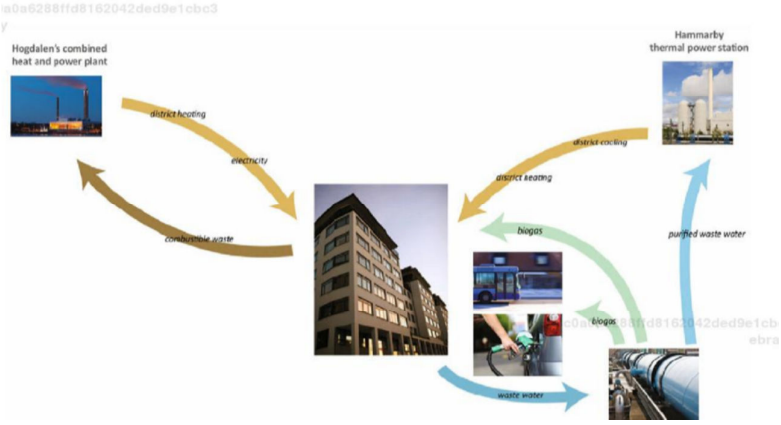


Figure 3.7. Hammarby Sjostad- TOD model and land use mix.

able 3: Breakdown of residential unit size in Hammarby Sjöstad

	Area (ha)
Studios	9%
1 Bedroom	35%
2 Bedrooms	32%
3 Bedrooms	21%
4 Bedrooms	2%
5+ Bedrooms	< 1%

City of Stockhol

able 4: Planned breakdown of land uses in Hammarby Sjöstad

	Area (ha)	Percent of Total Area
Residential	90	56%
Public green space	30	19%
Other	40	25%
Total land area	160	100%

City of Stockhol

Figure 3.8. Hammarby Sjostad – Plate.

3. Urban design principles / strategies

Urban Design Strategy and tools supported the council in its objectives (Cervero & Sullivan, 2011).

a. Density

Urban form was integrated with transit line design. Six to eight stories tall structures line up along the 37.5 meter Wide Boulevard, designed as the transit corridor linking the different districts. Narrow grid-patterned street organized the circulation between eighty meter long blocks with semi-public courtyards. Blocks around courtyards typified most district morphologies. A series of competitions produced varied design interpretations of the block typology, ensuring a unique modern architectural expression for each district. Academic institutions and Swedish design companies participated and presented their concepts for the various districts. The winning schemes were used to generate the urban design guidelines of that particular district.

b. Diversity

Uses across districts mixed vertically and horizontally. In particular, jobs and residences were planned in proximity of each other. Therefore, they lead to increasing internal transit share to 80% among those who live and work there. Although small retail businesses occupied the ground floor, building street fronts were not active. The visual transparency was not respected and made the street facades passive.

Community diversity depended on the provision of libraries, schools, health care units, and recreational amenities. Residents' daily needs of goods and services were located within 1 km, accessible by feet or by a bus stop served by three internal bus lines. The multiplicity of the housing typologies contributed also to the communal

diversity. In fact, 400 student's flats, 59 senior housing units and 30 assisted care units were distributed in the various districts in proximity of bus stops for major internal bus routes. Senior citizens preferred Hammarby in comparison to other housing projects in Stockholm because of ample green spaces, safe and convenient pedestrian access and the availability of health clinics. Families, as well relocated to Hammarby due to the availability of educational facilities and social infrastructure. In fact, five pre-schools, three primary schools, and two high schools have been built to serve the thirty five thousand residents.

Small retail businesses benefited from two-year free rent scheme for local small businesses. Small businesses moved from city center to Hammarby. More than 5000 new residents either worked or owned a business there. One hundred street retail shops, small cafes and restaurants opened providing daily needs for residents and animating the mostly passive street fronts.

c. Walkability and Public Realm

The pedestrian friendly and cyclable boulevard intersected in strategic points with the internal network of parks, green spaces, quays, plazas, cycle routes and walkways. Most of the major sidewalks and pedestrian shortcuts are designed to be within 300 m of transit and local bus lines. In particular, access to transit node increased the mobility of diverse social groups and provided them with access to the city center.

d. Climate Responsive Design

Building typologies maximized daylight reducing heating loads. However, building orientation did not respect east/west sun direction. So, it could not harness the sun more efficiently to heat indoor areas. In fact, buildings are oriented towards the lake

to benefit of its views and increase heating loads despite the embedded triple glazing used in most building facades.

D. Rio Vista west San Diego

1. Description

Rio Vista is one of the first Transit oriented Development (TOD) designed by Calthrope Associates based on San Diego TOD guidelines. It won the Merit award by pacific coast builder. 1070 housing units were master planned around a planned trolley line and a large retail mall.

2. Sustainability

Rio vista was designed to reduce automobile dependence, caused by the nearby mall car-dependant large urban block configuration. Rio vista depended on residential as a transit-supportive use. The master plan proposed diverse housing typologies aiming at attracting multiple residents' profile especially those who depended on transit for their mobility. Financially, the development depended on the mall to sustain its construction and maintenance costs. Thus, the proposed master plan preserved the mall and its surrounding surface parking.

3. Urban Design principles / strategies

As a first generation transit oriented development, Rio Vista west was designed by Calthrope as an embodiment of the main principles listed in the generic transit oriented model. However, it has failed in reaching the outcomes it has set to do (Inam, 2012; Katz, Scully & Bressi, 1994).

Figure 3.9. Rio Vista West – Master plan plate.

a. Density

Rio Vista west light rail stop is the center of a planned dense mixed-use core. The plan extended horizontally rather than radially from the transit node. The grid patterned local streets connected the residential areas with the transit node in addition to long walkways.

However, the urban form was fragmented. The transit only served the southern part of the development while the residential part is disconnected. The disconnection was due to the lack of an integrated legible pedestrian network connecting the transit node and neighborhood beyond the 200 m walkable radius.

Densities dropped suddenly beyond the mixed use, core limiting the access to employment areas. A gradual decrease in density from a denser mixed-use core would have better integrated the housing with the commercial areas.

The large mall urban block reduced site permeability. In order to counter this deficiency, tree lined pedestrian paths were built within the large surface parking as a way to retrofit it for pedestrians. However, the paths were not synchronized with the mall gates. Consequently, residents still use their cars for their daily needs and shopping trips.

Figure 3.10. Rio Vista West – Urban spaces plate

b. Diversity

The mixed use core mixes used vertically and horizontally. Specialty stores, restaurants and multi-screen cinemas were located next to office building, civic spaces and community buildings. This mixity did not extend to the other areas of the development that are otherwise exclusively residential. The development tackled

partially diversity through the use of different housing typologies: three story apartment buildings, medium density housing, and low-density townhouse development.

However, the development lacked the social infrastructure supporting the residential community, such as libraries, community centers. The master plan did not assign specific and exclusive plots to locate them and did not include a policy that provides adequate incentives for developers to build them.

c. Walkability and Public Realm

Walkable tree-lined streets and pedestrian paseos connected the riverside to the residential areas. Paseos were small alleys that are particular to San Diego. The proposed pedestrian network based on narrow paseos did not include cycling tracks that connect the residential areas to the riverside; cycling could have transformed the riverside into an active recreational space.

Streets were also wide, lacking frequent crosswalks to increase walkability on the main paths leading to the riverside. This, in addition to the low visibility of the riverside from the streets, contributed to the riverside passivity as an open space and limited its use by the residents.

Street frontage in residential areas made walkways safer since entries, porches, porticos, and bay windows overlooked it. However, Streets fronts were mostly passive because of the mono-functionality of the residential blocks.

d. Climate responsive design

Courtyard was oriented internally to maximize shading. Building and block typologies were designed to be climate responsive. Specific design guidelines encouraged the use of Irving Gill's - a notable traditional architect - building elements. Spatial and dimensional drawings as well as illustrations provided the different

consultants working on the project with details for trellises, pergolas, courtyard, patios, porches, arched windows and arcades. The various architectural elements were designed to respect climate and contribute to the unique urban character of the blocks and buildings.

In conclusion, although Rio Vista West was designed according to the TOD model, specific urban design issues prevented it from achieving the objectives of density, diversity and walkability it is set to do. However, its urban design guidelines provided ways to make it more climate responsive through the use of different architectural elements for shading.

E. SubiCentro - Australia

1. Description

SubiCentro was considered as the best living example of TOD in Australia. The development won awards by the Planning Institute and the Urban Development Institute in Australia. It was considered as an exemplary built district for Transit Oriented Development. Subiaco Development Authority undertook SubiCentro as part of a large redevelopment scheme for 80 ha in the old suburbs in Perth. Perth's most distinctive heritage buildings were found in this old suburb that emerged in the 1800's. The undergrounding of rail line provided extra land on which the TOD was built (Subiaco Redevelopment Authority, 2010).

Figure 3.11. Subi Centro Australia – Master plan plate.

Area (ha)	80
New Homes	800-900
Social / Affordable Homes	33
New population	1,500
Commercial / Retail Space (m^2)	90,000
New Workers	3,200
Government Investment	$130 million
Investment Attraction	$500 million

Source: Subi Centro Concept Planning 1994

Figure 3.12. Subi Centro Australia – Urban spaces plate.

2. Sustainability

SubiCentro master plan set out a comprehensive sustainability Strategy covering environmental, social and financial aspects (Subiaco Redevelopment Authority, 2010).

First, the sustainability strategy included guidelines for climate responsive landscape design , building energy efficiency guidelines and an overall utility strategy based on the use of renewable energy sources. Second, housing affordability, building cultural programs for the different ethnicities and increasing site accessibility for the disabled as well as increasing the mobility of disadvantaged groups were the cornerstones of the social diversity site-wide policy. Third, the site was designed in order to attract large companies in the service sector in order to fund the implementation of the site public realm strategy and its phased construction activities.

Nevertheless, the keystone in the site sustainability strategy was the integration between land use and transport to increase transit share, reduce emissions and make the site more accessible. (Australian local Government Association, 2009).

3. Urban Design principles /strategies

a. Density

The plan proposed to concentrate built densities around transit nodes and increasing heights beyond the allowable five stories high. Urban Form integrated transit node as a center transversed by a north/south axis boulevard connecting the different neighborhoods of the development physically. A public square was proposed at the intersection point, surrounded by a mixed use buildings.

However, the square was designed to accommodate large events and therefore became too large to be enclosed by surrounding buildings. Therefore, its center became an empty void space during daytime.

b. Diversity

Density across the site decreased. This translated into a mixity of typologies and uses such as townhouses, apartments, offices, and retail shops. Special amenities for companies in the service sectors were provided to tempt them to relocate there from Perth city center.

The urban design guidelines prescribed varying uses vertically. So, different uses were assigned for street level, floors above ground level, and upper floors. Night entertainment was assigned as a special use for specific areas.

Despite allowing entertainment uses, the site was still not fully active at night. Currently, art programs and cultural festivities are held with great success to induce night activities. These programs were taking advantage of the expansive public square and the small open spaces to host their events.

c. Walkability and public realm

A network of bikeways, greenways, and civic squares connected the transit node to existing buildings. The network was planned to be universally accessible and won urban design mentions for its public realm accessible design guidelines. Civic used border pedestrian walkways for the residents and employees to complete their daily errands on their way to transit. Special considerations for safety especially on pedestrian walkways dictated that buildings needed to place their balconies and entries on streets, parks and gardens. However, the plan did not specify Active Street Fronts guidelines for all the development areas. Streets beyond the mixed use core are passive and empty particularly at night.

d. Climate responsive design

SubiCentro was particularly unique because of its innovative townhouse typologies which were later adopted by Perth. The townhouses specifically designed to respond to Perth unique sub-tropical climate. Blocks orientation respected natural ventilation corridors and provided summer shading to courtyards to reduce energy consumption. In particular, Water sensitive urban design strategies were used to collect storm water and retain it for re-use as irrigation water. The new housing typology had made it attractive to both residents and developers.

In conclusion, SubiCentro has successfully addressed the issues of diversity and climate responsiveness through varying their buildings typologies and designing new ones specific to sub-tropical climate. However, it did not fully apply urban design tools associated with designing dense walkable environments, thus limiting the activation of its public spaces and streets.

F. Conclusion

Most of the above developments that have been planned using the Transit Oriented Development model showed an increase of transit share compared to other areas. Hammarby Sjostad recorded and increase to 80 % of all trips compared to an average of 30% in Stockholm. Their urban form enclosed an expansive network of green spaces and pedestrian networks supporting walkability such as Warner Center in Los Angeles. Compact Dense Urban form of TOD was achieved through courtyards and perimeter block sand high building coverage as in Rio Vista West.

These developments attracted diverse groups increasing their mobility. Senior citizens and children were given special consideration. The provision of civic uses,

schools, and community amenities encouraged families to relocate next to transit thus adopting it as their main means of transport.

Transit oriented Development financially sustained their construction by including public realm improvement in their first phase especially in the vicinity of transit nodes. SubiCentro was able to attract more than one billion dollars in private investment because of investing 55 million US dollars in building high quality public realm around the transit node.

The analysis of the case studies confirmed the relationship between the tools proposed in the TOD alternative climate responsive model and the three pillars of sustainability. As illustrated in the table below, increasing densities animated the development economically. Diversity in uses, building typologies and open spaces contributed to the social sustainability in TOD. However, only two case studies used climate responsive passive design strategies for environmental sustainability.

Table 3.1. Summary of case study analysis.

	Sustainable Development Pillar					
	Economic Vitality		**Social Diversity**		**Environmental Integrity**	
	Urban design	**Planning and programs**	**Urban design**	**Planning and programs**	**Urban design**	**Planning and programs**
	Tools used in the Case studies					
Identity	Warner Center- Los Angeles- 32.9 million square feet divided into 4 TOD in order for each building to be at walking distance from transit Rio Vista west- mixed use core around transit node	Warner Center- Los Angeles-existing zoning policy (FAR) increased to 4.5 in order to allow additional densities on site Subi Centro – Australia Increase in allowable densities in order to concentrate commercial use around transit node	Warner Center- Los Angeles- Street Frontage Guidelines and typologies sections prescribed vertical mixity Subi Centro Australia Mixity of apartments, townhouses, offices and retail Plan included specific section for each typology to promote vertical mixing	Warner Center –Los Angeles- zoning policy of non-residential cap levied on all lands to mix horizontally	Not mentioned in case studies	Rio Vista West – building guidelines adopted the Spanish architectural elements developed by Irving for the local climate of san Diego
Ecology	Hammarby Sjostad - Sweden 25 million square feet concentrated on37.5 m wide transit boulevard 80% of residents walk, cycle or use transit to do their daily trips Rio Vista West Buildings framed streets and public spaces Subi Centro Australia Compact urban form centered around transit station		Hammarby Sjostad - Sweden Housing typologies included senior housing units, students flats and assisted care units Daily needs of residents(4 libraries, 17 schools, healthcare clinics and recreational amenities) located within 300m Rio Vista West Blocks centered around neighborhood parks as civic space	Rio Vista West - San Diego Hammarby Sjostad-Sweden Affordability maintained through government assisted housing fee Warner Center (Los Angeles): additional built up areas allowed for developers that build one of the listed social infrastructure facilities. Warner Center- Affordability controlled by unit sizes – averaging of sellable unit policy	Hammarby Sjostad - Sweden 5 sq,m of courtyard and 30 sq. of parks within 300 m of each apartment Pedestrian network runs through an interconnected greenway connecting the internal courtyards of the urban blocks Subi Centro Australia A network of greenways And bikeways connect transit to various locations	
Urban Design Dimension **Infrastructure**	Hammarby Sjostad - Sweden 100 local retail units around transit. Warner Center –Los Angeles Entertainment use guidelines to induce night activities Rio Vista West – USA Retail mixed use on transit node framed with cinemas in order to encourage night time activities Subi Centro – Australia Night entertainment use assigned to specific areas in the master plan	Hammarby Sjostad – Sweden Two year grace period granted for local retail business who operated from it Warner Center- Los Angeles	Hammarby Sjostad - Sweden Narrow grid patterned streets Pedestrian network followed accessibility guidelines and healthy living guidelines Main boulevard designed as ‘’complete street’’ Rio Vista West- safety of the pedestrian network maintained through entries, porches, porticos, and bay windows overlooking it Warner Center- Los Angeles Fine grained street network subdivided large auto-oriented plots 75% of street fronts need to be visually accessible	Subi Centro- Australia Bikeways were planned in order to form a comprehensive network and is connected to the overall city wide cycling network	Hammarby Sjostad – Sweden Permeability and fine grained urban fabric enabled people to choose to walk, cycle or go by bus to the nearest transit station Rio Vista West Urban fabric composed of urban blocks organized around grid patterned streets and focused internally on green spaces.	Hammarby- Sjostad – Sweden Attention was given to increase street crossings and design it in a way to be safe specially on bus stops Subi Centro – Australia Hammarby Sjostad – Sweden Rio Vista West – Australia Specific zoning measures indicated allowable blocks typologies
Public Space	Rio Vista West Major civic square planned next to transit surrounded by cafes and restaurants and framed by higher commercial buildings Subi Centro Australia Large square acting as civic space for large events near transit station Smaller civic spaces hold cultural programs inducing their activation at night	Subi Centro Australia	Warner Center –Los Angeles Public spaces were divided into passive and active areas in order to be inclusive Open spaces such as areas for picnics attracted visitors from the city in weekends Subi Centro Australia Open spaces designed to host different cultural programs for different ethnicities	Subi Centro Australia Public realm design included comprehensive accessibility guidelines for senior citizens and also for physically disabled residents Public realm design underwent a CPTED analysis based on which all building entries and balconies faced streets and open spaces Water sensitive urban design used to collect rainwater and use it for irrigation Warner Center –Los Angeles- Public realm guidelines adopted accessibility considerations for elderly	Hammarby Sjostad - Sweden Buildings were oriented to maximize sun exposure (cold climate) in order to reduce heating .however, prioritizing lake views challenged building orientation Warner Center – Los Angele Green roof guidelines used as a greening strategy Use of drought tolerant landscaping Trees used for shading Rio Vista West- USA Tree lined streets and narrow pedestrian streets link urban blocks to riverside providing shading through continuous tree canopies	
Private Development	Hammarby Sjostad - Sweden Rio West – USA Warner Center – Los Angeles Subi Centro – USA All case studies adopted a phasing plan whereby priority was given to release development in phases Subi Centro attracted 1 billion $ in investment through improving the public spaces around the transit node Warner center provided each developer with detailed urban design and landscape guidelines that his proposal need to respect	Subi-Centro Australia Specific measures were taken in order to gradually release the site development areas	Hammarby Sjostad - Sweden Block typified as 80m long perimeter blocks with internal courtyard 5000 jobs provided to entrepreneurs relocated to flexible office schemes Rio Vista West Diverse housing typologies – apartment buildings and townhouses Subi Centro – Australia Detailed urban design and landscape guidelines for each typology – new housing typology introduced in order to maximize use.	Hammarby Sjostad –Sweden Urban design competition held in order to engage local design community in coming up with innovative architectural expressions of the typical perimeter urban block. Rio Vista West - San Diego Proposed new zoning densities for new added typologies	Hammarby Sjostad - Sweden Building orientation towards the lake was prioritized over prevailing wind 45 degree orientation Rio Vista west Building and block typologies with details for trellises, pergolas, courtyard, patios, porches, arched windows and arcades. Building orientation to minimize sun exposure in sunny san Diego compromised the view of the river Subi Centro – Australia Blocks orientation respected natural ventilation corridors and provided summer shading to courtyards in order to reduce energy consumption	SubiCentro – Australia An authority was set up in order to review each development proposal in accordance to the updated master plan

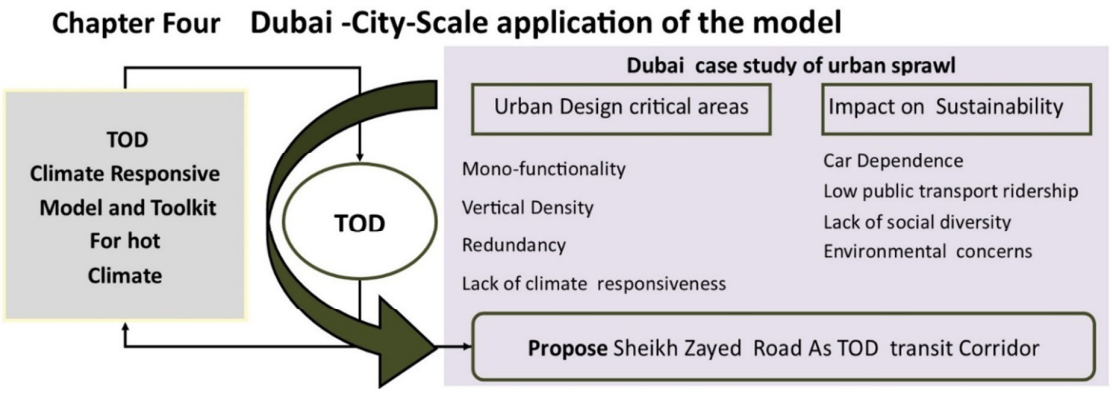
CHAPTER FOUR

UN-SPRAWL DUBAI

A. Introduction

This chapter aims at proposing the application of the alternative climate responsive TOD model on a city scale in Dubai as a possible tool to un-sprawl it. It investigates the critical urban design features resulting from Dubai's urban sprawl and their associated sustainability challenges. It ends with a proposal to retrofit Dubai's main urban growth corridor into a regional TOD corridor.

Figure 4.1. Chapter Four roadmap.



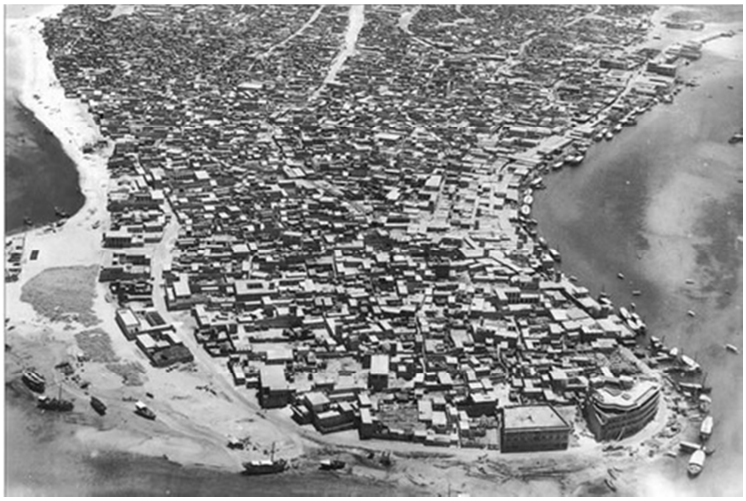
B. Dubai Urbanization

Dubai has one of the highest rates of urbanization in the last two decades growing from a city center in the 1960's to a sprawling urban region. Dubai grew from a fisherman's town to a multi-nodal expansive metropolitan region. Its population grew from 56,000 in the 1950's to 2.2 million, posing pressure on its urban sustainability.

The historical overview shows that Dubai actually sprawled post 1990 although the seeds of its urban sprawl were first planted in the modernist land use approach in its 1965 structural plan.

Dubai metropolitan area expanded through four fundamental phases: the first phase extended from 1900 to 1955, the second from 1955 to 1970, the third from 1970 to the 1990's, and the fourth from 1993 to present (Al Awadi, 2011).

Figure 4.2. Dubai 1950 - Source Gulf news retrieved March 2015.



1. Stage 1 -1900-1955

From 1900 until 1955, Dubai land area, limited to the two townships of Deira and Bur Dubai was mostly residential with scattered grocery shops for the residents' daily needs. Buildings followed two typologies: a vernacular structure made of palms named Barasti or wind tower homes influenced by the architectural style of Bastak village in Iran i.e. the hometown of migrant tradesmen who settled in Dubai. Buildings were clustered in neighborhoods (Freej in Emirati) planned in accordance to the tribe of

the residents. Privacy throughout the neighborhood was maintained through internal courtyards that do not open on the public space.

Figure 4.3. Dubai 1970 - source world times middle east- retrieved March 2015.

2. Stage 2 – 1955 -1970

The second stage of Dubai's urbanism extended from 1955 to 1970. The urban expansion was still contained and its block morphology still followed a compact form. Due to the significant increase of its population in the 1950s, Sheikh Rashid Dubai's Ruler appointed John Harris as Dubai Town Planner. The master plan (adopted officially as Dubai structural plan until oil discovery in 1969) was based on three pillars that became the cornerstones of Dubai's urban structure. These pillars were an expansive road network to manage car traffic, modernist land use zoning to rationalize its growing activities and a proposed central urban node in Deira. A secondary urban node was proposed in Bur Dubai, putting in the foundations of an infrastructure-dependent multi nodal model which Dubai would follow in its subsequent plans. The

segregation of city activities set the future adoption of mono-functionality as the commercial and governmental in Deira became separated from the residential areas in Bur Dubai.

Figure 4.4. World trade center - a modernist icon symbol of the start of Dubai urbanization - architect John Harris - source: john Harris and partners

Figure 4.5. Harris Master plan - Dubai -Source: Dubaization. Word press.com.

3. Stage 3 – 1970-1990

In a period of rapid expansion, planned suburban growth started in the 1970s and continued into the 1990s. The urban areas in this phase increased from 18 km^2 in 1971 to 149.3 Km^2 in 1993 The population increased from 100,000 in 1971 to 674,000 in 1993(Elsheshtawy 2004).Oil discovery provided the necessary financial support for developing Dubai as a regional trade and employment centre. Specifically, the government focused on major infrastructural projects and in particular on mobility. John Harris proposed an updated master plan which emphasized expanding residential areas through suburban detached typologies, developing the city along major roads corridors and using infrastructural elements such as bridges and tunnels to connect it. This phase in particular was important since the opening and expansion of Port Rashid, Port Jebel Ali, and Dubai International airport strengthen Dubai's position as a regional hub. The concept of a free zone – which will be later used to develop 20 free zones from 1999 till present - was used for the first time Port Jebel Ali was built to attract multinational companies to base their regional headquarters and ultimately became one of the largest free zone sea ports in the world Therefore, the city urban morphology was shaped to intensify trade activities, ease transportation routes by sea through massive investments in roads, utility and transportation infrastructure (Ramos, 2010).

4. 1990-present

As the above economic policy came to be named diversification in 1995 Dubai developed footprint has grown by 400% or about 1287 km^2 (ibid). The current phase of Dubai urbanization occurred along a regional road corridor connecting it to the different emirates through car-dominated leap frog developments. These mega-developments followed emerging forms of urbanism. Dubai urban space was shaped through global investments and at the same time was designed to attract global investments.

C. Dubai Urbanization – critical overview

1. Growth of mono- functional fragmented developments

Prior to 1993, districts - such as Jumeirah or al Quoz - were designated for single land use. Retail was the only use breaking this zoned mono-functionality. However, retail took the form of enclosed air-conditioned environment such as the Oasis mall on sheikh Zayed road (built in 1995) and Mercato mall on Jumeirah road (built in 2003);its form failed to reconnect the spatial segregation of the different districts. Starting 1993, office areas were also designed as enclosed open environments. Dubai internet city and Dubai Media city became the first commercial free zones to be designed as an enclosed suburban office park. Emirates Hills was launched as the first large-scale gated community targeting exclusive properties and grew to about 7000 villas in the span of 11 years. This phenomenon was directly linked to the privatisation of development. Following 1993, development companies such Emaar, Nakheel, Dubai Properties, Majid al Futtaim and Union Properties were launched and gradually invested in large scale developments in Dubai.

Figure 4.6. Urbanization along sheikh Zayed road - comparison between 1990 and 2013 -source worldobserveronline retrieved March 2015.

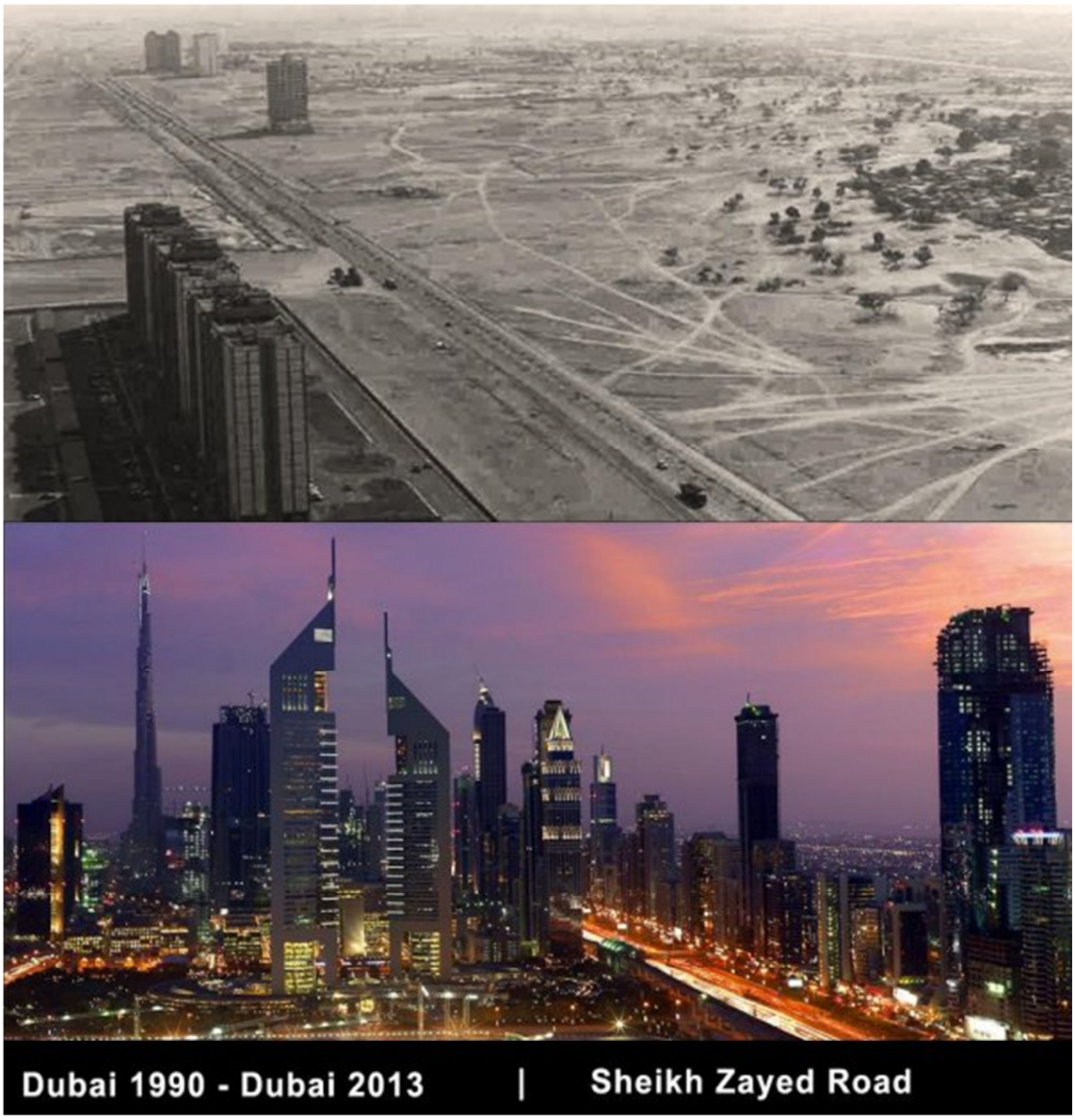


Figure 4.7. Dubai Urbanization source: (Elsheshtawy 2008).

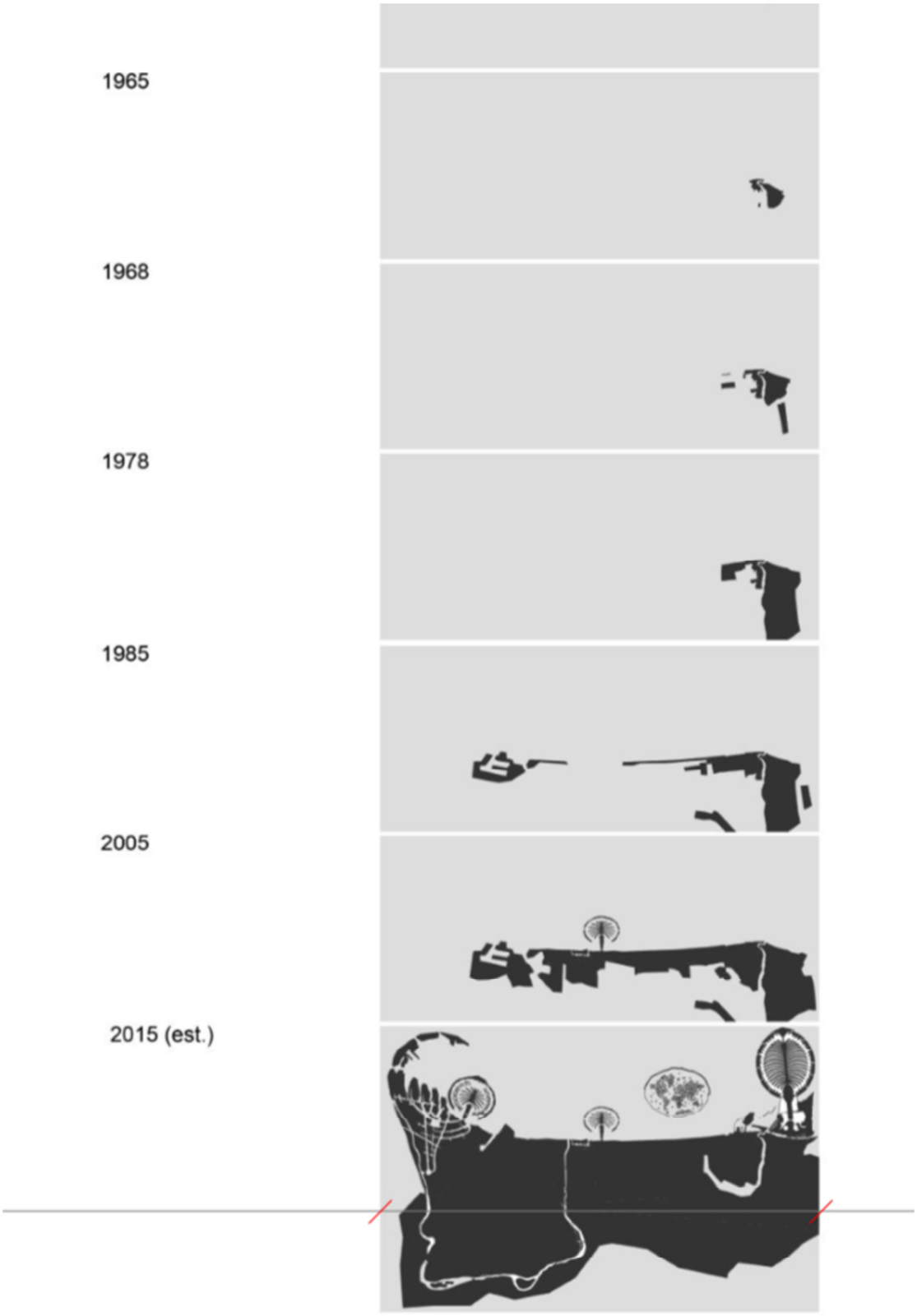


Figure 4.8. Dubai Mega projects - source Kubat, Guney (2009)

Since the 1990's until 2012, the lack of an updated Dubai structural plan and the legal framework of the freehold investment areas and free zone laws allowed developers to experiment with the urban form, character and density in particular.

As illustrated in the figure below, the resulting urban form was fragmented and disconnected. Sarkis (2005) stated the importance of reflecting on ways to connect and integrate these different development patches. The latter might also be the tool to forge a common identity for the city diverse expressions.

Figure 4.9. Figure ground of Dubai Suburban developments - source Al Awadi, K. (2011).

2. Density

Prior to 1993, Dubai's tallest building was the World Trade Centre. Subsequently, Emirate towers and Burj al Arab followed to represent Dubai as its architectural icons. Dubai's aspiration to build taller structure culminated with the construction of Burj Khalifa that marked the milestone in a city journey of perceiving density as an effect of increasing heights.

Post 1993, Dubai witnessed the edging of Sheikh Zayed Highway – the development corridor on which Dubai grew with skyscrapers ranging from 20 to 130 stories. Dubai urban structure became organised into a wide development corridor with

urban nodes distributed on its edges. Density of activities, uses and built environment have taken the urban form of high rise buildings sitting on podiums overlooking on one side Sheikh Zayed Road and on the other an expansive lake. Such form was repeated across the city in downtown Dubai, Dubai Marina, Jumeirah Lake towers and Jumeirah Beach residence.

Figure 4.10. Dubai vertically dense new suburban centers on both edges of Sheikh Zayed Road- source emirates 247 - retrieved March 2015.

3. Redundancy in Urban Typology

Each of Dubai development companies established an urban planning and design department responsible for reviewing the development applications of the different developers. Each department established robust design guidelines to guide the sub-developers. Although these Design guidelines booklets succeeded in forging a

distinct identity for each district as set in its overall master plan, nevertheless it has transformed the city's urbanscape into heterogeneous patches of developments. City-wide identity from an urban design perspective became linked to its nature as an urban experimentation field where one is exposed to multiple expressions at the same time. There was a growing need now that these developments have been there for more than one decade to think of a tool that forges identity not based on architecture. Infrastructure-mainly Road and transportation networks were the main principle on which John Harris built his first master plan and could be used as the foundation for attempting to shape such city-wide identity. It was in a way the only factor linking these developments.

Figure 4.11. Dubai suburban areas - juxtaposition of multiple architectural expressions - sources: homearound.com – retrieved march 2015.

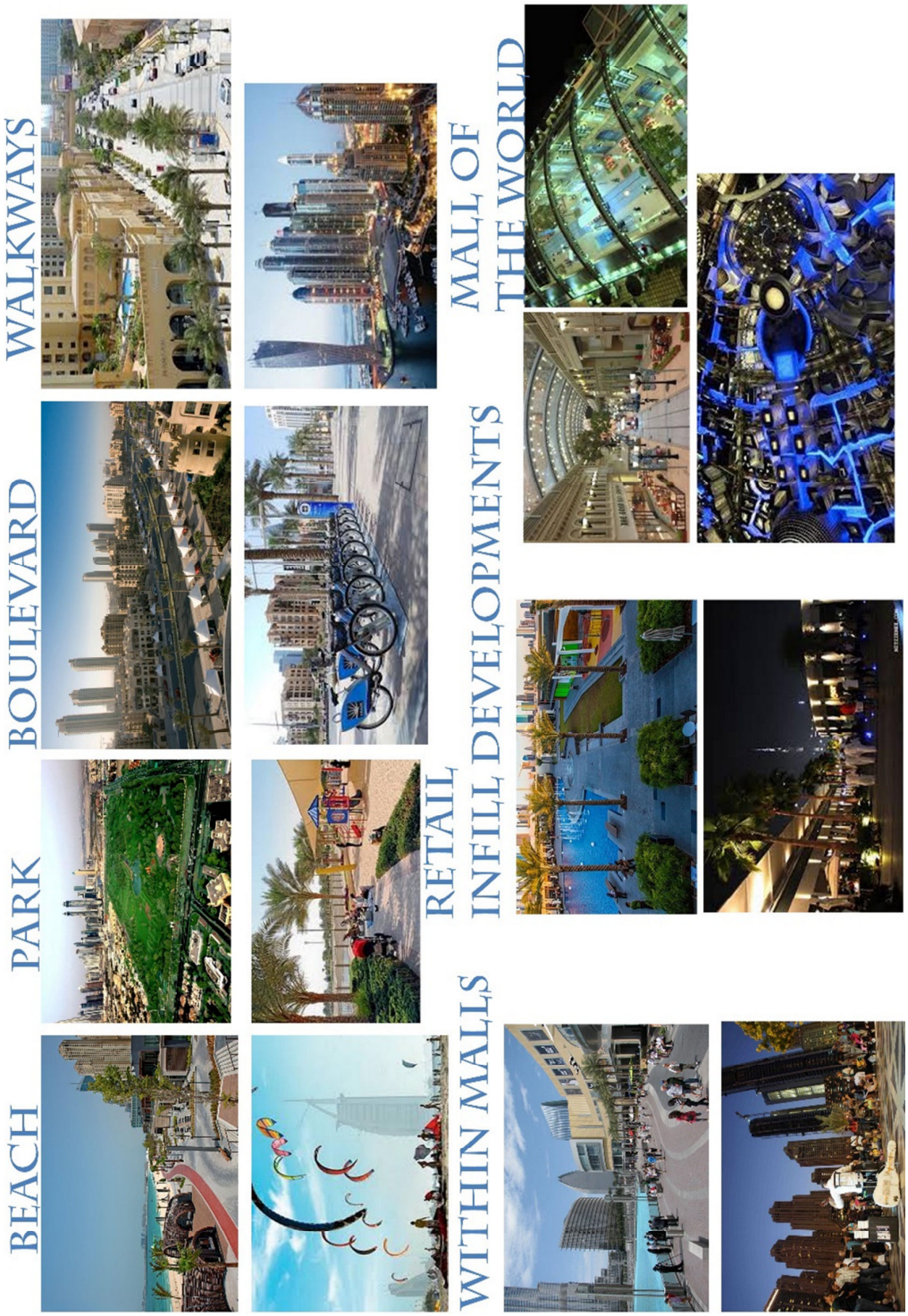
4. Lack of climate consideration when designing walkable environments

Most of Dubai's large scale developments are particularly sensitive to open space providing multiple typologies of green spaces and walkable environments. The walkable environments are usually designed as a network of alleys and sidewalks linked to walkways around water bodies especially lakes. Restaurants and cafes are planned on the banks of these lakes. In residential areas, the network of pedestrian and cycling would cross with parks, tennis courts, basketball courts, and skating parks.
However, most of these walkable environments are completely empty six months of the year. Dubai climate is a desert climate with peak temperatures and humidity from May till October, and medium temperatures and humidity from November till April.

Figure 4.12. Dubai temperature per month.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Max. Temperature °C	23.9	25.4	28.4	33.0	37.7	39.5	40.9	41.3	38.9	35.4	30.6	26.2
Average Min. Temperature °C	14.3	15.5	17.7	21	25.1	27.3	30.0	30.4	27.7	24.1	20.1	16.3
Mean Rainfall	18.8	25.0	22.1	7.2	0.4	0.0	0.8	0.0	0.0	1.1	2.7	16.2
Mean # of Days with Rain	5.5	4.7	5.8	2.6	0.3	0.0	0.5	0.5	0.1	0.2	1.3	3.8
Sunshine Hours Per day	8.1	8.6	8.7	10.2	11.3	11.5	10.7	10.5	10.3	9.9	9.3	8.2
Mean Sea Temperature °C	20.9	20.6	22.3	25.0	28.5	31.2	32.2	32.8	31.9	29.7	27.1	23.3

Figure 4.13. Types of walkable public and open spaces in Dubai.



These environments are not designed to be climate responsive and thus became unused, and in a way a burden on developers during the hot months of the year. The urban morphology of the developments either low dense detached villas developments or vertical towers connected by a podium do not take advantage of passive design strategies as well to be more climate responsive.

Figure 4.14. The beach - Dubai - newest beach retail development - on a sunny day.

Figure 4.15. Dubai souq - shaded arcade allow visitors to come even in summer.

Figure 4.16. Street during summer in a new suburban residential community.

In Dubai's old district of Bastakiya, alleys, sidewalks and enclaves are closely knitted with buildings and aligned with wind direction to lessen temperature. Dubai Souks stand as a witness to the local knowledge of using microclimate as it is still frequented even during the hot days of the year.

Figure 4.17. Views of an alley way in Dubai old city center in the morning and evening showing a continuous all-day shaded area.

In conclusion, Dubai current urbanisation shows its own unique signs of urban sprawl.

These signs are:

- Mono functionality resulting in fragmentation and use segregation
- Vertical densification resulting in highway edging
- Lack of city wide identity due to district based urban character
- Lack of climate responsive open spaces decreasing its walkability from May till September.

D. The sustainability concerns of Dubai Urban Sprawl

1. Car Dependence

Vehicles in Dubai take 3.1 million trips a day, a figure expected to increase by 2020 to 14.3 million trips a day. The annual increase of traffic expenses is 4.3 billion AED and the expected increase in Dubai population is 296% by the year 2020. This will bring the expected number of private cars in Dubai to 1.5 m car by the year 2020 (RTA, 2015).

Residential areas are not built close to commercial areas; they are usually separated through district roads or highways. Consequently, car became the main mode of transport between home, office, school, hospital and even grocery. For example, for a resident in springs - a residential community - it takes him 50 minutes to go to his office in Dubai Internet City using the bus in the morning, 35 minutes driving in rush hour and 160 minutes to walk.

RTA builds an extensive network of roads and bridges that linked Dubai Development areas. Its powerful mandate has allowed it to break the enclaves of gated communities and introduce local and collector roads connecting gated residential

communities, commercial areas and business campus. It is particularly evident in the case of the Al-Asayeel road that links Emirates Hills, Jumeirah Park, and Jumeirah Lake towers. In a way, RTA proposed road network is the main connector of the diverse development enclaves, increasing the city's permeability. However, traffic does not subside and soon, the importance of a public transport system capable of transporting large numbers of employees from their residential areas to their employment areas became necessary.

Figure 4.18. Traffic congestion at rush hour - source; the National.ae retrieved March 2015.

RTA designed a transit rail to link Dubai residential with the rest of Dubai, and encourage Dubai residents to adopt a more sustainable mode of transport. Dubai Metro followed the development corridor of Dubai - Sheikh Zayed Road. Its stations are

carefully located on gates or entrances of the large scale developments, malls, or urban areas on the other side of Sheikh Zayed Highway. Pedestrians use air-conditioned passages over Sheikh Zayed Highway to cross from one side to the other.

Spatially, Dubai Metro stations do not all equally perform. Stations located within industrial areas or on the edge of residential or commercial areas do not show high ridership numbers. These low average numbers are closely related to what it is termed in transit the "first and last mile". In order to dissect the first and last mile issue in Dubai, we will provide examples of the three means to reach and leave a station. These means are cars, bus, and taxis. Walkability around transit stations is low as pedestrian paths are not shaded and difficult to take in the hot months. If one decides to take his car, he has to pay additional parking fees to the metro ticket in stations where parking is provided as "park and ride facility". These types of stations actually underscore their incapacity to affect behavioral change as the first mile and last mile is still functioning on a car dominance paradigm.

Taking the bus is a viable solution. RTA has established 734 regional and local bus lines that cover most of Dubai. 1860 dedicated bus stops serve each area, out of which 500 are wayside shelters. However, due to the lack of exclusive bus lanes, such journey can take up between an additional 15 to 45 minutes depending on the traffic condition of roads. On an average day, buses cover 264,000 km. Dubai's statistical data showed that no more than 6% of the population (estimated at 300,000 trips) use the bus system compared to motor vehicles which increase by an annual average of about 12% (Dubai Statistics Center, 2014).

Finally, taxi is the third mode of transport available for metro users, managed through private companies and highly regulated by RTA possessing a fleet of 8,662

cars. Taxi sharing, car sharing, and carpooling are practices gaining popularity in Dubai, supported by RTA. However, depending on car transport to use a public transport decrease the environmental added values of a public transit. As such, transit needs to be re-designed as not only a node in the transit system but as a place in order to solve the first and last mile issue.

2. Social sustainability

Dubai Urbanisation led to a population growth fuelled essentially by influx of foreign workers. Currently Dubai population accounts for 2.2 million - out of which 80% are expatriates residing in UAE and 20% are Emirati Citizen. A study conducted by Benton-Short, Price, & Freidman (2005) ranking cities in terms of immigration indicated that Dubai had the highest percentage of foreign-born residents (82%), followed by Miami (51%), and Amsterdam (47%).

Another aspect on the difficulty of defining social diversity for Dubai is the high proportion of male bachelors living in the city - which spurs discussion especially in the spheres of the local Emirati population that adopts a family based social structure. The large gap between the local cultural preferences in housing and the wide range of housing preferences for the 202 nationalities living in Dubai has contributed to the typology redundancy described above. Each area was built to target a set of preferences leading to its own spatial segregation from the rest of the city.

Mono-functional zoning contributed further to diminishing social diversity. Suburban Residential communities offered the community facilities and sports amenities which attract families. Highly specialized clusters such as media city did not have the facilities which large families with two or more children would prefer to live next to. Due to above-mentioned issues, proposed sustainability strategies in Dubai needed to account for inclusivity and social diversity.

3. Environmental Concerns

Car–dependent urbanization has led to high levels of air pollution. A study indicated that Dubai ranks among the worst in the world using an On-road Vehicle Emission Measurement device, which assigns a percentage score for the levels of harmful pollutants including hydrocarbons, carbon monoxide, nitrogen oxides, and carbon dioxide (Corder, 2008).

High level of air emissions has created an urban heat effect. In fact, the Meteorologist Office indicated that in May 2009 temperatures soared to their highest levels in 23 years. The daytime temperatures on May 26th reached 46.3° C, just marginally lower than 47° C, the record temperature recorded in May 1986 (AlAwadi, 2011).

Due to the current development being unresponsive to climate, Dubai is ranked number one in the world in terms of growth in energy and water requirements. For example, electricity growth was 6% and water almost 6% (per capita) in 2014. From April to November each year, 75 to 85% of power consumption is used for cooling purposes. UAE has one of the highest water consumption levels in the world (almost 130 gallon/day) compared to western countries. This stems from its extreme climatic condition and high per capita income (The Economist Intelligence Unit, 2014).

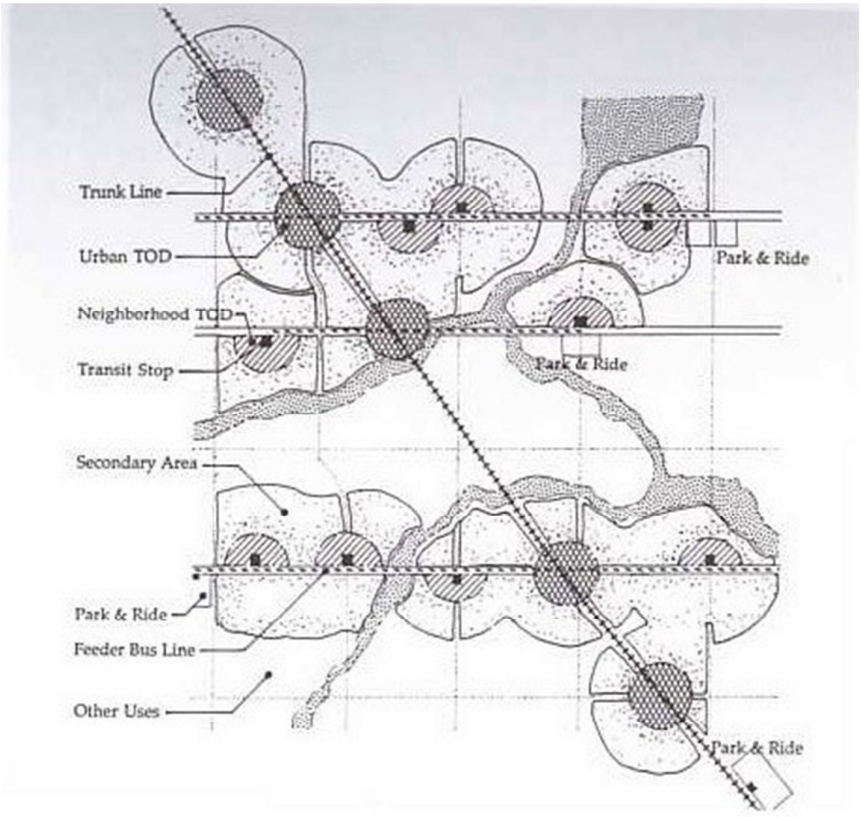
The UAE had one of the highest ecological footprints in 2014. According to the Worldwide

Fund for Nature (WWF) Living Planet Report 2014, the global ecological footprint was 2.2 global hectares per person, while the ecological footprint of the UAE resident is 7.8 hectares, the highest in the world (World Wild Fund, 2014).

E. UN-Sprawl Dubai; Transforming Dubai development corridor into a regional transit corridor

An urgent need is arising for a sustainable mode of development in Dubai. It would reduce car dependence, promote social diversity and address environmental concerns linked to increased traffic congestion and high ecological footprint. TOD can be this alternative designed as climate responsive urban centres on the regional level, transforming the station area into mixed use, compact and walkable central area among each of the city's districts.

Figure 4.19. TOD as regional centers (Calthrope 1993).



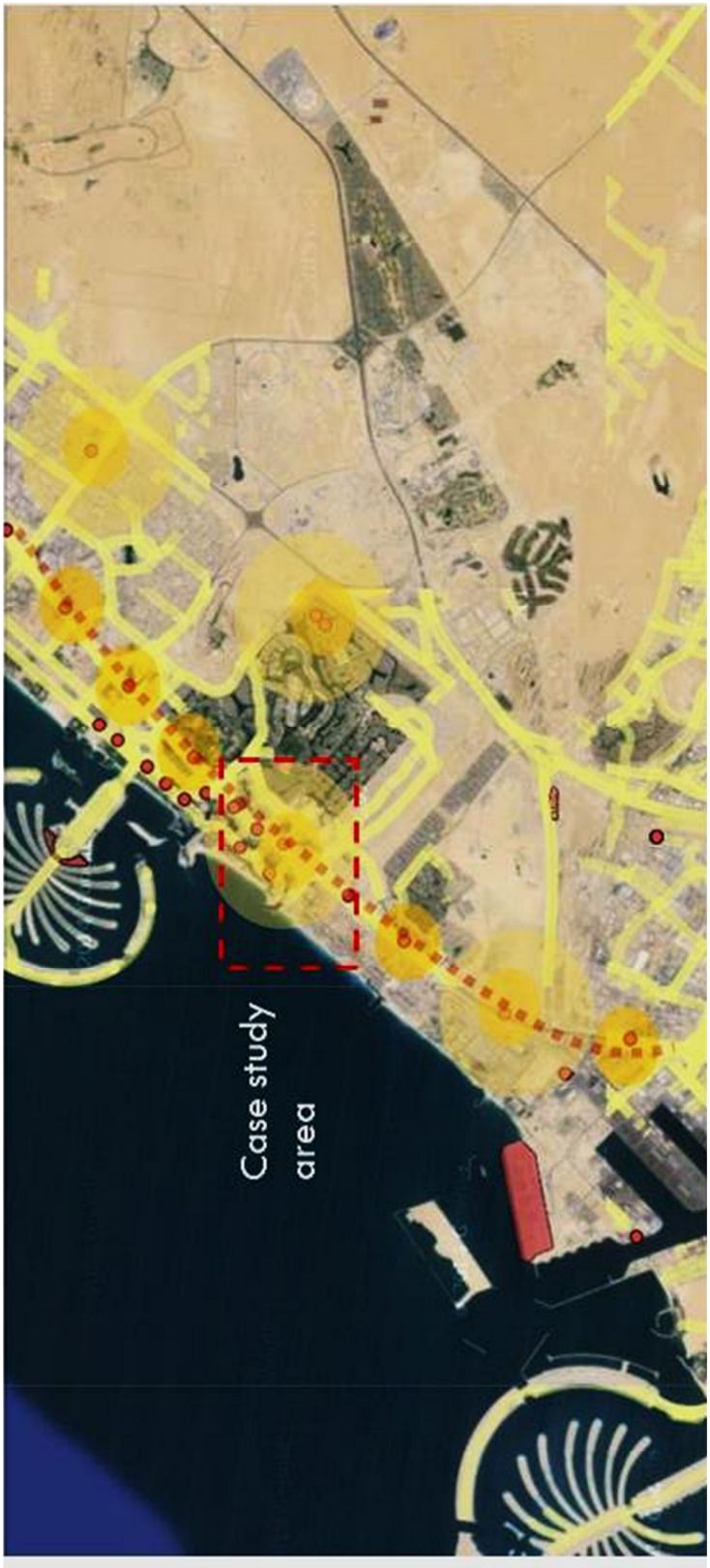
As discussed above, Dubai fast urbanisation has followed Sheikh Zayed Highway as a development corridor. Also, most of the public transport networks

whether bus or metro run parallel or intersects with it. Thus, Sheikh Zayed Highway can become a test ground for integrating land use and transport around Dubai metro stations, transforming it into a regional transit corridor. Key stations become Transit oriented developments designed in accordance with the alternative climate responsive model, refocusing urban growth into a dense compact development that is socially diverse and resilient to hot climate

Based on the TOD climate responsive model and toolkit, such strategy would need to achieve the below objectives:

- Integrate spatially fragmented suburban developments and contribute to smart growth through establishing primary dense mixed use primary and secondary centres
- Improve connectivity of pedestrian, roads and bus networks to increase public transport share across the city
- Diversify housing typologies in each TOD and thus increasing the social diversity of the different areas.
- Mix uses especially retail and housing contribute to decrease car trips for daily needs, thus reliving traffic congestion and addressing the growing environmental concerns of car air emissions
- Design TOD in accordance with the climate responsive alternative model thus retrofitting existing suburbs into walkable communities with multiple types of civic and green spaces.

Figure 4.20. Proposed Dubai's regional TOD corridor.



Al Suffouh – highlighted in red, in figure 4.20, is one of the first suburbs to be impacted by Dubai's last stage of accelerated urbanisation starting in the 1990's and is a central station on the Metro red line connecting the city's different districts. Therefore, it presents an opportunity to analyse urban sprawl effects on a local site scale and use the alternative TOD climate responsive model toolkit to assess opportunities and challenges for retrofitting it.

F. Conclusion

In this chapter, we have diagnosed how Dubai urban sprawl is impacting the city uses, urban form and urban spaces as well as assessing its direct effects on its sustainability. This diagnosis validated the use of the TOD alternative model as a tool that can be applied on a city-scale to reverse this condition. As a consequence, the model was applied to retrofit Sheikh Zayed Road- Dubai's urban growth corridor into a regional transit corridor and informed the selection of the case study in Al Suffouh Area.

CHAPTER FIVE

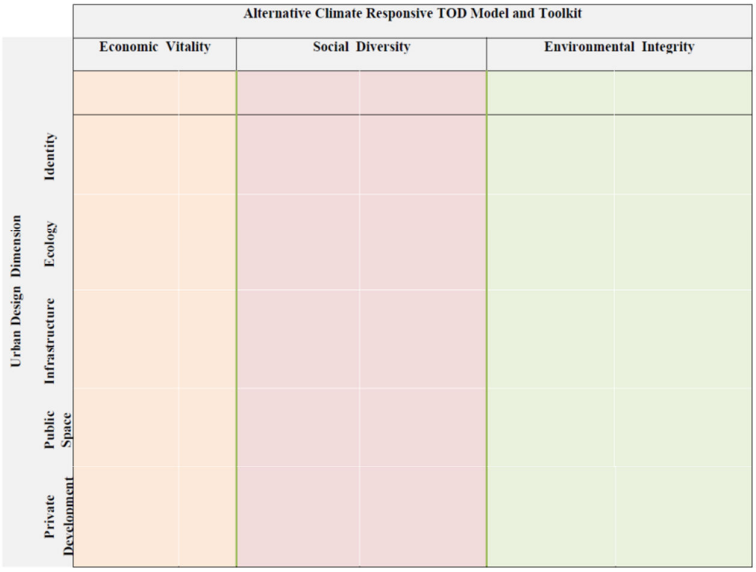
ALSUFFOUH

A. Introduction

In the last chapter, the alternative climate responsive model was applied on a city-scale to propose a TOD regional transit corridor on Dubai's main development corridor i.e. Sheikh Zayed Highway, and to reverse the critical sustainability situation of Dubai's sprawling suburbs.

In this chapter, the study area around Nakheel Metro Station ,one of the stations on Sheikh Zayed Highway serving Al Suffouh suburb, is analyzed according to the toolkit themes to diagnose district-wide urban design issues. The results of the evaluation will be used to select the Action area that will form the basis for the proposed TOD.

Figure 5.1 Alternative TOD Model Matrix.



B. The Context

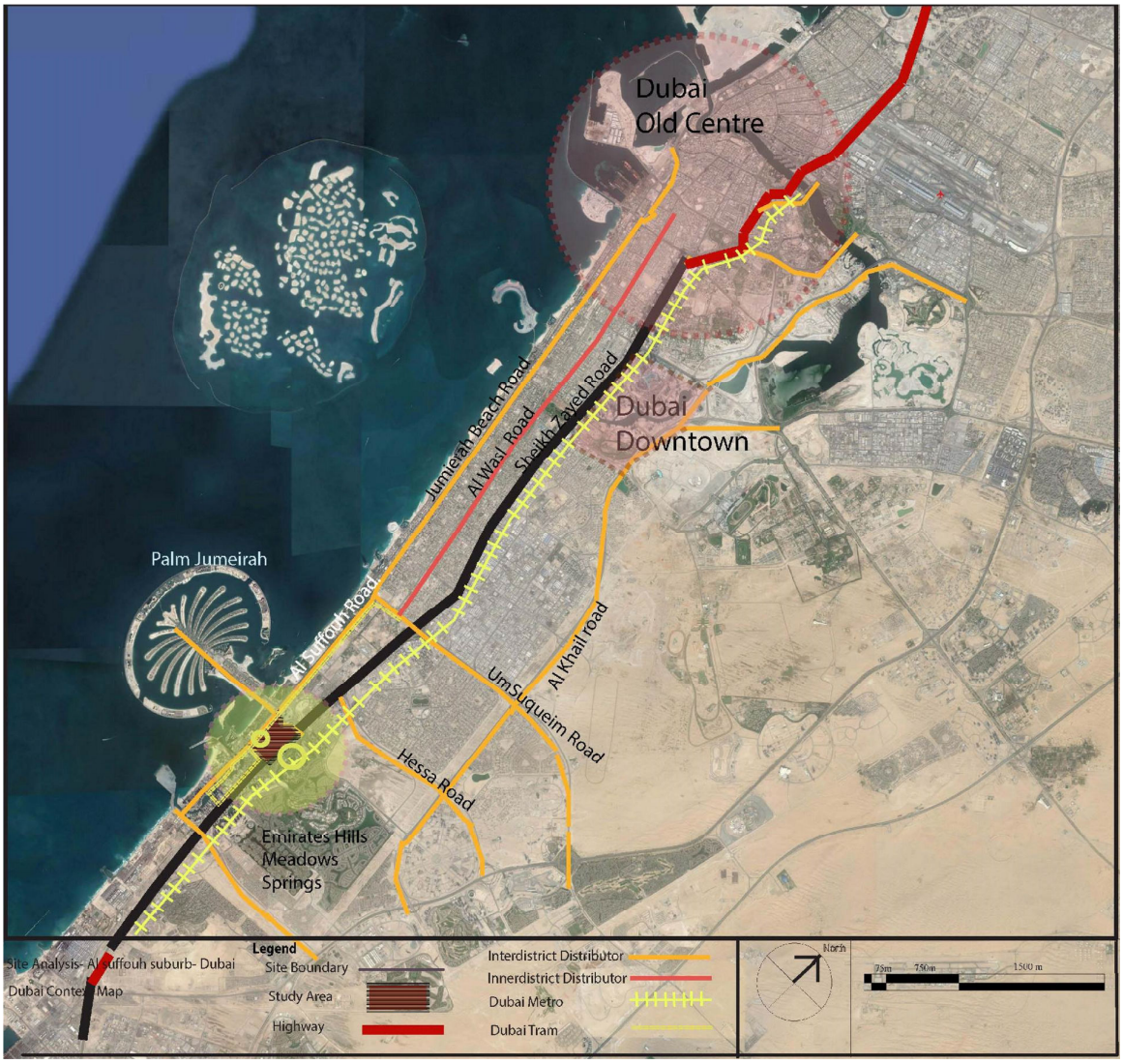
1. Study Area in relation to Dubai

The study Area is located in Al Suffouh, a suburban administrative area on the eastern end of Dubai, spreading over 7 km^2 and located 26 km from its city centre.Al Suffouh is connected to Dubai City center through four linear road corridors . Sheikh Zayed Highway, a national road, connects Al Suffouh to Dubai Downtown Area and other Emirates. Alkhail connect Al Suffouh to the expanding inner desert areas.Al Wasl and Jumeirah beach roads link Al Suffouh Road to the coastal beach areas.

Sheikh Zayed Road channels the city's traffic flow from suburban areas to the Downtown area and to Deira and Bur Dubai, located within the city's old centre. Jumeirah beach road and Al Wasl act as tertiary district distributors for the different suburban beach communities of Um Suqueim and Jumeirah. Hessa and Al Nassem roads connect the site to Al khail road, a secondary distributor road cutting through Dubai's western desert areas.

Due to its strategic location, the site is well served by public transport lines. On the North East, Dubai Metro Red line stops at the site via Nakheel Metro Station whereas on the North West, Dubai tram, running parallel to by Al Suffouh road stops at the site via Dubai Media City stop (as shown in Map 5.1).

Map 5.1. Dubai Context Map.



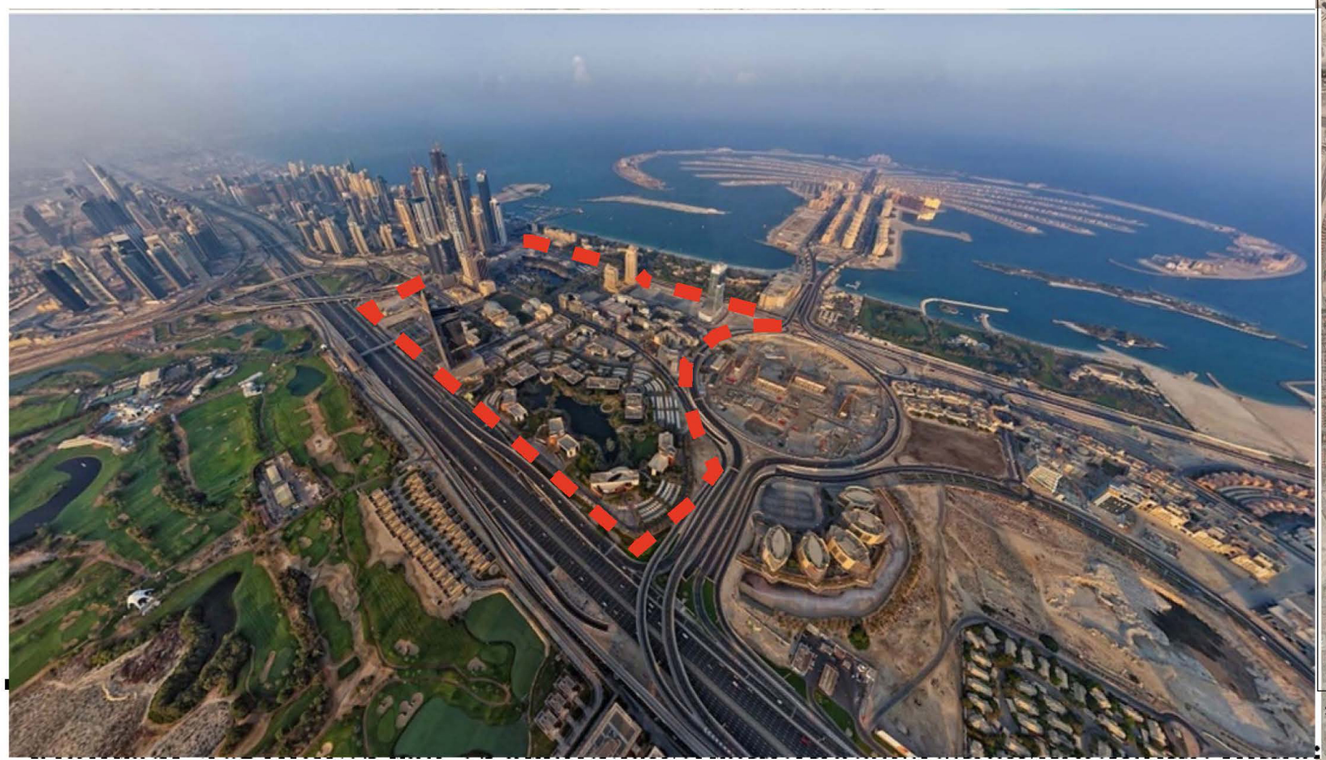
2. Study Area in relation to the surrounding

The site is a suburban center of the secondary urban node of Dubai. This secondary node contains Dubai large-scale waterfront developments such as Jumeirah Palm, Dubai Marina, Jumeirah Beach residence and Jumeirah Lake towers. On the North West of the site, private palaces and luxury beach resorts – such Royal Mirage and Westin Mina Siyahi overlook Al Suffouh beach area. Farther away, is Jumeirah Palm, Dubai's largest man-made island. On the Southwest and South, large scale dense mixed use developments -Dubai Marina development and Jumeirah beach residence - border the site. Further south, Jumeirah Lake Towers, a mixed-use development from a vertical edge to Sheikh Zayed Highway. Further South East, a flyover bridging over the highway connects the site to Dubai's prominent gated residential communities such as Emirates Hills, Meadows, Springs, Jumeirah Park and Jumeirah Islands.

As such, the area acts as a functional catalyst for this expansive heterogeneous landscape due to the high concentration of its commercial activities. It is also a transition zone between the vertically dense developments of Dubai Marina and Jumeirah Beach residence as well as the surrounding low dense suburban areas of Emirates hills, Springs and Meadows. The proximity of the site to the surrounding suburban communities is an opportunity to further reinforce Al Suffouh role as a service and business node, providing much needed civic and encounter space for their residents and introducing new urban forms reflecting its transitory character (see Map 5.2).

Map 5.2. Surrounding use

View Towards the East



View Towards the West

C. The Site

1. Description

The site is located on the southwest area of Al Suffouh Suburb, taking on 20% of its surface area. In 2001, a part of it was included as phase one in the Technology, E-commerce and Media Free Zone (TECOM) master plan.

Map 5.3. Al Suffouh suburb administrative boundary.

a. Land use

Hotels form the Northwestern border responding to the adjacent beach resorts on the other side of Al Suffouh Road. Towers edge the south and southwest boundary of the site mirroring the Dubai Marina towers typologies on the opposite side of Al Assad street. The site also contains a university campus, two office parks and two small residential complexes. The site diversity of uses influenced greatly the decision of building an onsite transit station to serve it (see Map 5.4).

b. Circulation

Arterials and highways bordering the site define its boundaries. On the North West, Al Suffouh acts as an arterial road distributing vehicular traffic flow from Dubai Marina Development to the beach areas of Jumeirah. On the South west, Al Assad road provide an entry point for residents of the expansive area of Emirates Hills through a fly over. On the North East, a circular road loop breaks the vehicular connection between TECOM phase 1 and TECOM phase 2 except for a tunnel joining their main collectors' roads (shown in Map 5.4).

Map 5.4. The site land use.

Map 5.5. Administrative framework.

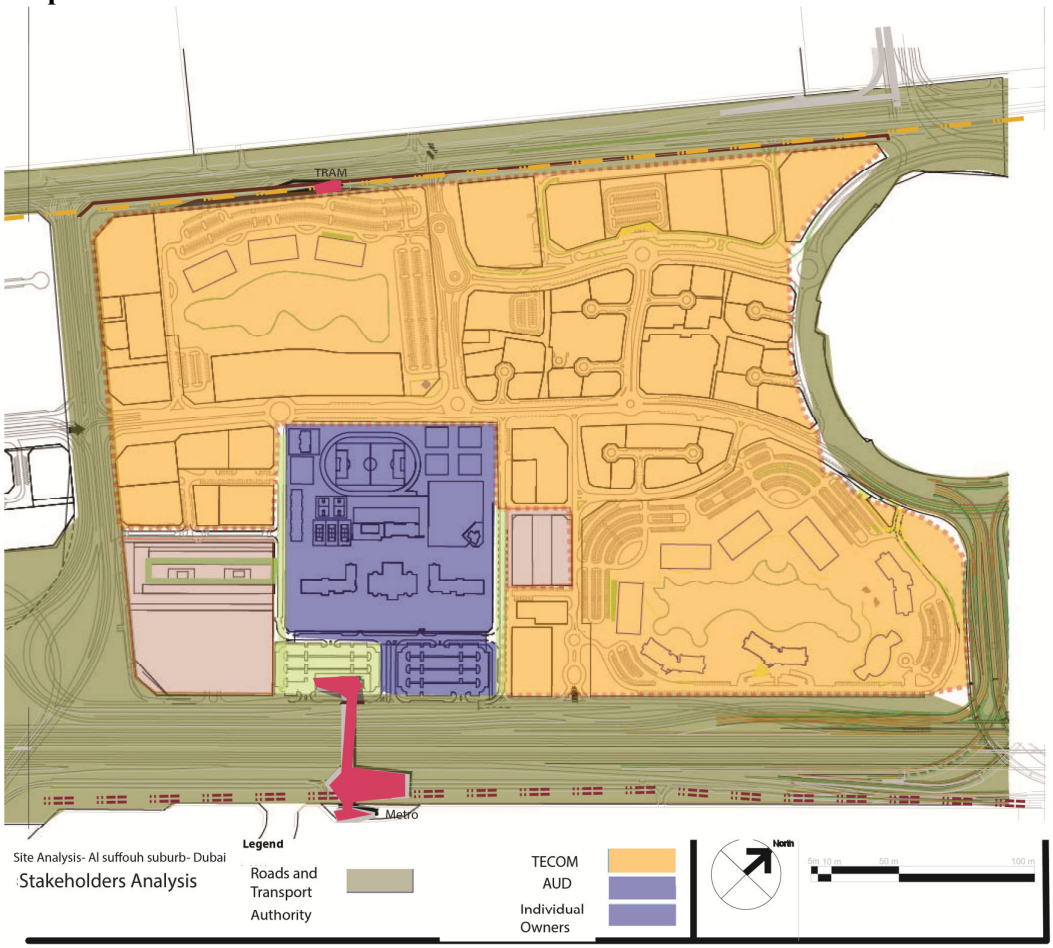


Table 5.1. Stakeholders' roles in relation to the development process.

Roads and transport authority	Tecom Investments	AUD	Private Owners
▪ Government authority ▪ formed by the decree number 17 for the year 2005. ▪ Planning and providing the requirements of transport, roads & traffic ▪ Design and Develop assets owned by them	▪ Semi – Government authority Real estate master developer Of freehold zones assigned by the government Operator of Dubai's leading business parks. ▪ business parks ▪ property development arm ▪ subsidiary holdings and investments.	▪ Private for-profit institution ▪ University ▪ Own and operate their campus and designated parking	▪ Private Companies ▪ Corporate headquarters /hotels/office building/residential complex ▪ Own the right to build on their plot after approval from TECOM

c. Legislative framework

The site is currently administered by different stakeholders. Technology, E-commerce and Media free zone (referred to as TECOM) controls most of the commercial use .Since it is a free zone, it has established its own regulatory framework and zoning authority known as TECOM Zoning authority. The latter reviews development proposals according to the formally approved TECOM master plan. Since TECOM master plan excludes 10% of the current site uses from its framework, other stakeholders manages these plots (see map 5.5 and Table 5.1).

Dubai's Roads and Transport Authority (RTA) owns and manages the surrounding road network, the transit nodes and their adjacent surface parking. As shown in the map below, it is the largest owner of surface area approximating around 30% of the total site area. The American University of Dubai owns and manages its campus and its adjacent surface parking. Individual owners of private plots only own the right to develop it.[5] Thus, if a development proposal submitted by a local authority such as RTA wins the formal approval of Dubai executive council, development rights- based on evaluation and compensation procedures for the owner- are transferable.

Therefore, the proposed TOD would be essentially a re-validation of the current TECOM phase 1 master plan by integrating within it the interests of the other stakeholders such as RTA, the university students and faculty and the private plot owners. It is also an attempt to align the development agenda of TECOM in regenerating the site with the public transport strategic goals of Dubai Roads and Transport Authority in increasing public transport uptake.

[55] Dubai has different legal restrictions on land tenure depending on the geographical area and the decree that governs it. these differences have been the subject of legal analysis.

2. Analysis and Diagnosis

a. Identity

The site-wide identity is influenced by its multiple character zones and its legibility (Map 5.6 and 5.7).

i. Character Areas

The site is composed of seven distinct areas ranging from office parks (Dubai Media city and Dubai Internet City), educational campus (American University in Dubai), a dense central zone (Media Village), Hotels zone and Towers Zone. As shown in map 5.5, each character zone stands as a spatial entity in itself, physically disconnected from the other zones. Intermediate areas in between the character zones lack special character. This results into a fragmented site lacking an overreaching character that defines it.

ii. Legibility

The Metro Station enforces site legibility on a city-level , being its most important landmark visible from the highway and its primary node of the site as the major public transport hub for the site (Lynch,1960).The tram station on Al Suffouh road and Al Falak main roundabout act as secondary nodes, forming a West-East axis connected to the metro station. This west-east axis is further reinforced as the different west-east paths act as distributors from the transit node to the different character zones.

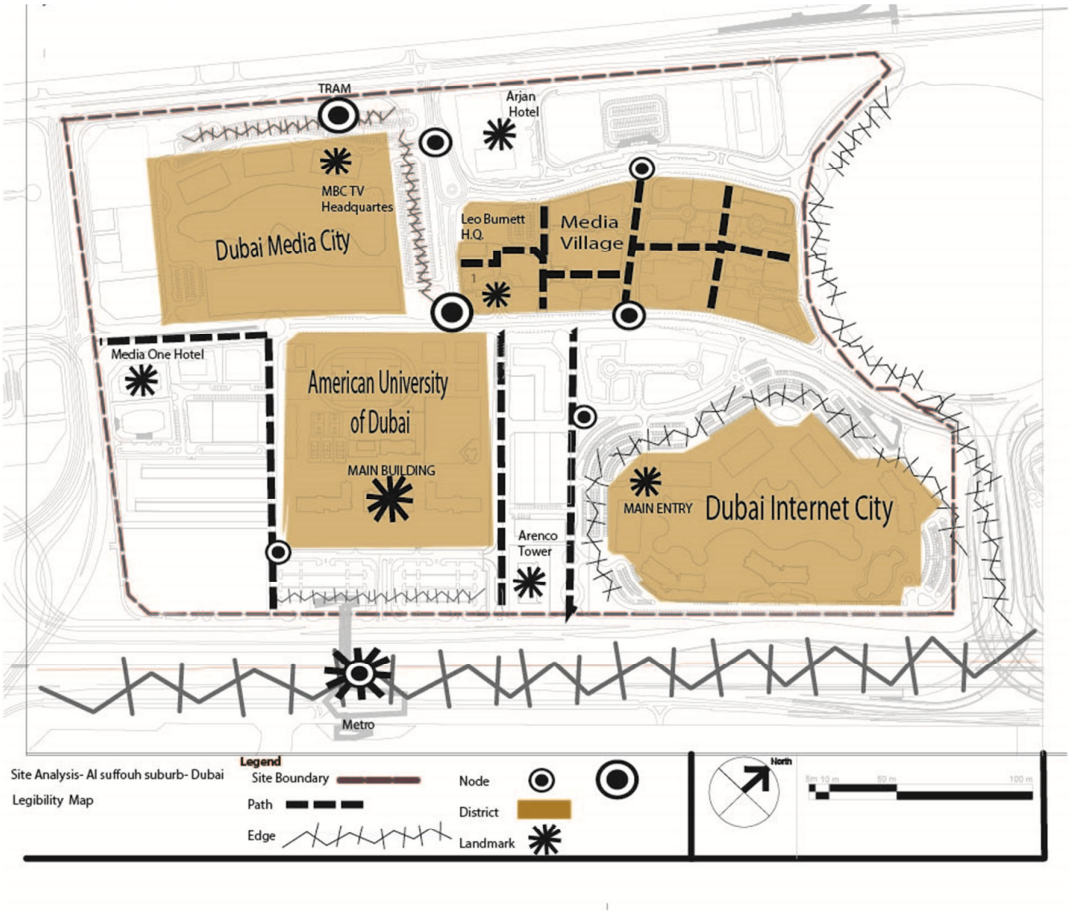
As shown in Map 5.6, the site overall legibility is low. First, the presence of a vacant empty plot adjacent to the Metro station decrease its prominence on the highway. Second, the site's different districts such as Dubai Media city and Dubai Internet city have strong inner legibility, as closed spatial entities. As for the Media Village, its unique morphology makes it an example of structuring for inner legibility but does not

add to the site overall legibility. The strong spatial enclosure of the three zones reduces their susceptibility to change. On the other hand, the American University in Dubai - though it is an independent district - responds more to the surrounding street network and thus would benefit from increasing its permeability.

As such, the proposed TOD plan needs to link the character zones together through and create permeability and linkages between the character zones along the west-east axis connecting the two public transport hubs. Nakheel Metro Station can play a major role as one of these transport hub and as a prime orientation feature and visual landmark, reinforcing the legibility and identity of the site at district scale.

Map 5.6. Character zones.

Map 5.7. Legibility map.



b. Infrastructure

i. Vehicular

The site is accessed from three exclusively vehicular entry points – exit 32 from Sheikh Zayed Highway, Al Assad road and Al Suffouh Road. The road network consists of one main road distributing vehicular flow from Al Assad entry point to the secondary and tertiary roads for the different site districts. This caused different congestion points as highlighted in Map 5.7. Traffic is actually very slow during morning (8:00-9:00 am) and afternoon (5:00-7:00 pm) on the main collector road from al Falak Street and the secondary collector road from Al Suffouh road. The tertiary

roads mainly ends unto large surface parking areas or structured parking which occupy 20% of the site area- See Map 5.7.

The site is well served by an extensive bus network .Based on the analysis of the major bus routes connecting the site to Dubai (See appendix –A); ped-sheds were generated based using a 200 m walkability radius. The analysis showed that bus stops are at walkable distanced from most of the site areas. Local bus takes from five to twenty-seven minutes to tour the site; their frequency is highly influenced by congestion on their routes because of lack of dedicated bus lanes on Dubai roads.

The analysis showed car dependence pattern on a local scale causing traffic congestion and extensive use of land for surface parking. A strategy reinforcing public transport relieves the current traffic congestion and decrease the need for the current expansive surface parking areas (see Maps 5.8 and 5.9).

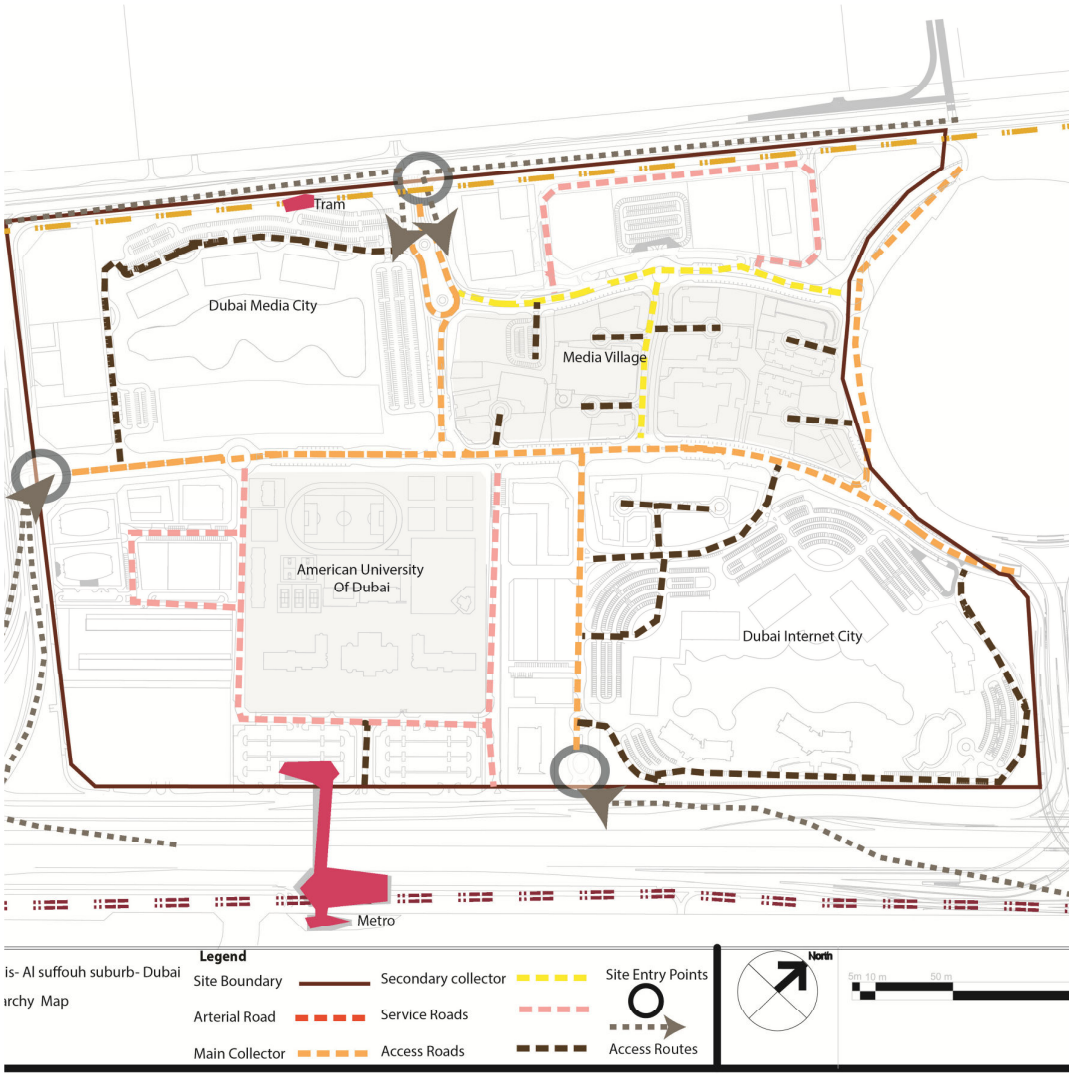
ii. Pedestrian

The only pedestrian entry points to the site are the two transport hubs on its two edges. However, the mapping of the pedestrian circulation of the site revealed that the majority of the pedestrian paths are confined within the enclosed spatial entities. This inner pedestrian circulation network is completely disconnected from the sidewalks network leading to the two transport hubs. In addition, major conflict areas between vehicular and pedestrian circulation occur next to the two public transport stations, due to the lack of pedestrian-friendly paths. In fact, one has to cross roads and surface parking in order to get to the stations (see Map 5.10).

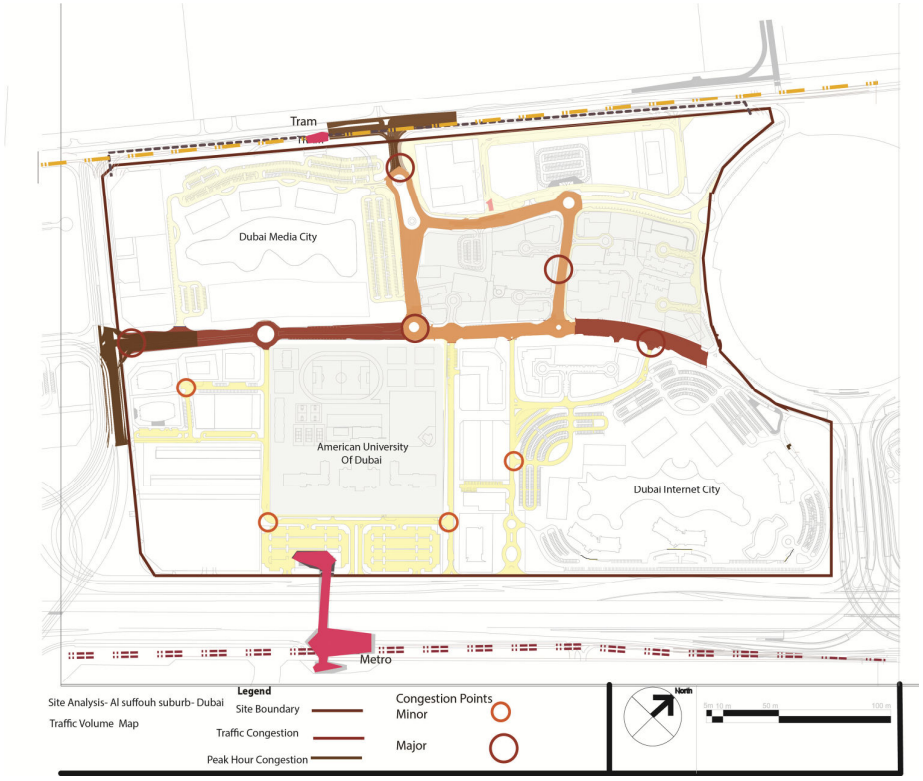
As such, redesigning the areas around the transport stations as poles of pedestrian activity concentration and diffusion would improve pedestrian circulation

and provide an opportunity for a district-wide pedestrian network connecting the isolated inner circulation networks of the different campus.

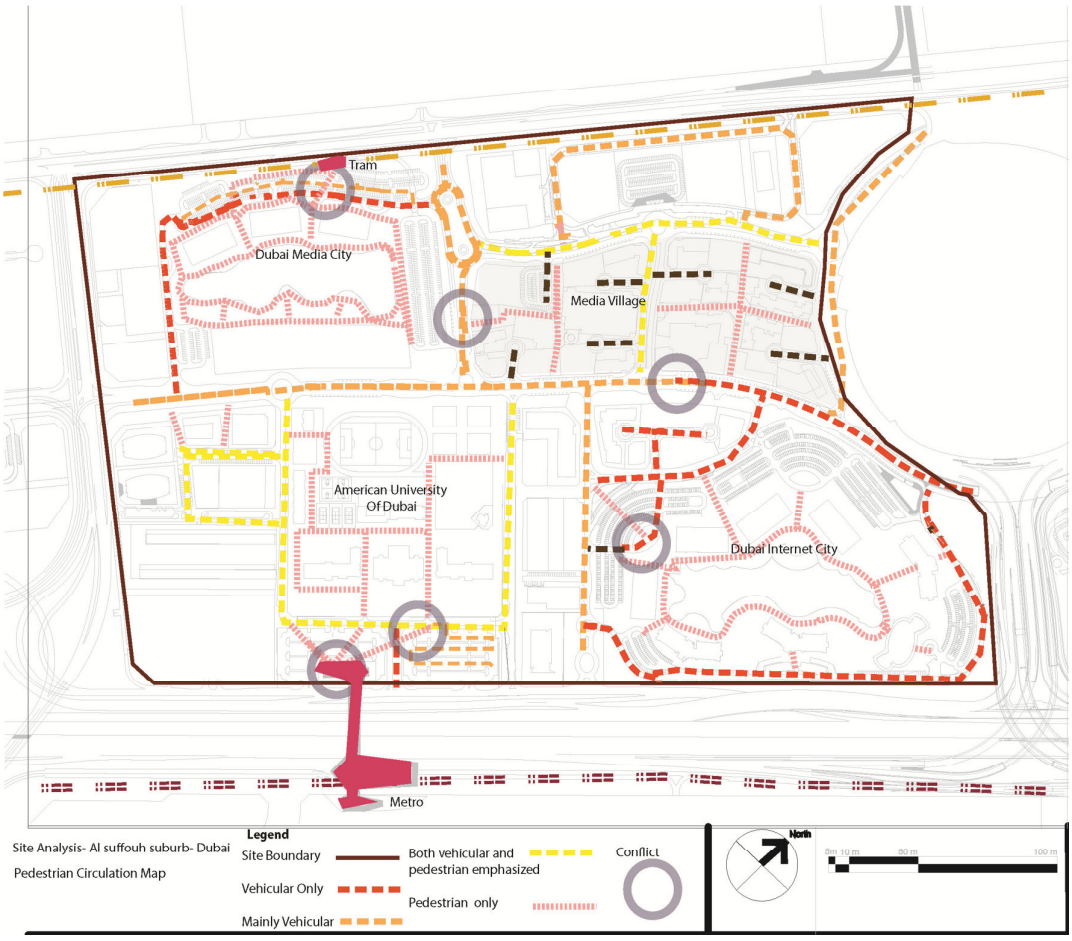
Map 5.8. Road network.



Map 5.9. Traffic flow and parking.



Map 5.10. Pedestrian network.



c. Public space

The site lacks completely public open and green spaces especially around the transit hub.

First, the intermediate space between buildings in Media Village form inner courtyards and paths that are mostly semi-public open spaces. The inner districts' open space in Dubai Media City, Dubai Internet City and American University in Dubai are heavily landscaped considered as semi-private inner green parks.

The remaining open spaces are the expansive surface parking areas and streets, which could be classified as public. First, the expansive surface parking areas do not

include pedestrian pathways and separating the inner landscaped areas from the two transit stations and from streets remain the only public linear open space. However, field and site visits revealed that they are not pedestrian friendly (see Appendix A). A visual survey revealed the last of exclusive pedestrian access in most of the formal and informal sidewalk networks leading to the transit node. In particular, at night, spaces were empty with minimal pedestrian traffic was minimal at night. The quality of the street sidewalks was not conducive to walkability and suffer from:

- Lack of active street fronts; most of the edges are fences or high walls.
- Monotonous pavements: most of the pedestrian routes were paved in concrete interlocks - regardless the importance, function or role.
- Absence of street furniture such as benches, light poles

The above analysis reveals the need for a public open space network connecting the transport stations to the different internal landscaped areas re-configuring the streets network around secondary civic spaces (see Map 5.11).

d. Private Development

The development of the site followed three phases (as mapped in Map 5.15) resulting into three different typologies:

1- Large scale low dense instant developments
2- Ad-hoc process of densification following a plot by plot pattern which contributed to the site diversity
3- Tall structures acting on the main site entry points benefitting from high visibility.

The three phases is confirmed through mapping the heights. Height of buildings evolved from low rise- low dense office buildings to high-rise towers on major entry

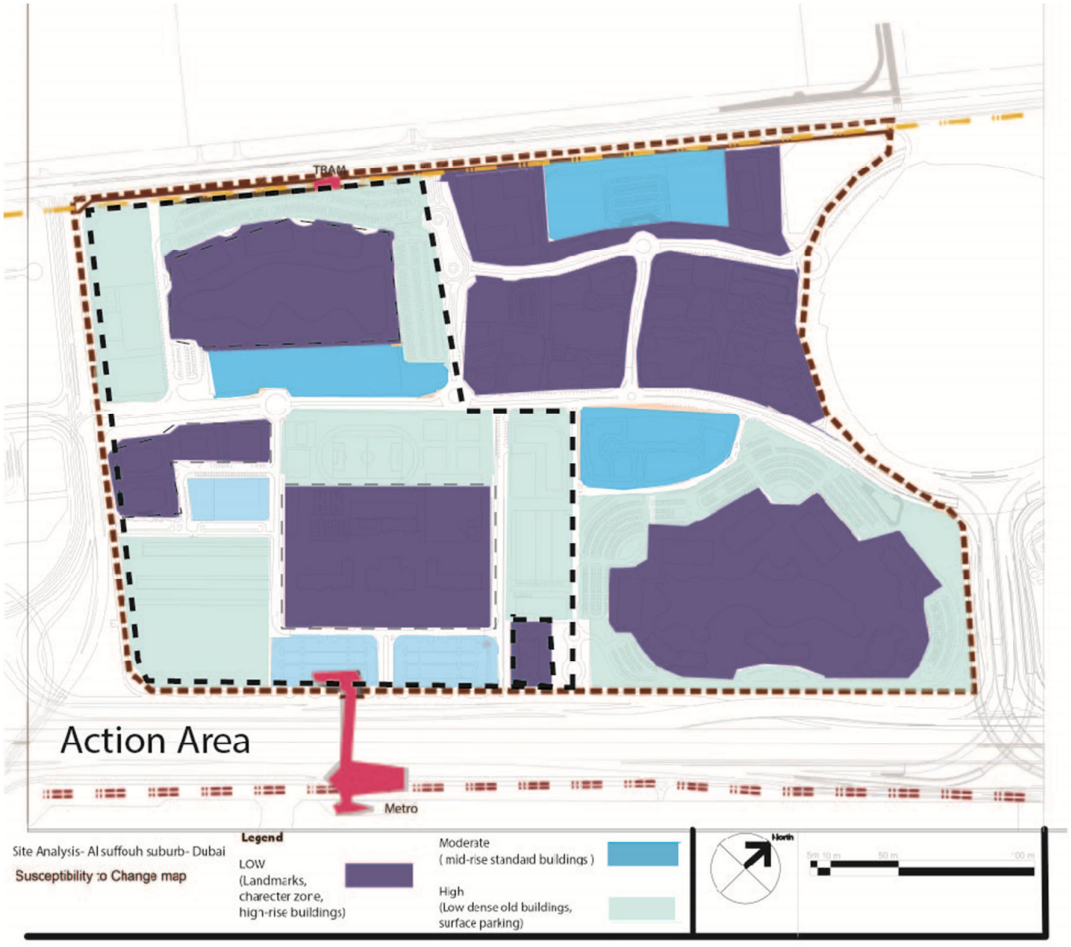
points and roads corridors. This evolution indicates the necessity to emphasize the highway and Al Assad frontage edges with high-rise towers and provides guidance on potential heights for the proposed plan that need to close the gaps between high-rise towers and low dense office buildings.

The susceptibility to change was mapped according to three categories. Landmark buildings, high-rise structures and character zones scored low on susceptibility to change whereas low dense old buildings and vacant plots were as greatly susceptible to change. The analysis showed that the areas around Nakheel stations are the most susceptible for change. Therefore, these areas will be included in the Action Area that will be designed in detail as part of the proposed TOD (see Maps 5.12 to 5.16).

Map 5.11. Public space.

Map 5.13. Building use.

Map 5.15. Building age.


TRAM
Action Area
Metro
Site Analysis- Al suffouh suburb- Dubai
Susceptibility to Change map
Legend
LOW
(Landmarks,
character zone,
high-rise buildings)
Moderate
(mid-rise standard buildings)
High
(Low dense old buildings,
surface parking)
North

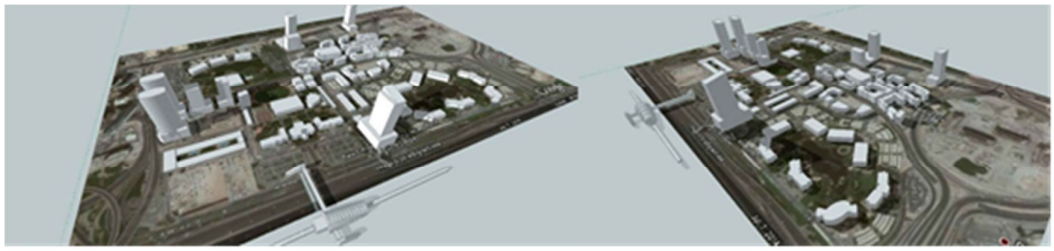
e. Sustainability

The site's sustainability is analyzed according to the three tenets of sustainability- economic, social and environmental.

i. Economic vitality

The current site is not financially sustainable; the current densification of the site is following an ad-hoc process jeopardizing its identity and consequently would affect its attractiveness as a free zone. The massing analysis (see Figure 5.2) reveals the potential of refocusing growth unto the plots within the development radius of both Dubai Metro and Dubai Tram. This densification proposal entails a re-validation of the TECOM phase 1 master plan and its guidelines.

Figure 5.2. Massing.



ii. Social Diversity

The current social groups of the site are the employees of companies located within the business parks and TECOM addition to the students and faculty from the American University of Dubai. As such, the site diversity is limited based on Table 5.2. Densifying around the transit node is an opportunity to provide the much needed social infrastructure and community services supporting the different user groups. New typologies such as student housing, entrepreneurs' hubs, faculty housing and retail would attract a more diverse site population.

Table 5.2. Diverse Groups Living and Working in TOD - Source: Queensland (2010)

Demographically diverse groups	
Age	Children (preschool (0–4 years) middle childhood (5–9) early teens (10–14)
	Young people (15–19)
	Young adults (20–29)
	Mature adults (30–54)
	Empty nesters (typically 55–64)
	Older people (65+)
Household/ family composition	Nuclear families (2 parents with child/children)
	Single-parent families
	Couples
	Large (including extended) families
	Single people (of all ages)
	Group households (unrelated individuals sharing a dwelling)
Other demographic characteristics	Disability
	Gender
	Alternative lifestyle (e.g. eco-villagers)
Socio-economically diverse groups	
	Middle- and high-income groups
	Low-income groups
	Renters
	Homeowners
	Homeless people
	Pensioners and self-funded retirees
Culturally and linguistically diverse groups	
	Established and recent immigrants
	Refugees
	Indigenous (i.e. Aboriginal and Torres Strait Islander) people
	Religious groups
Workforce groups	
	Students
	Key workers
	Temporary workers (seasonal and holiday workers)
	Home workers
	Other workforce groups
	Unemployed workers

iii. Environmental Integrity

The role of the two transit stations in reducing car dependence and increasing the viability of public transport is undermined by the lack of site walkability. Walkability across the site was assessed through: Ped-Shed analysis, Visual survey and shading analysis (see Map 5.17 and Figures 5.3 and 5.4).

The Ped-Shed analysis used data collected from Wijhati[6] on existing sidewalks during Weekends and Weekdays at morning, afternoon and evening. The analysis showed that AUD can be accessed in around seven minutes from the transit node station (see Appendix A).

Table 5.3. Duration for walking inside the site from Nakheel Metro station.

Destination from the Nakheel Metro Station	Time taken
Nearest bus stop	7 minutes
The Towers zone on the south west	17 minutes
Dubai Internet city main pedestrian entry	15 minutes
Dubai Media City entry	20 minutes

The durations for walking from the transit node range from seven minutes to twenty minutes. These durations are high if compared with the ''Comfort sheds'' of 3 minutes established as per the literature review for subtropical desert climate (refer to Section 2.C). However, walking to one of the existing bus stops inside the study area takes two to seven minutes- falling within the range of acceptable durations of the comfort sheds.

[6] Wijhati is a smart application analyzing the different ways a destination is reached using different transport systems.

These results reveal the need to reduce the time it takes to reach the transit stations. An interconnected fine grained street pedestrian network would shorten walking distances and increase the site walkability.

Climate responsiveness is another issue limiting walkability. Shading analysis of the main pedestrian routes leading to the transit node revealed their continuous exposure to the sun; walking to the transit station becomes unbearable during noon and morning time.

As a conclusion, the current development pattern that the site is adopting is not sustainable on the long run; its master plan needs to be re-evaluated in order to refocus its growth, increase its social diversity and re-design its networks and spaces for walkability.

D. Recommendations

The outputs of the site analysis are summarized in Table 5.4.

Map 5.17. Walking through feet versus taking the bus for various destinations.

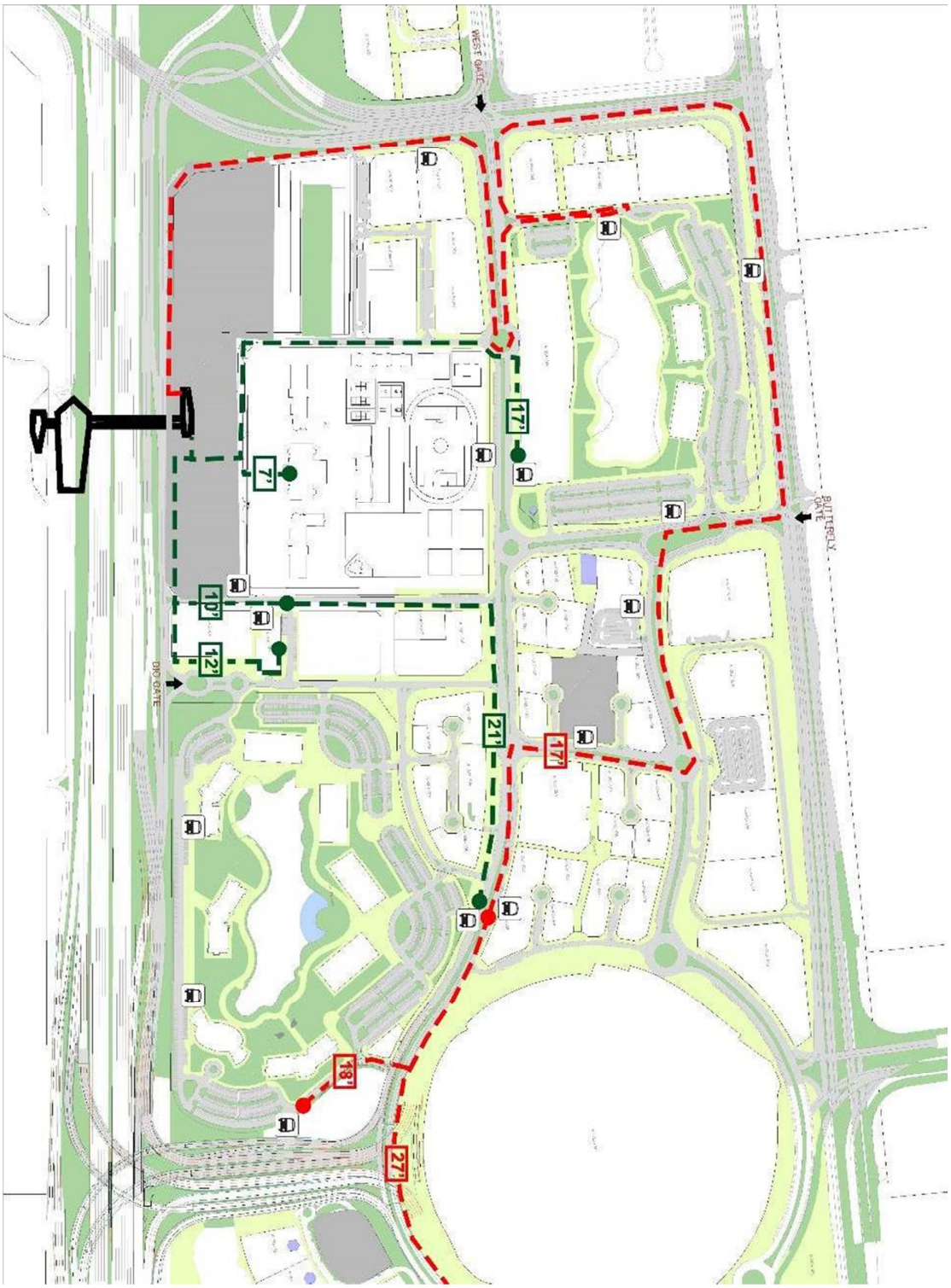


Figure 5.3. Shading analysis of areas around transit node.

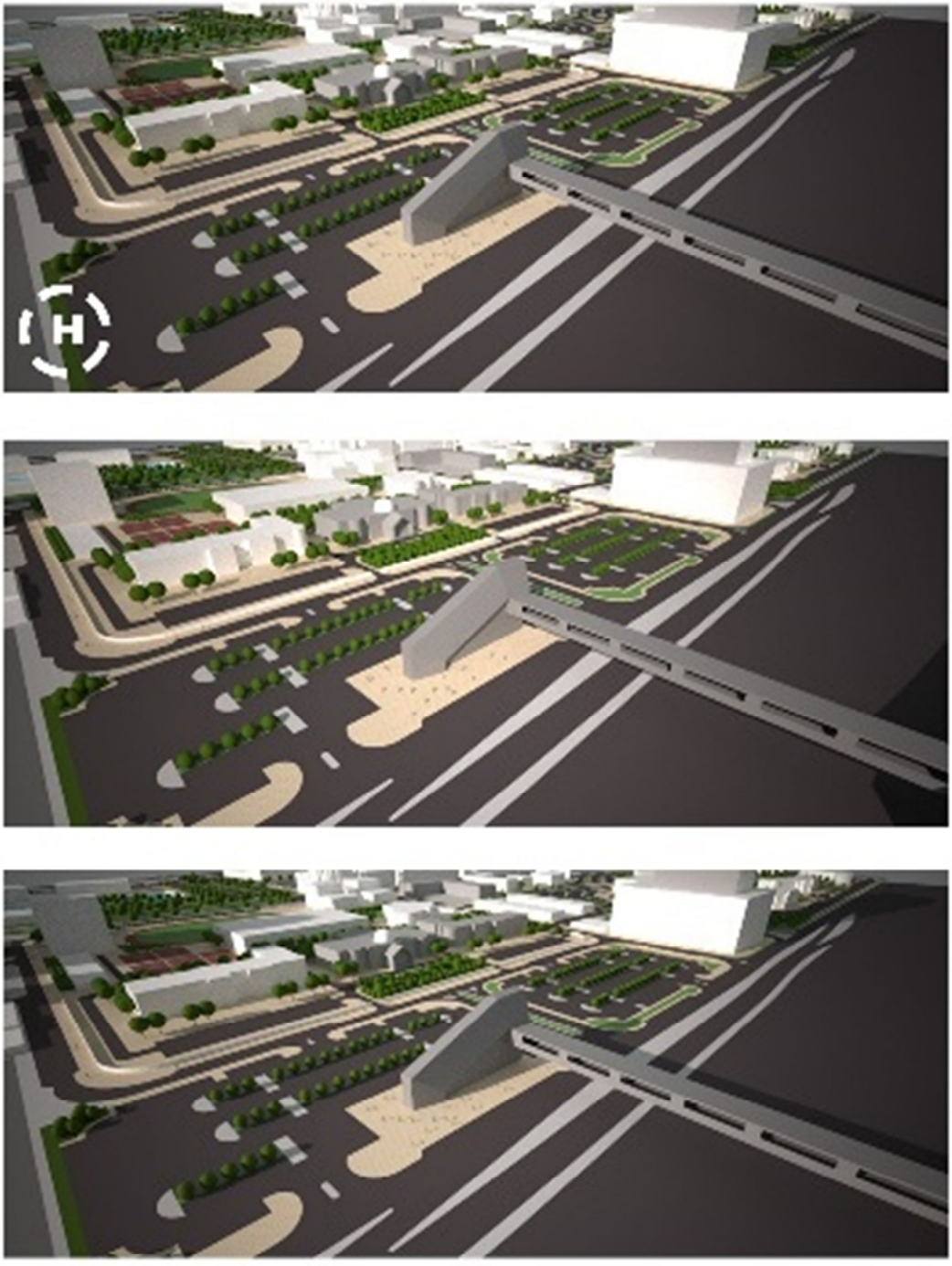


Figure 5.4. Shading Vignettes for major pedestrian paths leading to the transit node.

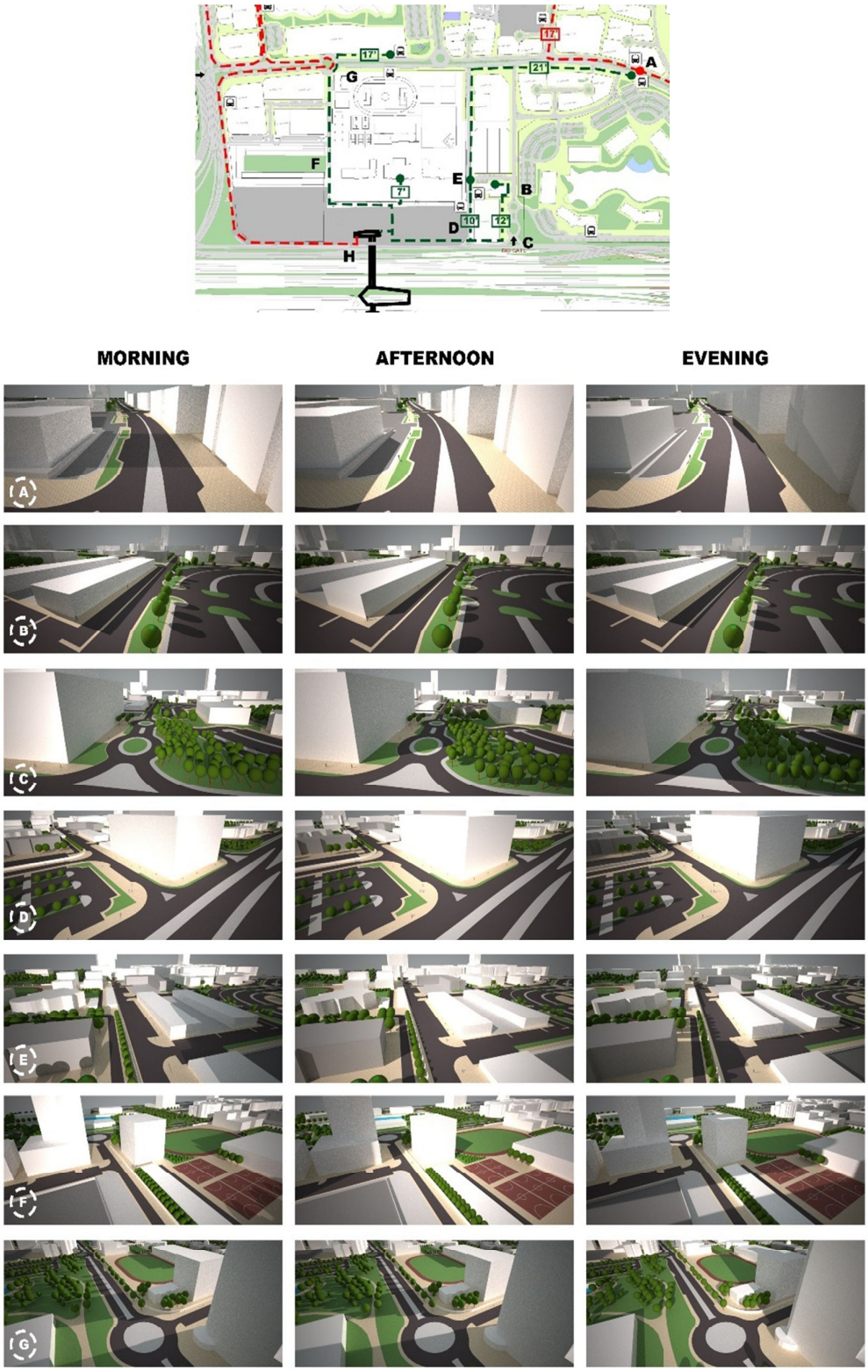


Table 5.4. Summary of the site analysis.

Urban Design Dimension	TOD as Sustainable Development					
	Economic Vitality		**Social Diversity**		**Environmental Integrity**	
	Principle stated in toolkit	**Issues highlighted during site analysis**	**Principle stated in toolkit**	**Issues highlighted during site analysis**	**Principle stated in toolkit**	**Issues highlighted during site analysis**
Identity	Transit as a point of density Convergence -Mixed use core -high density around transit node -density decrease away from transit node	Nakheel metro station is surrounded by surface parking and empty plots Urban form does not respond to Nakheel Metro Station as a major landmark and node	Mixed use development -transit supportive uses -Mix horizontally and vertically -Mix to be determined according to surrounding and development need	Limited use diversity Limited building typologies	Break the 600 m catchment - 100 m segments - node at the origin and end of each segment - accommodate air-conditioned indoor gathering spaces at strategic locations	The design of the existing pedestrian network does not lead to transit node Pedestrian are not designed according to ped-sheds
Ecology	compact urban form in a radius of 400 -600 m: building to plot edges vertical densities limited to strategic location	Fragmented built form Buildings are scattered and do not relate to each other Buildings do not frame streets Vertical density	Diverse housing typologies building Social infrastructure to support it Civic uses and institutional services for the community	Housing limited to student and faculty housing inside the university campus Housing on site is not integrated with the site plan and do not have adequate social infrastructure to support it	Green spaces network connect transit to various locations Conserve important local ecosystem and habitats	lack of a green space network connected to Nakheel Metro Station and Tram Station Major green spaces within the three site campus – DIC ,DMC and AUD
Infrastructure	Plan a retail mixed use area community retail for residential neighborhood concentrate convenience stores around transit node, bus stops and on major pedestrian routes Introduce night time activities to increase transit use off-peak hours	Lack of retail areas Lack of central area accessible Lack of night activity around transit	pedestrian and street network: Safe, Convenient, Comfortable, fine-grained ,connected to nodes with active street fronts	Streets are designed for cars Sidewalks are dis-continuous Lack of integration between internal pedestrian circulation for campus and external pedestrian paths	urban structure : fine –grained, permeable ,transit as center ,respect wind corridors, Human Scale	Large blocks separated by surface parking Large blocks limit site permeability Urban structure is determined by roads and vehicular site access Wind corridor analysis was not conducted on site
Public Space	Major civic place around transit Secondary civic spaces based on 18 hour activity Public space planned as positive space frame by buildings	Lack of central civic space accessible from metro or tram Lack of secondary civic spaces on site \Open space undefined, amorphous, fragmented	Diverse types of open spaces	Lack of a network of open spaces Lack of public spaces on site	climate responsive walkability strategies Shading strategies Greening strategies	Sidewalks and pedestrian paths are not shaded-and not designed for hot and humid climate Green areas not shaded and not designed for hot and humid climate
Private Development	Gradual Intensification of uses over time Development phasing plan Development design Program Priority to public realm improvement around the transit node	Chronological development of the project showed that each development was conceived as a unit by itself leading to site fragmentation No phasing plan devised for the site	Diverse residential, commercial and retail typologies Flexible to host multiple sizes Encouraging perimeter urban blocks	Site typologies limited to office buildings, towers and low dense residential complex On-site buildings are stand-alone structures and do not relate to the street or each other	climate responsive urban design guidelines to guide development proposals: provide shaded areas on urban blocks edges Use wind for natural ventilation by orienting corridors to prevailing wind directions	Media village was designed for climate responsiveness ; other site areas were excluded from planning report Shading was not taken into consideration in landscape strategy Wind was not taken into consideration during planning and design phase

CHAPTER SIX

PROPOSED MASTER PLAN AND INTERVENTION

A. Introduction

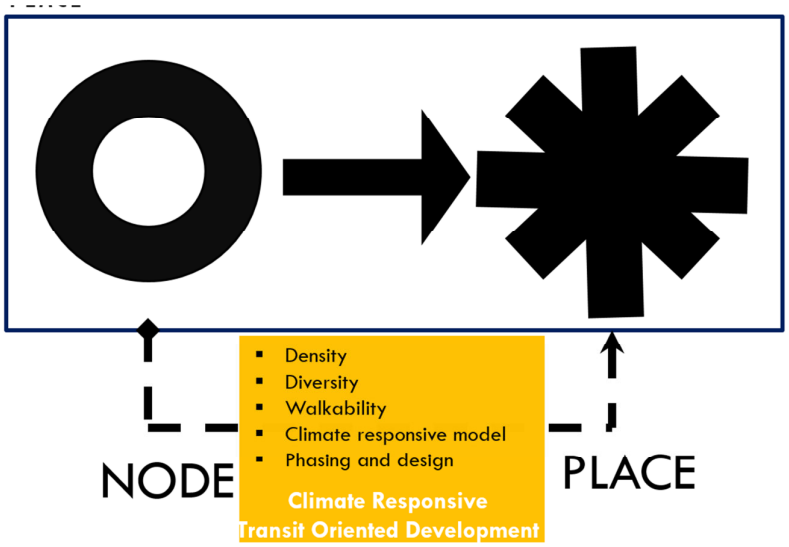
This chapter describes how the Climate responsive TOD model is applied on a district level and local level to re-master plan Al Suffouh. The chapter follows the layout of a typical master plan report.

B. Proposed Urban Design Strategy

3. Strategy

The overall strategy is to re-frame the transit station from a transport node to a center around which a place revolves using the Climate responsive TOD model and Toolkit.

Figure 6.1. Diagram showing the urban design strategy.



2. Structuring the master an around three transit nodes: bus, tram, metro

Transit oriented development densities concentrate on a 400 m catchment radius. Accordingly, the proposed master plan is structured around three transit nodes.The catchment area of Nakheel Metro station intersects with Dubai Media City tram station on the northern and eastern side of the American University in Dubai. Based on catchment area analysis, for blocks located beyond the 800m development radius, a third local bus terminal serving TECOM area is proposed as the center of a third TOD.

The proposed use for the third TOD is residential subject to detailed master planning at a later stage. The terminal feasibility would increase as public transport ridesrship to access the site, therefore justifying an internal transport system. The presence of the bus terminal in subsequent phases will also decrease parking needs for the proposed surrounding residences.

3. Objectives and goals based on the toolkit

Based on the last chapter analysis of the current situation and the customized toolkit, the urban design strategy account for the below objectives, grouped according to the five dimensions and summarized in Table 6.1.

Map 6.1. Al Suffouh - proposed TOD's.

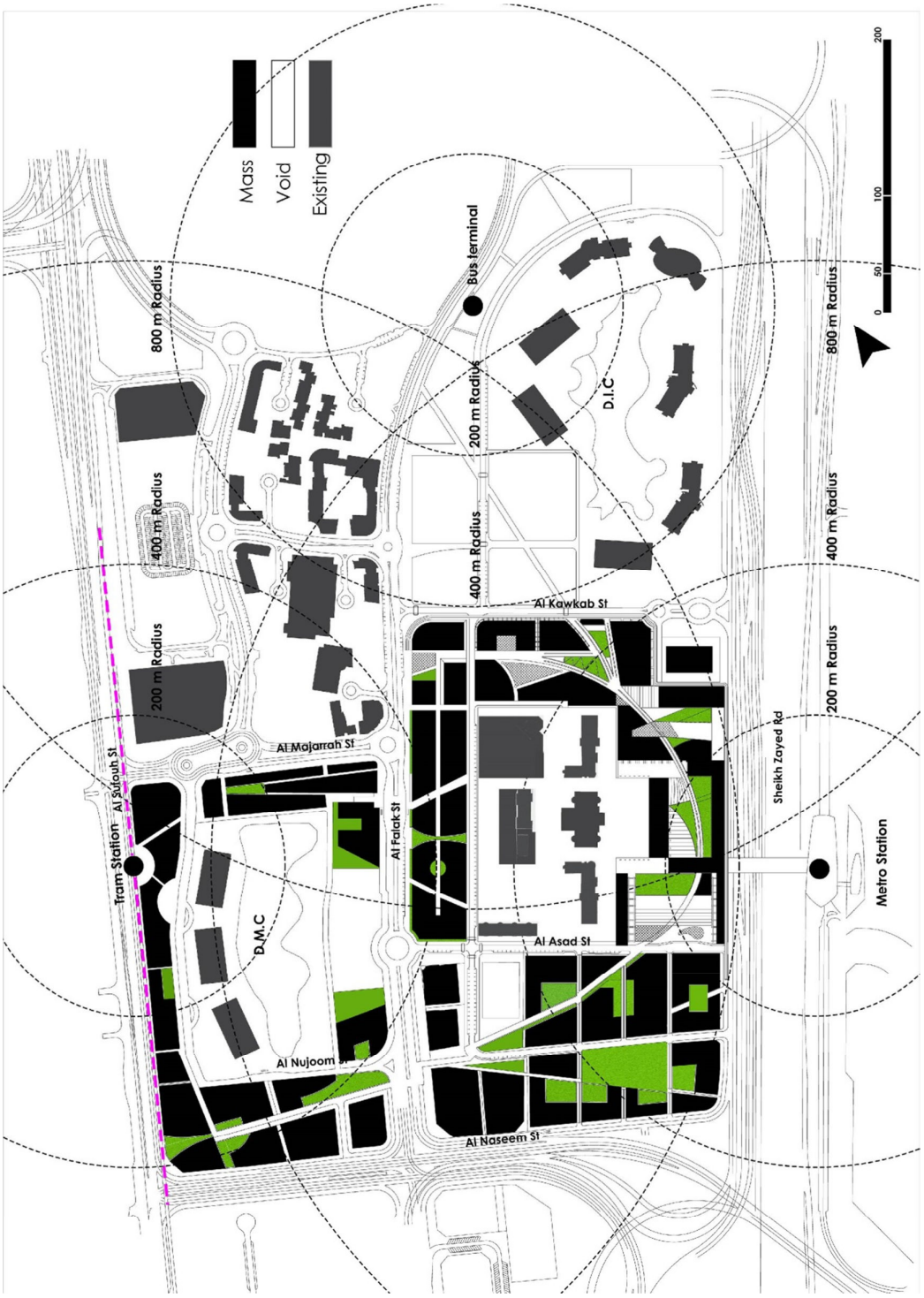


Table 6.1. Urban Design strategy.

Urban Design Dimension	Proposed Strategy to retrofit Al Suffouh based on the alternative climate responsive TOD model and toolkit					
	Economic Vitality		**Social Diversity**		**Environmental Integrity**	
	Principle stated in toolkit	**Proposed AL Suffouh TOD -Urban Design Objectives**	**Principle stated in toolkit**	**Proposed AL Suffouh TOD -Urban Design Objectives**	**Principle stated in toolkit**	**Proposed AL Suffouh TOD -Urban Design Objectives**
Identity	Transit as a point of density Convergence -Mixed use core -high density around transit node -Density decrease away from transit node	Dense mixed use core around transit station	Mixed use development -Transit Supportive Uses -Horizontal and Vertical Mix -Mix to be determined according to surrounding and development need	Inject retail ,housing ,flexible offices and cultural uses, community infrastructure and mix them horizontally and vertically	Break the 600 m catchment Pedestrian network to be designed as 100 m segments Nodes at the origin and end of each segment Accommodate air-conditioned indoor gathering spaces at strategic locations	Design a network of 100 m tertiary and secondary courtyards breaking the 400 m and 200 m into manageable chunks during hot weather Iintroduce air-conditioned gathering spaces at transit node and major squares
Ecology	Compact urban form on a radius of 400 -600 m Building extend to plot edges Vertical densities limited to strategic location	Densifying around 200m and spread densities on 600m and 800 m Buildings next to the highway need to be designed as an edge that does not visually obstruct American University of Dubai	Diverse housing typologies building Social infrastructure to support it Civic uses and institutional services for the community	Student housing, faculty apartment , studios and midrise housing introduced building Plan for social infrastructure and amenities in order to support and attract diverse groups such as elderly, families, and young entrepreneurs to the site	Green spaces network connect transit to various locations Conserve important local ecosystem and habitats	Conserve the large two green spaces of Dubai Internet City and Dubai Media city Plan a green space network to link the internal inner circulation networks
Infrastructure	Plan a retail mixed use area Community retail for residential neighborhood Concentrate convenience stores around transit node, bus stops and on major pedestrian routes Introduce night time activities to increase transit use off-peak hours	Propose a retail area that serves DIC, DMC, media village and AUD on the East-West Axis	Pedestrian and street network: Safe, Convenient, Comfortable, fine-grained ,connected to nodes with active street fronts	Introduce complete streets connecting residential, commercial and civic nodes introduce jogging and cycling track Building typologies need to account for vertical mixity making sure that ground floors uses support active street frontages	urban structure : fine –grained, permeable ,transit as center ,respect wind corridors, Human Scale	Break down large blocks into smaller blocks Propose new streets in order to increase accessibility Massing needs to respect wind corridors Orient buildings where possible 45 degrees
Public Space	Major civic place around transit Secondary civic spaces based on 18 hour activity Public space planned as positive space frame by buildings	Sunken plaza around metro station Secondary civic spaces based on 18 hour activity Civic spaces framed by landmark buildings in retail	Diverse types of open spaces	Diverse types of open spaces and for children, elderly, residents, employees, visitors Major pedestrian walkway collect pedestrian flow from secondary paths and lead to Nakheel Metro station	climate responsive walkability strategies Shading strategies Greening strategies	Climate responsive walkability strategies Shading Greening
Private Development	Gradual Intensification of uses over time Development phasing plan Development design Program Priority to public realm improvement around the transit node	Propose a Phasing plan with the civic spaces around the transit node as the first phase	Diverse residential, commercial and retail typologies Flexible to host multiple sizes Encourage perimeter urban blocks	Introduce new typologies for office buildings, commercial and residential buildings Blocks designed as perimeter urban blocks	Climate responsive urban design guidelines to guide development proposals: Provide shaded areas on urban blocks edges Use wind for natural ventilation by orienting corridors to prevailing wind directions	Study massing in order to enable wind ventilation and introduce courtyard and narrow streets for shading

C. Master Plan

1. Identity

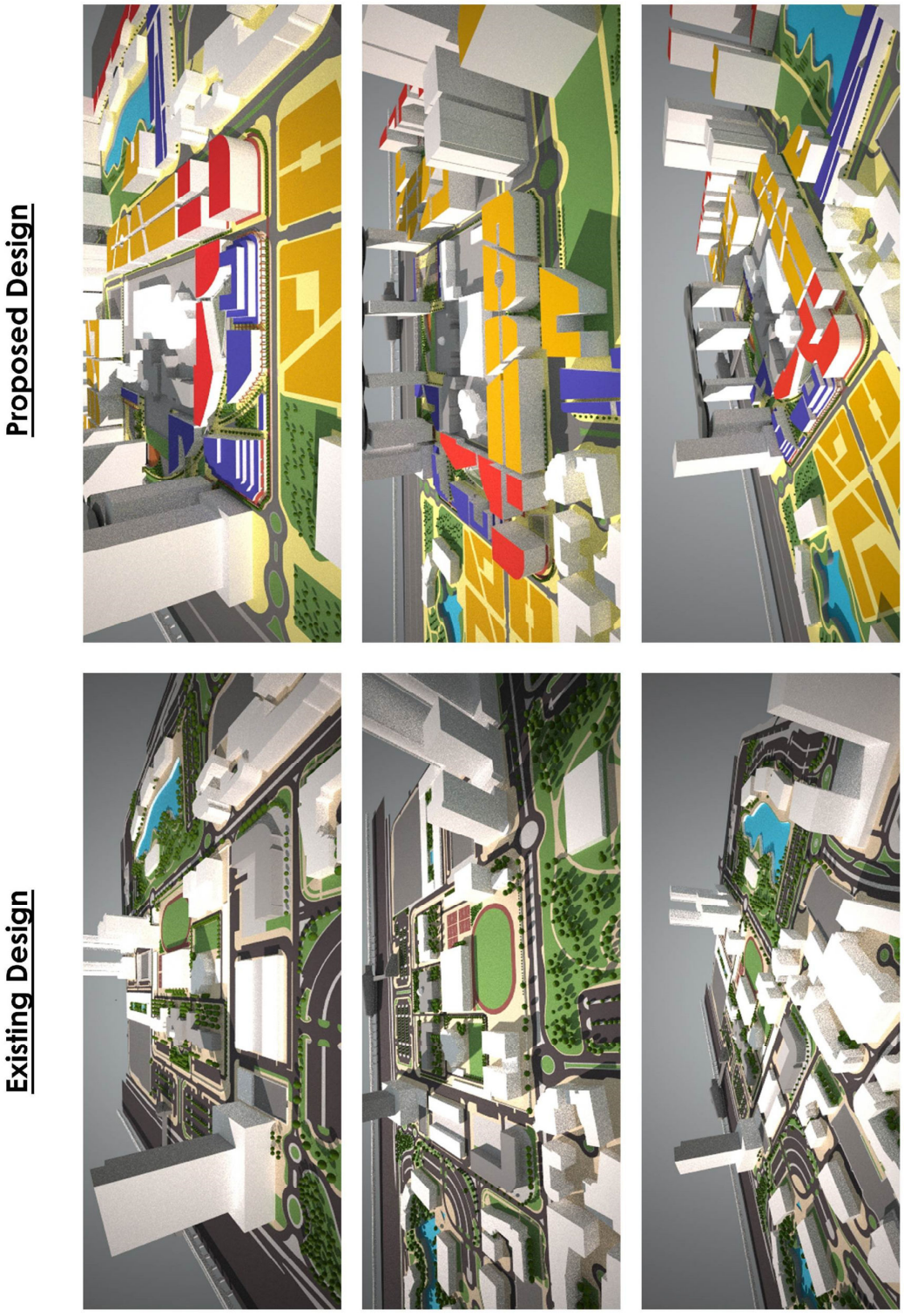
a. Massing – existing /planned

The proposed massing of the site shows a denser fabric due to the high building coverage reaching an average of seventy percent of total land area. Built form is composed of perimeter urban blocks framing green spaces instead of standalone tall structures. The proposed morphology takes inspiration from the existing morphology of the media village. The buildings define a major 7m pedestrian walkaway as they enclose it.

The proposed built form was shaped in accordance to prevailing wind's corridors. Towers fronting the highway could not be oriented to face prevailing winds to respect the visibility of because of AUD main buildings. Therefore, Towers in front of the highway were planned as perpendicular to the highway corridor, shading the green areas and sunken plaza below. A proposed shading steel superstructure on top of the towers channels air to the site and filters highway emissions, thus contributing to a more clean air.It will also act as a visual symbol on Sheikh Zayed Highway of the developments reinforcing its identity on a city-scale.

Based on the diagnosis and recomendation of the site analysis, the built form considered two main principles. First, towers are proposed on AlAssad street continuing the vertical edge formed by the existing tower zones and the opposite Dubai Marina towers. Second, the site massing resulting from an average height of five to ten floors, reinforced the role of the site as a transitional area between the dense high rise towers of Dubai Marina and the low dense suburban areas of Al suffouh and UmSuqueim.

Map 6.2. Al Suffouh TOD perspectives.



Map 6.3. Al Suffouh Proposed TOD- Massing and Wind Analysis.

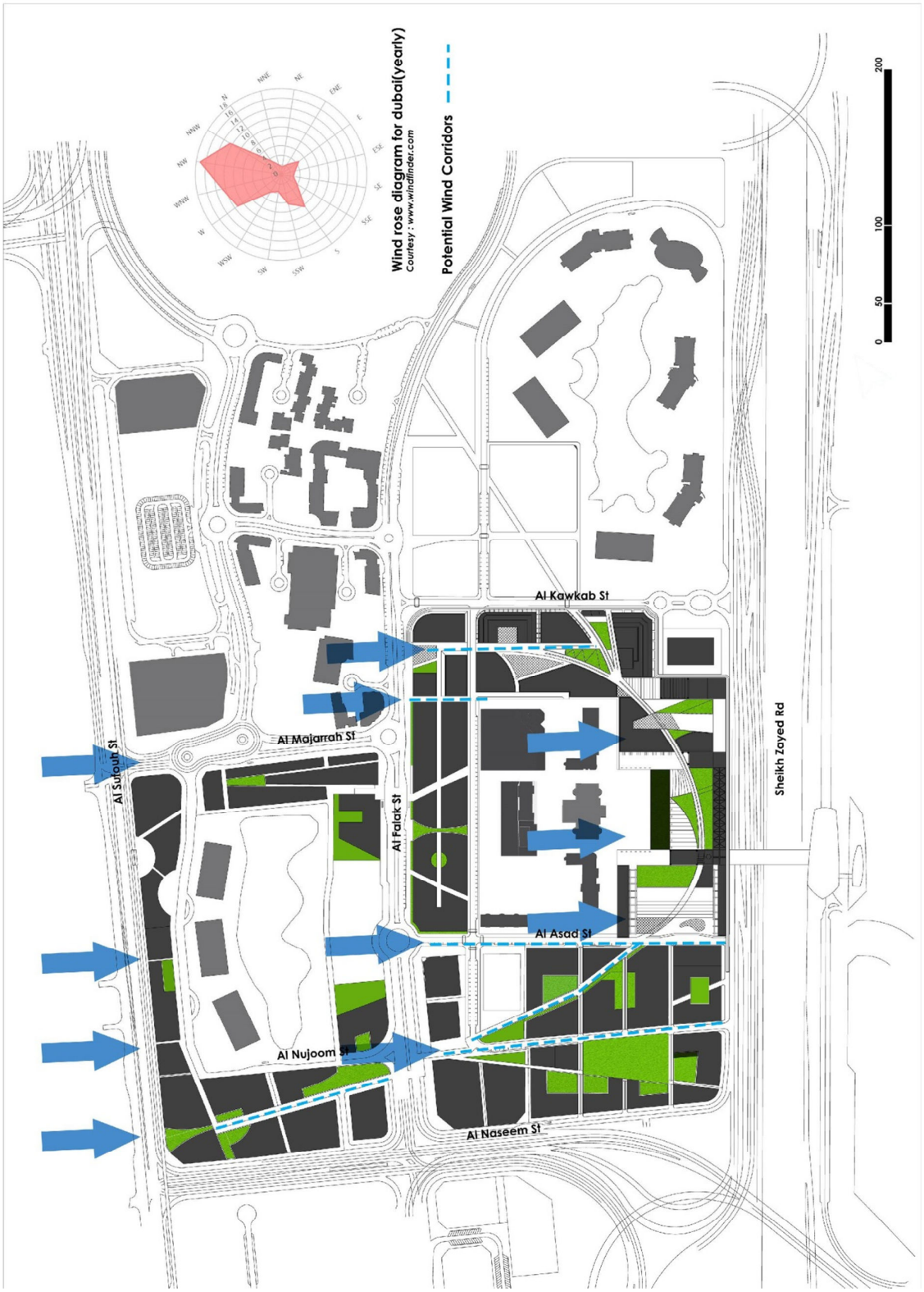
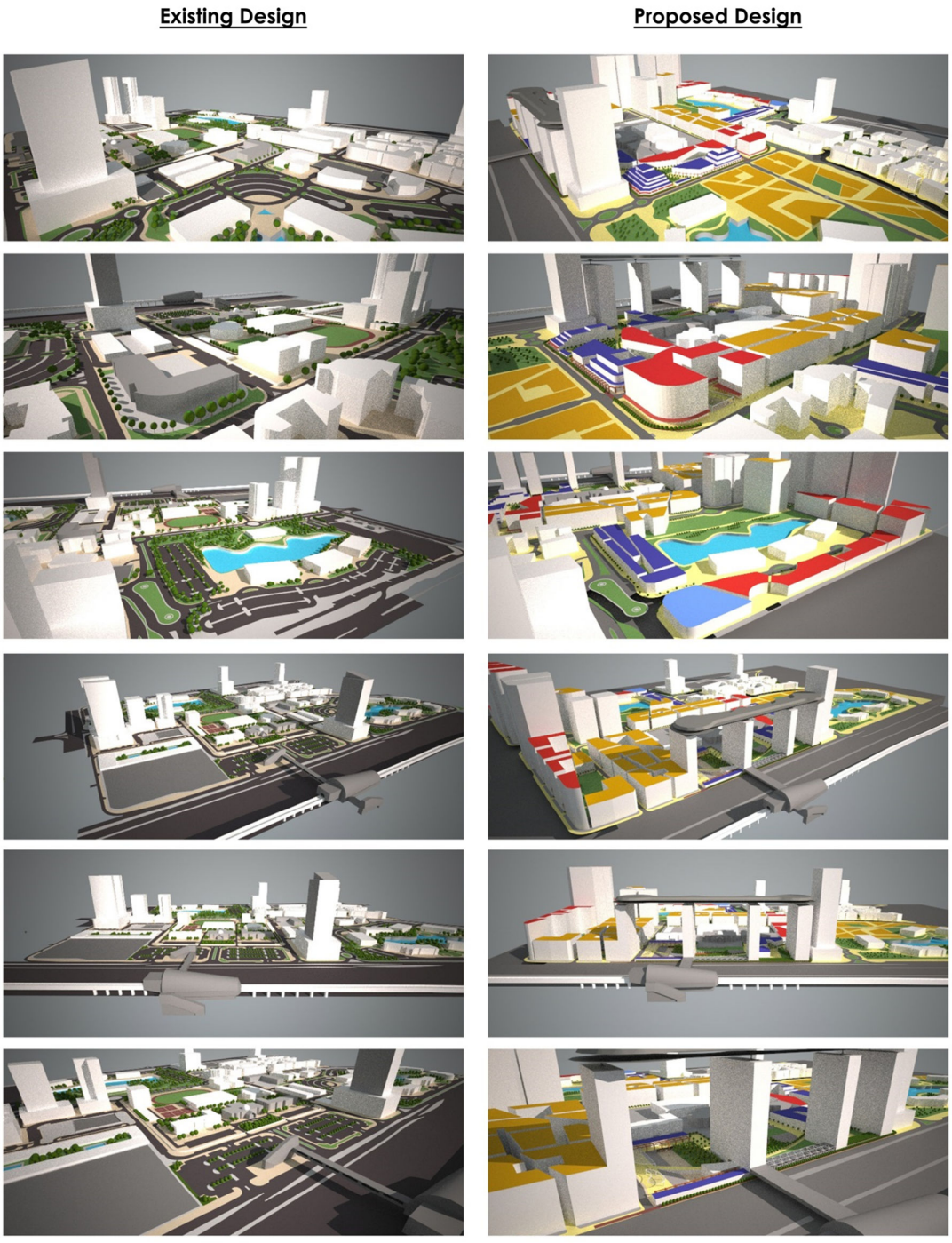
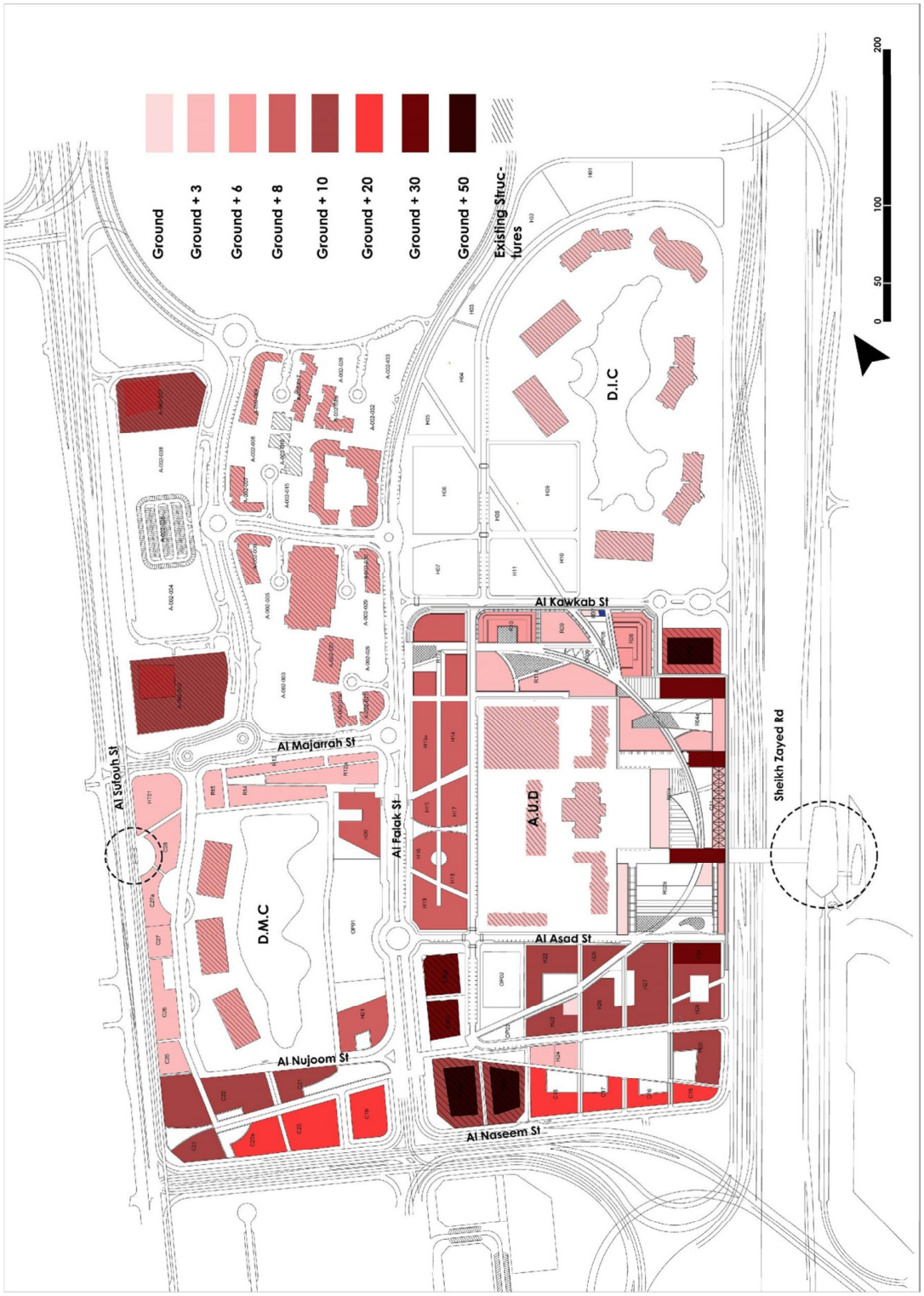


Figure 6.2. Perspective view from sheikh Zayed road.



Map 6.4. Al Suffouh Proposed TOD - Heights Plan.



b. Height

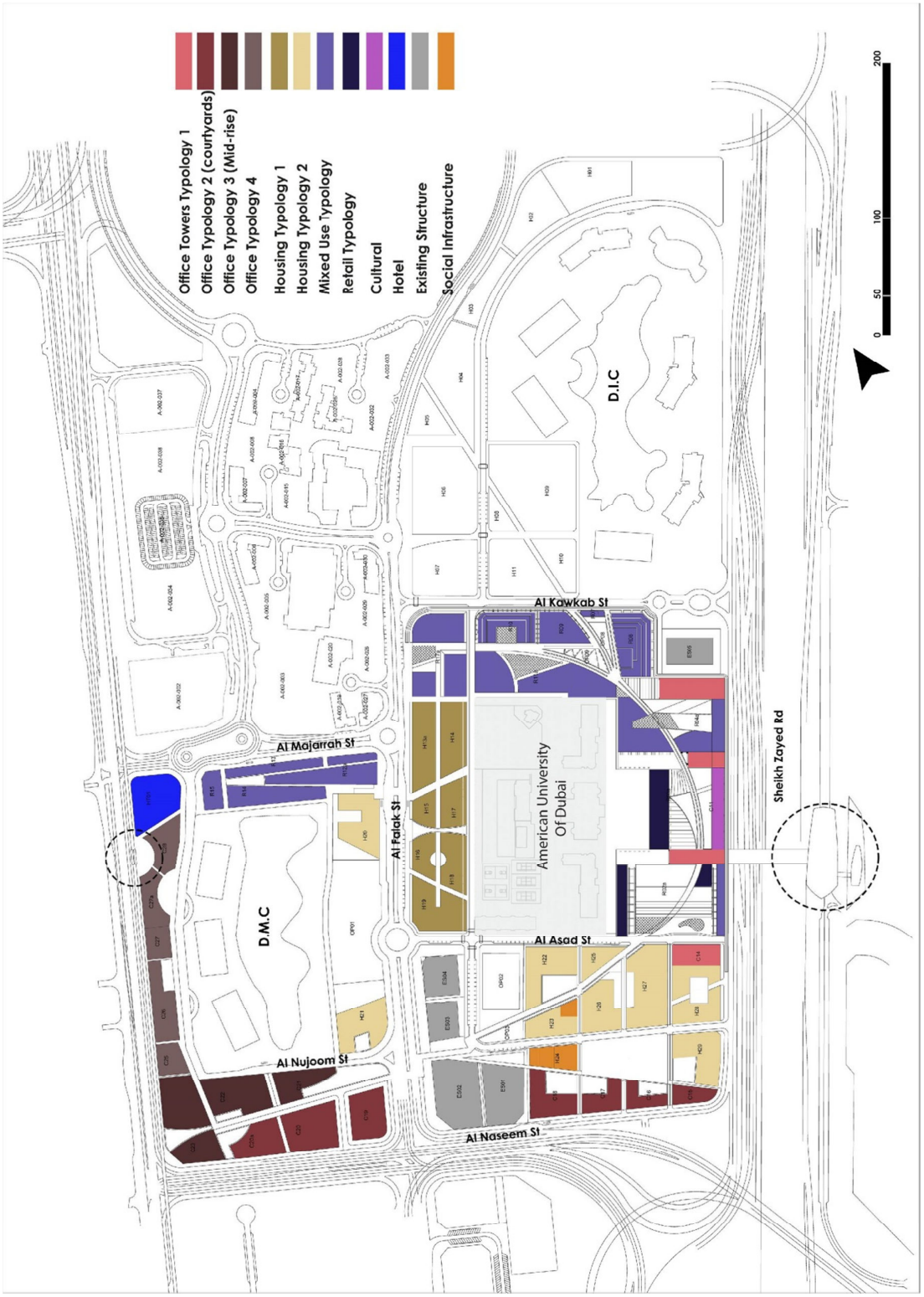
Heights in the proposed master plan were affected by wind direction, highway edge, and existing tall commercial structures. The highest structures are lined next to the existing Media 1 Tower, Al Thuraya towers marking the site entry point on AlNaseem Street. Heights gradually decrease internally across the site from 10 floor to three floors. Only three floors were proposed in front of Dubai media city buildings to maintain the visibility of its landmark buildings as shown in the site analysis in Chapter five.

c. Land use – horizontal and vertical mixing (ground floor uses + active street frontages)

The site applied the different diversity tools mentioned in the toolkit to achieve the goals of the urban design strategy mentioned in Figure 6.2.

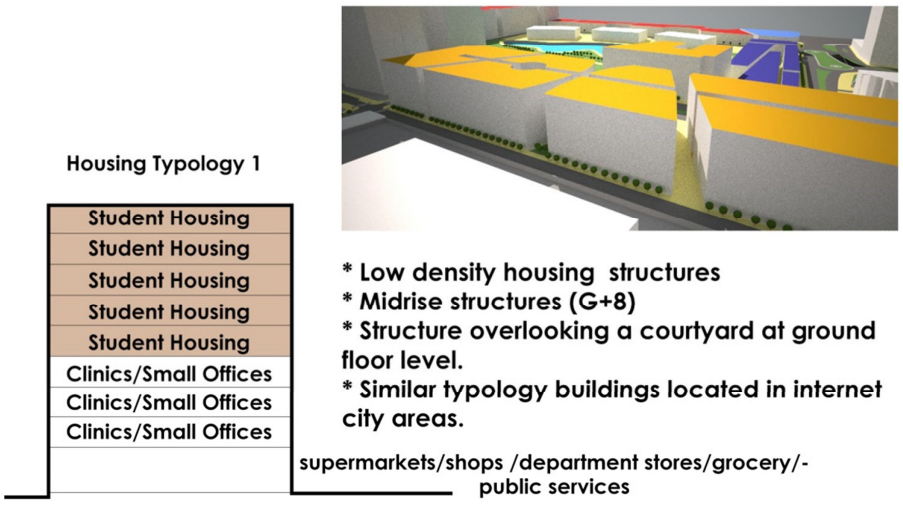
The proposed scheme injects new site uses; new residential areas based on three different typologies provide faculty and student housing and medium size apartment units for DIC and DMC employees. On Al Suffouh road, a mixed-use low rise retail area encloses a network of squares and is connected to the Tram station. On the edge of Al Majara and Al Marsad streets, an additional mixed use area links the tram to the transit node along the East-West Axis connecting them.

Map 6.5. Al Suffouh TOD-Proposed Building use Plan.



Vertical Use mixity was prescribed through the building typologies guidelines shown in the figures below 6.6,6.7 and 6.8). For each typology, the proposed guidelines reinforces walkability, provide community amenities accessible from the street level, set the allowable height and building coverage. In Particular, the proposed retail and mixed use typologies form linkages between the different character zones.

Figure 6.3. Al Suffouh Proposed TOD - Housing typology Guidelines.



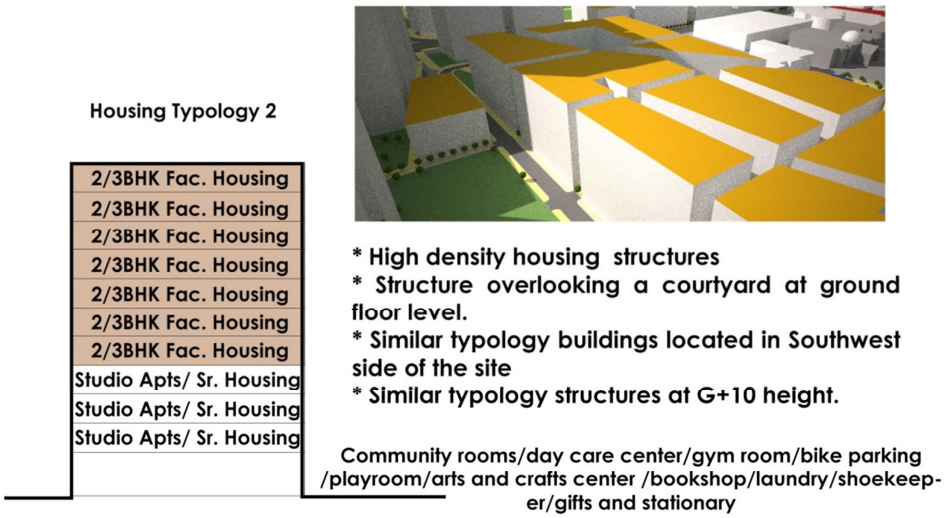


Figure 6.4. Al Suffouh Proposed TOD - Retail Typology Guidelines.

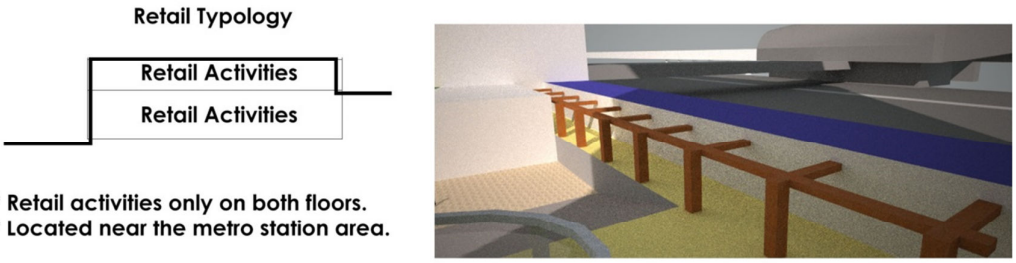
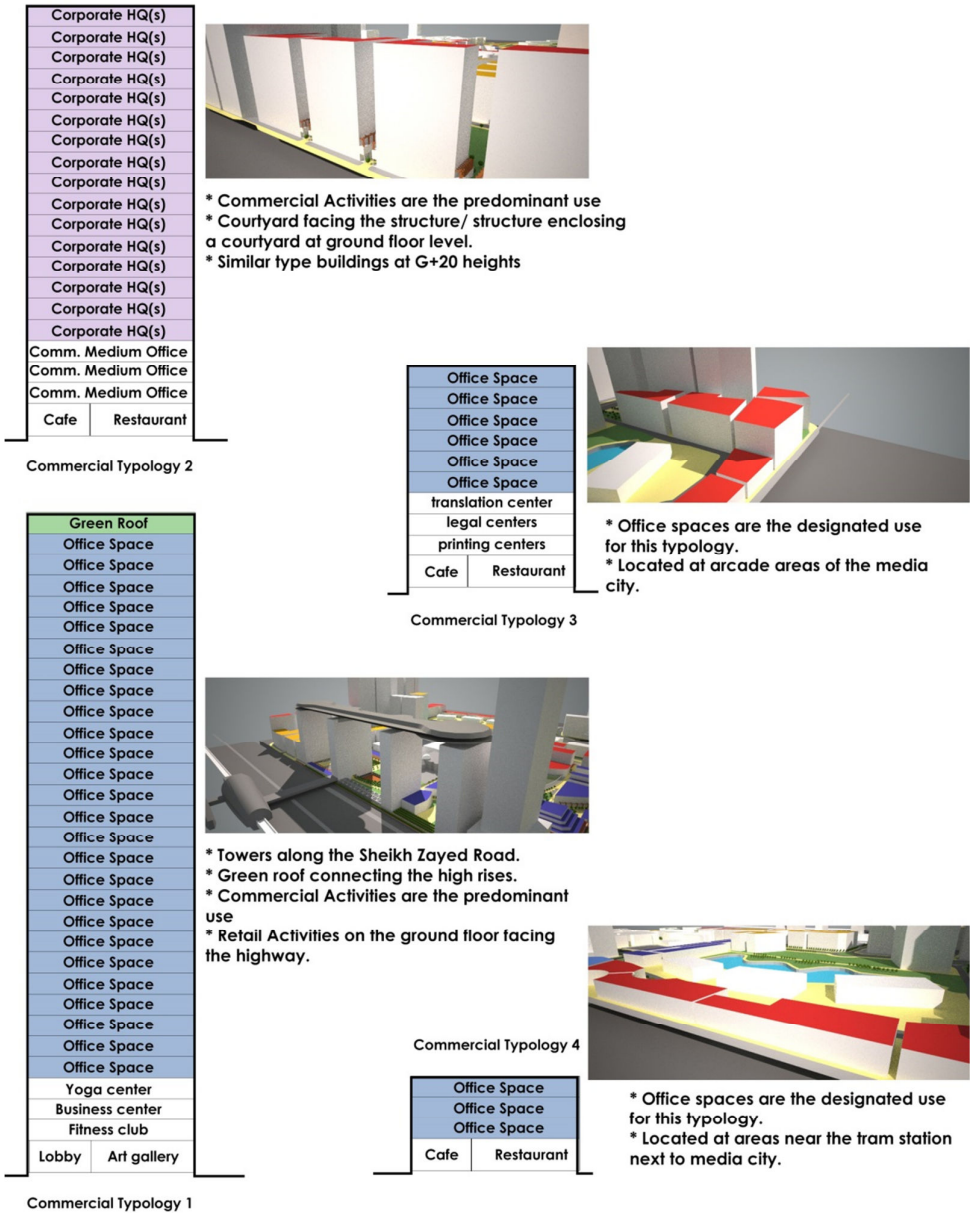


Figure 6.5. Commercial Typology sections.

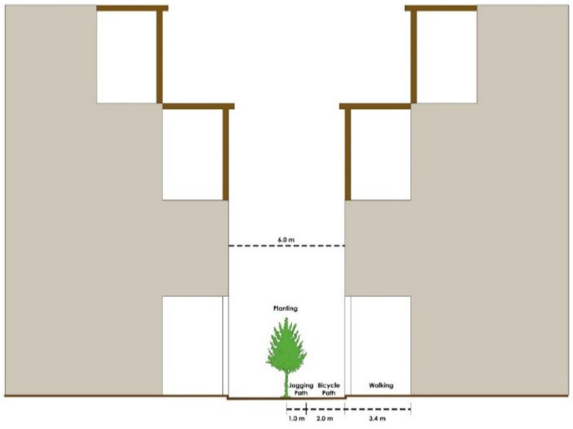


d. Comfort sheds

The pedestrian network is structured around an East-West axis linking the bus stops, the tram and the metro station integrating the different internal circulation networks of the three campuses. This 8m walkway is designed as a loop divided into 70 to 100 m Comfort sheds; each segment begins and ends with an activity node. Secondary pedestrian paths lead transit users to the different zones and intersect with the green spaces network; these intersections were designed as small resting areas for transit passengers.

A network of nodes alternates on 100 m intervals throughout the pedestrian main walkway; they are positioned at strategic locations, adjacent to active uses at ground floor level. The nodes change forms depending on their location in the urban fabric; they could take the shape of shaded semi-public space, a pocket park, a café seating area shaded by awnings, shaded benches, buildings courtyard, or shading structures such as pergola or trellises. Their design has been driven by the tools listed in the toolkit for climate responsive TOD.

Figure 6.6. Al suffouh proposed TOD - proposed pedestrian street section for residential areas.



Map 6.6. Pedestrian network plan.

Figure 6.7. Al Suffouh street perspectives.

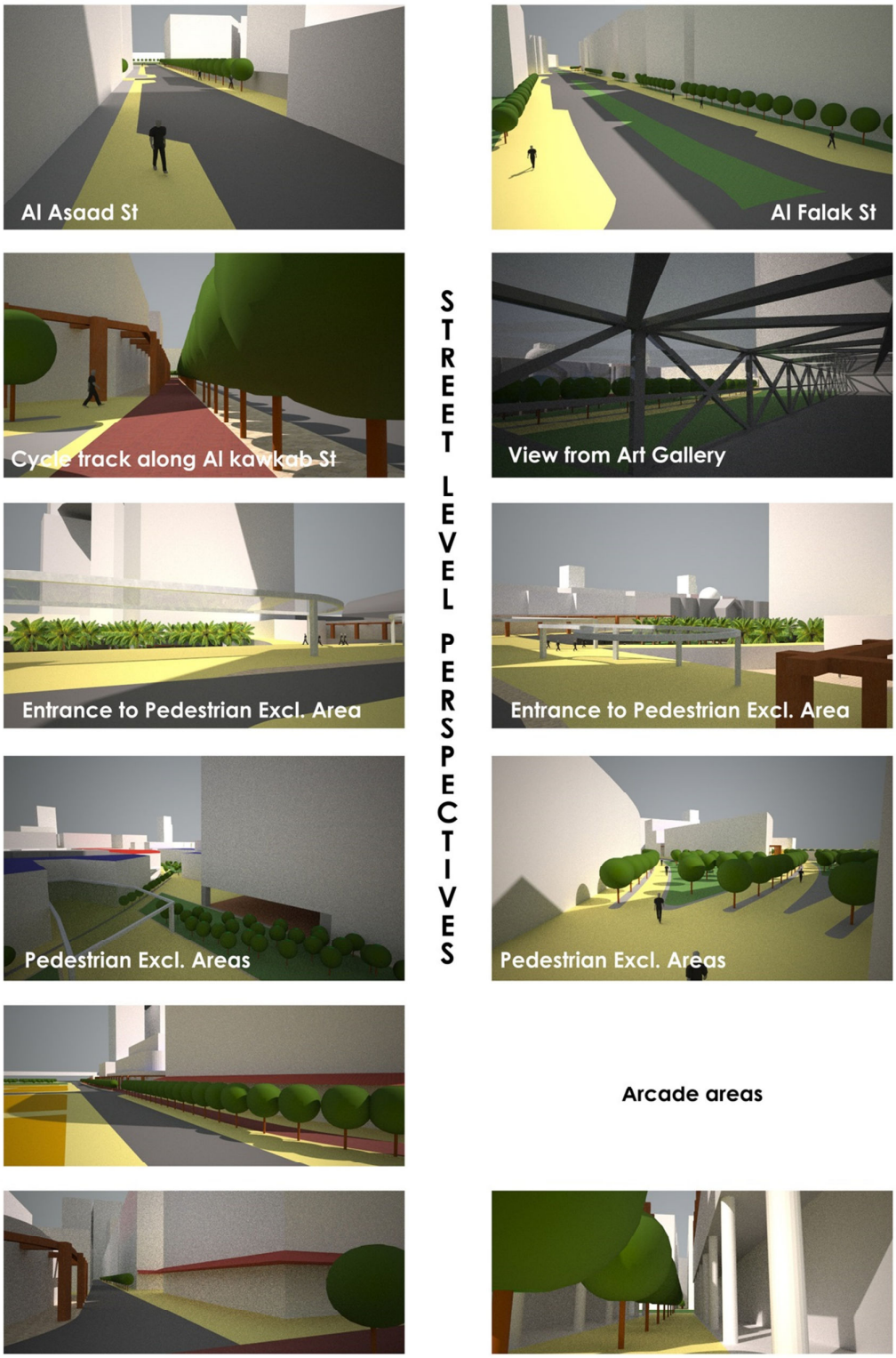
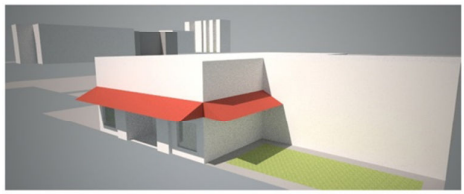
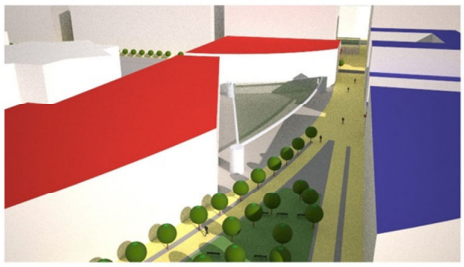


Figure 6.8. Al Suffouh Proposed TOD - Street Guidelines - shop fronts and awnings.

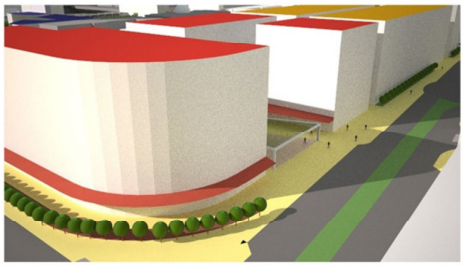
Shopfront

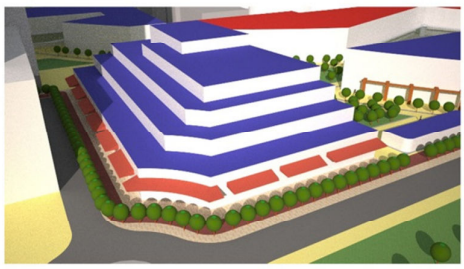




* To be used in retail areas wherever arcades not possible.
* Defines the Ground floor of a building –typically 4-6 metres in height.
* Should express the building order.
* Should consist of at least 70% glazing.
* Should include lighting and signage.
* May be built out of a wide range of materials

Awnings

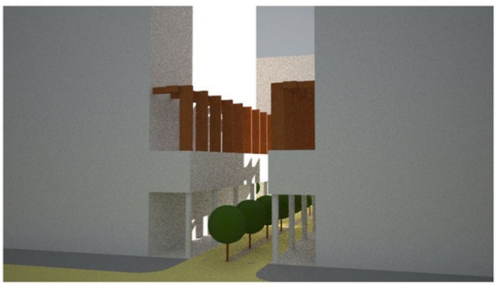




* To be used in retail areas particularly at retail typology and mixed use typology structures.
* To provide protection from sun and weather for the building openings.
* Fabric, Bracketed and Suspended/Cantilevered types allowed.
* Fabric awnings may be retractable to adapt to weather conditions.
* Suspended awnings may project up to 3 metres from the building

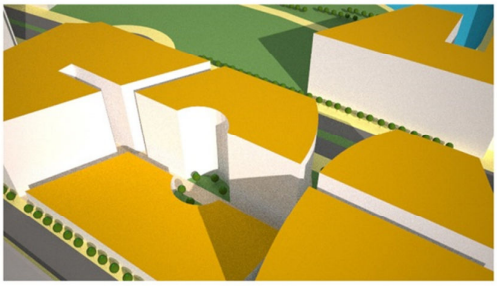
Figure 6.9. Al Suffouh Proposed TOD - Street Guidelines - arcades, forecourts.

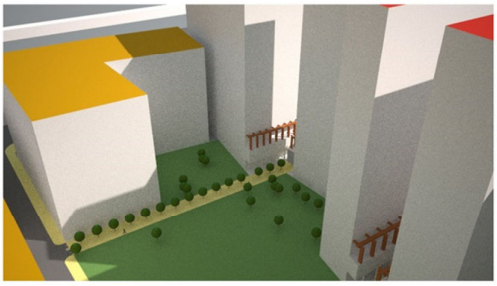
Arcades



* Suggested minimum depth of 4 metres.
* The best means of street enclosure.
* Provisions to accommodate for signage and lighting.
* Provides pedestrian with excellent protection from sun and weather
* Provisions can be made to accommodate exterior seating for cafes, bistros and uses of retail nature as long as hindrance to free flow of pedestrians does not occur.

Forecourts





* Semi-public space.
* Transition between public and private realm.
* May be used for vehicular circulation, building circulation, or vegetation.
* Separation from public space with a low hedge, wall or slight elevation change defines the pedestrian path of travel.
* Creates visual interest with the undulation of a single building or multiple buildings

2. Ecology

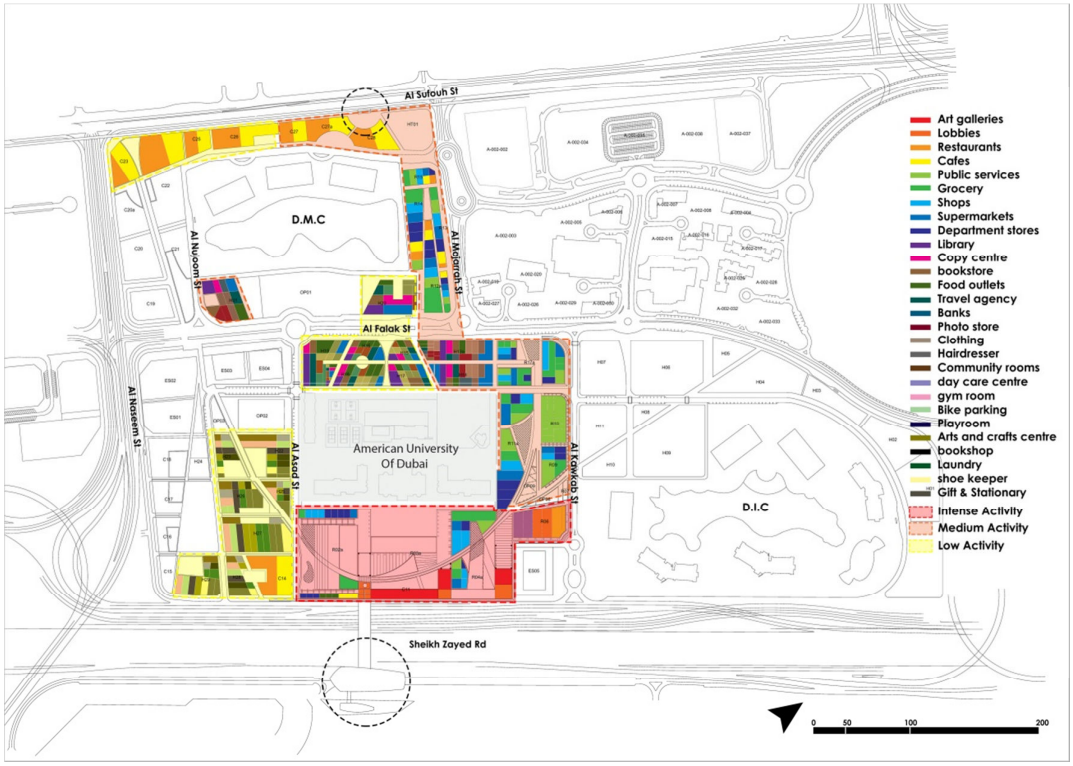
a. Social Infrastructure

Social Infrastructure included amenities for three social groups: residents, entrepreneurs and students. I have adopted an average unit size of 120 square meters to forecast the total population of the site. Although this average is not confirmed through statistics, it is yet the standard unit size for two bedrooms in Dubai which occupancy is estimated at four persons per dwelling. Hence, based on the map attached, the site population reached about 3000 persons. This qualifies it as a neighborhood unit according to Dubai Community Guidelines Standards issued in 2008.Based on these guidelines, social infrastructure requirements is a school, a nursery, a mosque. These facilities were clustered together in a central location from the different housing areas and located at 100m from a proposed football field. Also, The football field is designed to be part of the social infrastructure , used for community gatherings and community sports events.

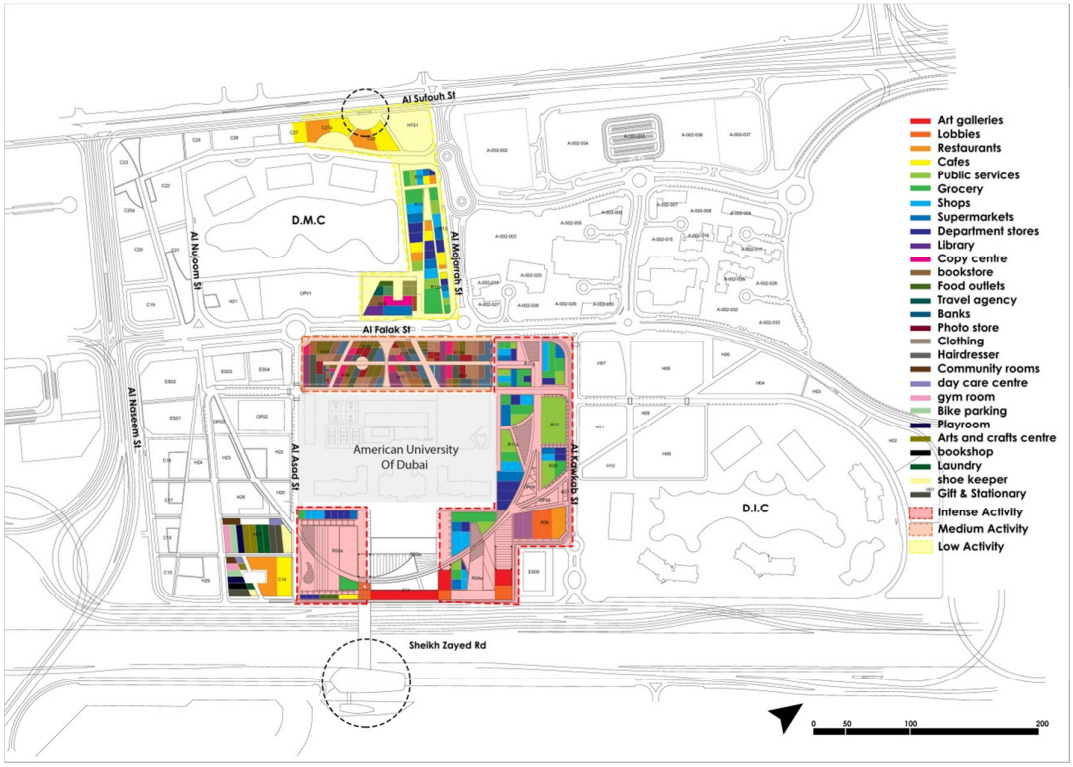
Amenities based on the needs of entrepreneurs and students are proposed at walking distance from the proposed future residential areas. The proposed amenities and community facilities are shown in Map 6. 7 and 6.10.

Map 6.7. Ground floor Usage as per typology guidelines.

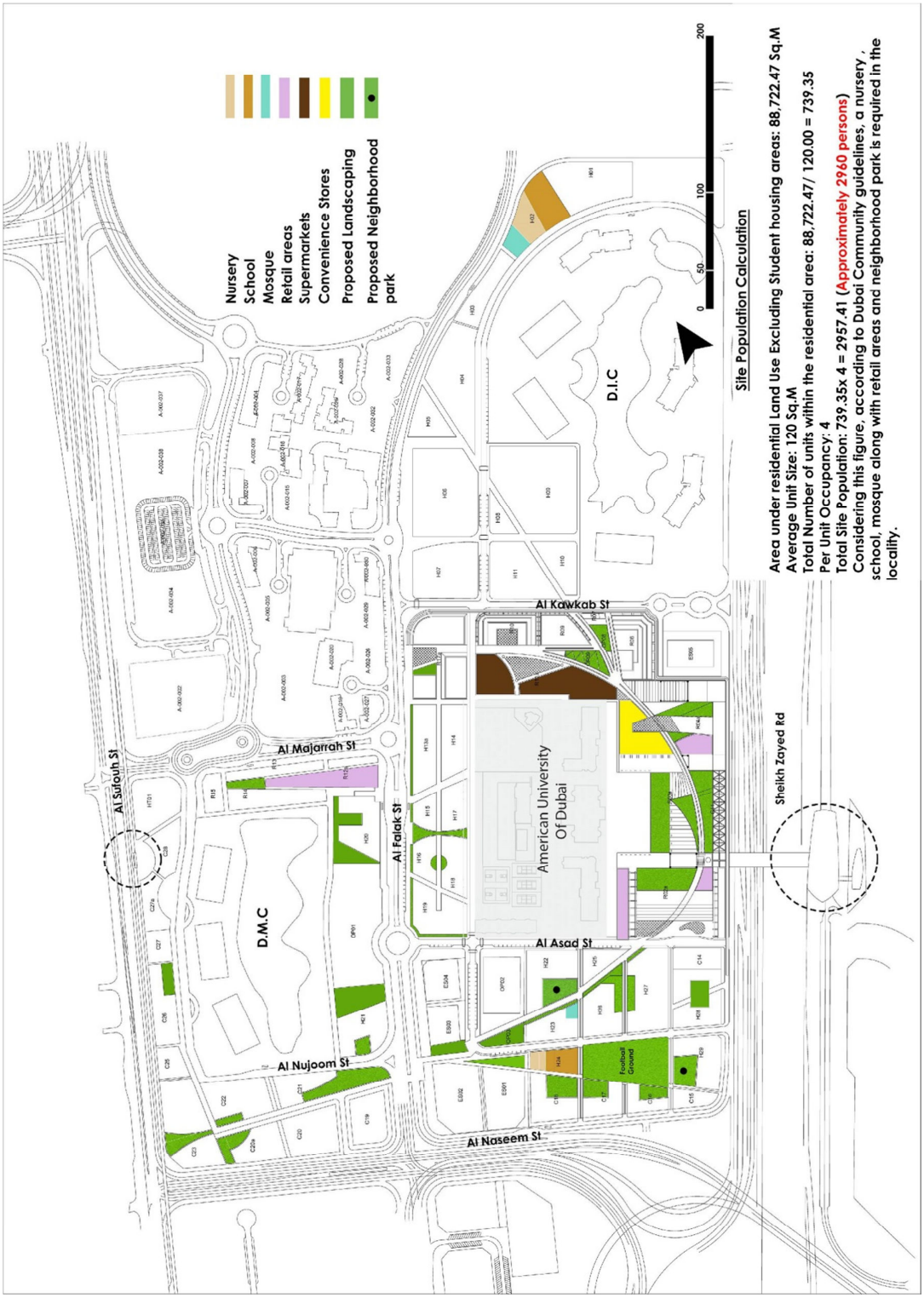
Map 6.8. Al Suffouh Proposed TOD - ground floor-Day Activity.



Map 6.9. Al Suffouh Proposed TOD - Ground floor Night Activity.



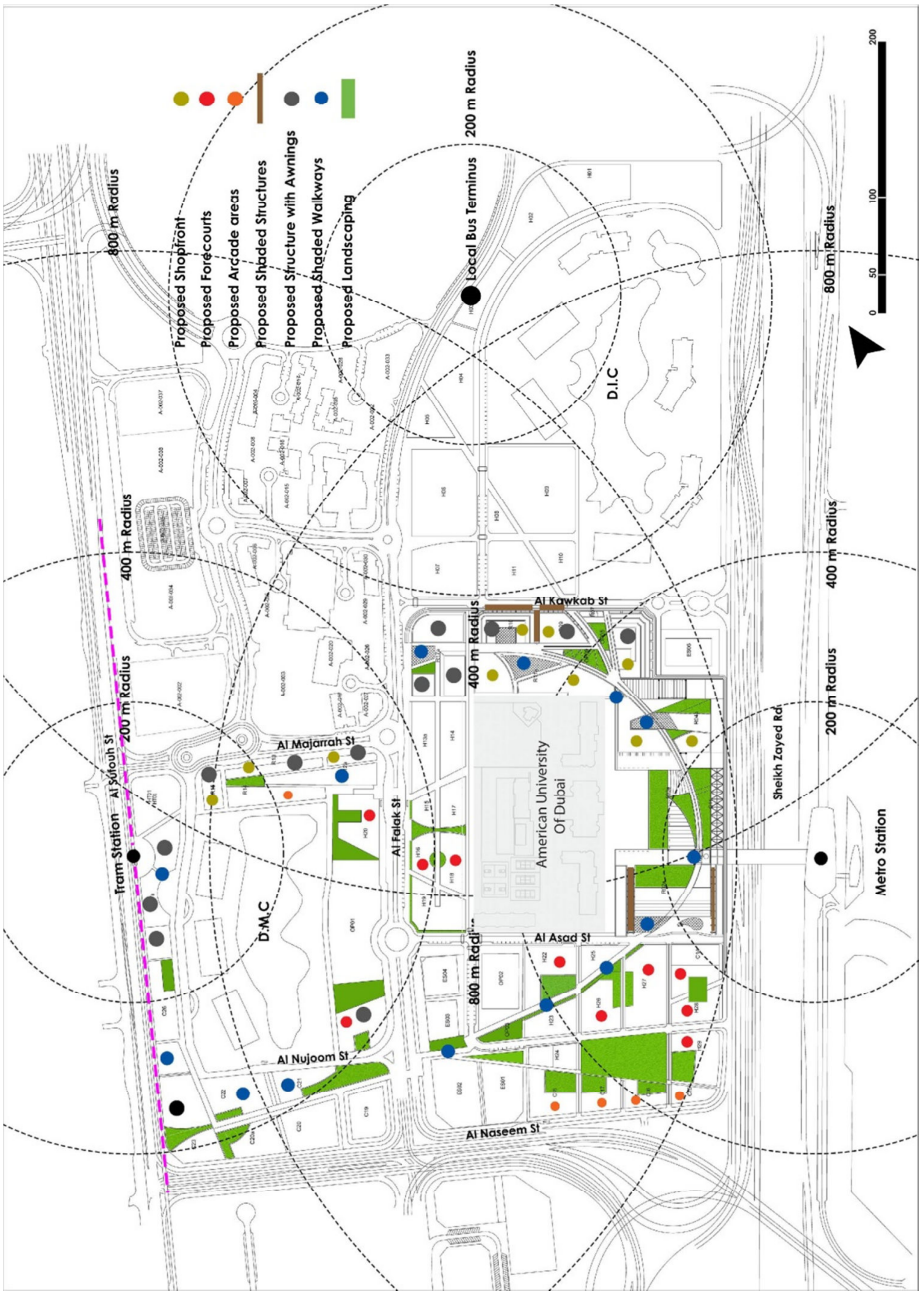
Map 6.10. Al Suffouh Proposed TOD- Social Infrastructure.



b. Green spaces network

The green spaces network is conceived as a local greenway connecting the three existing inner green open spaces of DIC, AUD, and DMC through a network of pockets parks ,tree gardens and tree lined walkways as shown below .

Map 6.11. Al Suffouh Proposed TOD - Green space network.

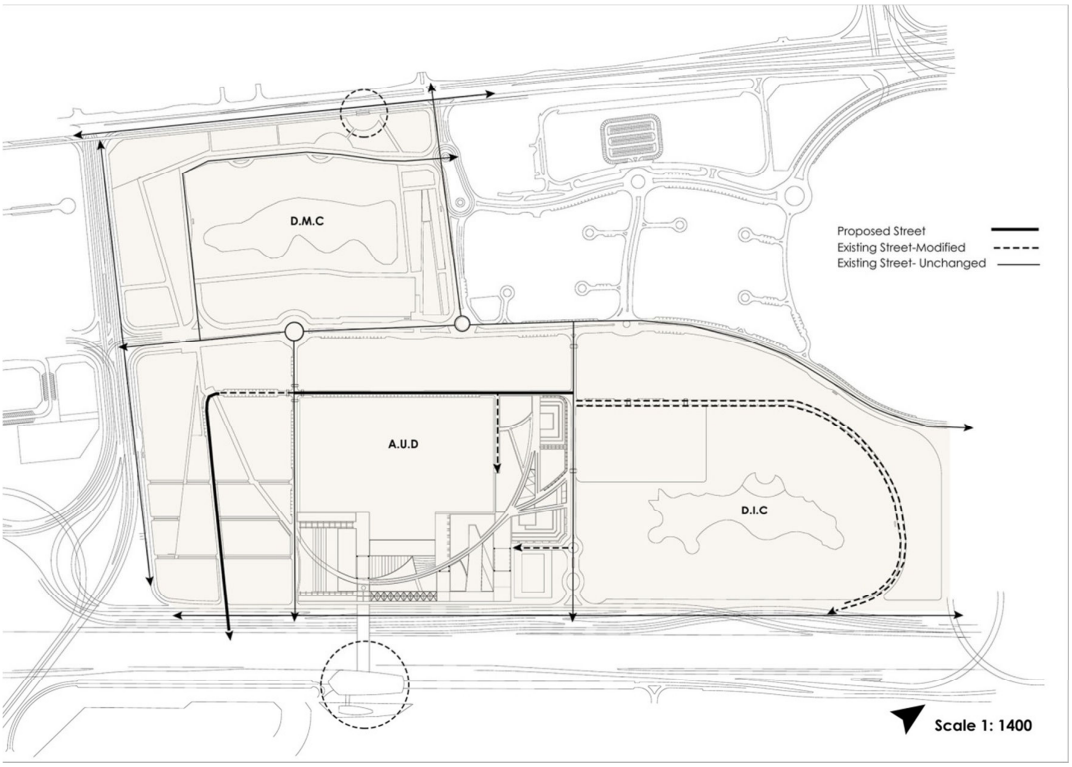


3. Infrastructure

The road network is reconfigured to increase the porosity and permeability of the site. Two new proposed streets break the larger urban blocks; a local street cuts through the American University of Dubai Campus and another breaks the large Dubai Media city urban block (see Map 6.12). Two streets have been modified; Al Assad street have been extended to connect to the service road running in parallel to Sheikh Zayed road redistributing traffic from the congestion areas of Al Falak Street.

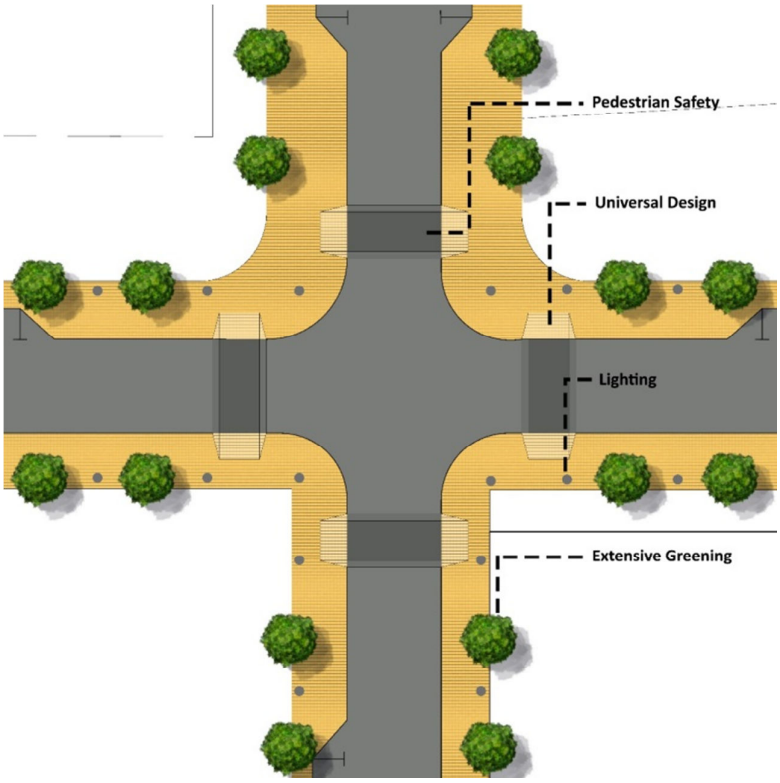
AL Marsad street lower section was expropriated as it interrupted the linkage on the East West axis whereas its upper section provided shared service access for the retail and university areas.

Map 6.12. Al Suffouh Proposed TOD existing versus proposed streets.



Additional crosswalks are added in Al Falak street in order to preserve the connectivity of the sidewalks and pedestrian paths on its opposite side .The below is a concept design for the different crossings on the main roundabout on Al Falak street.

Figure 6.10. Al Suffouh proposed TOD-proposed crosswalk guidelines.



4. Private Development

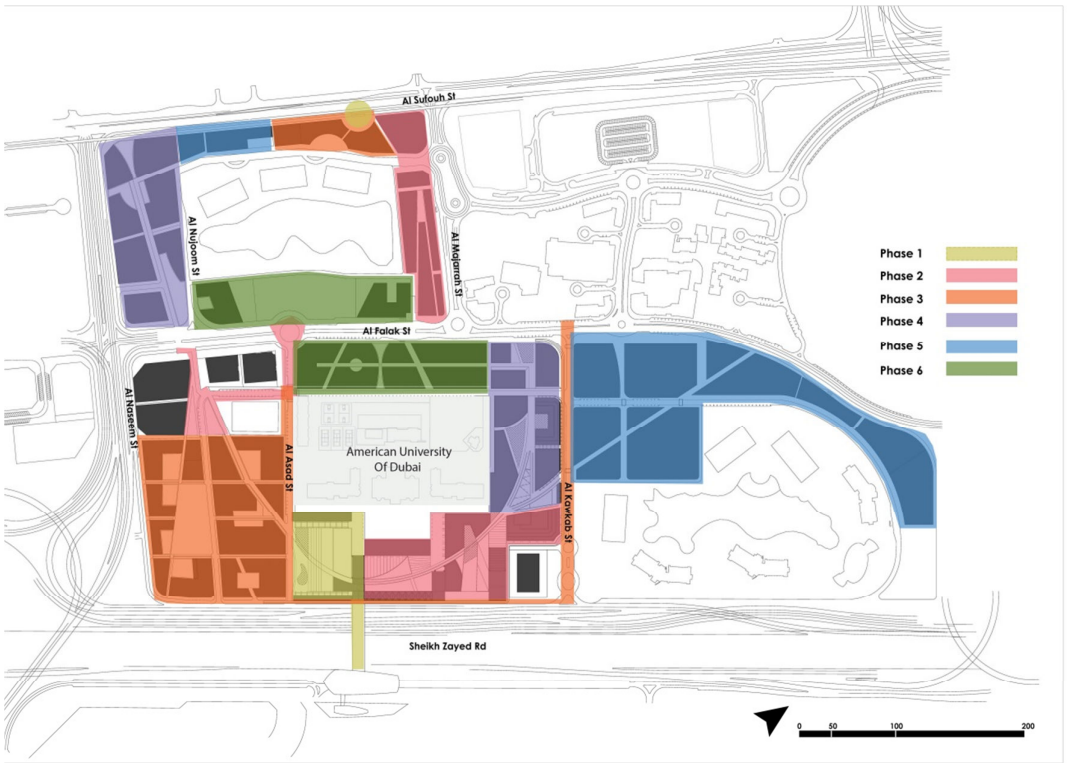
a. Phasing plan

In order to manage the development over time, a proposed phasing plan (shown in Map 6.13) recommend that the various sectors of the plan are released in five packages. Although different packages would be owned by different stakeholders, this plan works under the hypothesis that TECOM Zoning authority would orchestrate its implementation.

Phase one consists of the design and construction of public spaces around the transit node: it needs minimal investment using the current surface vacant parking owned by RTA. Developing the highway towers and the green spaces in between them form the second phase, reinforcing the metro station as an urban node; since these plots are jointly owned by AUD and TECOM, this phase could be undertaken through a partnership between them.

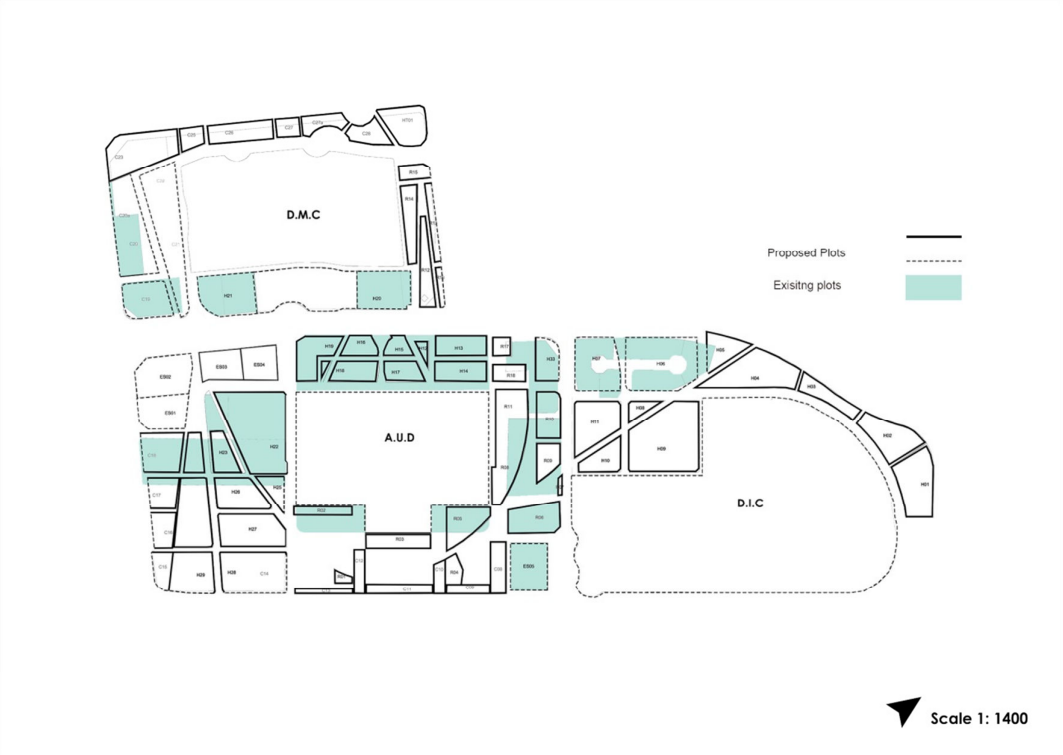
Then, the development expands on an east-west axis as shown in Map 6.19.The plots around the tram station are built in phase two and three. The east west areas in between the Metro Station and the Tram station along AlFalak and AlNojoom streets are built in Phase four ,Five and Six.

Map 6.13. Al Suffouh TOD- Proposed Phasing Plan.

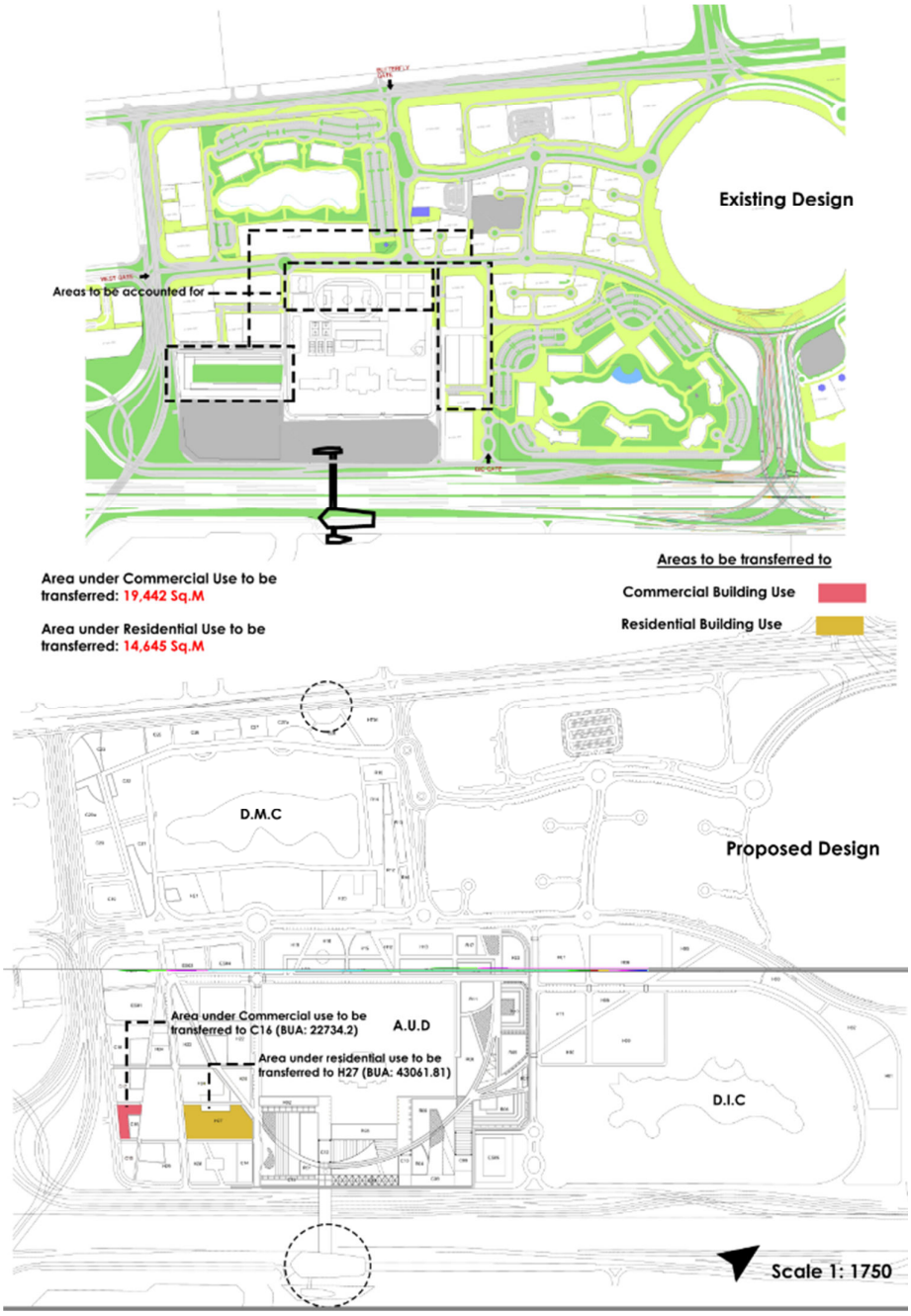


The proposed master plan breaks down the existing large lots and blocks plots. The proposed master plan Plots' average area correspond to the average plot size of the Media Village embodying the original master plan intention of building dense walkable spaces. The existing 49 plots were subdivided into 85 plots to provide a fine-grained urban fabric. The proposed average plot size (3183 square meters) dropped 10,000 sq. ft. compared to the average for existing plots (13,000 square meters). This Subdivision enabled the proposed plan to increase the site permeability. The proposed built up areas have a higher exploitation ration reflecting the higher site density. The overall Floor o Area Ratio increased from 2.5 to 7.0.The increased bulk was distributed between the new residential areas (45 %) and mixed use areas (22%).

Map 6.14. Al Suffouh Proposed TOD - existing versus proposed plots.



Map 6.15. Al Suffouh proposed TOD - development right transfers.


Existing Design
Areas to be accounted for
Area under Commercial Use to be transferred: 19,442 Sq.M
Area under Residential Use to be transferred: 14,645 Sq.M
Areas to be transferred to
Commercial Building Use
Residential Building Use
D.M.C
Proposed Design
Area under Commercial use to be transferred to C16 (BUA: 22734.2)
A.U.D
Area under residential use to be transferred to H27 (BUA: 43061.81)
D.I.C
Scale 1: 1750

d. Built Up area Analysis -Transfer of built up area

The susceptibility to change analysis used in the site analysis section in order to define the action area limited the structures that need to be amended .

The total built up areas of the demolished buildings, respectively for commercial and residential, are 19,442 square meters and 14,645 square meters. These development rights were transferred into two new plots as shown in map 6.15.

During the construction of the new faculty and student housing, students and faculty residing on site need to be relocated in alternative location next to the university. The new proposed location – shown in map 6.15- is accessible from the university.

5. Public Space

The areas around the transit node were transformed into a mixed use area centered around two main public spaces – the sunken plaza and the walkway. These areas were designed in detail in order to apply the alternative TOD climate responsive model on a site scale.

a. Activities and Programs

The proposed detailed design focuses on five urban design elements which integrate the proposed public spaces with their surrounding use.

The proposed major walkway would be one of the few inner district pedestrian paths in Dubai designed as a 2 km loop. Its section is divided into three zones; a central zone used for shading structure and trees to shade the walkway, a resting zone furnished with benches and smart and newspaper kiosks. The central zone is designed as a plug and test for smart city kiosks such as Instagram selfies kiosks, traffic management kiosks and others. Smart kiosks need a special electrical and Telecommunication infrastructure and specific plugs. The kiosks also will enable the walkway to become a

testing ground for smart technology applications for young entrepreneurs and start-ups working in the nearby proposed hubs. This zone of the walkway seeks to link the site's public space identity to the identity of the site as part of Dubai Technology and Media Free Zone. Therefore, it transforms it into a hybrid space that would change over time as kiosks are designed ,plugged in or plugged out. As such, it is a spatial embodiment of the concept of Time as discussed in the literature review.

Figure 6.11. Walkway diagrammatic representation.

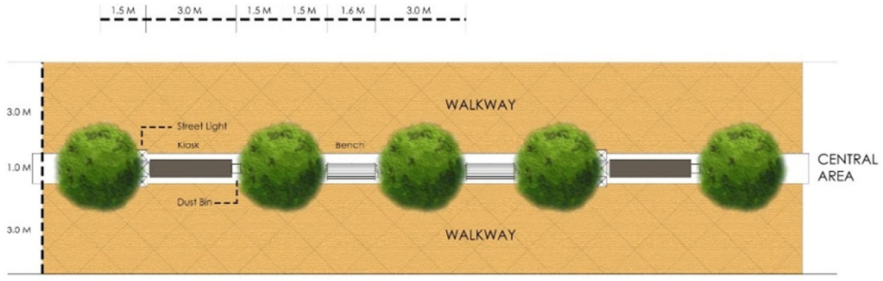


Figure 6.12. Recently installed Smart Kiosks in Dubai; the lack of proposer electrical and internet infrastructure made its installation hazardous and unsafe - source china telecommunications.

Figure 6.13. Comprehensive smart kiosks with multiple city services and applications such as paying bills, checking traffic or just looking at city events.

The proposed sunken plaza in front of Aud directly reinforces the metro station as an exclusive pedestrian entry to the site. The plaza was sunken to 4m below ground in order to maintain the visibility of AUD's main buildings. The difference in ground floor level between the Nakheel Metro Station and the plaza account for 11m i.e. three floors approximately. Thus, the proposed design scheme transforms into animated urban spaces. In front of AUD main gate, a terraced seating areas is proposed to offer a semi-public space for students outside the fences of the university campus .At the western

side, a large steeped square is proposed in order to provide ‘’encounter space’ between the diverse social groups on the site i.e. students, employees, residents and visitors. Also, the sunken plaza edges were transformed into multi-level retail stores and restaurants. The plaza plan included semi-private areas to rest. The plaza is essentially a hybrid space that functions at multi scale incorporating multiple programs. Site-scale programs such as retail uses respond to the needs of the future residents. District-scale programs such as library and public squares respond to the functional role of the site as the main pedestrian entry point to the district .City-scale programs such as the major green roof park on top of the retail area respond to the lack of walkable climate responsive spaces.

Map 6.16. Al Suffouh Proposed TOD - detailed urban design map.

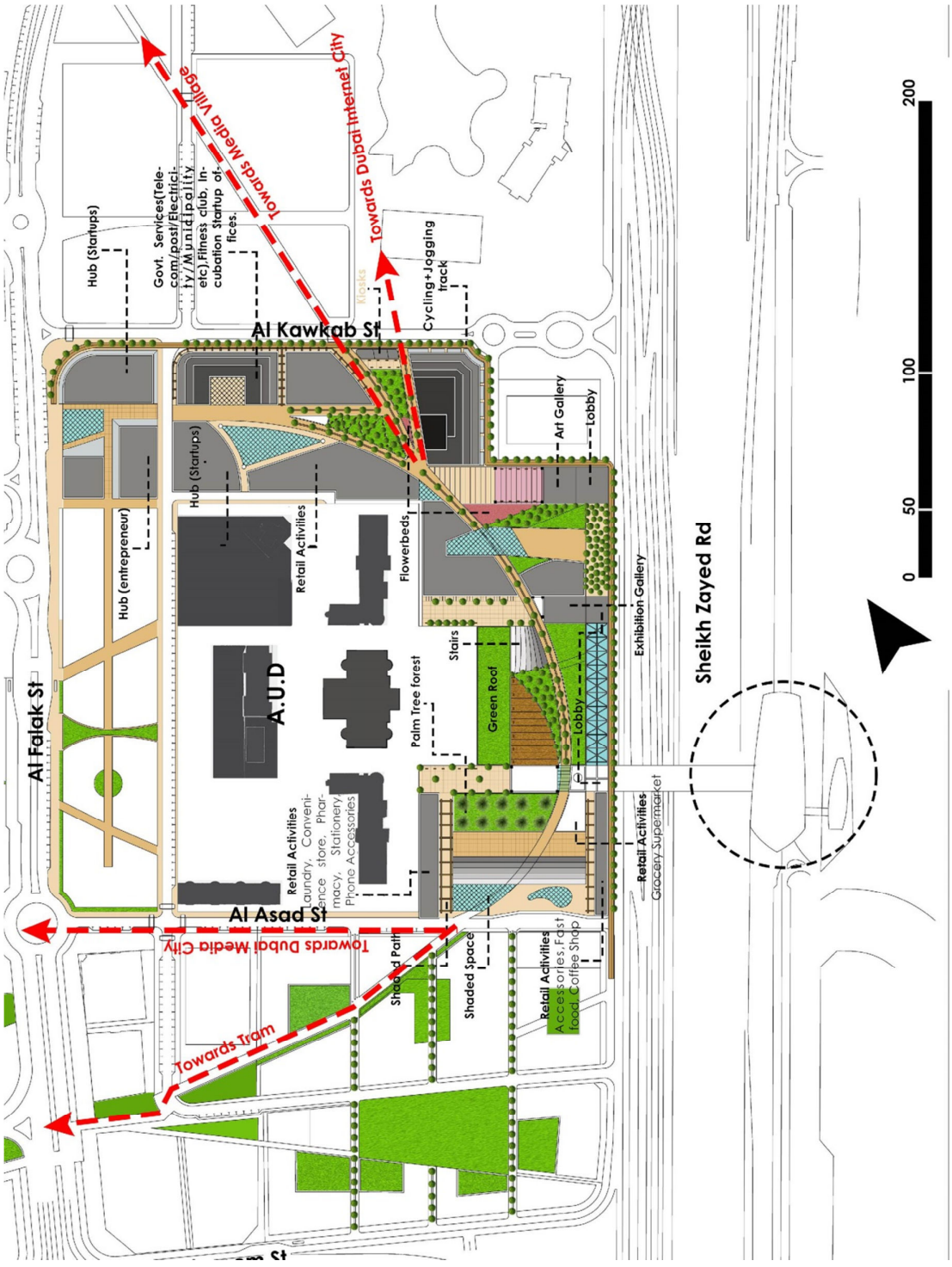
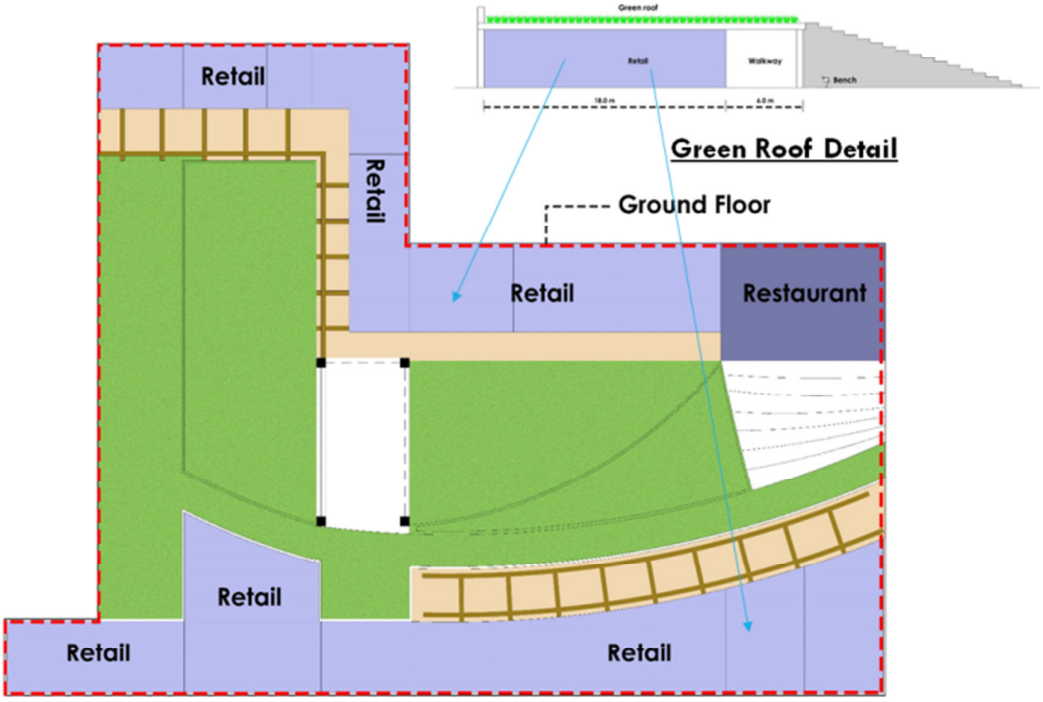


Figure 6.14. Al Suffouh Proposed TOD - Sunken Plaza Details.

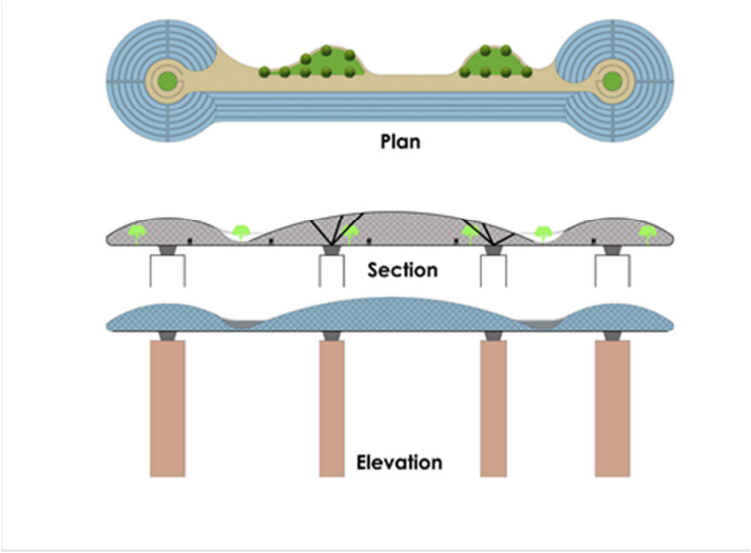


The retail and offices areas are planned as a low rise mixed-use area along AlKawkab Street. The ground floor was used to provide spaces for government departments, convenience and specialty stores, services stores, and cafes. Hubs for entrepreneurs were proposed on AlFalak roundabout in order to reinforce it as a node. This intensification of the ground floor uses increase site's community diversity and legibility as city-scale. This intensification of uses and activation of the ground floor feed into prioritizing transit as the station is located 200 m away i.e two minutes, walking time .

Nodes such as awnings, arcades, shaded areas, semi-public spaces and courtyards are planned every 100 m applying the confort sheds measurements of the alternative climate responsive model

Towers are articulating densities in front of the highway; a horizontal large steel structure connects the towers. Climbing plants will green the structure composed of steel trellises acting as a shading device and also air purifier for the highway emissions for the entire site. The steel structure will run horizontal to the building to reduce their energy demands.

Figure 6.15. Shading superstructure plans, elevations.



Map 6.16 shows in detail the different activities and uses planned on the site following the four listed design elements. Map 6.8, 6.9, 6.10 and map 6.14 show how these activities would animate the site day and night.

b. Shading analysis

Shading modeling was conducted in order to test the climate responsiveness of the proposed design. Spaces are shaded most of the day. The application of the climate responsive model shows that the use of combined strategies of shading and greening

and comfort sheds have transformed the action area into a pedestrian- friendly , comfortable ,accessible and climate responsive transit oriented site.

Figure 6.16. Al Suffouh Proposed TOD - Shading analysis 1.

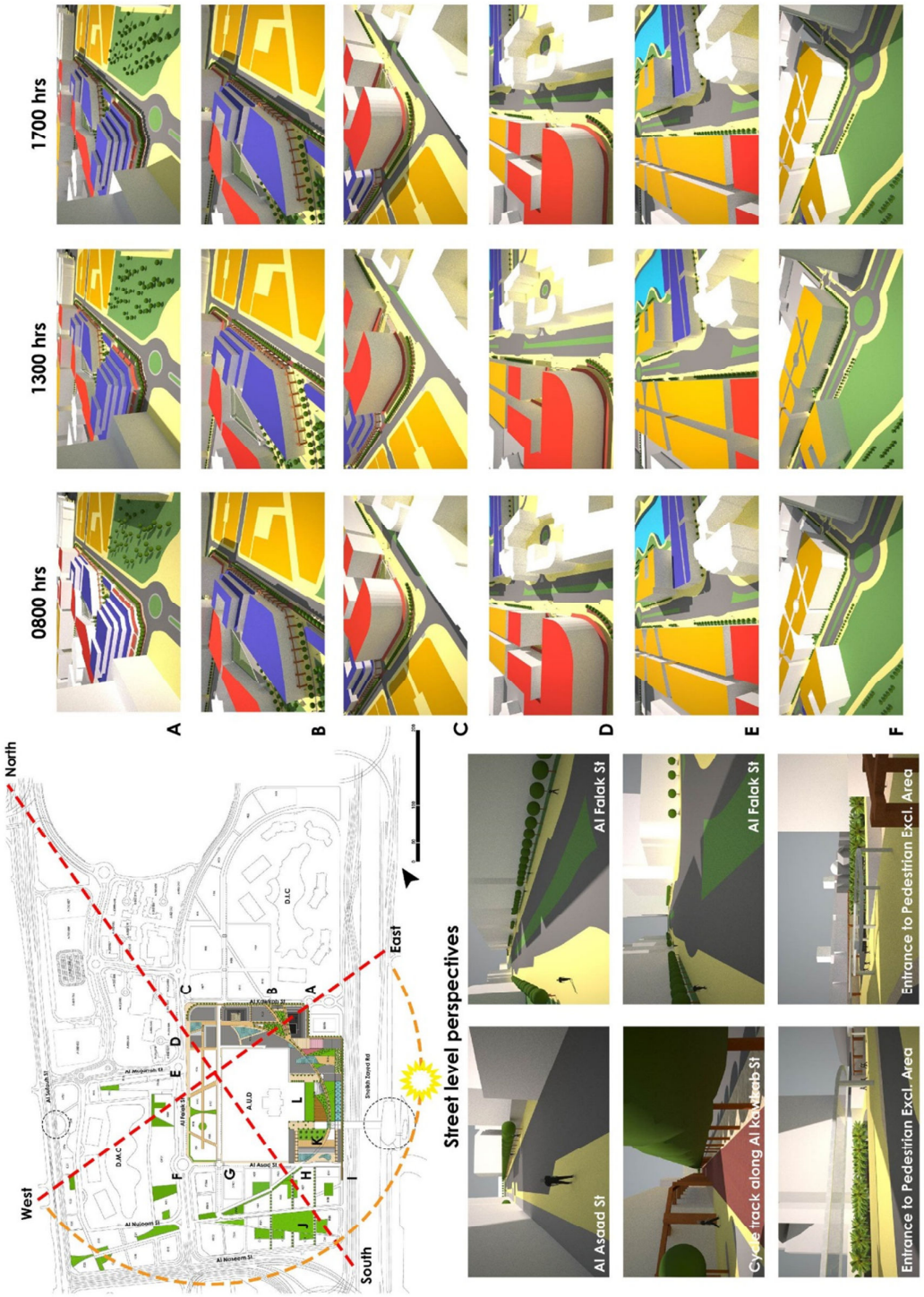
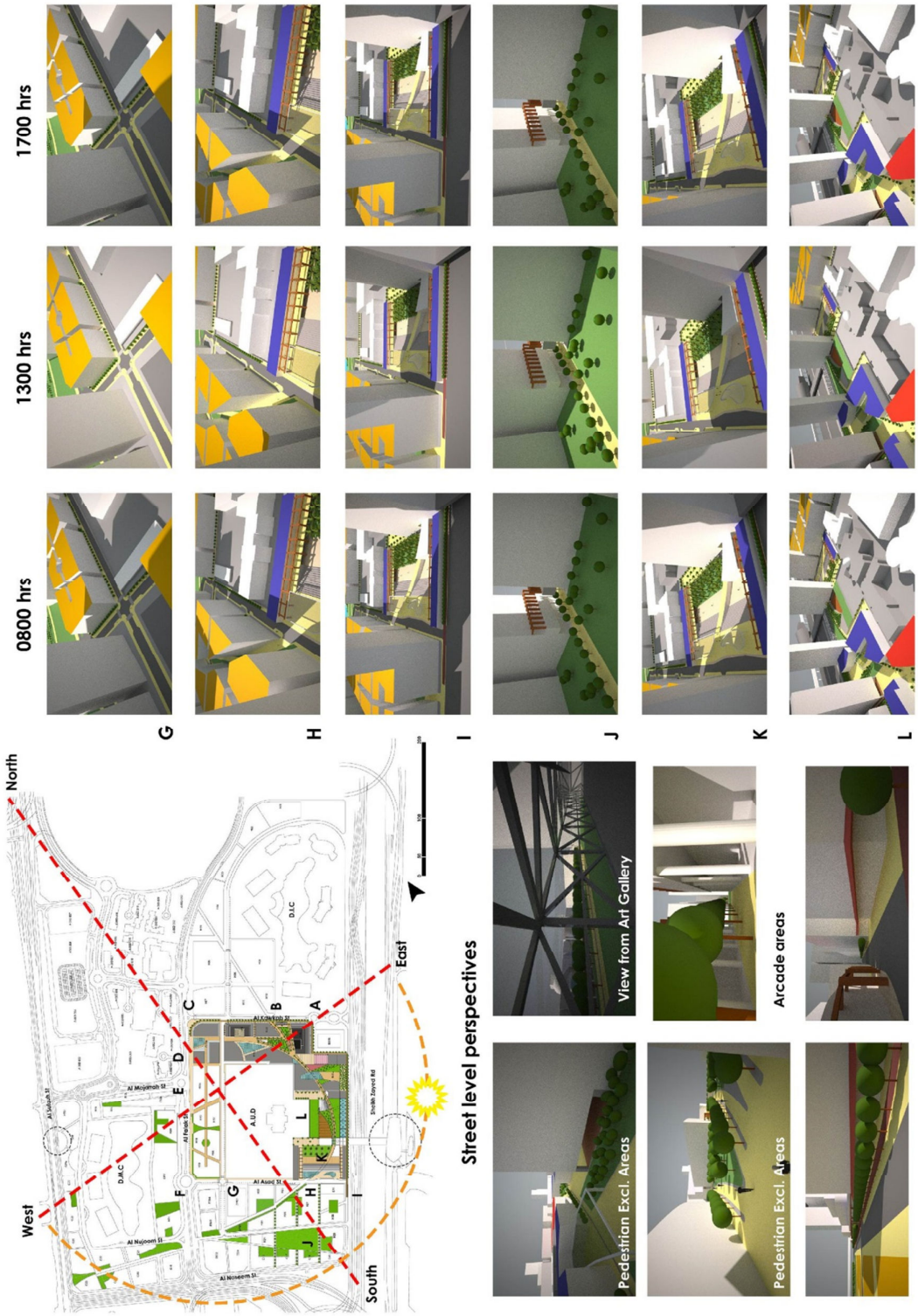


Figure 6.17. Al Suffouh Proposed TOD - Shading analysis 2.



D. Evaluation and Conclusion

The Responsive climate model was applied to intensify density around transit node, establish a network of comfort sheds to enable walkability, connect the existing large green spaces through a network of green spaces, reinforce the district identity through connecting the different character zones through redefined block morphologies and new building typologies .The summary of the applied design tools is provided in figure 6.18.

Challenges to apply the model comprehensive climate-responsive design tools were the visibility of important landmarks, the preservation of existing buildings, and the vertical densities on the site edges; these prevented the 45 degree orientation of high buildings to trap prevailing winds. In order to compensate for this issues, the built form included multiple wind channeling prevailing wind.

Table 6.2. Evaluation table.

Urban Design Dimension		Proposed Strategy to retrofit AlSuffouh based on the alternative climate responsive TOD model and toolkit					
		Economic Vitality		**Social Diversity**		**Environmental Integrity**	
		Principle stated in urban Design Strategy	**Evaluation of AL Suffouh proposed TOD -Urban Design Objectives**	**Principle stated in urban design strategy**	**Evaluation of the Al Suffouh proposed TOD – Urban Design Objectives**	**Principle stated in urban design strategy**	**Evaluation of the Al Suffouh proposed TOD – Urban Design Objectives**
	Identity	Density highest at transit node and decrease as distance to transit increases	Objective met The Highway edge was designed as a "'’green gate"'’ a way that does not visually obstruct the American University of Dubai	Inject retail , Housing ,flexible offices and cultural uses, community infrastructure and mix them horizontally and vertically	Objective met Site uses mixed; 20% of additional built up area residential and retail. The new proposed plan included a major retail area, a residential neighborhood, hubs for flexible offices and galleries that host cultural events	Design a network of 100 m tertiary and secondary nodes breaking the 400 m and 200 m into manageable chunks during hot weather Introduce air-conditioned gathering spaces at transit node and major squares	Objective met The network was designed around a major pedestrian walkway in order to lead to transit node. Air-conditioned gathering spaces used as galleries hosting multiple community events
	Ecology	Densifying around 200m and spread densities on 600m and 800 m	Objective met Allowable built up areas for commercial, residential densities are at its their highest within the 400m catchment areas of Nakheel metro station and Dubai tram station.	Student housing, faculty apartment , studios and midrise housing introduced building and social infrastructure to support	Objective met Social infrastructure and amenities broken into three categories : daily grocery needs , fitness , playrooms and convenience store for residences Government services for entrepreneurs. Student housing such as travel agency services, laundry.	Two green spaces network connect transit to housing, DIC and DMC. conserve DIC and DMC water bodies and green spaces	Objective met A network of green spaces link them And continuous trees canopies in order to establish an urban ecology local corridor.
	Infrastructure	Propose a retail area that is central for DIC, DMC, media village and AUD	Objective met A hub for small entrepreneurs, small and medium size companies, and young technology start-ups are proposed on top of the retail areas.	Introduce complete streets connecting residential, commercial and civic nodes introduce jogging and cycling track	Objective Partially met -Challenges faced –street patterns and cycling A grid street pattern was not possible because of considerable investments in re-aligning infrastructure lines. only two streets changed drastically . A jogging and cycling track was proposed on the highway side .Cycling network was not planned as extensive as pedestrian network.	Break down large blocks into smaller blocks Propose new streets in order to increase accessibility Massing to respect wind corridors Orient buildings where possible 45 degrees	Objective Partially met-Challenges faced –Building orientation Buildings could not be oriented 45 degrees to prevailing wind because: ▪ Maintaining view corridors of important landmark buildings at AUD ▪ Conserving existing streets ▪ Respecting site edges
	Public Space	Sunken plaza around metro station and secondary civic spaces based on 18 hour activity framed by landmark buildings in retail	Objective met Detailed day and night use analysis was included in the master plan taking into considerations the list of permissible and in some case prescriptive ground floor uses for each typology	diverse types of open spaces and for children, elderly, residents, employees, visitors	Objective met frequent crossings were planned to encourage walkability A proposed large green open space can be used as a football field in between the commercial areas and residential areas; and further links north to the grouping of community facilities. Community canters, yoga studios, playrooms overlook	climate responsive walkability strategies- shading and greening	Objective met Typology guidelines proposed for awnings for awnings, arcades and shaded structures. Patches of large tree canopies running in the centre of a 2 km major pedestrian walkway A large green shading superstructure connecting the edge towers on the highway proposing a palm tree garden in the sunken plaza.
	Private Development	Propose a Phasing plan with the civic spaces around the transit node as the first phase	**Needs further assessment** Preliminary phasing proposed but need to be further evaluated according to the proposed entity that will manage the site	Introduce new typologies for office buildings, commercial and residential buildings Blocks designed as perimeter urban blocks	**Objective met** **typology guidelines covering massing, sections, vertical uses, built up areas, FAR, building coverage , ground floor uses and, active frontage guidelines**	Study massing in order to enable wind ventilation and introduce courtyard and narrow streets for shading	**Objective met partially** **Massing could not be oriented fully to account for prevailing wind**

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

This study reviewed current research on Transit oriented Development and identifies two gaps:

The current research partially addressed aspects of urban design and did not link them to the three pillars of sustainable development

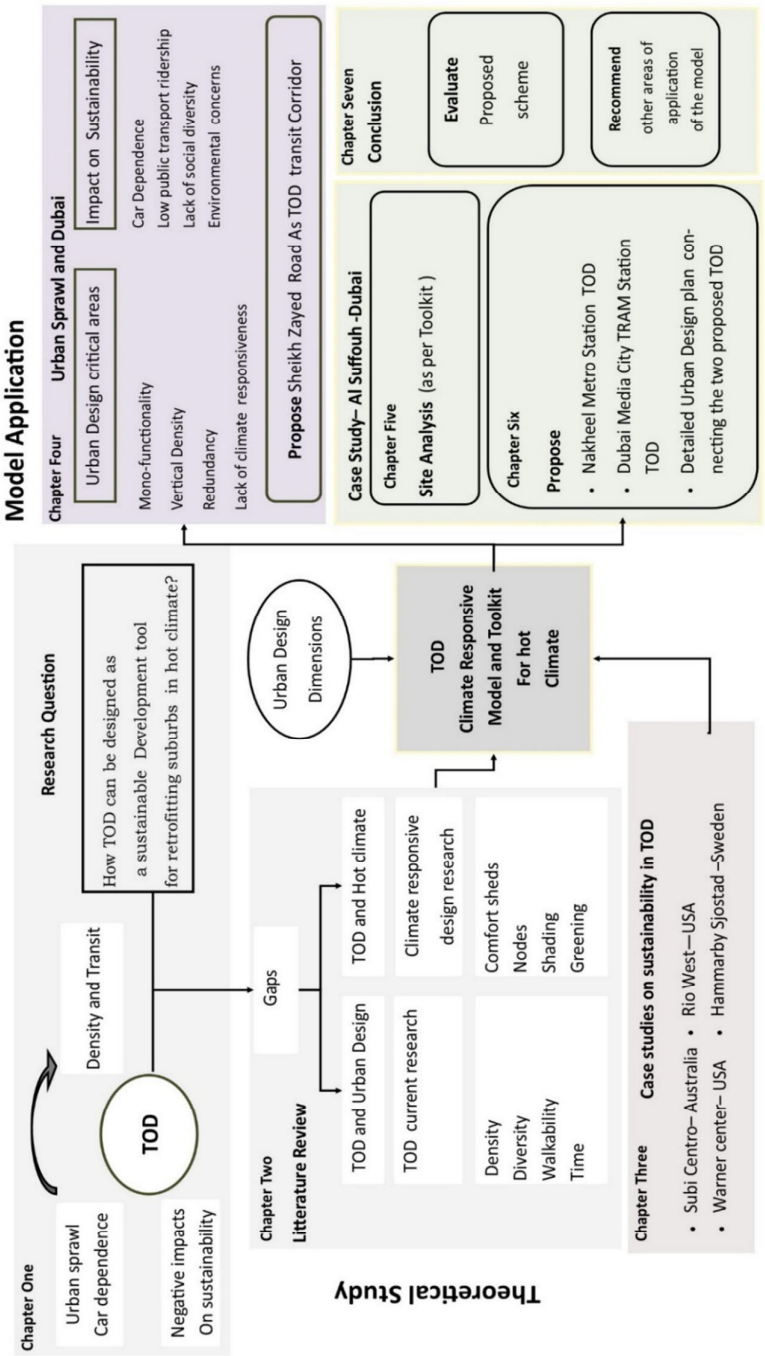
The current research was limited to temperate climates

As an attempt to bridge these gaps, Density, Diversity, Walkability, Time and Climate Responsiveness were the main urban design points deducted from the review of the current TOD and microclimate control studies. These principles induce a revision of the current transit oriented model, proposed in 1993 by Peter Calthrope .This study proposes an alternative climate responsive TOD model and a detailed toolkit that lists the multiple and various design and planning tools depending on the urban design dimension it reinforces. The five generic dimensions of urban design i.e. Identity, Ecology, Infrastructure , Public space and Private Development are proposed as an urban design framework by Saliba (2015) in order to 'subject global paradigms to regional and local realities'(Chapter 1).

The model and toolkit were applied across three scales: city-scale, district-scale and site-scale. Dubai – as an example of gulf cities in the middle east- is selected to test the model and toolkit. The study assessed Dubai's urbanization and linked it to a major urban corridor – Sheikh Zayed road which also supports its major transportation lines - Dubai metro and Dubai Tram. So, the study suggests its transformation into a regional

TOD transit, proposing that each station is planned to function as the major node and landmark of a transit-oriented development.

Figure 7.1. Methodology Diagram.



Al Suffouh, one of Dubai's oldest suburban districts is selected to generate a proposed TOD based on the model and toolkit around Nakheel Metro Station. The detailed site analysis showed how its current urban form, networks and built environment inhibit the adoption of public transport as the main mean of accessing and moving through the site.

The TOD and toolkit were applied to the specific context of Al Suffouh in order to address this critical condition. The resultant urban design strategy and objectives generated a master plan that densified and diversified the site uses around transit; and proposed an extensive network of walkable and active climate responsive public spaces.

A. Further applications

The proposed climate-responsive Transit Oriented Model and toolkit can be tested across geographies in the Arab world. Cities such as Amman, Riyadh, Kuwait, Cairo, and Algiers offer opportunities to test its principles within their complex urban fabric with its history and culture. Testing the model across different cities adds to the toolkit the resilience needed to be applied across different cities incorporating their unmatched vernacular local knowledge.

The model and tool kit can also be applied across different urban regions (urban, peri-urban and urban edges) to observe how the different urban elements function. For example, urban inner city offer less opportunities for injecting green spaces, so ecological approaches would focus more on vertical greening. TOD built on the urban fringes might not have sufficient population densities. Hence, its planning policies might offer incentives for people to work and live in the same area..

Finally, the TOD model and toolkit might incorporate urban geography, public policy, financial planning and urban planning tools to investigate the wider legal, environmental, financial and regional aspects for built form to influence the uptake of public transport as the main transport mode in the suburbs reversing their traditional car dependence.

B. Recommendations

Above all, I would like to end this study with a series of recommendations that incentivize the adoption of Transit oriented model as a development paradigm in Dubai in particular, and the Arab cities in general.

1. Urban policy

TOD needs to be embedded into a regional transport strategy that includes specific policies to attract the private sector to invest. These policies and their incentives need to be supported by specific legal vehicles.

This study is an applied research study in urban design built on the hypothesis that built form influence suburbanites to prioritize public transport. Notwithstanding, the shift towards public transport on a city level depends on other tools such as studies in behavioral change and transit mode. Another set of studies concern tax policies in affecting the shift towards public transport such as emissions tax, car ownership tax and road tolls. Environmental health studies on causal effects between car dependence and health in cities such as the relationship between respiratory illnesses and increased carbon emission .Urban policies can also be incentivized to change the modes of transport and therefore, would provide further support to the adoption of TOD.

2. City planning

City structural and framework plans need to embed sufficient land bank around proposed transit stations in order to be used in the future for transit oriented development. TOD regional transit corridors can be used to structure urban regions and thus limits their sprawl.

The urban planning framework might include specific transit oriented development guidelines taking into consideration local climate thermal comfort, current urban densities, available zoning and planning spatial tools to guide urban blocks within TOD and public realm based on the toolkit.

Alternative urban forms for transit-oriented development can be generated through experimental urban design studies. Recent research highlighted the existing discrepancies in exploring new morphologies for TODs. Such study can propose investigating the use of the "Adaptive Design Process" presented by Paul Lukez in 2007 as a theoretical framework to generate new morphologies in suburbs. The adaptive design process is a method that uses six phases – Mapping, Editing, Selecting tools and typologies, Projecting and Recalibrating. The process defines current and desired identity through proposing an open platform capable of finding linkages between urban form and time.

Fourth, the research is significant within the Planning framework in which it operates. The zoning laws applicable for Dubai Technology and media free zone call for the submission of an updated master plan report determining each use, built mass and guidelines for each plot within the master plan. Other areas of investigation of planning transit-oriented development could be based on re-programming them as urban catalysts in Dubai Older inner city core such as Deira and Bur Dubai.

3. Urban Design

Urban design theory is still in its infancy- a fact repeated frequently in the scholarly circles. However, this discourse fails to account for the available urban design theoretical frameworks that could generate new urban design models and tools. The theoretical framework (Saliba,2015) adopted in this study ,has been instrumental in re-structuring and re-framing the principles of TOD rooted in transportation and planning into a new urban design model and tools.

Urban design is about cities and cities are the most complex human creations and as such they embody the soul of the context of which they emerged. As such, urban design is by essence contextual and always reframing universally accepted realities to the specific situation it deals with. This study is an attempt towards a more regional urban design that is rooted in deeply understanding the character, habitats, networks, spaces and interests of the region it belongs to.

Finally, this study proved that urban design is central to the current discourse on climate change as it presents a variety of tools within its body of knowledge which cities have crafted over their 3000 years of existence in dealing with their environmental crisis. As such, urban design is by essence ecological, not by choice because it is the only design discipline that actually designs the human habitat and perceives its cities as an integrated system guiding collective actions simultaneously rather than orchestrating individual elements.

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APPENDICES

APPENDIX A

AL SUFFOUH SITE ANALYSIS

Regional and local bus lines

Dubai Internet City - aerial photo – 2008

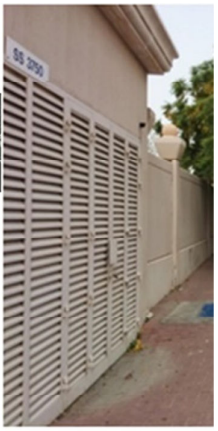
.

Dubai Internet City – 2003

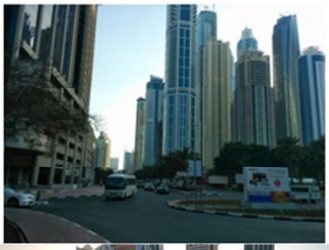
Pedestrian paths - mapping duration across Weekend, Weekdays at multiple times

8-9 A.M.

NOON

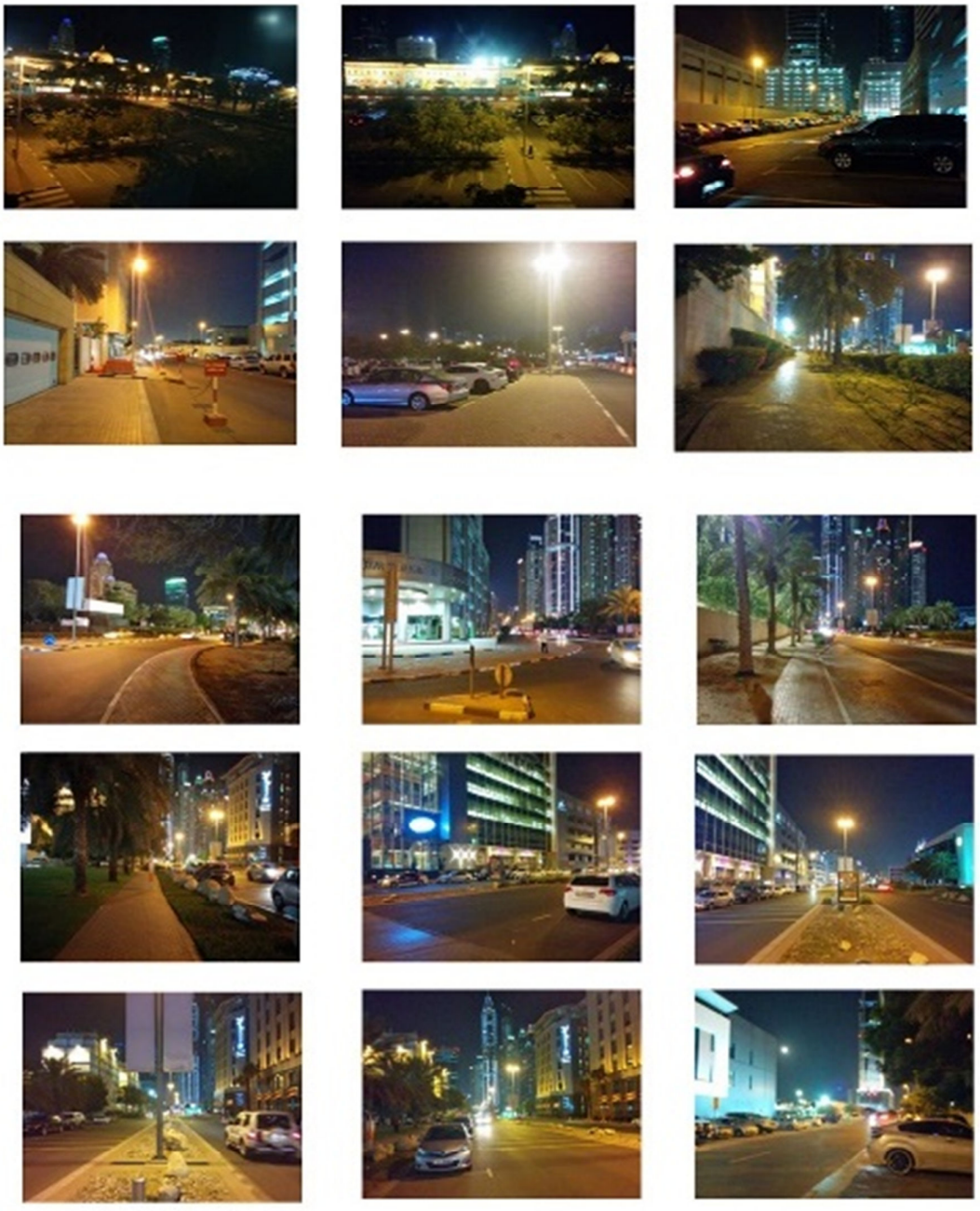


5 -6 P.M.

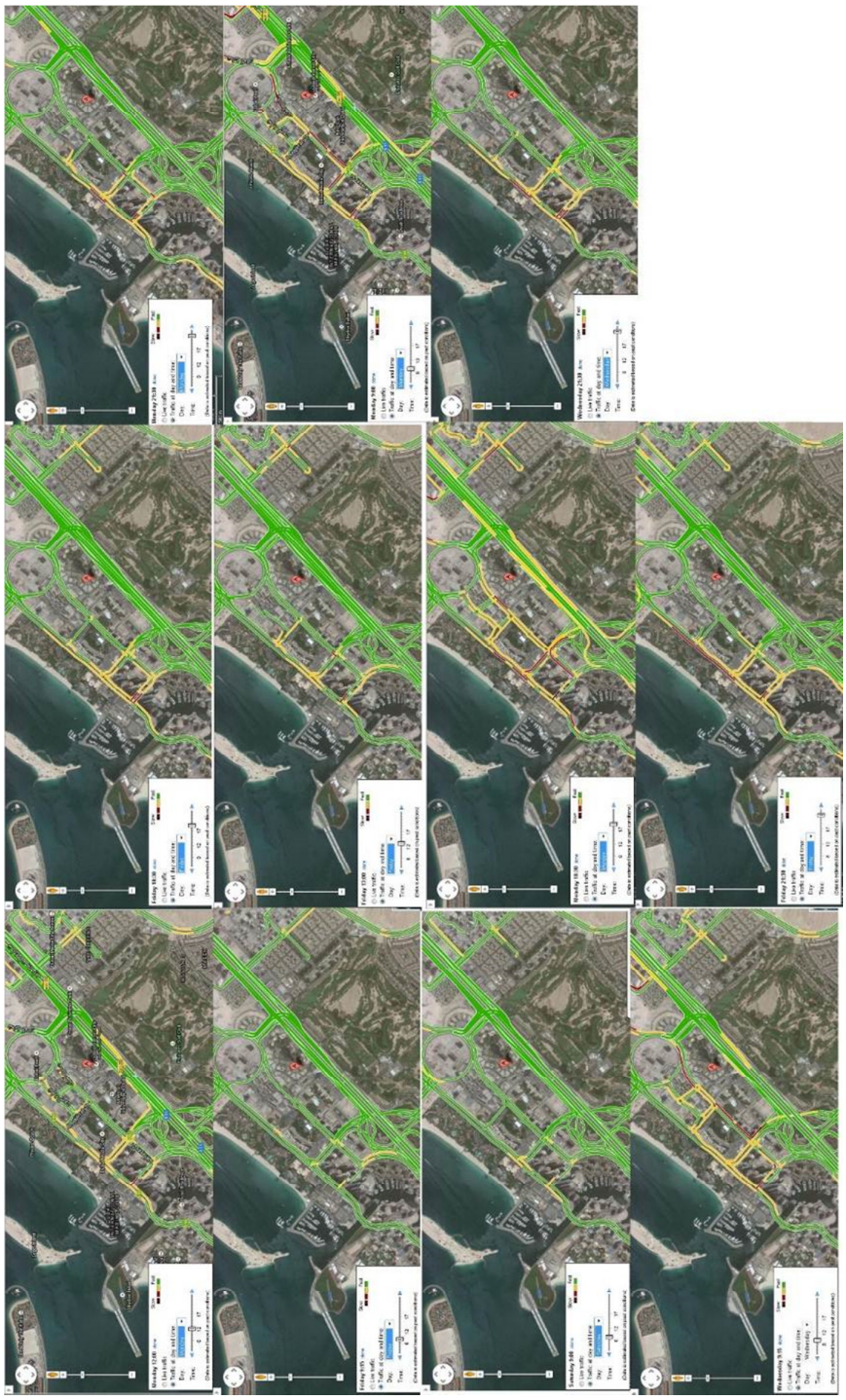


Sidewalks throughout the site area

Streets views during night



Traffic data - adapted from google and RTA



APPENDIX B

PROPOSED LAND USE SCHEDULE

Type	Plot No.	Plot area	Ground Coverage	flooors	BUA
Commercial	C08	1719.87	1719.87	G+30	55,036
	C09	1104.7	1104.7	G+10	12,152
	C10	1293.26	1293.26	G+30	41,384
	C11	1230.46	1230.46	G+10	13,535
	C12	1947.07	1947.07	G+30	62,306
	C13	2196.88	2196.88	G+10	24,166
	C14	1700.49	1642.17	G+30	50,907
	C15	1579.59	1129.91	G+20	23,728
	C16	1778.37	1136.71	G+20	23,871
	C17	2325.58	1544.85	G+20	32,442
	C18	3754.71	2385.22	G+20	50,090
	C19	4120.01	2783.57	G+20	58,455
	C20	3744.15	3744.15	G+20	78,627
	C20a	3378.05	2483.92	G+20	52,162
	C21	3055.94	2054.58	G+10	22,600
	C22	4379.66	3078.05	G+10	33,859
	C23	6470.79	5431.57	G+10	59,747
	C25	1367.76	1367.76	G+3	5,471
	C26	3219.88	2644.73	G+3	10,579
	C27	1303.97	1303.97	G+3	5,216
	C27a	1804.03	1804.03	G+3	7,216
	C28	2120.02	2120.02	G+3	8,480
Retail	R01	3677.91	1998.23	G+3	7,993
	R02	6784.88	2811.7	G	4,218
	R03	829.54	2498.63	G	3,748
	R04	1074.76	1074.76	G+3	4,299
	R05	3329.21	2884.88	G+3	11,540
	R06	5450.47	3738.1	G+6	26,167
	R07	3182.26	206.46	G	310
	R08	3579.68	3514.61	G+3	14,058
	R09	1509.11	2007.62	G+3	8,030
	R10	4532.7	2437.37	G+6	17,062
	R11	5476.3	2242.3	G+3	8,969
	R12	2038.03	2795.58	G+3	11,182
	R13	2095.51	1510.11	G+3	6,040
	R14	2042.96	2770.84	G+3	11,083
	R15	1513.76	660.27	G+3	2,641
	R16	1211.2	1211.2	G+3	4,845
	R17	930.4	930.4	G+3	3,722
	R18	1511.49	1511.49	G+3	6,046
	H33	2272.82	2272.82	G+3	9,091
	H01	5156.32	0	G+8	0
	H02	4238.14	0	G+8	0
	H03	2411.06	0	G+8	0
	H04	6553.63	0	G+8	0
	H05	2081.28	0	G+8	0
	H06	8112.6	0	G+8	0
	H07	5209.7	0	G+8	0

Housing	H08	1108.4	0	G+8	0
	H09	10899.64	0	G+8	0
	H10	2549.84	0	G+3	0
	H11	4787.81	0	G+3	0
	H12	537.97	537.97	G+8	4,842
	H13	2739.34	2492.74	G+8	22,435
	H14	2739.34	2739.34	G+8	24,654
	H15	1245.52	1165.47	G+8	10,489
	H16	1688.74	1477.42	G+8	13,297
	H17	1947.9	1947.9	G+8	17,531
	H18	2308.88	2208.88	G+8	19,880
	H19	4191.7	3409.03	G+8	30,681
	H20	5607.2	3211.09	G+8	28,900
	H21	5462.92	3071.24	G+8	27,641
	H22	4788.05	3141.6	G+10	28,274
	H23	2968	2255.86	G+10	20,303
	H25	1421.1	1304.29	G+10	11,739
	H26	3766.63	2793.51	G+10	25,142
	H27	5592.83	4905.81	G+10	44,152
	H28	4518.92	3441.75	G+10	30,976
	H29	4457.13	2782.49	G+10	25,042
Open Spaces	OP01	9788.64			0
	OP02	5879.6			0
	OP03	976.1			0
	OP04	1964.99			0
	OP05	2005.47			0
	OP06	766.31			0
	OP07	1442.98			0
	OP08	552.9			0
	OP09	851.98			0
	HT01	3739.07	3739.07	G+3	14,956
Existing Structures	ES01	5356.82	5099.41	G+50	260,070
	ES02	4804.78	4607.34	G+50	234,974
	ES03	3150.57	1900.83	G+30	60,827
	ES04	2877.96	2236.32	G+30	71,562
	ES05	4424.92	2050.79	G+50	65,625
		266,311.91			

BUA	Existing	Proposed in addition to existing
Commercial	1688858	1725087.28
Residential	0	385977.51
Retail	0	161043.92
Hotel	261000	14956.28
Existing	Included in commercial	
Total	**1949858**	**2287064.99**

Type	Plot Area	Ground Coverage	Percentage
Commercial	55595.24	46147.45	20.88
Residential	109090.59	42886.39	40.96
Retail	53042.99	39077.37	19.92
Hotel	3739.07	3739.07	1.40
Existing	20615.05	15894.69	7.74
New open spaces	24228.97	0	9.10
Total	**266311.91**	**147744.97**	**100.00**