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Towards an Approach to Residential Neighborhood Planning in Riyadh According to "Smart Growth" Design Principles

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Abstract. The paper sets out to analyze neighborhood design and development in Riyadh based on the data provided by the ADA 2005 Riyadh digital map. It starts by discussing the principles of sprawl-oriented neighborhoods and "Smart Growth"-slant ones. For the purpose of comparison between neighborhoods of different styles, the Riyadh city was subdivided into four study areas. The first area consists of the urban core which has primarily a traditional smart growth oriented neighborhood development pattern. Three successive 5 km ring buffers surrounding the city core were then executed using ArcMap analysis tools provided by ESRI programs.

The study is undertaken under the contention that the farther from the urban core the more sprawl-oriented the neighborhood will be. A continuum ranging from smart growth to sprawled neighborhoods was set to examine a whole gamut of variables such as land use intensity, mixed use diversity, pedestrian accessibility and street network patterns. The results seem to indicate that Riyadh cannot afford the pursuit of such current unsustainable pattern of neighborhood development. Adopting a smart growth approach is therefore recommended to make a brake to such unsustainable patterns. A sound approach to developing newer residential neighborhood design would be to build upon the locally established patterns of design as revealed by the traditional core at the inner city.

Introduction

Since the oil-booming economy during the seventies of the last 20th century, urban residential neighborhood planning in Riyadh has increasingly taken the form of single-use, automobile-dependent, low-density, scattered development. As a result, the city shape has taken the pattern of strip development, sprawling in fractal, split into parts and spider-like configurations. In response to such "sprawling" pattern that still represents the dominant mode of growth in Riyadh, many academics and planners are raising extensive debate over its desirability as a pattern of land use development (Eben Salah, 2002; Mubarek, 2004). Alternative forms are being discussed with much of the attention being given to Smart Growth or New Urbanism (Eben Salah, 2004; Alskait, 2003).

In fact, the issue of urban sprawl is not peculiar to Riyadh. Many cities of the world are experiencing it. The growing concerns over the sustainability of the urban future have led to the issue of unchecked urban development being put under question. In the case of Riyadh, the threat of sprawl has prompted city officials to introduce many land use and growth boundary management regulations in an effort to curb the rapid expansion of sprawl on the fringes of the city.

Over the last two decades, many academics and professional planners have been rallying this "anti-sprawl" movement not only to seek for a cure to the ills of urban sprawl, but also in quest for sustainable city development patterns (Duany, 2001; CNU, 2001). By so doing, they are trying to get answers to these issues of environmental protection, land consumption, traffic congestion and urban sprawl in the principles of "Smart Growth or New Urbanism" movement. It is precisely such concerns that are making sustainability and smart growth to become a dominant issue in city building and residential neighborhood development in Riyadh.

Definitions of sprawling neighborhood development

Sprawling Urban Neighborhood Development, also known as Conventional Suburban Development (CSD) arose as a result of the modernist planning principles being put into practice. It is a pattern of urban land use development and a pace of city expansion in which the rate of land consumed for urban use purposes exceeds the rate of population growth. Sprawling developments are not simply the increase of urban lands in a given area, but the rate of this increase relative to population growth. In this sense, Urban Sprawl should be considered in a space-time context. It occurs when the rate of land conversion and consumption for urban uses exceeds the rate of population growth for a given area over a specified period of time (Ewing, 1997).

As far as the city of Riyadh is concerned, the ADA data show that during the last five years (2005-2009) Riyadh population has risen from 4.2 to 4.9 million. Its developed land for urban uses however, has jumped from 577 to 749.6 square km during the same period. This means that the rate of Riyadh population increase during this period was about 15.02%, whereas its developed urban land has sprawled at a much higher rate reaching up to 29.8% which is twice as much approximately. This has led to three basic spatial forms of sprawling neighborhood development being distinguished in Riyadh. The low-density sprawl development, the strip or ribbon sprawl development and the leapfrog development. These sprawling forms have generated piecemeal extensions of basic urban infrastructures such as water, power, and roads causing along the way excessive consumptive use of land for urban purposes.

The main features of this sprawling pattern of neighborhood development are low density residential areas, non-compact morphologies at the periphery of the city, particularly to the east and north of Riyadh, scattered, leapfrog developments over open space, commercial strips and malls along the main city arteries, and rigorous separation of uses causing predominant reliance on the automobile for travel. It also offers limited transportation alternatives, lacks public open spaces which results in an inefficient and consumptive use of land and its associated resources (Fig. 1).

Characteristics of sprawling neighborhoods

Sprawling neighborhood development has several characteristics that make it one of the most pressing concerns facing Riyadh city. Sprawl is a relatively wasteful method of urbanization, characterized by uniform low densities. Land is often developed in a fragmented and piecemeal fashion, with much of the intervening space left vacant or in uses with little functionality. Sprawled neighborhoods of the city are generally over-reliant on the automobile for access to resources and community facilities. Aesthetically, these areas are often regarded as displeasing, commonly applied to urban landscapes with a blandness of design that robs vast swathes of the city of their appeal, (Ewing 1997).

The term urban sprawl generally has negative connotations due to the unfavorable assessments of its impacts on people, the environment and the quality of urban life. It has been denounced by many scholars on aesthetic, social, economic, and environmental grounds. For the Congress of New Urbanism, the characteristics of Urban Sprawling Residential Neighborhoods or Conventional Suburban Development (CSD) can be summarized in the following characteristics (CNU, 2001):

1) It consists of housing subdivisions, shopping centers, business parks, retail stores, service facilities, open spaces, and municipal buildings.
2) It keeps all these uses separate.
3) It maintains a street pattern that is dendritic rather than interconnected.
4) It has no district center.
5) It is less compact and non-conducive to the use of public transportation.
6) It is low density and it tends to spread out.
7) Its street system is designed with respect to the automobile scale not the human scale.

Recently, serious objections and criticism have been leveled against the doctrine of sprawling urban

Fig. 1. Two Google earth views of sprawling neighborhood development in the outskirts of Riyadh.

neighborhoods. Many attempts have been made to prevent the out-ward growth of cities. Such attempts were either in the form of land-use regulations, development guidelines, or transport policies. Containment policies and their benefits have thus been advocated and green belts and compact-city policies have been implemented (e.g. Breheny, 1995; Gordon and Richardson, 1989). Being taken by the compelling need to come to grips with sprawl, the side effects of such policies, like compaction seem to have been overlooked and underestimated.

The smart growth movement

To mitigate the negative impacts of urban sprawl, a number of planning concepts and models of neighborhood design have flourished under the umbrella of "Smart Growth" movement, like for instance, the "New Urbanism", the "Traditional Neighborhood Development" (TND), neo-traditional development, urban villages, compact communities, transit-oriented development, and pedestrian pockets. They all share similar themes, mainly to take into account sustainability issues, reduce automobile traffic and limit sprawling neighborhood developments.

Both academics and professionals are increasingly adopting the Smart Growth approaches in the creation of new communities. The most popular sets of planning and design tenets that are often used can be boiled down to two models. The first model, traditional neighborhood developments (TNDs), or "neotraditional designs" which insist heavily on the use of historical precedents and are closely associated with architects Andres Duany and Elizabeth Plater-Zyberk. It follows a fairly prescriptive set of historically informed design considerations that center on land use, density, circulation and architectural character (Bookout, 1992). TND developments have a greater focus on architectural details and street design, as well as social, economic and environmental goals.

In its quest for the basic development patterns of the community, the Smart Growth or New Urbanism draws upon the historical precedents to shape the residential neighborhoods physical form of the community. For that, it favors the rediscovery and reuse of such traditional features as prominent front porches, backyard garages, multi-use buildings and housing clustered near commercial service areas. Such neighborhoods and communities are designed with the primary focus on promoting a sense of place and on creating people-friendly environments.

Principles of "Smart Growth"

Although not all "Smart Growth" advocates agree to a single set of design principles, Emily Talen (1999) has pointed out five elements shared throughout this movement, which include historically informed architectural styles and regionally appropriate site design, an increased density related to a pedestrian scale, more compact streets designed as public space, the inclusion of neighborhood gathering spaces and an appropriate mixing of land uses (Talen, 1999).

The *Charter of the New Urbanism* outlines more or less a different set of principles that include but are not limited to the promotion of community, the inclusion of diversity, the support of mass transit and the reflection of the context in the design and construction of the urban fabric (Duany, *et al*., 2000). The Charter further recommends that neighborhood design should reinforce the unique identity of each place, commonly referred to as a sense of place, by adopting a consistent and distinctive architectural style that draws on local history, culture, geography and climate (Congress for the New Urbanism, 2000).

A Smart Growth neighborhood is essentially a walkable neighborhood that resembles to a great extent the traditional village or hamlet where homes and businesses are clustered together. Compactness, walkability, sense of community and sustainability are of paramount importance in Smart Growth or New Urbanism communities. Instead of driving on highways, residents of "Smart Growth" neighborhoods can walk to shops, businesses, mosques, schools, parks, and other important services. Buildings and recreational areas are arranged to foster a sense of community closeness. New Urbanist designers also place importance on earth-friendly architecture, energy conservation, historic preservation, and pedestrian accessibility.

"Smart Growth" also supports the development of neighborhoods that are diverse in use and population, the design of communities with multiple modes of transportation where the pedestrian and transit as well as the car can share the spaces for movement. Accessibility of public spaces and community institutions is a characteristic that is of paramount importance for this movement. The architecture and landscapes framing urban places should reveal and celebrate local history and patterns, aesthetics and artistic tastes. For that, the movement supports context-appropriate architecture and planning while insisting on a balanced development of jobs and housing. It also tries to reduce traffic congestion, increase the supply of affordable housing and reins in urban sprawl.

An interconnected and dense network of narrow streets with reduced curb radii constitutes an essential feature of "Smart Growth" design. This network serves to give primacy to pedestrian over vehicular movement. Such interconnected narrow streets would not only lead to both slow and disperse vehicular traffic, but also provide a pedestrian friendly atmosphere. The advocates of "Smart Growth" design insist that the overall function, comfort and safety of a multipurpose or "shared" street are more important than its vehicular efficiency alone. For that, "Smart Growth" street design should have high interconnectivity, sidewalks and paths. This does not mean however, that cars would be excluded from the streets, but streets and rights of ways are shared between vehicles, whether moving or parked, modes of public transport, bicycles and pedestrians (Fig. 2).

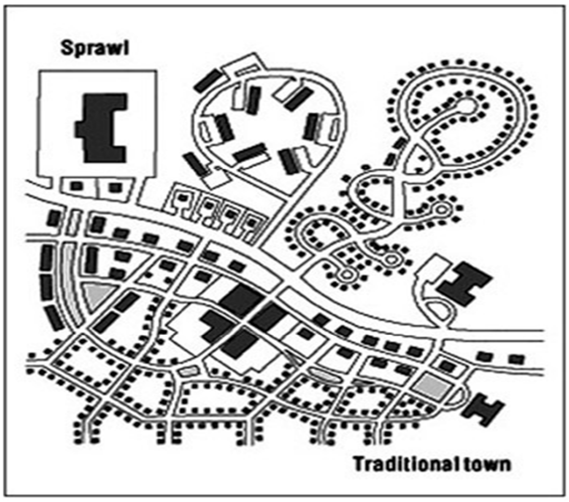

Fig. 2. A Comparison between Sprawled and Smart Growth Design Layouts.

The present study consists of a comparative analysis of smart growth and sprawl neighborhood layouts in the context of Riyadh City. The following section attempts to describe measurement methods of such neighborhood built forms.

Methodology of neighborhood measurement

Although the issue of urban neighborhood design and residential subdivisions has been the subject of extensive research from various disciplines, it has always been and still remains a hotly debated matter. In much of the debate, however, residential neighborhoods are often classified as "traditional urban" or "sprawled suburban". The characteristic differences between the two types along physical design and socioeconomic dimensions are then analyzed and scrutinized.

While useful as a general characterization, this simple dichotomous distinction fails to capture the tremendous variations in the physical form and planning attributes of urban neighborhood landscapes. Several problems are associated with this dichotomous approach. First, the "traditional-suburban" neighborhood type is not an either-or condition; rather, it is a continuum along which it is possible to fall (Fig. 3). Further, it is not a monolithic construct; rather, neighborhood type designation is a composite of a number of traits and it is possible for a neighborhood to look more traditional on some traits and more suburban on others.

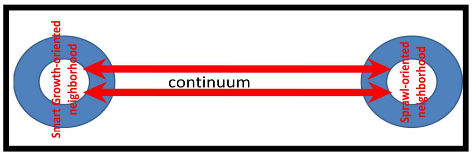

Fig. 3. The Smart Growth-oriented and Sprawl-oriented Neighborhood Continuum.

Many recent studies have raised questions showing the limits of such dichotomy. In their attempt to develop richer characterizations of urban neighborhoods, researchers like Aurbach (2001) and Song and Knaap (2003) criticized the coarse dichotomous classification as it only recognizes two neighborhood types: urban traditional and suburban conventional. They argued that there are many different types of neighborhoods with many different design and planning features and hence, they cannot be adequately characterized as simply traditional or suburban.

A similar approach has been developed by Duany Plater-Zyberk & Company (DPZ) in which the Urban Transect has been established as a more comprehensive classification system of neighborhood types. The central notion of the Transect is a gradient of area types, ranging from rural to urban. Components of the built environment: building, lot, land use, and streets, can then be organized into each area type (Duany and Talen 2002). As shown in Fig. 4, the rural-to-urban continuum is segmented into six discrete area types: rural preserve, rural reserve, sub-urban, general urban, urban center, urban core. As one moves along the gradient of these area types, differences in design, form, density, land uses and social structure are apparent. According to Duany and Talen (2002), the transect can be used as the basis for a regulatory land use code to systematize differences in design attributes and to plan for the character of places. Urban elements such as housing

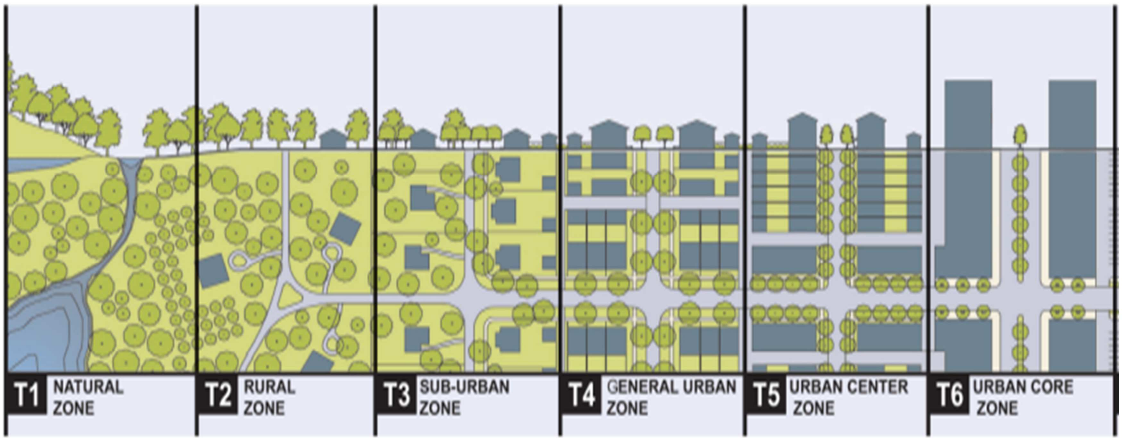

Fig. 4. The Rural-Urban Transect by DPZ.

types, street design, and housing setback can be specified, using the transect, by each area type.

Measures of the study's neighborhood types

For the purpose of the present study, a quantitative method of classifying neighborhoods that goes beyond the dimensions of neo-traditional versus suburban types is developed. It begins by identifying the two types at both ends of a continuum ranging from a perfectly neo-traditional residential neighborhood type to a perfectly suburban conventional type.

To carry out the study, measures deriving largely from the literature covering several aspects of residential neighborhood design and planning were used. The relevant attributes of physical form, residential layout characteristics, indicators of street pattern, density, mixed land uses, and accessibility of each type are quantified and measured.

Neighborhood development types in which the design-based aspects are directly related conceptually to Smart Growth are compared to those that characterize "conventional suburban" development in order to differentiate and evaluate the two development types.

However, before elaborating on the set of measures mentioned above, it is essential to adopt an appropriate unit of analysis. The literature review shows that many researchers have used the neighborhood as determined spatially by an administrative/geographical unit, e.g., Traffic Analysis Zones (TAZ), street blocks or Census Tracts. Such neighborhood boundaries are thus taken as a unit of analysis to compute measures of neighborhood types (Sampson et al. 2002; Dietz 2002; Kitamura *et al*., 1997; Krizek 2003). The concept of neighborhood type is introduced to define a group of neighborhoods with similar traits. As far as the present study is concerned, the residential neighborhood as determined by Riyadh Municipality (Fig. 5) is taken as a unit of analysis.

Quantitative measures of Riyadh neighborhood forms

The Riyadh 2005 ADA survey data provided considerable new evidence on the problem of urban sprawl. The data show that the urban area continues to grow faster than its population, causing urban densities to fall. This trend suggests that Riyadh neighborhoods tend to adopt a more sprawling pattern of development and hence are getting more unsustainable.

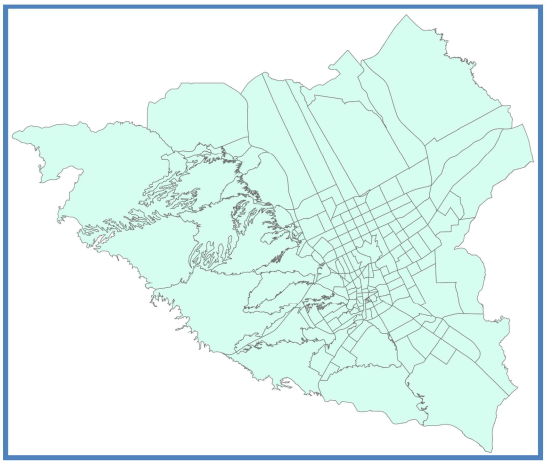

Fig. 5. GIS Shapefile Map of Riyadh Residential Neighborhoods as Determined by Riyadh Municipality. It Shows Clearly the Domination of the Square Superblock Neighborhood Shape (Source: Riyadh Development Authority-ADA).

The old Riyadh was a small city established along traditional planning patterns at the heart of Saudi Arabia. It was unable to cope with the soaring influx of new comers seeking to settle down in Riyadh. The city has witnessed as a result, a staggering urban expansion on all sides. Newer residential neighborhoods were successively built around the traditional core to cater for the enormous demands for housing units. The city core refers to the traditional neighborhoods that make up old city of Riyadh. This core known locally as Deerah (Fig. 6), is notorious for its traditional compact neighborhood planning pattern much in line with the principles of the "Smart Growth" Movement.

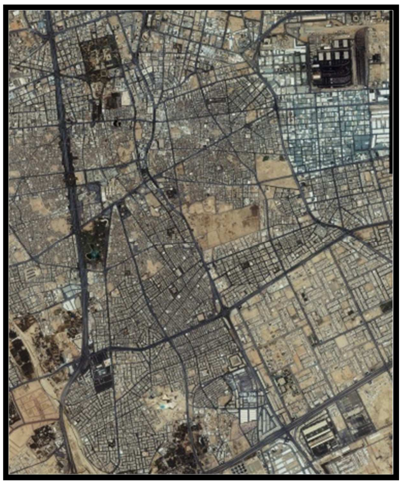

Fig. 6. View of the City Core Area (Deerah) and Its Environs Parts of the 1st Ring Buffer (Source: ADA).

As stated earlier, a continuum ranging from "Smart Growth" to "Sprawling" development was set up for the methodology to test the study's hypothesis. The core neighborhoods would be expected to be more Smart Growth-oriented, whereas the peripheral neighborhoods would be more sprawl-slanting. The contention is that the farther the residential neighborhood from the urban core the more sprawl-oriented it is. Thus, for the purpose of examining this claim, Riyadh was subdivided into four successive areas with the traditional core at the center. A multiple ring buffer around the city core was executed every 5 km using the data analysis tools provided in ArcMap version 9.3. Since the standard neighborhood in Riyadh is usually a 2 by 2 km in size, a 5 km buffer would be roughly equivalent to two juxtaposing neighborhoods. The outcome of this procedure was three concentric ring buffers around the traditional urban core (Fig. 7). The third ring buffer is the farthest from the core. It must be noted that when the buffering line intersects with a neighborhood, not only the part falling into the buffer is considered, but the whole neighborhood is included in the study ring area because the analysis unit of the study is undertaken at the neighborhood level. This explains the irregularity of the ring buffer shapes.

Once values have been accumulated for each neighborhood and summed up for each of the four areas, the mean values were then analyzed for each neighborhood design variable. The objective of such analysis is to identify any significant differences between neighborhoods of different areas of the city using ANOVA and F tests. Comparisons were made between the four areas, that is the traditional urban core neighborhoods and the successive additions in the three ring buffers as outlined in Fig. 7 above.

For the purpose of the study of urban sprawl in Riyadh, a neighborhood level analysis of urban sprawl is used. It includes measures of development density, land use mix, street network patterns, residential proximity and pedestrian access to commercial uses and other day-to-day amenities. These measures for neighborhoods of varying development patterns in the four study areas are then computed. The neighborhood-level measures provide not only richer information on the design character of Riyadh neighborhoods but offer new interesting insights into how this character has changed over time.

For each area, measures are calculated for the above five categories of neighborhood design components. The density component includes average lot size, and the proportion of single-family dwelling units in each neighborhood area. Land use is captured in a ratio comparing the area of non-residential uses

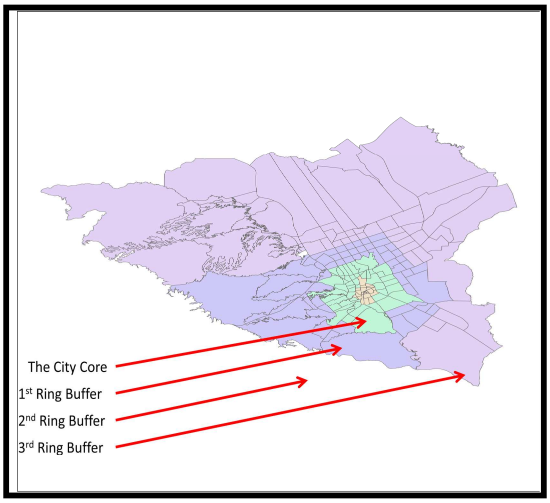

Fig. 7. The City of Riyadh Showing the Traditional Core Together with the Three Ring Buffers.

to residential uses. Two diversity measures are also implemented in which the proportions of multiple land use types are being compared. The street network design component includes a connectivity measure that considers street length per hectare, and street density. Block perimeter and block size are the other measures used. Accessibility is captured through mean distance to the nearest commercial uses, schools, local mosques, neighborhood parks and primary care services. Pedestrian access is captured by calculating the percentage of single-family housing units within 7 minute walk of these above-mentioned amenities. A definition of each measure and how they were computed is provided below.

Land use intensity*:* The first category of variables used to assess Riyadh urban neighborhood development covers land use intensity measures. Conventional suburban developments are dominated by single-family detached housing units on large lots. Such pattern would lead to lower density use of land. It is assumed that low-density development increases automobile dependency, consumes land and raises the cost of public infrastructure (American Planning Association, 1998).

To capture the intensity of land use at the neighborhood level, several measures were computed using data available from The 2005 Riyadh land use survey conducted by Ar-Riyadh Development Authority (ADA) and The Atlas of Land Uses in ring buffer are much more pronounced in exhibiting the principles of sprawling conventional planning.
Riyadh (ADA; 2005). These measures include the following:

- Gross and net population density for each neighborhood (persons per hectare)
- Housing density (dwelling unit per hectare, housing units per residential hectare)
- Household density (households per hectare)
- Residential lot size (average lot size of residential dwelling units in the neighborhood; the smaller the lot size, the higher the intensity)
- Lot size (average lot size of different land uses in the neighborhood)

Results and Findings

It is commonly stated in the relevant academic literature that density is a well-established descriptor of urban sprawl which is often defined as low-density development. Riyadh residential neighborhoods are no exception to such pattern. When residential densities are examined across different neighborhoods, the results were striking. The pattern seems to indicate that the farther the neighborhood from the traditional urban core area, the lower the residential density. This pattern is much more pronounced particularly to the northern direction of Riyadh. Table 1 below shows that population densities tend to be higher in the traditional urban core neighborhoods of the city (232.28 persons per hectare). This density decreases markedly for neighborhoods in successive ring buffers. The average density for all such neighborhoods in the first ring buffer is only 62.80 persons per hectare, and 38.2 for the second and finally 18.94 persons per hectare for the last ring buffer which is the farthest from the core (Table 1). In other terms, population density has dropped by about 91.8% from the urban core to the fringe neighborhoods of the city. When examining the planning pattern of each area, urban core neighborhoods exhibit a more compact planning of a traditional-like pattern, whereas the ring buffers ones tend to adopt a different planning pattern, often in line with the precepts of the modern movement in urban planning. Hence, population densities are remarkably lower. This result seems to indicate that judging from gross population densities, the core neighborhoods tend to be more tilting towards the Smart Growth end of the continuum. However, the farther the neighborhood from the urban core the more sprawl-oriented it is. Neighborhoods of the last ring buffer are much more pronounced in exhibiting the princip-les of sprawling conventional planning.

Table 1. Land Use Intensity- Density measures

Density	Traditional Core	Ring Buffer 1	Ring Buffer 2	Ring Buffer 3	% Change Core-Ring3
Population Density (persons/hectare)	232.28	62.8	38.2	18.94	
Percent Change		72.96%	39.17%	50.42%	91.85%
Net Population Density (people/ha)	738.91	243.07	193.78	142.64	
Percent Change		67%	20%	26%	67.10%
Housing Density (dwelling unit/ha)	41.06%	11.79	6.03	2.91	
Percent Change		71%	49%	52%	71.29%
Dwelling Units per Residential Hectare	141.59	49.32	31.35	32.77	
Percent Change		65%	36%	-5%	65.17%
Household Density (Household/hectare)	42.94	11.71	6.4	3.47	
Percent Change		73%	45%	46%	72.73%

Gross population and dwelling density

Gross density is sometimes calculated using the entire land of a study area. This crude approach however, was not really appropriate for our case since many of Riyadh neighborhoods, particularly the peripheral ones, have large areas of undeveloped land.

With the aid of GIS database and the parcel use information, it was possible to modify the boundaries of the study areas to exclude large tracts of peripheral undeveloped land. However, planned areas with undeveloped lots within the development boundary were retained. To compute gross density, the land area of the resized sectors was calculated using Analysis Tools provided in GIS ArcView extensions. Population and dwelling data were taken from the Atlas of Riyadh (ADA, 2005).

From Table 1, it can be seen that population density between the city core (the old city of Riyadh) and the first ring buffer has dropped by 73% (232.28 vs. 62.8 people per hectare). A comparable drop is also revealed for dwelling density by 71.4% (41.06 vs. 11.71 units per hectare). The declines in the following buffers are slightly less severe, with population density decreasing by 39% (62.8 vs. 38.2 people per hectare) and dwelling density decreasing by 48.8% (11.79 vs. 6.03 units per hectare) between the first and second ring buffers. The drop in population density between the second and third ring buffers is 50.4% (38.2 vs. 18.94 people per hectare), whereas the density of dwelling units has fallen by 51.7% (6.03 vs. 2.91 units per hectare). In sum, the density slump is more pronounced between the city core and the last ring buffer where population density has decreased by 91.8% and dwelling density by about 92.9%. However, it is difficult to gauge any usefulness of these comparisons due to the different rates of neighborhood development. Some neighborhoods are nearly fully built out and mature as in the city core where the average development rate amounts up to 88.38%. For others however, development is still incomplete as for the fringe neighborhoods in the third ring buffer where the average development rate is only 44.36%.

When shifting the investigation to net densities, neighborhoods of the traditional urban core area show a net population density as high as 738.91 persons per hectare and a residential dwelling density of 141.59 units per residential hectare. These figures are notably higher than those neighborhoods outside the inner city. The density for the first ring buffer immediately surrounding the core shrank by 67.1% (243.07 people/ha). This density drops even further as one moves away from the central city. The data show for example a density of 193.78 and 142.64 people/ha for the second and third ring buffers respectively.

A lower density residential housing unit is another attribute of sprawling neighborhoods. When looking at housing density (Table 1), a striking difference is revealed between the city core neighborhoods at the central area and the remaining areas determined by the three ring buffers defined earlier. The gross housing density is about 41.06 units per hectare for the urban core against only 11.79 units per hectare for the first buffer immediately around this core. The second ring buffer shows a density of 6.03 housing units per hectare and only 2.91 units/ha for the last ring buffer.

Similarly, the dominance of single family housing is another salient feature of urban sprawl. Apart from the traditional core at the central city which exhibits a household density of about 42.94 households per hectare, the next ring buffer area of residential neighborhoods shows a much lower household density of about 11.71 households per hectare. Residential neighborhoods at the third ring buffer however, reveal a much lower density of single family housing of only 3.47 families per hectare (Table 1).

Judged by their population densities, Riyadh neighborhoods excluding those at the urban core area tend to show very low land use intensity. The traditional core neighborhoods however, are an exception to such trend as they show a much higher gross population density reaching the cap of 431 persons/ha for New Manfuha quarter or 371 for Um Sulaem or again 337 for Thulaem as shown in Fig. 8 below (ADA; 2005).

The average population density for the whole Riyadh is 60.47 persons per hectare. This means that inner city neighborhoods like the ones just mentioned, are six to seven times denser than the average Riyadh neighborhood. The density factor is of paramount importance to the implementation of smart growth principles. The higher the density the higher the land use intensity and the more pedestrian friendly the neighborhood environment (Figs. 9 and 10).

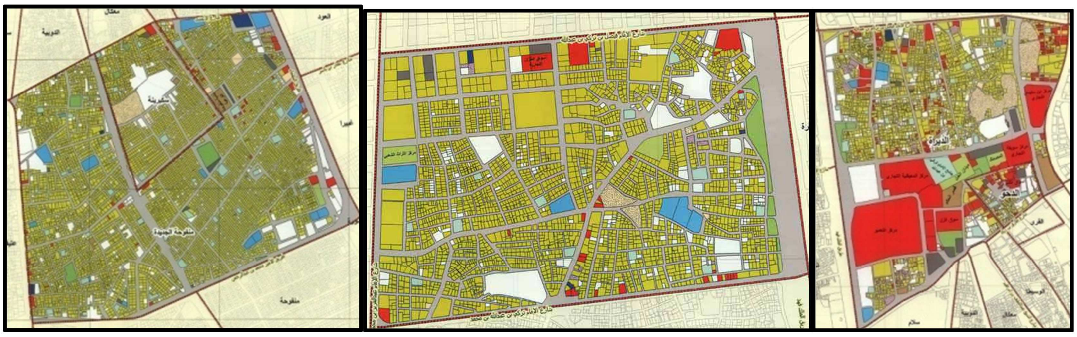

Fig. 8. New Manfuha, Um Sulaem and Thulaem neighborhoods in the city core (Source ADA 2005).

Fig. 9. View of a commercial street on both sides in the urban core of Riyadh showing the density of pedestrians and vibrancy of economic activities.

Fig. 10. View of another commercial street in the 2nd ring buffer to the North of Riyadh (King Abdullah Road) shows the predominance of the car and absence of pedestrians on its sidewalks even though these malls and shops drain a high number of customers who rely essentially on the use of the private car to do their shopping.

Table 2. Residential & commercial lot sizes of Riyadh study areas neighborhoods

	Riyadh Study Areas			
Indicators	**Core**	**Ring1**	**Ring2**	**Ring3**
Residential Lot Size	200.27	1468.61	780.18	1144.73
Count of Residential Lots	43995	22165	82315	38069
Total Residential Area	8811049	32551752	64220187	43578911
Residential lot density	49.93	6.81	12.82	8.74
Commercial Lot Size	967.88	2478.11	2499.87	3440.79
Count of Commercial Lots	1937	2838	4044	2281
Total Commercial Area	1874785	7032870	10109480	7848437
Commercial lot density	10.33	4.04	4.00	2.91

The fact that successive urban expansions around the traditional core have adopted a density development similar to the Riyadh average for the first ring buffer (62.8 pers/ha) to then drop sharply down to 38.2 and 18.94 for ring buffers 2 and 3 respectively, is an indication that the city of Riyadh has taken on a sprawling neighborhood development. It is therefore time to review Riyadh urban planning development policies to restrain the current sprawling trend in favor of Smart Growth development approaches. Luckily enough, these areas still hold large tracts of undeveloped lands which ease the implementation of alternative planning options.

A more revealing descriptor of sprawl is residential density as indicated by dwelling units per residential hectare. The data show that the average of such density for the traditional core neighborhoods is as high as 141.59 units per hectare (Table 1). This density drops sharply when it comes down to other residential neighborhoods outside the city core. The results show the average density per residential hectare for the first ring buffer area has decreased by 65% from what it was in the inner city (141.59 vs. 49.32 units per hectare). It then drops again even further for the next second ring buffer to 31.35 units/ha. The last ring buffer area however, indicates a more or less comparable density to the previous buffer of 32.77 dwellings per unit area. These figures indicate that the existence of vacant land either as pockets within the neighborhood or as areas of extensions at its vicinity may have had an impact on the above findings.

Residential lot size: One way to investigate land use intensity in any residential neighborhood is to look at residential lot sizes. The data provided in Table 2 below show the median lot size in Riyadh city core is 200.27 m^2 whereas the first ring buffer area immediately surrounding this core reveals an increase of 633.3% to attain a much higher lot size of about 1468.61 m^2 (Table 2). However, when looking at the average size for the second ring buffer, the residential lot has surprisingly shrunk by 88.2% to reach only 780.18 m^2. It increases once again by about 46.7% for the fringe neighborhoods of the third ring buffer to get to an average lot size of 1144.73 m^2. The sizable decrease in mean lot size seen between the first and second ring buffer areas as mirrored in the data presented in Table 2, can in part be explained by the booming economy of the mid-seventies which has led to the first urban expansion in Riyadh. Such circumstances have pushed the city's real estate market to flourish allowing larger segments of society to build up bigger housing units. This may explain to a large extent the larger residential lot sizes exhibited for the first ring buffer. However with the skyrocketing of real estate prices, many owners faced hardships either to buy or sell or even develop their own larger parcels. As a result many of them have applied to the planning authorities seeking permission to proceed to a subdivision of the original lot so that they can sell half of its area and keep the remaining half to build their own house. This practice was very common among many people of the middle class households. Peripheral neighborhoods which constitute to a large extent the last ring buffer tend to be populated by the more affluent households who can afford to build larger residential lots. Needless to say that in Riyadh, larger houses are an indicator of social prestige which may explain why many high and upper-middle class families would be willing to put the price to fulfill the requirements of their social status.

However, when looking at the average commercial lot sizes, the data presented in Table 2 seem to confirm the trend that has been outlined earlier in which the farther the neighborhood from the city core the larger the commercial lot size. The data indicate that this size is the lowest at the urban core with only 967.88 m^2 in average. The data also reveal a sharp increase of over 156% of the mean commercial lot size for the first and second ring buffer neighborhoods (2478.11 m^2 and 2499.87 m^2 respectively). This average lot increases even further for the peripheral neighborhoods to reach a much bigger size as high as 3440.79 m^2 (Table 2). This suggests that neighborhoods at the outer ring of the city are the most sprawling of all with larger lot sizes and lower land use intensity (Fig. 11).

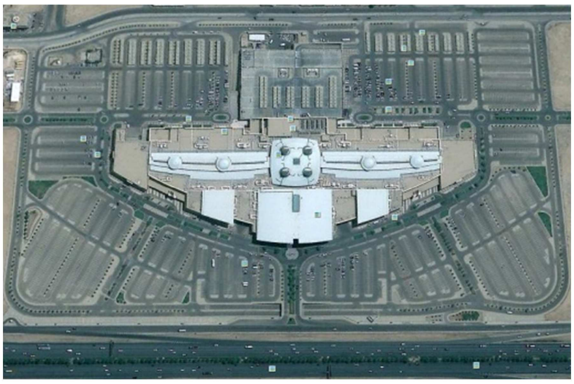

Fig. 11. Google Earth View of a big box shopping mall "Grenada Center" with 4500 parking spaces at the third ring buffer (the outer ring) is a sign of the sprawling development taking place to the north east of Riyadh.

Smaller residential and commercial lots are a proxy for higher lot density. Higher density development puts different destinations in proximity to each other and thus facilitates walking and lowers vehicular burden in the neighborhood (American Planning Association, 1998). It may also as a result, lessen associated air pollution and heighten individual and group socialization.

For a closer examination of the pattern shown in Table 2 above where the average residential lot sizes did not follow a linear straightforward increase from the core area to the fringe neighborhoods, it was necessary to control for the effects of vacant undeveloped land. Using Arcview GIS analysis tools, only developed built up lots were selected for comparisons between different study areas. The contention is that the existence of many large vacant residential lots may have distorted the expected pattern. The data presented in Table 3 below show that the average built up residential lots are remarkably of comparable values for the three successive ring buffers (766 m^2, 635.98 m^2 and 645.13 m^2 for Ring buffers 1, 2 and 3 respectively). The city core neighborhoods still maintain the lowest average built up lot size.

Table3. Actual built up residential lots

Built up Residential Areas				
	City Core	**Ring1**	**Ring2**	**Ring3**
Lots	41043	20133	78358	36087
Area	7775661.16	15421939	49833816	23280785.77
Average	189.45	766	635.98	645.13

From the above findings, it is quite clear that the examination of the crude average residential lot size values do not tell the whole story. When only built up lots were selected, the trend was totally different. The urban core area lot sizes tend to be notably more Smart Growth-oriented than those in the more recent neighborhoods as shown in the successive ring buffer areas. The sharp decrease in average residential sizes for the intermediate ring buffer may suggest that, with economic downturn, neighborhood planning in Riyadh may have taken a brake against the further intensification of sprawl-oriented developments.

Land use mix: The second category of variables is related to mixed land use patterns. Two measures are set to characterize land use mix at the neighborhood level. One is used to evaluate the diversity of land uses and the other to assess the accessibility to such uses. The contention is that homogeneous neighborhoods would be pedestrian unfriendly thus hindering accessibility. Lack of mixed land uses would also increase reliance on the private car and its associated air pollution. Smart growth planners contend that greater mixing of uses facilitates walking and enhances accessibility to shopping areas and other educational, recreational, health or public amenities. The following points are the measures implemented to capture land use mix.

- Percent of land uses within a neighborhood (proportion of mixed land use)
- Area of commercial land uses within the neighborhood
- Number of commercial lots within the neighborhood

Table 4. Proportions of land uses in the traditional core of the city and the rest of the city

Land use type	Riyadh Study Areas							
	Core		Ring1		Ring2		Ring3	
	Total area	%	Total area	%	Total area	%	Total area	%
Residential	8811049.05	41.5%	32551752.03	15.1%	64220186.67	6.2%	43578911.32	2.6%
Commercial	1874784.75	8.8%	7032870.08	3.3%	10109480.31	1.0%	7848436.86	0.5%
Vacant Land	4321530.92	20.4%	125095787.48	58.0%	901039028	87.1%	1455521783	87.2%
Industrial	18617.04	0.1%	3603662.7	1.7%	5133492.04	0.5%	13143489.81	0.8%
Governmental	1238840.75	5.8%	6455972.59	3.0%	5723165.09	0.6%	56127654.82	3.4%
health	47578.53	0.2%	2345032.91	1.1%	708833.09	0.1%	1862197.63	0.1%
Farming	604715.87	2.9%	3448636.77	1.6%	9449456.45	0.9%	4662878.12	0.3%
Educational	831348.65	3.9%	4216735.31	2.0%	5235247.96	0.5%	10513073.6	0.6%
Parks Areas	550962.52	2.6%	1494640.62	0.7%	1998390.97	0.2%	924072	0.1%
Recreational	549697.52	2.6%	3277540.64	1.5%	5321768.17	0.5%	22074189.26	1.3%
Warehousing	270201.73	1.3%	5571997.74	2.6%	9936819.94	1.0%	11241703.25	0.7%
Unknown	215597.5	1.0%	2003555.9	0.9%	6157225.39	0.6%	8651459.86	0.5%
Mosques	430881.11	2.0%	1971209	0.9%	2604074.22	0.3%	1639322.65	0.1%
infrastructure	680573.21	3.2%	16585992.52	7.7%	7385615.15	0.7%	32118047.6	1.9%
Cemeteries	766990.87	3.6%	135224.87	0.1%	805485.6	0.1%	629833.68	0.0%
Grand Total	21213370.02	100	215655386.3	100	1035022784	100	1669907220	100

- Number of lots for other uses than residential within the neighborhood
- Total areas of other uses than residential within the neighborhood

Measures of diversity

When Looking at the distribution of land uses in different neighborhoods, the data reveal that neighborhoods in the traditional core area of Riyadh show a higher proportion of residential uses than any other area of the city. The figures indicate that the city core area accounts for about 41.5% of residential use areas against only 15.1% for the first ring buffer of the study area, then 6.2% for the next buffer and lastly only 2.6% for the third ring buffer (Table 4). Higher proportions of residential uses in a neighborhood would be a proxy for higher intensity and more walkability as long as there would be higher proportions of amenity and service use areas appropriately distributed within the neighborhood. The contention is that more residents would be within the catchment areas of these services and amenities. Proximity to such amenities would lead to people being more inclined to get to day-to-day activities without relying much on the use of the private car or any other means of transportation. Propensity to walk within the neighborhood would increase even further if there are higher proportions of commercial uses. This is precisely the case for the city core where such uses occupy about 8.8%. On the other hand, the car is king in neighborhoods where such commercial uses are of relatively lower proportions. This is the case for example for the ring buffer study areas where commercial activities hold only 3.3%, 1% and 0.5% for the first, second and third ring buffers respectively (Table 4).

The examination of lot densities for different uses within the neighborhood would also reveal important discrepancies between Smart Growth and Sprawl-oriented neighborhoods. The data indicate that the residential lot density in the city core is 49.93 lots per residential hectare against only 7.24, 12.81 and 8.61 lots/ha for the ring buffers 1 through 3 respectively (Table-3).

Vacant land in a neighborhood is another measure revealing the land use intensity. These areas amount

Table 5. Frequency of various land use parcels within the four neighborhood areas of the study

Land Use	Riyadh Study Areas			
	Core	**Ring1**	**Ring2**	**Ring3**
Residential	4395	22165	82315	38069
Commercial	1937	2838	4044	2281
Vacant Land	4001	13556	131154	111459
Industrial	25	305	414	696
Governmental	128	234	263	299
health	54	107	123	70
Farming	20	148	207	254
Educational	187	537	666	405
gardens &Parks	57	153	255	56
Cultural &Recreational	109	1004	3031	5172
Warehousing	478	1842	1893	775
Unknown	302	663	4204	3607
Mosques	431	722	964	517
Services infrastructure	259	584	939	595
Cemeteries	29	6	5	5
Total	12412	44864	230477	164260

Fig. 12. Three neighborhoods showing built up areas and vacant land (in white)

up to 432.15 hectare in the city core, making about the fifth (20.4%) of the total core area. This proportion is notably higher in the three buffer rings of the study area. Well over half its total area (58%) is vacant in the first ring buffer. This proportion is even higher reaching up to 87% for each of the two remaining ring buffers (Table 4).

The other factor affecting land use intensity is the way these vacant areas are distributed within the neighborhood. The more dispersed these areas the higher the intensity. Vacant areas within the traditional city core are much like interstices or pockets dispersed throughout the core area, whereas in other parts of the city, it is more like extended surfaces at the vicinity of the built area (Fig. 12).

Table 5 highlights the frequency of various land-uses within the four neighborhood areas. Overall, the traditional core neighborhood area has a significantly higher land use mix index than other areas in the study. The area contains a broad range of activities, including industrial, recreational, commercial, institutional, and residential which makes sense because it is situated at the heart of the downtown commercial district. The third ring buffer neighborhoods however, are located on the fringe of the city. This location coupled with the relative recent time of development of the area make it an incomplete residential neighborhood lacking a full range of accompanying services and amenities.

To better interpret the assortment of land-use types in any area it is helpful to use a single measure that takes into account these various land-uses. For this purpose, a Land-Use Mix Index (LUMI) is established. It takes into consideration all land use types excluding vacant lands and residential areas. Main streets were also considered because Riyadh urban regulations require that urban services should be located along main streets whereas local streets are kept only for residential uses. The Land-Use Mix Index (LUMI) is the sum of all land uses divided by the total number of main streets. As the variety of land-uses increases so does the land-use mix index. That is the higher the LUMI value, the more assorted the distribution of land uses. Prior research has indicated that the Land-Use Mix Index (LUMI) is a valid and reliable measure of land use mixture (Song and Knaap, 2004).

As a high index means there is a diversity of land-uses, it is a proxy of walkability and of the area's attractiveness to pedestrians. Higher proportion of vacant land however, reduces walkability as it lowers the number of destinations per unit area.

The results indicate that the LUMI is significantly higher at the traditional core (63.75) compared to the other areas in the survey (Table 6). The first two ring buffers have the respective following scores (12.16 and 24.37), while the third ring exhibits relatively more land-uses per segment than all other two ring areas of the city as revealed by a LUMI of 31.68.

Table 6. The Land-Use Mix Index (LUMI) for different study areas in Riyadh

Areas	LUMI
Core	63.75
Ring1	12.16
Ring2	24.37
Ring3	31.68

The data presented in Table 7 below show that the person's share in residential uses is the lowest in the urban core area with only 12.90 m^2 per person. This share increases by about 77% (22.84 m^2/person) for the next ring buffer area. It rises sharply once again by 108.5% (47.64 m^2/person) for the second buffer to reach its peak at the third ring buffer of the study area with the highest share of all (59.23 m^2/person). This suggests that Riyadh citizens are likely to use excessive residential space if they choose to live in a neighborhood at the outskirts of the city. On the contrary, they are less likely to consume a lot of residential space if they happen to live in the inner city neighborhoods.

Another way of capturing the sprawling characteristics of neighborhoods is to examine the share of the automobile in terms of road space. Here again, a sizable proportion of the neighborhood area is in use for roads. The data show that the share of the car in the core area for example, as measured by road space per car, is about 47.28 m^2. This share jumps to a staggering percentage of 293% (185.81 m^2 per car) in the next ring buffer. It also goes crescendo for the two remaining ring buffers as it amounts to 485.4 m^2 per car for the second buffer to hit finally the highest point at the third ring buffer with 732.05 m^2 per car, which is about fifteen times what it was in the inner city area (Table 7).

Table 7. Averages shares of residential area per person and road area per car

Indicators	Riyadh study areas			
	City Core	Ring1	Ring2	Ring3
Residential area per Person (m^2/Pers)	12.90	22.84	47.64	59.23
Road area per Car (m^2/Car)	47.28	185.81	485.41	732.05

In other words, the share of the car in terms of road space exceeds the average household dwelling unit in the peripheral neighborhoods of Riyadh (732.05 m^2 vs. 645.13 m^2). This indicates that these areas privilege more automobile use and therefore tend to be "pedestrian unfriendly". In fact, it is unlikely to see people walking in the street in these areas. In the old city however, the car share hardly gets the fourth of the average household dwelling unit (47.28 m^2 vs. 189.45 m^2). The city core area is therefore, a much more pedestrian friendly environment.

Proportion of uses other than residential (neighborhood services)

To examine the proportion of uses other than residential, their proportions were summed up and renamed as neighborhood services. Such service uses include commercial, industrial, governmental, health, educational, green areas and parks, cultural and recreational and religious uses. The data show a very sizable proportion of such neighborhood service uses in the city core amounting up to 26.1%. This proportion however decreases sharply for the next ring buffer to about 14.1%. The following ring buffers show only very tiny proportions for neighborhood uses other than residential (3.6% and 6.8% respectively). However, when comparing these proportions with residential uses, the results were striking. The first ring buffer shows nearly comparable areas of residential and service uses

Table 8. Number of lots for commercial and other service uses in different parts of the city

Indicators	Riyadh Study Areas			
	Core	**Ring1**	**Ring2**	**Ring3**
No Commercial lots	1937	2838	4044	2281
commercial area (m^2)	1874785	7032870	10109480	7848437
No all service lots	4256	10873	17107	16122
All service area (m^2)	8061758.89	57936754.7	65087468.6	178294424
Residential lots	4395	22165	82315	38069
residential areas (m^2)	8811049	32551752	64220187	43578911
residential/commercial lots	2.27	7.81	20.35	16.69
residential/commercial area	4.70	4.63	6.35	5.55
residential/total service lots	1.03	2.04	4.81	2.36
residential/total service area	1.09	0.56	0.99	0.24

(15.1% vs. 14.1%). This ratio is about 2 to 1 for the second ring buffer (6.2% vs. 3.6%) whereas for the last buffer, services areas prevail over residential spaces (6.8% vs. 2.6%). This finding should not conceal the fact that these ring buffers are not fully built up yet. The last two ring buffers still contain about 87% of vacant land reserved essentially for residential uses. This suggests that once developed, their neighborhoods would regain their mainly residential character. Such service use proportions are not enough to indicate any diversity of uses in neighborhoods of the three ring buffers.

With regard to the traditional core neighborhoods, the relatively higher proportions of service uses can be explained by the fact that this area is nearly fully developed and mature. It is therefore, expected that the services and commercial activities in particular would be concentrated in the city center as any other central area in any city.

Number of commercial lots

To capture the extent to which the land uses are diversified within the neighborhoods in different areas of Riyadh, one can look at the number of commercial lots and their cumulative areas to compare them with their residential counterparts. Table 8 above shows the proportion of residential to commercial lots is about 2.27 in the traditional urban core area of Riyadh. This proportion is much higher for the remaining areas of the city. It attains 7.81 for the first ring buffer. It then amounts up to 20.35 for the second ring buffer and 16.69 for the third. This indicates that the city core area is more diverse in terms of land uses and therefore more “Smart Growth” planning-oriented than the other ring buffer areas. Areas of the second and third ring buffers are the least diverse in uses as they show the highest proportion of residential to commercial lots (20.35 & 16.69). This suggests that they are the most sprawl-oriented areas of Riyadh. But when comparing the proportions of total residential areas to commercial ones, the difference was very low indeed.

The four study areas show some comparable proportions ranging from 4.63 to 6.35 (Table 8). This indicates that commercial lots tend to have far larger sizes than residential ones. It also suggests that the city center ranks better towards the smart growth or new urbanism end, than the rest of the city on the continuum ranging from sprawling to smart growth neighborhoods along the dimension of diversity of land use mix.

Lots for other uses other than residential

When taking into account the number of lots for all other uses and services other than residential within different parts of the city, the differences shrunk dramatically. The proportion of residential to services uses in the urban core area was about 1.03 for lots and only 1.09 for areas. The first ring buffer shows only slightly higher proportions with 2.04 for lots and 0.56 for areas. The proportion of residential areas to all other uses is a lot higher for the second ring buffer (4.81), whereas it is quite half that figure for the third ring buffer (2.36). The proportion of residential to services areas is even higher for the second ring buffer (0.99 vs. 0.24) (Table 8).

Average lot size

When examining the average lot area in different study areas of the city, it appears that the ratio is 1.69 to 4.83 in favor for commercial lots. When comparing these averages between areas, the average

Table 9. Average lot size for different land uses in different study areas of Riyadh

Land Uses	Riyadh Study Areas			
	Core	Ring1	Ring2	Ring3
Average Commercial lot area	967.88	2478.11	2499.87	3440.79
Average Residential lot area	200.27	1468.61	780.18	1144.73
Commercial/residential	4.83	1.69	3.20	3.01

commercial lot in the first and second ring buffers is about two and half times higher than what it is in the urban core area of Riyadh (2478.11m^{2}and 2499.87m^2 vs. 967.88 m^2 see Table 9). The average size of the third ring buffer commercial lots are slightly over three and half times larger than their counterparts of the core area in the inner city. This indicates that a big box phenomenon is likely to appear in this part of the city as a result of its larger commercial lot areas. In fact many hypermarkets are being built over these areas (Fig. 13).

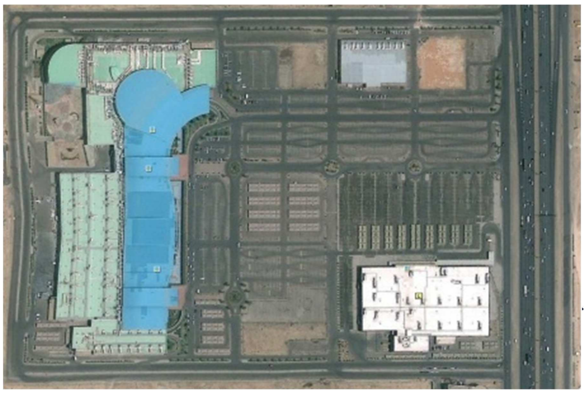

Fig. 13. Google earth view of Rimal Center and IKEA hypermarkets on the east Ring Road between Exits 16&17 indicating the emergence of a big box phenomenon leading to more sprawling development on the fringe neighborhoods of the city.

and external connectivity measures as indicated by main streets depicting route options between neighborhoods. Both types of connectivity are therefore captured by the whole street network as portrayed by both street types, local and main streets together.

As far as the internal connectivity is concerned, it is measured by total local and minor street length per hectare. This assessment is undertaken under the contention that the higher the street length the greater the internal connectivity of a neighborhood and the better its walkability. It goes without saying that these features of street connectivity are of paramount importance to "Smart Growth" neighborhood design.

The other factor of street network design is related to external connectivity which is measured by major street extent within the neighborhood as indicated by the length of highways, arterials and collector roads in meters per hectare. The existence of more major streets is hypothesized to increase automobile traffic and travel speed which by the same token hinders pedestrian movement. Therefore, if more major roads tend to improve neighborhood connectivity with its adjacent bordering areas, they would also lead to poorer walkability outcomes within the neighborhood as they hamper pedestrian street crossings and discourage walking along main street sidewalks.

The whole neighborhood street network interconnectedness is thus measured by total street density (number of all major and minor streets per hectare). The contention is that the higher this street density the greater the street interconnectedness of a neighborhood and the better its walkability.

In fact, in designing road networks with the primary goal of increasing automobile efficiency, urban planners of modern sprawling neighborhoods have shifted their attention to the development of more arterial and collector roads. This approach to design efficiency for automobile transportation has had the opposite effect on pedestrian access and walkability. Pedestrians often have to take out-of-the-way, circuitous routes because direct pedestrian walkways are truncated by major roads. Hence, many modern suburban sprawling neighborhoods tend to limit pedestrian access in exchange for increased automobility (Cervero, 1997; Crane, 1998). Major roads are intended to carry more traffic at higher speeds than neighborhood streets, which leads to a more dangerous walking environment for residents. As a result, the longer the major streets are in an area the poorer its walkability.

Street network connectivity depends also to a large extent on block attributes. It is argued that smaller blocks offer greater connectivity as they present a multiplicity of route configurations which

Table 10. Centerline street length per hectare in different study areas Riyadh

Riyadh Areas	Interconnectedness: Street Network Density Measures			
	Main Street Length (m)	Minor Street Length (m)	Total Street Length (m)	Centerline Street Length /ha
Core	78643.17	798319.1	876962.27	284.09
Ring1	1411686.46	4437188.5	5848874.9	171.21
Ring2	1761206.03	7606339.3	9367545.3	77.43
Ring3	1301953.02	6532526.2	7834479.2	20.63

encourages walking by providing a more interesting pedestrian environment (Jacobs, 1961). As such, many studies have included one or more measures related to block characteristics to evaluate the street network patterns at the neighborhood level. The claim is that street network characteristics are affected by block attributes such as average block perimeter, average block size, and the percentage of “small” blocks (smaller than 2.5 hectare) (Ewing, Pendall and Chen, 2003; Song, 2005).

Other scholars have used in their assessment the concept of route directness to describe the nature of a street network (Hess, 1997; Lee and Ahn, 2003). Route directness is a comparison between “network” or road distance and “as the crow flies” distance. The contention is that the ratio of network distance to direct distance would be much higher in areas with major streets and much lower in areas with a grid-based, small block street network.

Still other researchers have used intersection density which is the number of intersections per given area, as an indicator of street connectivity (Owens, 1993; Southworth, 1997). Intersections are a neighborhood-level measure of walkability that proxy for the variety of route choices available to pedestrians within a given area.

In sum, the measures of street connectivity would therefore include the following variables:

- Street length and Major street length per hectare
- Street network density: centerline distance of streets per hectare
- Street length per capita: total street centerline distance divided by total residents
- Street length per car: total street centerline distance divided by total number of cars within the neighborhood
- Average block perimeter within the neighborhood
- Average block size within the neighborhood
- Block density
- Percent of small blocks (Block size smaller or equal to 2.5 ha)
- Directness: ratio of distance between two points along road network and straight line distance. street network and “as the crow flies” distance Ratio
- Intersection density: number of intersections per hectare

Calculations of major and minor street lengths, block areas and perimeters together with street network and “as the crow flies” distances, and the number of intersections were computed using ArcMap data analysis tools.

Street connectivity measures:

One way of looking at street network connectivity is by examining the linear centerline street length per hectare. The contention is that the longer the linear centerline street per hectare the more sprawl-oriented the neighborhood. The data provided in Table 10 below show that the traditional core area has the longest street length per hectare (284.09 m/ha). This indicates that the planning pattern of this area is more smart growth-oriented. However, as one moves away from the core, linear street distance per area unit decreases which means that the neighborhood development pattern shies away from new urbanist principles to embrace a more sprawl-oriented pattern of development. The results in table 10 seem to corroborate this trend as it reveals 171.21 m/ha, 77.43 m/ha and 20.63 m/ha for the first, second and third ring buffers respectively. This means that a remarkable decrease by 92.7% from the core area (the smart growth-oriented neighborhood) to the peripheral ring buffer (the more sprawl-oriented pattern of neighborhood development).

Street length per capita

When examining street length per capita and street length per car, the results confirm the above findings outlined in the previous paragraph dealing

Table 11. Street density and street length share per car and per capita

Riyadh Areas	Street Count	Street Density	Total Length	St-Length/ha	Street/Car	Street/capita
City Core	18799	6.09/ha	798319.1	258.61	3.9	1.3
Ring1	54628	1.60/ha	3323707.1	165.95	13.7	4.1
Ring2	79763	0.66/ha	2672671.6	35.88	24.6	6.9
Ring3	58699	0.15/ha	4219029.2	36.06	32.2	10.6

Table 12. Interconnectedness: Block Density Measures

Riyadh Study Areas	Interconnectedness: Block Density Measures			
	Average Block Area (m2)	Average Block Perimeter (m)	Block Density/ha	Block Count
Core	4001.09	245.12	1.72	5303
Ring1	15533.87	444.44	0.49	16804
Ring2	64060.56	780.64	0.12	14843
Ring3	220501.1	827.97	0.05	21454

with centerline street length per hectare. Here again the share of the car as well as the share per person have the lowest value in the city core with 3.9 m per car and 1.3 m per capita, whereas the fringe neighborhoods in the last ring buffer indicate a value of 32.2 m/car and 10.6 m/capita, the highest of all. The intermediate ring buffers reveal an average street length per car of 13.7 and 24.6 m and an average street length per capita of 4.1 and 6.9 m for the first and second ring buffers respectively (Table 11).

Block size and block perimeter measures

To measure these variables, the study computed block perimeters and block areas for Riyadh neighborhoods in the four study areas of the city. The argument is that sprawling neighborhoods are pedestrian unfriendly environments with longer blocks, whereas smart growth neighborhoods are pedestrian friendly with relatively shorter blocks.

The results reveal that the traditional core area of the city has by far the smallest blocks with an average block perimeter of 245.12 m and an average size of only 4001.09 m2 (Table 12). This average block perimeter has increased by about 81.3% for the first ring buffer compared to what it was in the core area (245.12 vs. 444.44). This average block perimeter goes crescendo to amount up to 780.64 m (75.6% increase) for the second ring buffer, and lastly up to 827.97 m for the third buffer with only a 6% change to what it was previously (780.64 m vs. 827.97 m).

When looking at block sizes, the figures presented in Table 12 below tend to confirm the trend revealed with block perimeters. The traditional core area has the lowest average block size in the city (4001.09 m^2). It then increases by about 288% for the first ring buffer compared to what it was in the core area (4001.09 m^2 vs. 15533.87 m^2). These block sizes get even higher as one moves away towards the fringe of the city core to reach up to 64060.56 (312.39% increase) for the second buffer. It also rises up to 220501.1 m^2 (244.2% change) for the last ring buffer containing the peripheral neighborhoods (Table 12).

When examining block density of neighborhoods, here again the traditional core area was singled out as having the highest density with 1.72 blocks per hectare. The block density decreases gradually from the inner city to the suburban areas. The first ring buffer has a density of 0.49 blocks per unit area. It then goes down to 0.12 for the next ring buffer and finally the lowest average density of all with only 0.05 blocks per hectare for neighborhoods constituting the last ring buffer at the outskirts of the city (Table 12 below). Smaller block sizes are equated with higher accessibility.

Destinations or points of interest

Another factor affecting walkability and accessibility within the neighborhood includes characteristics of destinations. In particular, the number of destinations or points of interests (POI).

Spatial data identifying the locations of the above-mentioned amenities were taken from ADA 2005 Riyadh Digital Map in a layer called Points of Interest (POI). A broad array of facilities is mapped in this product, from grocery stores to residential hotels and mosques. These features appear as points in a GIS database, and can be overlaid on a street network map for the purpose of calculating distances, and optimal routes.

ArcMap 9.3 geographic information system (GIS) software was used to analyze geo-spatial distributions of Points of Interest (POI) along the street network. Extracting any service use or amenity of a particular type is simply a matter of querying the “points of interests” (POI) spatial database to find their appropriate positions within the street network.

The data provided in Table 13 indicate the density of destinations or Point of Interests (POI) in the urban core is much higher than any other part of the city indicating that this area is much more pedestrian friendly. That is the resident of the urban core is more likely to encounter more services and destinations while roaming around in his neighborhood area.

Table 13. Major destinations or Point of Interests (POI) in different study areas

Riyadh Areas	Points of Interest	
	Points of Interest	Points of interest/ha
Core	736	0.24
Ring1	2473	0.07
Ring2	1764	0.01
Ring3	1706	0.00

Measures of accessibility:

One of the fundamental principles of the “Smart Growth” or New Urbanist design philosophy is that neighborhoods should have a mixture of uses in order to facilitate social interaction, reduce automobile use, and create a sense of place. These are things commonly thought to be absent in single use conventional developments. Not only should mixed uses be present, they must also be easily accessible and placed so that the maximum number of residents can benefit from them. Therefore, it is necessary to go beyond simply evaluating neighborhoods for the number of mixed uses to test their accessibility as well. One method of doing so is by looking at the service areas of local amenities, a measure of how many households are within a given distance.

Most of the programming required to calculate service area of an amenity is built into ArcView and its extensions. One of the useful tools provided as part of these extensions is the “calculate service area” option. The procedure consists of specifying a spatial data layer containing an amenity (e.g. schools) as well as a “cost” unit (distance or time). ArcGis can then compute the number of household units within the service area of the facility using these parameters.

The five indicators to measure pedestrian accessibility are commercial establishments, primary governmental schools for both male and female, local mosques, neighborhood parks and primary health care establishments. For each study area, the numbers of household units covered by the amenity service area were calculated for the five amenity indicators using distance as the “cost” field. A threshold for each amenity service area was set at about half kilometer distance “as the crow flies” (approximately 5 minutes walk), except for local neighborhood mosques for which the catchment area is defined by only 275 meters radius. These threshold distances are adopted in this study as they are required by Riyadh Municipality urban regulation standards for approval of any neighborhood residential subdivision plan. Commercial establishments include day-to-day businesses like grocery stores, retail shops, restaurants and the like. The five minutes’ walk which is approximately half kilometer, is a distance that is commonly used to define “walking distance” in residential neighborhood research (e.g. Bartlett, 2003; Lee and Ahn, 2003; Lund, 2003; Randall and Baetz, 2001).

Measures implemented*:* percentage of dwellings within five minutes walk (about half kilometer) of each of the four types of amenity except for local neighborhood mosques where the threshold is set for only 275 meters. The hypothesis is that the greater the percentage, the greater the pedestrian accessibility in the neighborhood.

Analysis of the Results

When looking at the data provided in Table 14 below, it is clearly shown that the percentages of households within the thresholds set for walking distance service areas is markedly higher in the traditional core area for the five amenities mentioned above. The data reveal well above 90% of the households in the core area are enjoying a full amenity coverage for primary educational services (94.7%), local neighborhood mosques (99.67%) and commercial establishments such as grocery stores, eating places, and other day-to-day businesses (93.6%). Such proportion decreases sharply when

Table 14. Percentage of households within walking distance of the five amenities

Ring۳	Ring۲	Ring1	Urban Core	Amenity
66.39%	53.55%	51.8%	94.7%	educational establishments
52.96%	49.74%	37.77%	93.6%	Commercial establishments
81.55%	80.45%	73.59%	99.67%	Worship establishments
4.5%	6.47%	11.64%	36.48%	Primary Health care
2.07%	31.51%	29.48%	53.69%	Neighborhood Parks

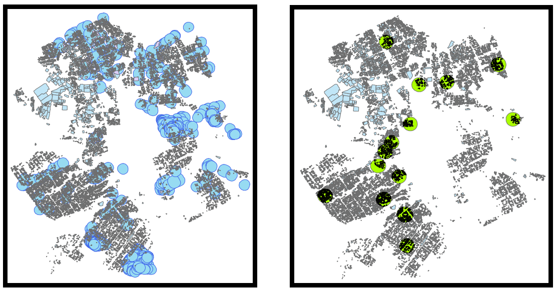

Fig 15. Buffers of households within walking distance of commercial establishments and primary health care services in the first ring buffer area.

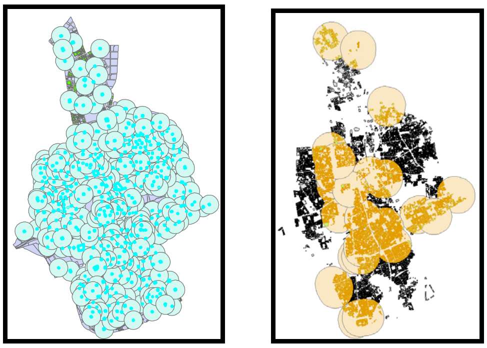

Fig 14. Buffers of household within walking distance of local neighborhood mosques, neighborhood parks within the traditional urban core area.

looking at service area coverage for households living in the remaining ring buffer areas. Only 51.8% of households in the first ring buffer tend to be within a walking distance from elementary schools. With regard to commercial establishments, the majority of households cannot get to within 7 minutes walk, as only a proportion of 37.77% of them are within the catchment area of these commercial services as defined by the 550 meters threshold.

When examining primary health care and neighborhood parks service area coverage, the data show that even households living in the core area of Riyadh tend to be disadvantaged since only a tiny percentage (36.48% and 53.69%) of households are within the 5 minutes walk threshold of primary health care establishments and local neighborhood parks respectively. Such percentages are much lower for households in the remaining ring buffer areas. The data for the third ring buffer for example, indicate only some elfin percentages of 4.5% and 2.07% of households covered by these health and recreational services.

There is little to differentiate the three buffer areas when comparing households served by various amenities in the ring buffers 1, 2 & 3, as shown in Table 14. There are minimal differences for three amenities (primary education, commercial establishments and places of worship as indicated by local neighborhood mosques). The only notable differences are the percentage of households within walking distance of local public neighborhood parks and primary health care services. The trend seems to indicate that the peripheral neighborhoods tend to show lower proportions of households covered by recreational services as measured by neighborhood parks, and primary health care services. The figures in Table 14 indicate that only 4.5% of household are within walking distance from primary health care services, and only a small percentage of household (2%) are within 5 minutes walk from neighborhood parks.

About twenty-five percent (24.84%) more households in the traditional core are within walking distance of health care services than in the first ring buffer area (36.84% vs. 11.64%). On the other hand, 24.21% more households in the traditional core are within walking distance of local neighborhood parks (53.69% vs. 29.48%). Overall, for all of the five amenities examined, the city core has a higher percentage of households within walking distance. In the light of these figures, it is clear that neighborhoods subdivision patterns of the traditional core area show far greater pedestrian accessibility than their counterparts in the more recent neighborhoods with modern conventional design patterns.

Concluding Remarks

The present study has covered several aspects and attributes of ‘residential neighborhood form’ in Riyadh. A number of quantifiable spatial characteristics, such as density, land use mix and street network connectivity were measured. The study’s attempt to quantify patterns of neighborhood form focused on the comparative characterization of Riyadh neighborhoods relative to central core neighborhoods.

In an attempt to identify who sprawls the most, growth in urban populations was compared with growth in urbanized areas. The results indicate that the spatial extent of sprawling neighborhoods tends to outpace the increase in resident population.

Riyadh city is growing in absolute size and population influx from many parts of the country is still being drained to the city. These trends have been catalyzed by a concurrent drop in average household sizes (from 7.2 to 5.2 in peripheral neighborhoods (ADA 2005)) and increase in the number of housing units. Urban growth has to go somewhere. To accommodate such growth, the city of Riyadh seems to have opted for sprawling neighborhood development.

Increasing density is a goal of Riyadh’s recent development policy, yet for all the density measures calculated in this research (population and dwelling density; average lot size, etc.), the central city core has performed far better than any other area in the city. The results also show that neighborhoods in the fringe of the city tend to show lower land use intensity than those of the central city core they surround. When the density of development is examined, the data show that urban population densities have fallen in neighborhoods in the peripheral ring buffer neighborhoods of Riyadh more than any other area of the city. The inner city neighborhoods tend to have the highest density development of all and hence greater land use intensity.

Because of the incomplete state of development in recent neighborhoods in different study areas, the most reliable of the measures is average lot size. The data show a substantial increase in average lot size (4 to 7 times) from the city core to the successive ring buffers surrounding it. One of the most obvious causes for this jump is economic boom coupled with social prestige.

These findings generally support “Smart Growth” claims that compact, pedestrian-friendly environments generate shorter automobile trips, more frequent non-motorized trips, and increased transit use.

Land use findings

The call for a mixture of uses in residential areas as part of the “Smart Growth” approach to Riyadh development departs most significantly from the ravages of conventional suburban development practices. Yet for almost all measures related to land use mix, recent neighborhood development in Riyadh fares worse than development in the inner city. For many of these measures, neighborhoods in the city core perform better than contemporary neighborhood development in the ring buffer areas around it.

A street network with high connectivity will not only contribute to the vitality of a community, it will also reduce dependence on automobiles. To that end, New “Smart Growth” advocates call for mixed use communities that include all necessary amenities to provide for people’s daily needs such as grocery stores, mosques, coffee shops, schools, places of employment, parks, and day care, etc. Neighborhoods should be designed so that residents are within walking distance of such day-to-day amenities. etc.

From the findings presented above, one would safely infer that the traditional core area would be more diverse in terms of the job structure provided in the area. Such employment diversity is another important dimension for smart growth neighborhoods. Other parts of the city are lacking such diversity which would make their sprawling character much more pronounced.

Street connectivity is one example of measures commonly used to assess “Smart Growth” neighborhoods. The issues of street network design and pedestrian travel options have always been a central point of contention among the advocates of “Smart Growth” Movement. In particular, neighborhood street patterns have been a consistent topic of study in terms of neighborhood walkability. “Smart Growth” urban designers argue that walking will increase in neighborhoods designed with more pedestrian friendly streets, such as connected sidewalk street layouts, increased mixed-use development, and high density commercial and residential development along the street network.

Measures of diversity

When examining the land use distribution, the data show that residential uses in Riyadh neighborhoods tend to dominate by far all other urban uses. However, when comparing the city core with the three ring buffers of the city, the differences were striking. Based on these findings, one may safely infer that land use diversity and intensity is much higher in the traditional city core than in any other area of Riyadh.

One important thing that should be mentioned here is the fact that Riyadh has mainly adopted a use-based zoning for its residential neighborhood regulations. The traditional city core however is an exception to such a pattern. Its regulations are much in line with the principles of Form-based codes. Such codes insist more on urban form and street walkability, whereas the use-based zoning regulations focus more on uses, building setbacks and car movement. It is thus recommended for Riyadh "Smart Growth" neighborhoods to adopt a new set of urban regulations in line with the form-based codes approach instead of the use-based zoning currently in use.

Walkability

Walkability measures are a good indicator of residential neighborhood type. Smart Growth neighborhood developments tend to favor more pedestrian movement, whereas suburban developments tend to rely more on the private car. The findings outlined so far tend to suggest that people living in more compact mixed-use and pedestrian oriented neighborhoods have on average a higher share of walking than those living in a typical suburban neighborhood.

It is therefore recommended that in designing "Smart Growth" Neighborhoods a whole set of variables must be considered to create pedestrian friendly residential environments. This set of variables can be composed of density measures (gross and net population and residential density, commercial and service lots per unit area, land use mix, etc.).

Block and street density is another important indicator of neighborhood walkability. This measure can provide a glimpse of the extent of the pedestrian pathways. Theoretically, areas with higher blocks and streets densities lead to more intersections, offer more destinations within walking distance of home, and make the street network more amenable to pedestrians. The appropriate density for "Smart Growth" neighborhoods should be within a range of 1.5 to 2.0 blocks per hectare. The block dimensions should range between 35 to 60 m in depth by 150 to 220 m length. Such block dimensions are likely to render the neighborhood more walkable as shown in central core neighborhoods. Larger blocks however, are an indicator of 'poor' walkability.

Areas with more major streets tend to provide less pedestrian access than neighborhoods with more minor or local streets, and therefore can be an indicator of 'poor' walkability. Relatively smaller blocks are an indication of 'good' walkability within the neighborhood. The required street density for Smart Growth walkable neighborhoods should be within the range of 150 to 280 m per hectare as demonstrated in the above findings.

Neighborhoods with higher centerline major street length and lower block density tend to privilege automobile use and therefore are "pedestrian unfriendly". Similarly, areas with homogeneous land use type would indicate automobile dominant/pedestrian unfriendly areas.

These results suggest that on a neighborhood level, centrally located neighborhoods are more walkable than those located on the city fringes because residents have more direct, and therefore shorter, routes to shopping areas and other service destinations. However, these findings do not indicate the quality of the walking experience. Moreover, neighborhoods with high street and intersection densities may actually increase the chances of pedestrian/vehicle collisions because residents cross more streets on their way to destinations.

The above findings are policy-relevant in the sense that policymakers can use to inform zoning and subdivision regulations to control density, street network connectivity, land use diversity and intensity as well as the location of schools and businesses, and all other services and amenities.

Today's sprawl could turn into compact and sustainable development in later years as the pace of urban extension drives developers to fill-in previously undeveloped sites. In fact, Riyadh contains large tracts of undeveloped land either within developed areas or at its vicinity. This constitutes an opportunity for city planners to curb the sprawling tendency of development in favor for more "Smart Growth" approaches to neighborhood planning and design.

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نحو مقاربة لتخطيط الأحياء السكنية بمدينة الرياض وفقا لمبادئ "التطوير الذكي"

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ملخص البحث. يقدم البحث تحليلا لتصاميم ومخططات الأحياء السكنية بمدينة الرياض معتمدا في ذلك على معطيات المسح الميداني للأحياء والمساكن الذي أجرته الهيئة العليا لتطوير مدينة الرياض عام ٢٠٠٥. تستهل الورقة بمناقشة المبادئ التخطيطية المعتمدة على مقاربات التمدد والتوسع العمراني في تطوير الأحياء السكنية ومقارنتها بنظيراتها من الأحياء التي تبنت مفاهيم تطوير المجاورة التقليدية الحديثة في تقسيمات الأراضي السكنية أو ما يصطلح على تسميته بالتطوير الذكي. لهذا الغرض عمدت الدراسة في منهجيتها إلى تقسيم مدينة الرياض لأربعة مناطق دراسية بهدف المقارنة بين مختلف أساليب التطوير والتخطيط. هذه المناطق هي مركز المدينة حيث الأحياء ذات الأسلوب التقليدي في التصميم ثم تليها ثلاث مناطق دراسية عبارة عن أحزمة حلقية محيطة بالمنطقة المركزية عند كل ٥ كم. تشمل الأولى الأحياء المطورة بعيد فترة الطفرة الأولى في سنوات السبعينات لتختم بالحلقة الأخيرة في الضواحي القائمة حاليا.

تنطلق الدراسة من فرضية مفادها أنه كلما ابتعدنا عن المنطقة التقليدية بالمركز كلما كان التوجه في تطوير الأحياء متبنيا لمبادئ التمدد والتوسع العمراني sprawl-oriented neighborhoods حيث مساحات قطع الأراضي الكبيرة والشوارع العريضة. للتحقق من هكذا فرضية تم إنشاء سلسلة تجريدية Urban continuum لمجموعة أحياء تمتد من الأحياء ذات أسلوب التطوير الذكي smart growth لتنتهي عند أحياء ذات مبدأ التمدد العمراني في تطويرها sprawl-oriented في الطرف المقابل وبينهما باقي الأحياء التي تجمع ما بين خصائص الطرفين. بعدها تمت عملية دراسة وفحص الأحياء بناء على جملة من الخصائص التصميمية من حيث كثافة استعمالات الأراضي وتمازج الاستخدامات وتنوعها، وتحفيز حركة المشاة وأنماط شبكة الشوارع.

تشير النتائج إلى أن الرياض لا يمكنها أن تستمر في النهج الحالي للتطوير إن هي أرادت أن تعير اهتماما لمبادئ الاستدامة والحفاظ على البيئة. وعليه فإنه ممن الضرورة بمكان تبني أساليب جديدة مستلهمة من حركة العمران الجديد والتطوير الذكي في تطوير أحيائها بشكل يحد من هدر الموارد كما كان ذلك ديدنها خلال عقود خلت حسب ما تدل عليه أحياؤها ذات الأسلوب التقليدي في تخطيطها وتصميمها.