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ACCESSIBILITY OF SPATIAL NETWORKS:

Using ArcGIS Network Analyst and Space Syntax to Investigate Accessibility to Urban Facilities

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ABSTRACT

Accessibility is a critical objective in the field of planning, particularly for urban facilities such as education and health services. Among many models and techniques that calculate accessibility, this study focuses on network analyst tool of ArcGIS and space syntax methodology. In the network analysis of ArcGIS, it is possible to calculate service areas for individual urban facilities within given distance/time limits. Space syntax measures on the other hand, help to understand the overall accessibility dynamics of the network. This study aims to associate space syntax based accessibility evaluation and service area measures of ArcGIS in the city of Mersin, Turkey.

Mersin is one of the most populated cities of Turkey with more than 1.5 million people. It has a sloping topography which has affected the development of both the road structure and the settlement structure of the city. Apart from the urban centre, there are villages with rural character in mountainous parts of the city that do not have proper access to most urban facilities. Health and education services are of vital importance and access to these facilities is a must for both urban and rural settlements. Therefore, accessibility of these particular facilities within the Mersin Municipal Area is the main focus of this study.

In 2015, the Greater Municipality of Mersin initiated the preparation of an urban development plan for Mersin. Urban development plans usually consider accessibility as a means to organize general transportation flows but not as a network issue that would affect individual accessibility of facilities. Therefore, it is important to understand the direction of development in cities before planning them. In order to comprehend development trends and needs of urban facilities, two types of accessibility analyses were carried out in Mersin. Firstly, health and education facilities were assessed using network analysis toolset of ArcGIS, separately for hospitals, school of medicine and small scale health facilities for health services; elementary schools, middle schools and high schools for education services. Secondly, segment based space syntax analysis was executed, in which integration measures were inspected.

Comparison and integrated evaluation of results of these two types of analyses are believed to serve to an improved comprehension of the morphological spirit of Mersin. Further analyses on such issues would play a crucial role in planning.

KEYWORDS

Space syntax, network accessibility, polycentric development, Mersin

1. INTRODUCTION

Accessibility to facilities, particularly regarding access time, is one of the critical indicators of quality of life, although alone it would not be adequate to ensure a high quality of life (Cooper & Roadman, 1994; Doi, Kii, & Nakanishi, 2008; Hewko, Smoyer-Tomic, & Hodgson, 2002).

Urban social facilities can be listed as health, educational, socio-cultural, administrative, religious, recreational, and sports facilities. Doi et al. (2008) refers to disadvantages of certain social groups such as children, elderly people and the disabled, in terms of scope of mobility. In planning, it is generally assumed that all social groups have equally high mobility (Doi et al., 2008). Accessibility of these groups to urban facilities must not be equated with other groups and should be considered separately. Among urban facilities, health and education services widely address children, teenagers and people in need of health care, which places them in disadvantaged groups. Therefore, accessibility of these facilities in certain time constraints is more fundamental.

Overall accessibility schema of a city depends highly on the operation of road networks (Liu & Yu, 2012). Space syntax is a method that analyses geometries of urban networks and provides mathematical explanations to evaluate accessibility (Hillier & Hanson, 1984). Traffic jam and urban sprawl are regarded as the most critical results of road networks, which are the common problems of large cities. To cure these problems, urban structure needs to be understood better (Roth, Kang, Batty, & Barthélemy, 2011).

Theories of urban structure, which are developed in order to understand and explain development trends of cities independent of planning, suggest three main theories (Keleş, 2010).

Concentric growth theory proposes that cities develop in concentric rings that are land-use zones. The centre is not only geometrically but also functionally the heart of the city with commercial and business functions. Series of concentric circles are defined as central business, transition zone, working class residents, middle and higher income residents, suburban zone. This theory is criticized for it underestimates the complex structure of cities (Keleş, 2010). Complex spatial structures of modern cities are far from their historical concentric characters (Roth et al., 2011).

Sector theory depends on the thought that land-use zones are separated from city centre through peripheries like "slices". Geometric centre is again occupied with business and commerce and residential areas are zoned according to different social classes. Main criticism about this theory is the way social classes are simplified. Besides, dynamics and localized systems of the 21st century are ignored (Keleş, 2010).

Polycentric growth theory claims that urban growth follows a multiple nuclei model. Size of the city affects the number of centres (Keleş, 2010). Common structure in industrial cities is the "monocentric" urban model, but modern cities are more complicated and they have a tendency to develop as polycentric (Legras & Cavailhes, 2016; Roth et al., 2011).

Polycentric urban development is a topic mainly in the field of geography and economics (Arribas-Bel & Sanz-Gracia, 2014; Burger, van der Knaap, & Wall, 2013; Yue, Liu, & Fan, 2010). One of the most effective qualities of this type of urban structure is that economic activity clusters in several centres. Although this type of polycentric structure is more than 100 years old, the term hasn't been quantitatively defined, yet (Roth et al., 2011).

In a monocentric structure, on the other hand, all economic activity and development pressure is concentrated on a single centre. In fact, agglomeration of activities in the CBD reduces costs of communication, access to information and access to material (Sasaki, 1990). However, overconcentration of economic activities on specific geographies and underutilisation of resources in other geographies creates an uneven development (Burger et al., 2013). Besides, a study that evaluates communication and commercial costs confirms that polycentric agglomeration performs better than monocentric city, under specific circumstances (Legras & Cavailhes, 2016).

In order to relieve the development pressure from city centres, business decentralization happens as a natural and mostly unplanned process. Low prices and possibility for larger parcels in the urban periphery attracts firms, leading to decentralization of businesses and triggering a development that is no longer monocentric (Sasaki, 1990). According to Yue (2010) decentralization is the main reason that evoked polycentric urban spatial structure. In the same way, Burgess et al. (2013) suggests that the reason behind polycentric growth policies was to ensure the balanced distribution of economic activities (Burger et al., 2013).

Different levels of commercial and industrial activity that can be observed in different parts of the city generate the hierarchy of urban structure, which indicates a polycentric model (Roth et al., 2011). This uncontrolled decentralization process is very similar to principles of the new economic geography that insists on models that are in general equilibrium and in which spatial structures emerge from the invisible hand process (Krugman, 1998). Sasaki (1990) refers to this unplanned polycentric growth as non-monocentric.

Analysing accessibility is a reliable way to explore and assess the morphological structure of cities and to identify sub-centres in polycentric cities (Martinez Sanchez-Mateos, Sanz, Francés, & Trapero, 2014). This study analyses network accessibility of Mersin to assess its morphological organization and its tendency towards a polycentric development.

Accessibility of urban facilities has two main components; road network that provides access to facilities and location. The reason that this study underlines polycentric structure relies on the fact that these agglomeration sub-centres are also centres of population agglomeration. Therefore, most of the services are provided from these centres to less central settlements. Hewko et al. (2002) states that spatial accessibility is generally an evaluation of relations between residential areas and existing facilities, rather than assessing locations for possible facilities. In this paper, the aim is to investigate the possibility of utilising two different accessibility models together, both to examine the morphological organization of Mersin, and to evaluate the location of urban facilities with regards to their accessibility in order to develop guidelines on location of facilities.

Within this aim, network analyst tool of ArcGIS and space syntax methodology have been utilised. In the network analyst of ArcGIS, it is possible to calculate service areas for individual urban facilities within given distance/time limits. This method has been used to evaluate spatial accessibility of existing facilities in Mersin with regards to the amount of population that can receive services in definite time constraints. This way, it would be possible to define deprived regions according to specified time limits.

Space syntax measures, on the other hand, help to understand the overall accessibility dynamics of the network. In this study, space syntax local and global integration measures have been analysed to understand the morphological character and to evaluate polycentric tendency of Mersin.

2. CASE AREA

Mersin is one of the most populated cities of Turkey located in the south, enclosed by Taurus Mountains on the north and the Mediterranean Sea on the south (Figure 1). It has the second largest port in Turkey, which enables sea transportation to all the countries that has a coast on the Mediterranean and the Middle East. Convenience of sea, air and land transportation gives Mersin a strategic importance in its region and attracts industrial investment.

Mersin and its surrounding region have hosted many civilizations; in chronological order Hittites, Phrygians, Assyrians, Persians, Macedonians, Romans, Byzantines and Ottomans have ruled in the region. Mersin has become a province of the Turkish Republic in 1924. According to the latest census of 2013, Mersin has a population of approximately 1.700.000, 22% of which lives in village settlements.

Mersin has a complicated planning history. Most of the previous plans have covered only the city centre and close environments, until 2007, when the 1/100.000 scaled environmental plan was approved. In 2008, another development plan (1/25.000) was approved, however was cancelled by the upper court. This process is followed by two regional plans in 1/100.000 scale in 2011 and 2013. These plans were not prepared specifically for Mersin; they included other cities since they were aiming regional development (Promer, 2015). In 2015, the Greater Municipality of Mersin initiated the preparation of a 1/50.000 scaled urban development plan for Mersin.

Due to Taurus Mountains, especially northern parts of the city have a sloping topography and both the road structure and the settlement structure of the city has evolved in line with these limitations. Topography of Mersin displays a pattern that draws "branch-like" traces of high elevation that are perpendicular to the sea. This pattern causes the road network to have a similar structure that is mainly in south-north direction. This road structure leaves gaps in east-west direction, which is the main reason behind poor accessibility. In most parts, roads draw zigzags in order to climb the steep topography. Apart from the urban centre, there are villages with a rural character in the mountainous parts of the city that do not have proper access to most urban facilities. Since access to health and education services are of vital importance for both urban and rural settlements, accessibility of these facilities within the Mersin Municipal Area is the main focus in this study.

Figure 1 - Location of Mersin in Turkey

3. METHODOLOGY

In order to understand the morphological structure of Mersin, two types of analyses have been carried out. First, accessibility to education and health services has been analysed through "Network Analyst" of ArcGIS software. For this set of analysis, "calculating service area" tool has been utilised. Accessibility analysis have been done separately for hospitals, school of medicine and small scale health facilities for health services; elementary schools, middle schools and high schools for education services. Second, segment based space syntax analysis were done, in which integration measures were inspected using DepthmapX (Varoudis, 2012).

Road-centre lines have been used for both types of analysis. The main road is an interprovincial highway starting from Mersin and reaching East Anatolian and South-East Anatolian towns. This highway has limited access from central road network. In ArcGIS, road-centre lines map has been revised to represent the connections accurately. In Depthmap, same revision to road-centre lines have been made using "unlink" tool to leave only the valid connections.

Calculating service area tool works with a road network that has time-cost data, which is calculated through segment length and average speed on the road. The tool creates a polygon data showing the areas within the given reach limits. For calculating service areas in Mersin, traffic flow data obtained from General Directorate of Highways has been used to get average values for different road types.

Calculated time limits are 5, 10 and 20 minutes for education services; and 10, 20 and 30 minutes for health services.

4. ANALYSES

4.1 NETWORK ACCESSIBILITY

In Turkey, elementary and middle school levels are regarded as "primary education" which is compulsory for all children in the 6-14 age group and is provided by the state free of charge. Regulations for Making Spatial Plans sets the maximum reach distance for educational services as 500m for elementary schools, 1000m for middle schools and 2500m for high schools; 500m for small scale health services. In Mersin, the city centre is more probable to comply with these regulations, however the rural parts of the city are far from standards. Taurus Mountains, which are within the city borders, enclose the city from north, lying in the east-west direction. The mountainous topography has critical effects on the road structure.

4.1.1 NETWORK ACCESSIBILITY OF EDUCATION FACILITIES

Although elementary schools are expected to be in 500m distance according to law, in this study, reach values are set in driving times, because 500m reach distances would not give a meaningful picture. Admitting that the actual schema is far from legislative standards, the values used for accessibility to educational services were 5, 10 and 20 minutes.

There are 454 elementary schools in the Mersin Municipal Area, most of which are located closer to central areas. Accessibility map for elementary schools shows that 280,000 ha area is covered in 5 minutes, 530,000 ha area is covered in 10 minutes and 790,000 ha area is covered in 20 minutes of driving distance (Figure 2). These figures appear as inadequate when the total area of Mersin Municipal area is considered: 1,625,000 ha. However, as mentioned before, most parts of the Municipal area is mountainous and settlements are sparsely located. Therefore, the number and population of the settlements that are within these catchment areas are investigated. Total number of settlements covered by this 5 min. reach distance is 398 out of 803. There is a population of 210,000 that does not have access to an elementary school within 5 minutes. When 10 minutes driving time is analysed, there is still 130,000 people out of reach of elementary schools and this number is 100,000 people when driving time is accepted as 20 minutes (Table 1).

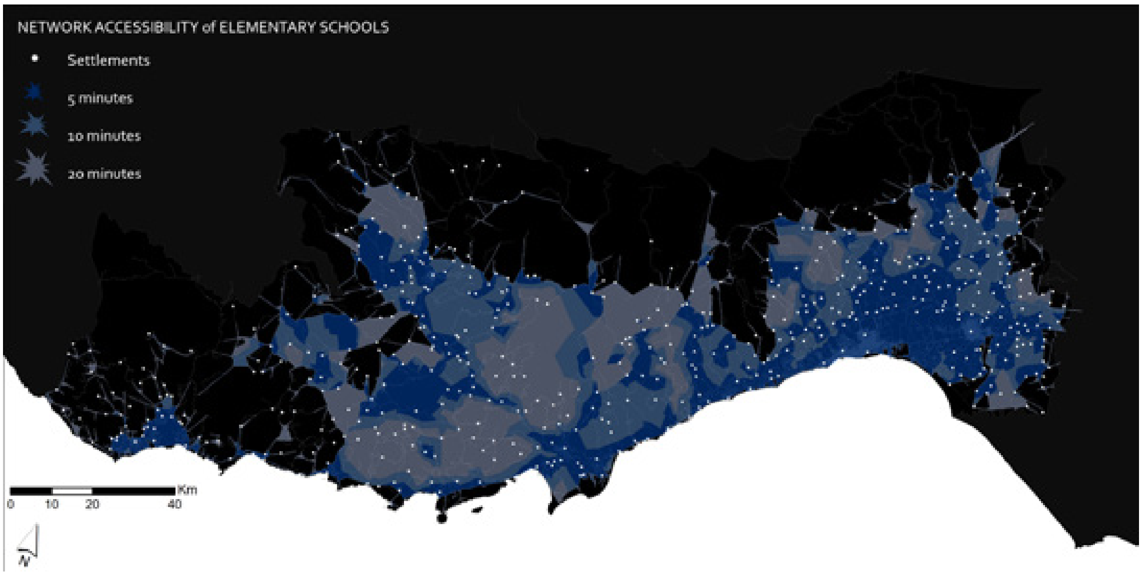

Figure 2 - Network Accessibility of Elementary Schools

Number of middle schools within the Mersin Municipal Area is 332. Regulations indicate that the standard reach distance for middle schools is 1000m. Nevertheless, the same accessibility problems apply to middle schools, as in elementary schools. Analysis of middle school accessibility in 5, 10 and 20 minutes reach distances show that the catchment area in 5 minutes driving distance is 195,000 ha covering 343 settlements. In 10 minutes, 415,000 ha and 475 settlements are covered, and in 20 minutes, 720,000 ha is covered serving to 603 settlements (Figure 3). Number of settlements that cannot reach to a middle school in 20 minutes is 200 with a population of 116,000 (Table 1).

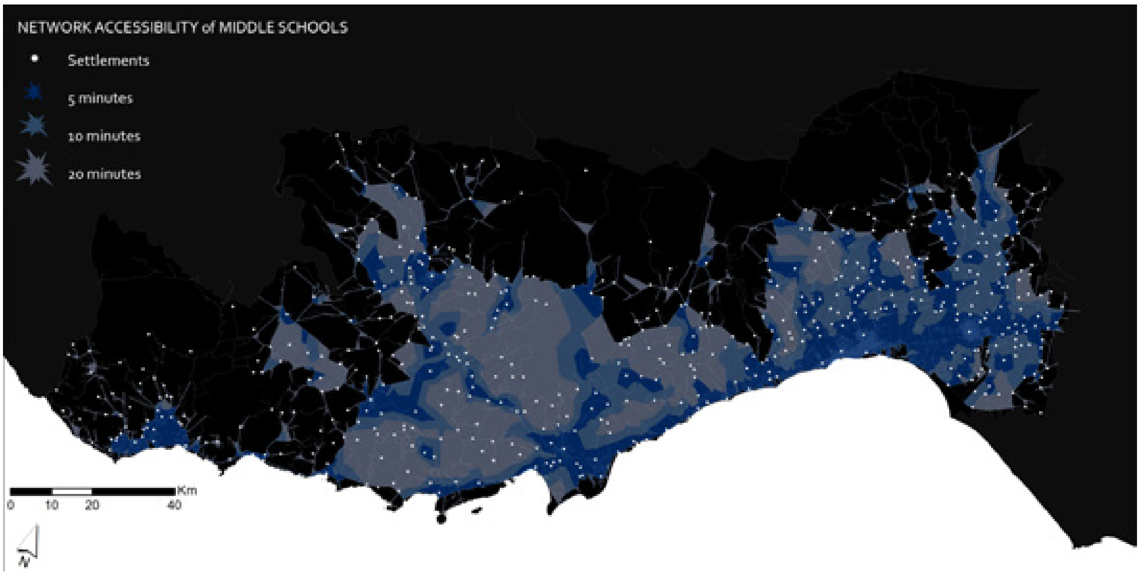

Figure 3 - Network Accessibility of Middle Schools

Number of high schools in Mersin Municipal Area is 142. Location of high schools and thus the reach extents concentrate on central areas such as Erdemli, Silifke, Mut, Gülnar, Anamur, Tarsus and Mersin City Centre. Tarsus and Mersin City Centre appear as a single core in all of the analysis, as well as in the road network. This is also apparent in the analysis of high school accessibility, since high school location is usually one of the indicators of sub-centre location.

Regulations do not constrain the reach standard for high schools in walking distances; maximum distance is 2500m. As mentioned before, average speed values for different types of roads have been calculated using the traffic flow data from General Directorate of Highways. Average speed for central road network has been taken as 40km/h, which is low mainly because of poor road conditions. With this average speed, it is possible to reach 2500 meters in less than 4 minutes.

5, 10 and 20 minutes reach distances have been taken as break values for the analysis of high school accessibility. Analysis shows that total area covered in 5 min. driving distance is 60,000 ha serving to 28 settlements with a 1,300,000 population (Figure 4). Total number of settlements that do not have access to a high school in 5 minutes is 775 with a population of 370,000. According to this analysis, around 400 settlements and more than 200,000 people cannot reach a high school in 20 minutes of driving distance (Table 1).

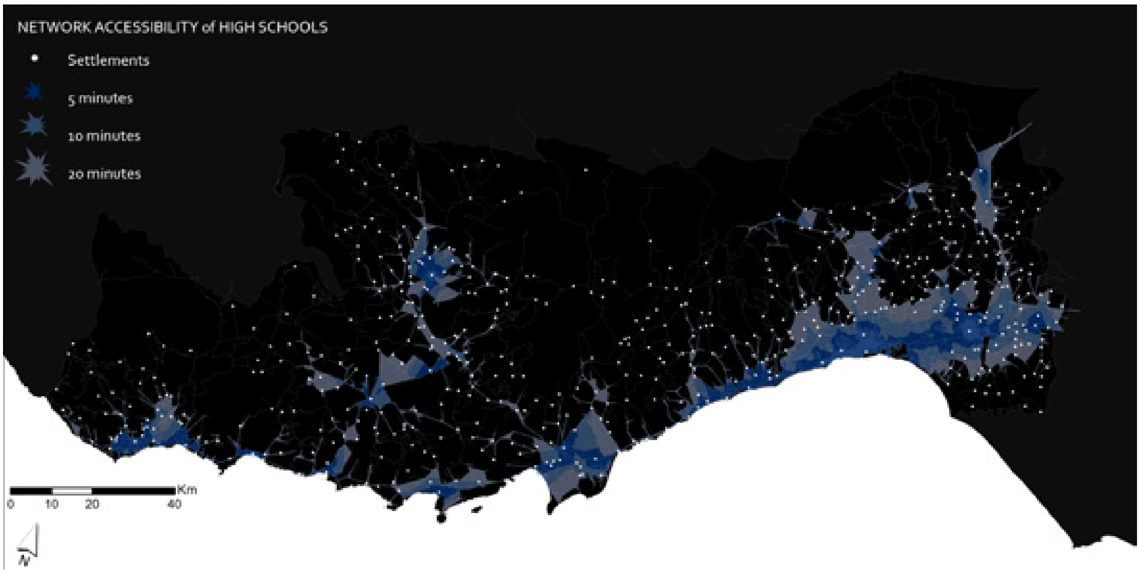

Figure 4 - Network Accessibility of High Schools

	5 min. reach distance		10 min. reach distance		20 min. reach distance	
	Nr. of settlem.	Pop.	Nr. of settlem.	Pop.	Nr. of settlem.	Pop.
Elementary Schools	405	212,695	267	131,689	172	100,287
Middle Schools	460	246,336	328	175,368	200	116,069
High Schools	775	371,415	497	265,626	406	206,541

Table 1 - Settlements that cannot access educational services within given time limits

4.1.2 NETWORK ACCESSIBILITY OF HEALTH FACILITIES

Network accessibility has been analysed separately for hospitals, school of medicine and small scaled health facilities for health services. Calculated time limits are 10, 20 and 30 minutes for all types of health services.

In Mersin, there is one university hospital that belongs to the Faculty of Medicine at the University of Mersin. It is located in the city centre, therefore even in the longest range (30 min) its access distance cannot reach to rural parts of Mersin. The area covered by the access distance of the University Hospital is 6,000 ha in 10 minutes, 30,000 ha in 20 minutes and 66,000 ha in 30 minutes (Figure 5). There are only 200 settlements in total that have access to the University Hospital in half an hour. However, since it is located in densely populated areas, approximately 1,200,000 people are within its reach distance (Table 2).

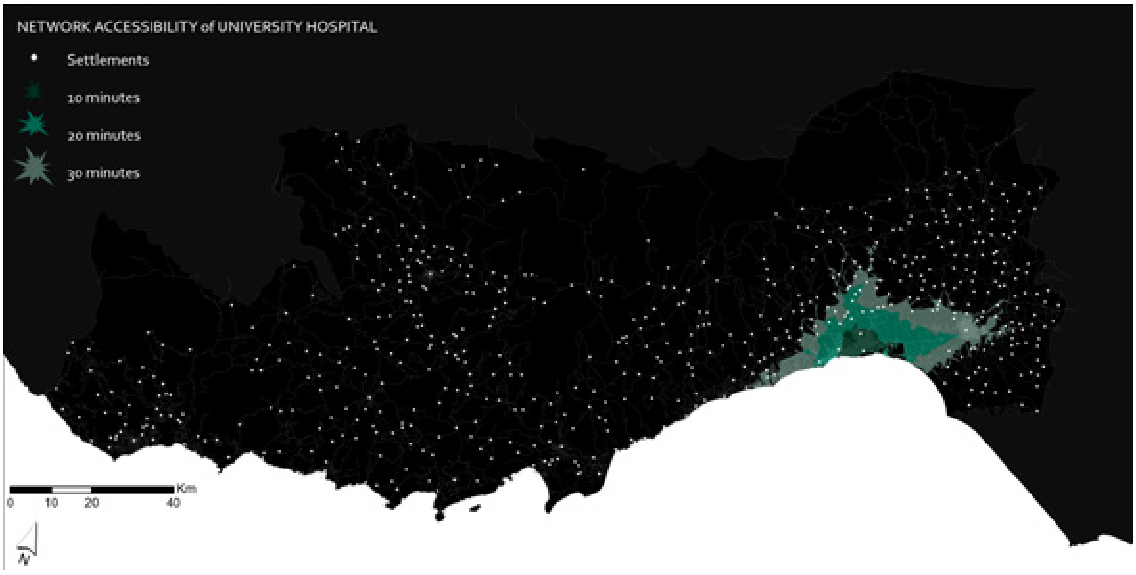

Figure 5 - Network Accessibility of University Hospital

There are 17 hospitals within the Mersin Municipal Area distributed around central areas. Their total catchment area covers 95,000 ha in 10 minutes, 260,000 ha in 20 minutes and 420,000 ha in 30 minutes (Figure 6). As their locations are central, their catchment areas correspond to a high amount of population, despite the low number of facilities. Almost 90% of the population can reach a hospital in 30 minutes (Table 2).

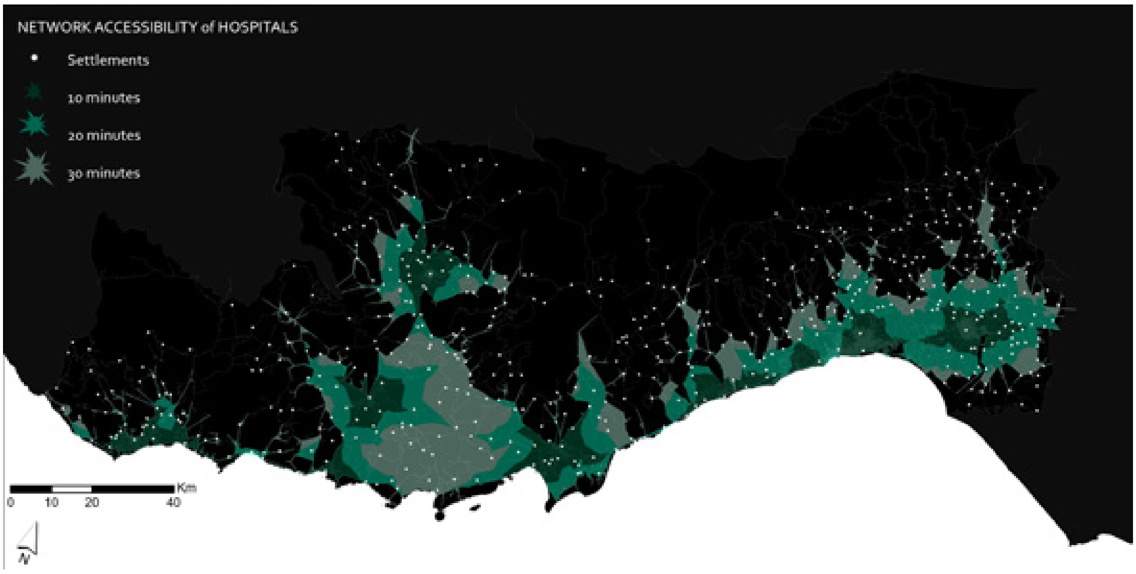

Figure 6- Network Accessibility of General Hospitals

Nevertheless, the number of small scaled health facilities is much higher but their spatial distribution seems to be favouring central areas. There are 224 small scaled health facilities composed of dispensaries, dental health centres, polyclinics, medical centres, family health centres and other small scaled health care units. Total catchment area of these health facilities in 10 minutes is 445,000 ha, in 20 minutes 830,000 ha and in 30 minutes, 900,000 ha (Figure 7). The catchment area of health facilities in 30 minutes cover most of the settlements however there are still over 80,000 people who do not have access to any type of health facility in 30 minutes (Table 2).

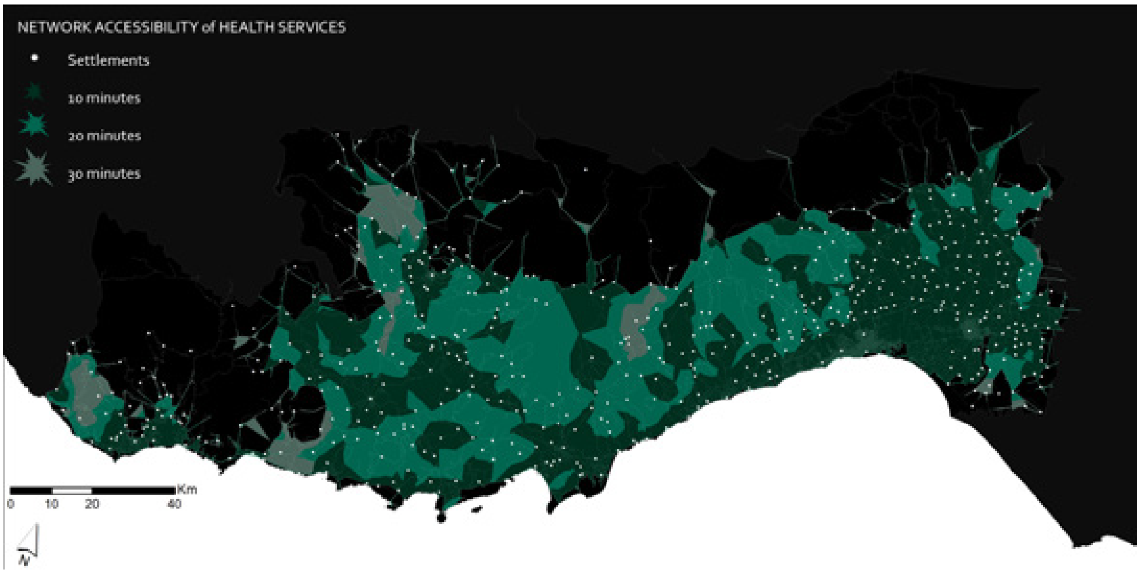

Figure 7- Network Accessibility of Health Services

The distribution schemas of health services and their access distances support that, when it comes to access, location of facilities is much more important than the number of facilities.

	10 min. reach distance		20 min. reach distance		30 min. reach distance	
	Nr. of settlem.	Pop.	Nr. of settlem.	Pop.	Nr. of settlem.	Pop.
Small Health Facilities	311	153,882	155	93,277	129	81,101
Hospitals	557	469,729	413	219,575	325	178,994
University Hospital	741	1,123,625	686	865,648	591	523,050

Table 2 - Settlements that cannot access educational services within given time limits

4.1.3 SPATIAL ANALYSES

For spatial analyses, road centre lines map of Mersin Municipal Area has been used. Segment based space syntax analysis have been carried out to calculate local and global measures of integration using DepthmapX (Varoudis, 2012).

The most dominant road in Mersin is an interprovincial highway connecting Mersin to East and South-East Anatolian towns. Connections of the interprovincial highway to central road network are provided through access roads, linked on specific junctions. In order to represent these connections accurately, revisions to road-centre lines have been made using "unlink" tool in Depthmap.

Road network and settlement structure of Mersin has developed greatly in line with topographical limitations. Road density is much higher in the central areas, which are close to the sea. Tarsus is located on the eastern side of the city and is one of the most important centres in Mersin. It is almost as large as the city centre and in time, also as a consequence of its proximity to the city centre, strong road connections have developed between these two parts of the city. On the western side of the city, another large centre, Silifke is located. Silifke was a separate province until 1930s when it was administratively linked to Mersin. As both settlements developed and spatially expanded, now Silifke and Mersin City Centre also have strong connections. As the city is bordered with Mediterranean Sea on the south and Taurus Mountains on the north, development in east-west axis would be inevitable. Linking with two main centres accelerated this development, thus creating a linear hub.

This linear structure is evident in global integration analysis (Figure 8). There is a linear integration core continuing along the sea in east-west direction, displaying high values between Tarsus and Silifke. It is interesting to see that, Silifke actually has more highly integrated lines than Mersin City Centre. These lines are connected to the city centre through coastal road that also has high values.

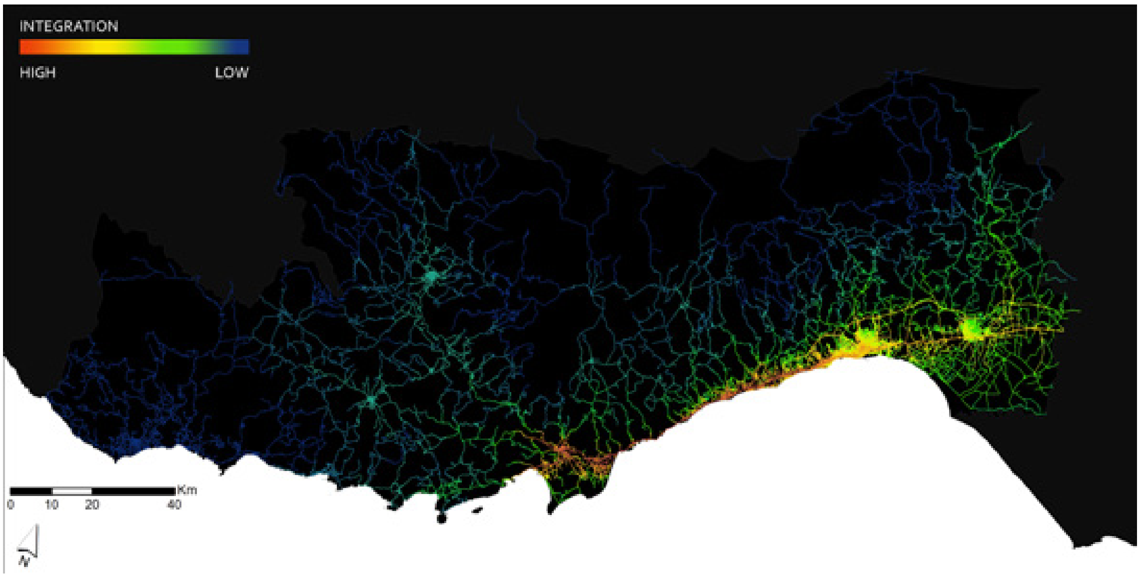

Figure 8- Global Integration Analysis of Mersin Municipal Area

In local integration analyses, 800m, 1600m, 3200m and 8000m radii are used. The central areas that create the linear integration core in global analyses, appear as separate centres in local analyses. Mersin City Centre and Tarsus are the most prominent and largest local centres in all of the local analyses. In addition, Silifke and Mut are displayed as local centres in 800m and 1600m (Figure 9).

Mersin Municipal Area has developed in a polycentric urban structure clearly due to geographical constraints. As accessibility analyses of urban facilities suggested, it is crucial to understand polycentric structure for a desirable urban development. Location of urban facilities are much more essential compared to number of facilities, to provide accessibility from different parts of the city. Central areas of the urban structure must be determined with regards to their potential and connection with the main centre. Space syntax local integration analyses provide valuable information to understand this structure.

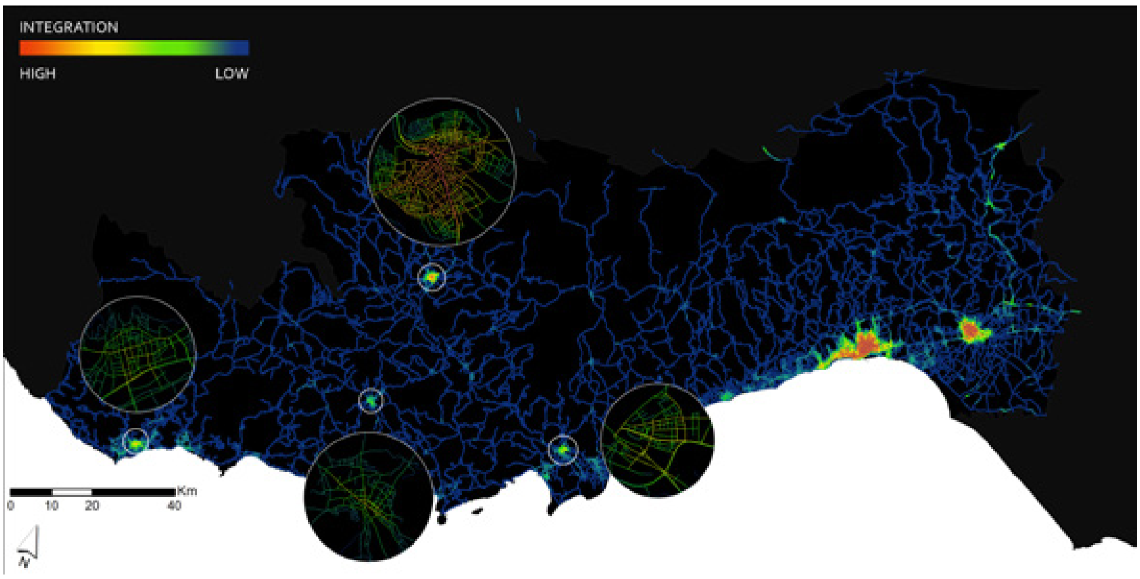

Figure 9 - Global Integration Analysis of Mersin Municipal Area

5. RESULTS AND DISCUSSION

Main objective of this study was to investigate the possibility of utilising the network analyst of ArcGIS and space syntax methodology together to develop guidelines on determining the location strategies of facilities.

Using the network analyst of ArcGIS, spatial accessibility of existing education and health facilities in Mersin has been evaluated with regards to the amount of population that can receive services in definite time constraints. Even though access distances to schools and basic health services are defined by law as 500m, 1000m and 2500m, the general layout of the city reveals how unrealistic these distances would be. Therefore, in this study, access distances have been calculated in driving minutes.

In Mersin Municipal Area, there are 454 elementary schools, but still a population around 200,000 people are out of the service area of any elementary school in a 5min driving distance. Elementary school children cannot be expected to take long distances to access their schools. Particularly, settlements located on the mountainous parts have a more problematic access. It is very justifiable that in every settlement unit, there needs to be at least one elementary school. For middle school and high school accessibility, there are respectively 115,000 and 200,000 people without service within 20min of driving, which suggests the need for additional educational facilities. Notwithstanding, number and location of these new facilities should follow a strategy of balanced distribution to cover all possible settlement areas.

The most striking result of this study has been achieved by comparing service areas of hospitals and small scaled health facilities. Total number of small scaled health facilities in Mersin Municipal Area is 224; hospitals is 17. Both of these facilities have been analysed using the same time limits. Results demonstrate that number of people that are in the service area of these facilities are not relevant with the number of facilities. Hospitals are in 30min access distance for 90% of the population, in which case we would expect 224 facilities to cover the entire population of Mersin Municipal Area. On the contrary, there are still over 80,000 people that cannot reach any type of health services in half an hour. In this case, either location of small health facilities is considerably imbalanced or location of hospitals is perfectly balanced. In any case, the need for additional education and health facilities is evident, although the bigger concern is obviously location strategy.

Space syntax measures on the other hand, have helped to understand the overall accessibility dynamics of the network. Syntactic analyses verify that Mersin Municipal Area has a polycentric structure, which is actually a result of its morphological formation. Evolution of the city has incorporated unification of settlements, and then enlargement of these settlements has created a dynamic whole. Still, these settlements preserve their independent character creating a polycentric city structure. Space syntax local integration analyses provided a visual and numerical presentation of these local centres, which are also consistent with the populations.

According to the analytic report (Promer, 2015), there is no data showing a significant difference among village settlements in terms of income. However, the topographical differences seem to have a great impact on the socio-economic structure. Areas that are up to 100m of elevation from sea level are where most of the urban settlements concentrate and where there is agricultural production. Mersin City Centre as well as Erdemli, Silifke, Anamur and Tarsus are located in this first zone. This zone harbours around 85% of the population of Mersin. Areas between 100m and 500m of elevation are identified as transition zones from urban to rural character. The area is divided by valleys and rivers, and is occupied with both forests and agricultural land (Promer, 2015). Mut is the biggest central settlement in this zone which is also one of the local centres defined by space syntax analysis. Areas between 500m and 1300m are characterized by forests, heathland or rocky lands. Another central settlement, Gülnar is located in this zone, which is the most elevated central settlement in Mersin. There are also some highland settlements where horticulture production is common. Areas over 1300m of elevation are mainly mountainous with very few settlements. These areas harbour 1% of the entire population of Mersin (Promer, 2015). This socio-economic structure is rather relevant with the accessibility schema provided by spatial analysis, since road network is more problematic in elevated areas, which are also areas with high slope.

The mentioned central settlements are also centres of district jurisdictions. In Mersin, there are 13 district jurisdictions, 4 of which have merged in time in the main centre of the city and are referred to as "Mersin City Centre". Erdemli, Silifke, Anamur, Tarsus, Mut and Gulnar are of the central settlements which emerge in local integration analysis. On the other hand, there are 3 more district centres that have not appeared in local integration analysis, which are Bozyazi, Aydincik and Camliyayla. Therefore, it would not be accurate to assume that all district centres have a central character. The local centres specified in local integration analysis are not only areas where road surface is denser but also areas with higher accessibility.

In order to develop a location strategy for facility planning, the road network should be examined and local centres which are part of the polycentric structure should be identified, so that these centres could also be considered as centres for facility services. In this way, the population that would receive service in definite time constraints can be used to calculate capacity requirements for facilities. Furthermore, spatial analysis with lower radii could be used to define centres of a lower-level for planning locations of small-scale facilities. In this framework, elementary schools can be planned for each settlement, while middle schools can be located in second-level centres and high schools can be placed in first-level centres. Similarly, small-scale health facilities can be planned for each settlement, while health centres can be situated in second-level centres and hospitals can be located in first-level centres. Local integration analysis could be used to identify locations and levels of centres, while ArcGIS network service area function could be used to define the access areas of planned facilities and calculate the capacity requirements for the population within those areas.

In conclusion, both types of analyses have provided valuable information for planning the Mersin Municipal Area. Network analyses have displayed the service areas of analysed facilities and the population they are serving. Syntactic analyses showed the powerful integrity of the city in global analysis, while indicating sub-centres of its polycentric structure in local analyses. Analyses also confirmed that planning for urban facilities is not simply an arrangement of adequate number of facilities, but a strategy. Findings of this study are believed to serve to a better understanding of urban structures.

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REFERENCES

Arribas-Bel, D., & Sanz-Gracia, F. (2014). The validity of the monocentric city model in a polycentric age: US metropolitan areas in 1990, 2000 and 2010. Urban Geography, 35(7), 980–997. http://doi.org/10.1080/02723638.2014.940693

Burger, M. J., van der Knaap, B., & Wall, R. S. (2013). Polycentricity and the Multiplexity of Urban Networks. European Planning Studies, 22(4), 816–840. http://doi.org/10.1080/09654313.2013.771619

Cooper, M., & Roadman, M. C. (1994). Accessibility and Quality of Life in Housing Cooperatives. Environment & Behavior, 26(1), 49–70.

Doi, K., Kii, M., & Nakanishi, H. (2008). An integrated evaluation method of accessibility, quality of life, and social interaction. Environment and Planning B: Planning and Design, 35(6), 1098–1116. http://doi.org/10.1068/b3315t

Hewko, J., Smoyer-Tomic, K. E., & Hodgson, M. J. (2002). Measuring neighbourhood spatial accessibility to urban amenities: Does aggregation error matter? Environment and Planning A, 34(7), 1185–1206. http://doi.org/10.1068/a34171

Hillier, B. and Hanson, J. (1984), The Social Logic of Space, Cambridge: Cambridge University Press.

Keles, Rusen (2010), Kentlesme Politikasi, 11th Edition, Ankara, Imge Kitabevi.

Krugman, Paul, (1998), What's New about the New Economic Geography?, Oxford Review of Economic Policy, 14, issue 2, p. 7-17

Legras, S., & Cavailhes, J. (2016). Environmental performance of the urban form. Regional Science and Urban Economics, 59, 1–11. http://doi.org/10.1016/j.regsciurbeco.2016.03.002

Liu, C., & Yu, R. (2012). Spatial Accessibility of Road Network in Wuhan Metropolitan Area Based on Spatial Syntax. Journal of Geographic Information System, (4), 128–135.

Martinez Sanchez-Mateos, H. S., Sanz, I. M., Francés, J. M. U., & Trapero, E. S. (2014). Road accessibility and articulation of metropolitan spatial structures: The case of Madrid (Spain). Journal of Transport Geography, 37, 61–73. http://doi.org/10.1016/j.jtrangeo.2014.04.003

Promer Planning Corporation (2015), Provincial Environmental Plan and Urban Area Research - Analytic Studies, Report prepared for Greater Municipality of Mersin

Roth, C., Kang, S. M., Batty, M., & Barthélemy, M. (2011). Structure of urban movements: Polycentric activity and entangled hierarchical flows. PLoS ONE, 6(1), 1–9. http://doi.org/10.1371/journal.pone.0015923

Sasaki, K. (1990). The Establishment of a Subcenter and Urban Spatial Structure. Environment and Planning A, 22(3), 369–383.

Varoudis T (2012), 'depthmapX Multi-Platform Spatial Network Analysis Software', Version 0.28 OpenSource, http://varoudis.github.io/depthmapX/

Yue, W., Liu, Y., & Fan, P. (2010). Polycentric urban development: The case of Hangzhou. Environment and Planning A, 42(3), 563–577. http://doi.org/10.1068/a42116