# *Study on Locations of High Schools based on Proximity and Connectivity: a case study in Istanbul, Turkey*

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# Study on Locations of High Schools based on Proximity and Connectivity: a Case Study on Istanbul, Turkey

by

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# Abstract

Accessibility has become the guiding principle in service planning from the last half century. In recent years interest in accessibility has increased due to multiple theories that describe the centrality of any location. With the aim to produce the composite index of accessibility form one place to others, the two measures namely proximity and connectivity are used for assessing locational behaviour, which gives the measure of how easy or difficult to have access on any other location from it. The proximity also called generic concept of accessibility defines how proximate or near an individual is to the opportunities. Here comes the cost which measures the nearness of individuals with the opportunities. Connectivity measures the total distance from one segment of street to all others segments. The shortest distance in network from a location to all other locations in planer graph measures the accessibility of the location.

The results of this study show that different theories of accessibilities can be combined together to study the facilities like high schools. By quantifying and measuring the centrality indices of high schools location and the segments of streets using different measures of local and global in scale are carried in the research. This provides the theoretical base for planning high schools using the contour measure and syntactical analysis can have added value in determining the locations in future.

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# 1. Introduction

This chapter introduces the research interest, background and need for such research. It brings into light the research problem, main objective, sub-objectives and research questions to be answered through the research. The conceptual model of the research has been explained in detail. The operationalisation of the concept is discussed in the research design.

## 1.1. Introduction

This study attempts to compare two approaches: Proximity and connectivity that addresses locations of high schools. In urban environment, locating high schools is a type of facilities planning that balance in between public demand for education and their provision. Desire of such provision is to benefit neighbourhood: locate schools centrally minimizing distances travel-to-school (Ewing, Forinash et al. 2005). Moreover, the service ranges of high schools are fairly large and students use different modes of travel-to-school like walking, bike, bus (school and public), car (Müller, Tscharaktschiew et al. 2008). They generate high volume of traffic and attract lots of public activities. This indicates high schools locations are important in urban settings.

In the most common method, the location of high schools and their capacity are determined with the number of school going children or the distribution of population in that locale (Geurs and Ritsema van Eck 2001). The planning identifies an un-served area on the basis of the assumed or known catchment areas of existing schools. Catchment areas are generally defined by the maximum distance to the school. Thus, network radius of (for example 1800 meters specified as walking) maximum distance for high schools are plotted around the existing schools (Sabean 2007; Langford, Higgs et al. 2008). These areas in the region which are not covered by the network are un-served and consequently tagged as potential area of school locations.

While in urban areas, the service network for high schools is complicated basically due to two reasons: first, increase in network density and second choices available between schools and travel-to-school mode (Foltête and Piombini 2007; Müller, Tscharaktschiew et al. 2008). This complication can be studied in some theories measuring school and travel-to-school modes. Networks can be represented by graphs or adjacency-matrices and their structure can be analyzed. These properties allow testing measures based on degree of closeness. Network analysis provides a variety of centrality indexes that can be applied and adopted for urban analysis (Hillier and Hanson 1984; Tomko, Winter et al. 2008). Examples of such centrality measures are degree centrality and closeness centrality. Degree centrality also known as connectivity, offers the possibility to estimate theoretical accessibility or natural movement by measuring the direct neighbours of nodes in the network (Hillier 1999; Tomko, Winter et al. 2008). Closeness centrality also known as integration, is a measure of the graph, provides the average length of the shortest paths to all other nodes (Tomko, Winter et al. 2008).

Since education is a universal human right, accessibility is a guiding principle to locate high schools. This thesis attempts to compare the accessibility of high schools using the above two perspectives, proximity and connectivity. It defines a model, which could be used to represent the accessibility of high schools by more integrated place of higher order.

## 1.2. Background

Istanbul is the largest city in Turkey with an area of around 5750 $km^2$ and a population of around 10.8 million in the year 2001. In 1980, the population was only around 4.7 million and so has more than doubled in only two decades (Kaya and Curran 2006). With the increase in urban population, the numbers of the perspective high schooled students' also increases. This certainly results in significant increase in enrolment in high school and there is constant need of supply i.e. new high schools are needed to accommodate the increasing demand of enrolment.

High school education in Turkey includes all education institutions of a general or vocational and technical character. These institute offer education for at least three years and enrolment in these institute is allowed only after following the compulsory primary education. The objectives of high school education are to give students a common minimum overall knowledge, to familiarize them with individual and societal problems and to seek solutions to these problems, to ensure that students gain necessary awareness that shall contribute to the socio-economic and cultural development of the country and to prepare them for higher education, and a profession or for life and employment, in line with their interests and aptitudes (Ministry_of_National_Education 2006-2007).

The Turkish government is focusing on increasing accessibility of school education to their school going population. The government has made the primary education compulsory and free to all. After these programmes the enrolment in primary education in Turkey is approaching almost 100% (Ministry_of_National_Education 2006-2007). The secondary school enrolment has yet to reach the same level of gross enrolment (ratio of total number of enrolment to the total population in the theoretical age group - age between 14 and 17 is defined as the theoretical age for the high schools in Turkey (Ministry_of_National_Education 2008-2009) is approaching about 77%. Though the net enrolment (ratio of total number of enrolment in the theoretical age group to the total population in the theoretical age group) in secondary school is below 60% (Ministry_of_National_Education 2008-2009).

To increase enrolment in high school, a better understanding of the present level of service and shortcomings in between supply and demand are needed. Unlike the primary schools, which mainly rests on access to potential clients; high schools belong to the category of service system which serve larger areas and populations and thus have demands that is responsive to the location of the facilities (Rahman and Smith 2000). A good knowledge of service use patterns can greatly improve the delineation of catchment areas and consequently can aid in identifying the priority areas for locating the services in future. The underlying assumptions of this research are that there is a scope for improving the present technique in planning for high school locations and this can be achieved through a deeper analysis of their service use patterns. Services used in this sense essentially represent the manner in which students travel from their home to school and the factors affecting their movements.

This research also tries to explore to what extent the theory of space syntax can be applied to specify the accessibility of the urban road network and how it impacts the layout of the high-schooling activities over the GIS based accessibility.

## 1.3. Justification

This study aims to aid local planning offices to play an active role for planning of services particularly high schools locations. Hence, it intends to focus on the spatial interaction of supply and demand and bridge the gap in between them.

Location of school is often used to facilitate one of the functions - for example – promote the equitable distribution of educational benefits within and between different regions and populations (Hite 2008). Here, the fundamental thing is to achieve the spatial equity within socially acceptable norms of facilities planning and their efficiency of provision. Since the goal of government has been set to educate all nationals providing the basic education of high school, the appropriate location of school is crucial. On the basis of quantitative indicators, spatial configuration of high schools for needs of geographically dispersed population can be assessed. Hence, relationship of school locations and urban spatial structure together with the population is becoming an important issue for urban spatial planning.

There are only few urban land use studies dealing mainly with the relationship between spatial structures and high school considering the concept of accessibility. The term accessibility has been considered as the mediating factor for determining the activities occurred in different locations and the demand for travel, which measures the cost or distance from a location to other activities or opportunities such as schooling, working and shopping (Iacono, Levinson et al. 2008). Planning of high schools is mainly guided by the service accessibility, however, many of the practices show that the demand for high school is not solely linked with the service area allocation that address the distance accessibility. The location preferences of the users also contribute a lot in planning high schools in urban areas. It is hard to capture the human subjective cognition and behaviors in urban mapping. This calls for a new perspective that is more resistant to the outer influence and can express accessibility (Jiang, Claramunt et al. 2000). Hence the theory dealing the connectivity measures together with proximity could be the right solution. Both of these theories deal with the configuration of the street networks as a relatively stable physical quality that can represent both the topological accessibility and behavioral choice of the people (Jiang, Claramunt et al. 1999; Foltête and Piombini 2007; Iacono, Levinson et al. 2008). The method of proximity indicators together with the connectivity could be useful technique that could express both the accessibility and choice factors for locations of the high schools.

## 1.4. Specific Research Problem

A number of studies have used GIS based geographic model in order to examine the accessibility measures (Ritsema van Eck and de Jong 1999; Langford, Higgs et al. 2008). Despite its strength to calculate the service locations based on demand, GIS based traditional model of accessibility also suffer from a number of weakness, for example, as explained by (Geurs and Ritsema van Eck 2001), "it seems to be common practice to stratify accessibility measures by economic sectors (service or industry) but not by market segment or type of good although the later is an important factor influencing the valuation of accessibility." The focus of such analysis is on the relative 'proximity' between (two) locations (Batty 2004). The geographic (proximity) model associates densities and intensities of activities which occur at different locations and along a link between them. However, proximity could not explain the accessibility to and from various areas of city, rather than two types of locations of supply and demand, for example, the locations, which are delivering the services and requiring the services (Lima 2001).

Alternative measures of differences in accessibility and location in urban form are obtained by investigating the relation between the structure and functions of cities (Lima 2001; Hillier 2007). One such proposal is produced by space syntax analysis. This method calculates the accessibility of each street segment with respect to rest of the streets segments rather than the direct distance measure.

Previously, services like high schools have been studied and analyze mostly with GIS based proximity measures. Both proximity and connectivity measures "analyze the patterns of connection, differentiation and centrality that characterize urban systems and relationships of parts to whole that they engender" (Peponis, Ross et al. 1997). The ability of space syntax (connectivity measures) to describe global configuration properties of street design as well as relationship of part-to-whole quantitatively provides an important advantage over the existing methods of measuring street connectivity and syntactical accessibility. By attaching configurationally measurements to each street segment in a study area, relationships between individual behaviours and those measurements can be examined. The evidence to date has focused mainly on the presence of activity on the street (Hillier and Hanson 1984; Hillier 1996; Baran, RodrÃguez et al. 2008; Hillier and Vaughan 2008). As expected, that the most accessible or central places could be examined through these theories of connectivity and these could be the best locations of services like high schools. Hence, here have also been moves to return to combine connectivity with more geographic accessibility models, for the study of locations and services demand (Jiang, Claramunt et al. 1999; Iacono, Levinson et al. 2008).

The study on locations of high schools on the basis of geographic based accessibility measures together with the theory of space syntax could be useful. Therefore, the research problem is specified as to what extent the proximity based geographic accessibility measures can assess high schools' locations and if and how connectivity measures could be used to further improve such analysis. In short, can the method of proximity indicators together with connectivity indicators contribute useful information for assessing locations of a set of high schools.

## 1.5. Objective and Research Questions:

To compare proximity and connectivity measures and determine whether connectivity measures could have added value to proximity based approach for assessing locations of high schools

### 1.5.1. Sub-objectives:

- To define the concept of proximity and connectivity used in assessing the locations of schools
- To analyze the characteristics and identify the existing provision of supply and demand of high school in Istanbul
- To determine if the spatial pattern of high school locations can be explained by variation in connectivity of urban transportation network
- To analyze how the spatial distribution of high schools meets education needs using proximity and connectivity measures and compares the results

### 1.5.2. Research matrix:

| Objectives | Research questions | Methodology | Data /Information required | Data sources |
|---|---|---|---|---|
| 1.To define the concept of proximity and connectivity | What is proximity and how can we assess accessibility of high schools locations? | Literature review | General information related to GIS based geographic accessibility and school planning | Literature |
| | What is connectivity and what significance does it play in urban facilities planning? | Literature review | Information related to principle of space syntax and its application | |
| 2.To analyze the characteristics and identify the existing provision of supply and demand of high school in Istanbul | What is the type and capacity of high schools and their current attendance? | Literature review, field survey | Statistics of education data | Literature, School records, MIP, education department, statistics bureau |
| | What are current norms of planning or locating high schools? | Literature review, field survey | Acts, by-lays, norms related to the high school | MIP, Dept of Education |
| | What are the existing problems of accessibility in current distribution of schools in the study area? | Literature, map overlay, statistics | Education data, road network, population, administrative boundary | MIP, Dept of Education |
| 3. To determine if the spatial pattern of high school locations can be explained by variation is connectivity of urban transportation network | What are the levels of connectivity of street networks in Istanbul? | Syntax analysis, map overlay | Road network, axial maps, bus routes and stops | MIP, Dept of Education |
| | What is the current distribution of pattern of high schools with respect to the urban network? | | | |
| 4. To analyze how the spatial distribution of high schools meets education needs | What are the similarities and dissimilarities between the proximity and connectivity based measures? | Overlays, Statistical analysis | Map/ results of proximity analysis and connectivity analysis | Results of proximity and connectivity analysis |

| | | | | |
|---|---|---|---|---|
| using proximity and connectivity measures and compares the results | How connectivity measures can help in accessing and identifying the suitable locations of high schools? | | | |

## 1.6. Conceptual Framework

The general concept behind this research is to identify methods and tools for supporting efficient facility planning where the facility of interest is high school. This research work is guided by a conceptual framework as shown in

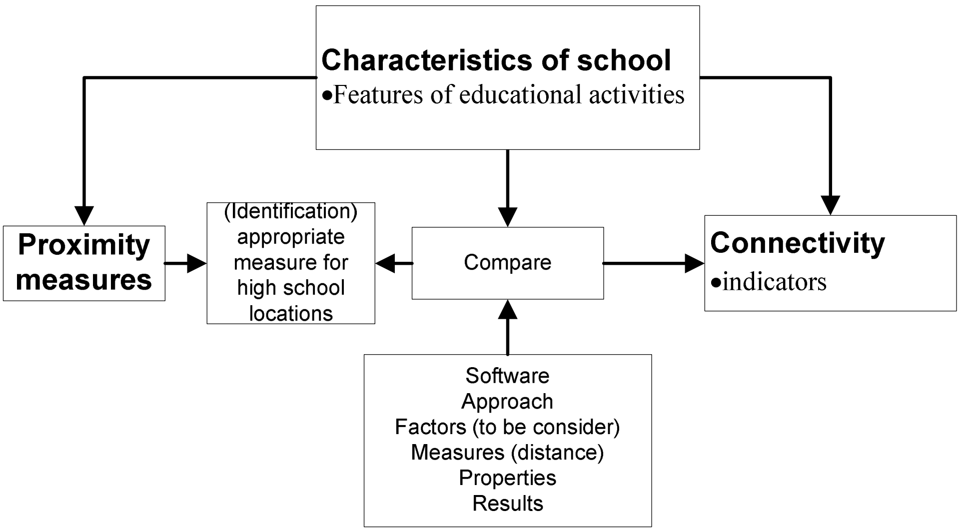



**Figure 1-1: Conceptual framework**

To compare, the measures of proximity and connectivity, we begin by considering the sample of centrality measures and examine how they are computed. First, based upon the existing study, we identify the most suitable measures of proximity that could assess the locations of high schools. In the process of comparison we extract the dimensions along which the measures vary. We begin with the descriptions of two methods. Then we compare them with the use of different tools as: which software used:, the approach used for the calibration of the measure (eg grid based or vector based etc):, which factors that these measures considers(population/density etc):, what type of distance or accessibility measures are applied to access the accessibility of the locations (network or Euclidian etc);, and finally consideration of particular properties of each measures (radius of population served, cell size, relative values of integration/depth etc). The variations in results produced by two methods are analyzed.

## 1.7. Research Design

This research is carried out in three phases. After setting up the theoretical framework, phase one involves the data acquisition, of both primary data (questionnaires) and the use of secondary data. Given the size of the city and scope of this thesis it was not feasible to carry out an extensive study on the whole city. Thus smaller area was selected to study high schools locations. This phase also involves the exploration of (existing) data to gain better understanding of Istanbul city. Second phase includes the analysis and interpretation of the collected data. Distribution of high schools and their accessibility is compiled using network based analysis in GIS. This phase also involves the connectivity analysis of axial map. The best connected locations will be determined based on hierarchy of streets using the space syntax analysis. The correlation between the best connected location and the accessibility indicators is performed in the third stage. This stage also includes the evaluation of results of the added value of connectivity over proximity. The details of the research framework are shown in Figure 1-2.

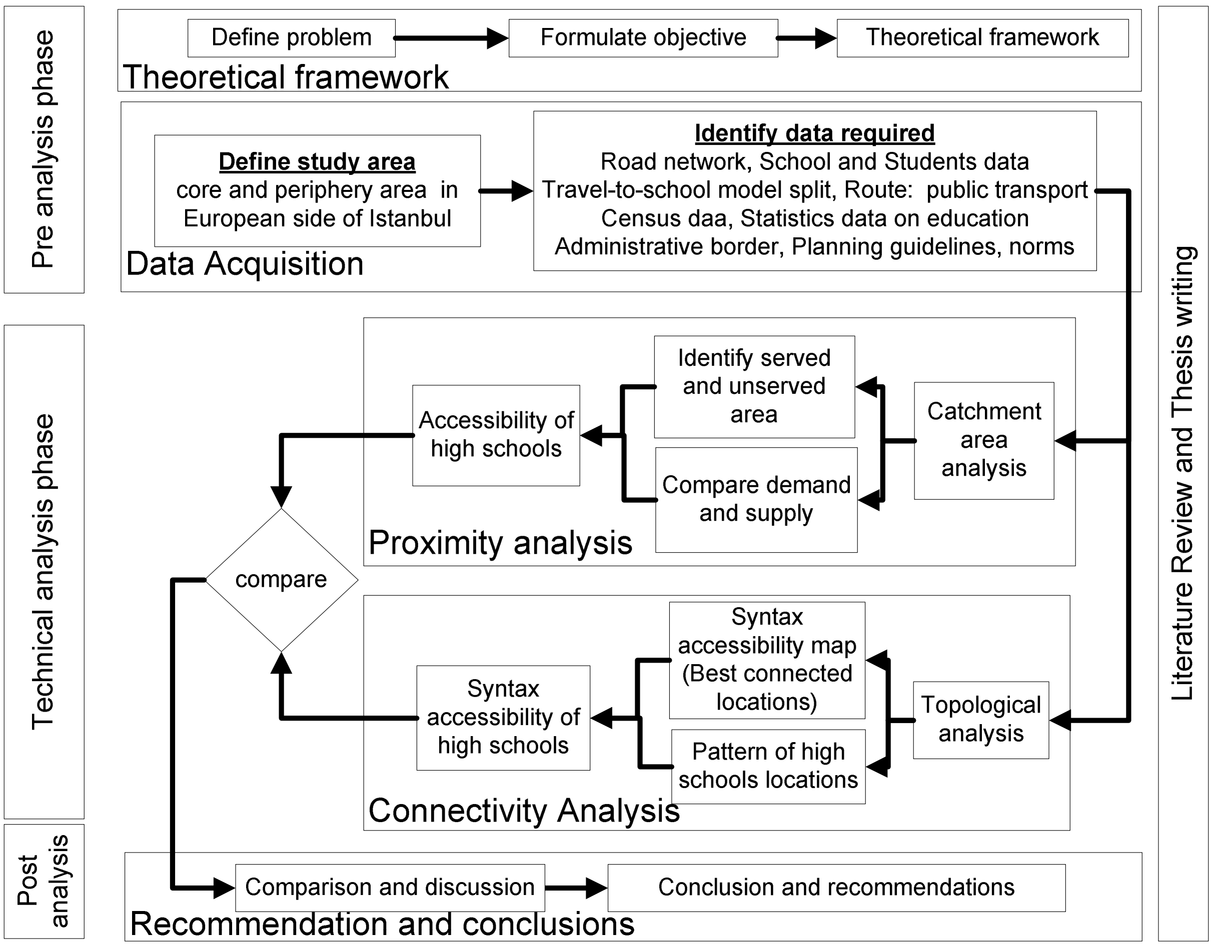



**Figure 1-2: Research Framework**

## 1.8. Organization of the Thesis

This thesis is structured into seven chapters and their contents are briefly described as followings:

**Chapter 1: Introduction**

In this first chapter, some general information is given that include background of the study, problem statement, research objectives, research questions and research design.

**Chapter 2: A Theoretical perspective on proximity and connectivity**

This chapter gives a theories review. First, Accessibility measures, their applications and choice of measure for urban public facilities planning in particular high schools are described in this section. Second this chapter review about urban topology and its parameters, which relative to this research topic.

**Chapter 3: Data collection and preparation**

A methodology for this research will be developed in this chapter, including the methods of space syntax to analyze topological analysis and accessibility analysis based on the high schools locations. This study presents some background of the Istanbul, Turkey.

**Chapter 4: Accessibility and locations analysis of High schools in Istanbul, Turkey**

Based on GIS, this chapter analyzes the accessibility of high schools locations, evaluates the current distribution and the profile of the high schools (education).

**Chapter 5: Space Syntax analysis of the urban networks and public transport networks**

This chapter presents some technical principles in space syntax analysis regarding the characteristics of high school locations and sums of the syntax accessibility pattern of selected areas of Istanbul through analysing the space syntax accessibility of transportation network and public transportation networks.

**Chapter 6: Comparison between the proximity and Connectivity**

This chapter analyze the current distribution of high school, identifies similarities and dissimilarities between the accessibility of high schools location with respect to the urban transportation network and the spatial pattern of high schools based on the results of chapter 5 and chapter 6.

**Chapter 7: Conclusions and Recommendations**

This chapter presents the conclusions derived from the results and findings of this research and provide some recommendations for supporting the added value of connectivity over the proximity measures for the high school planning in future.

# 2. A theoretical perspective on proximity and connectivity

This chapter introduces the theory related to proximity and connectivity. This gives an overview of theories related to central places an use this to examine issues of services in urban centre and the concept and measurements of accessibility and connectivity measures that could be useful in public facilities planning as identified in the existing research.

## 2.1. Central Places; the Origions and Definitions

The term central place was coined back in 1931 by an American geographer (Jefferson 1931). However, the Central place theory is formulated by the German economist Walter Christaller in 1933. The theory suggests that the number, size and distribution of cities as central places are organized by invisible laws and form an orderly hexagonal hierarchical pattern. Activities could be ranked with respect to the population size and number of central activities (Beavon 1977). It was also suggested that the population of an urban centre could be specified as a function of the number of business firms of each type of business. As like the Christaller's suggestion that through the working of the income mechanism the population of a central place is a function of the number and types of central commodities and services it provides.

However, the study of centrality has a long history in network analysis. Within the graph theory and network analysis there are various measures of the centrality of a vertex that determines the relative importance of a vertex; for example, how important a person is within a social network, or, in the theory of space syntax, how important a room is within a building or how well–used a road is within an urban network. Zemljic and Hlebec (2005) suggest different measures of centrality that includes degree centrality (Freeman 1978; Tomko, Winter et al. 2008), eccentricity, closeness (Freeman 1978; Tomko, Winter et al. 2008), stress, betweenness centrality (Freeman 1978; Freeman, Borgatti et al. 1991; Tomko, Winter et al. 2008), eigenvector centrality (Bonacich and Lloyd 2001), community centrality and connectedness. It is not easy to find a strict definition but the least to require is that a centrality measure is a real-value function that depends only on the structure of the graph and no other outside information.

Among the proposed measures of centrality and prominence 'degree centrality' is the simplest and most straightforward of the centrality indices. Degree centrality is based on the number of units directly connected to the unit under scrutiny (Zemljic and Hlebec 2005). The simplest definition of actor centrality is that the most central actor must be the most active, in the sense that this actor has the largest number of ties to other actors in network (Freeman 1978; Zemljic and Hlebec 2005). The measure is focused on the level of communication activity. In a directed network we have two distinct degrees of centrality measures: in-degree and out-degree. The connectivity is the measures of direct access to lines and points from the same elements that are immediately adjacent to them, that link with them directly (Batty 2004). More appropriate measures of distance although taking account of such adjacency based on indirect links between the system elements. The usual form is to calculate shortest routes between the elements, thence computing the associated in-degrees and out-degrees which provide measures of potential accessibility.

'Closeness centrality' is defined as the inverse function of geodesic distance between the actor and the all other actor in the network also called the shortest path (Freeman 1978; Zemljic and Hlebec 2005). It is also apparent that all of the measures considered so far count the number or volume of walks of some kind joining each node to all nodes. Another set of centrality measures assesses the lengths of the walks that a node is involved in (Borgatti and Everett 2006). We called these length measures. It refers to what property of paths (their number and their lengths) is being measured. Direct measures of closeness can be obtained by transforming the distance matrix into a 'nearness' matrix. In this case this matrix is an indicator of social proximity among nodes (Borgatti and Everett 2006). This proximity is more associated with accessibility, which interns more related to facilities planning.

## 2.2. Centrality in the context of facility planning

It is generally felt that the close the facilities are to the users, the better the service provided. In urban context, these facilities are more accessible in spatial terms, due to transportation links, which supports possible interaction, both social and economic, the possibility of getting from home to a multiple destinations is relatively easy (King 1984; Batty 2004; Dargay and Hanly 2004).

The coverage of public facilities affects residents in two ways. "One is the service range of the public facility, which is equivalent to the accessibility to a public facility such as a park or school that supplies services via traffic networks. The other one is the impact range that results from site-noxious facilities; its effect on residents is determined by the shortest distance, a straight-line distance where possible" (Tsou, Hung et al. 2005). According to the service/impact range, urban public facilities are subdivided into three levels: municipality, community, and neighbourhood. For example, the service range of municipal facilities such as town parks, universities, museums and dump sites covers the entire city. The service radius of community facilities, including junior and senior high schools, generally depends on social norms in terms of a minimum service delivery, for example, 20 minutes or roughly 1.8 km of walking from home to the high school location as explained in Canadian and Taiwanese cities (Hallak 1977; Tsou, Hung et al. 2005; Sabean 2007). In current practice, GIS based proximity measures are used to determine the areas that are properly covered by existing public facilities with consideration of spatial equity and accessibility of the location (Tsou, Hung et al. 2005). This concept of proximity is discussed in 2.3.

In recent years, space syntax has evolved into a set of tools linked to some nature of these theories, the two together giving rise to a set of interpretative models for different socio-spatial phenomena (Vaughan 2007). Space syntax models the spatial configuration of urban spaces by using a connectivity graph representation. Such a configuration of space identifies patterns that can be used to study urban structures and human behaviours (Jiang, Claramunt et al. 2000). As like the movement, land use patterns, social and economic performance, crime patterns and many other aspects of function have all been investigated using this method (Hillier 1999), high schools locations are studied. The details of this concept are discussed in the section 2.4.

## 2.3. General conncept of Proximity

A public facility or service is defined as a facility to which people must travel to receive the service, or from which a service is provided to the whole community of interest in administration, economy, education, health, scientific research and physical training. In reality, these services are actually not consumed and benefited from jointly and equally by all (Amer, Ottens et al. 2007). But within a defined territory, public services have to be located at particular point(s). These services are theoretically equally available to all. To have access to these points of supply, individuals will have to bear the cost of travelling to the facility as well as any costs related to their actual use. The costs are time or money or effort or all of them. The frequency with which service will be consumed will decreased with increasing distance from the facility up to a point where demand for that good or service will became zero (Dicken and Lloyd 1990; Amer, Ottens et al. 2007). Hence to have an efficient use of facility, different aspects of accessibility have to be studied.

### 2.3.1. Concept and components of Accessibility

Accessibility is generally associated with the ability of people to reach their desired goods, services, activities and destinations. It usually relates the people (origins) and services (destinations) through the transport link between them. Moseley (1979) argues that the basic notion of accessibility embraces three components: People, activities and the transport or communication link between them as shown in Figure 2-1. Jiang, Claramunt et al. (1999) view accessibility as the relative 'nearness' or propinquity of geographic locations of one place to another. In other words, accessibility is widely used spatial analytic measure defined as the relative 'proximity' of one place i to other places j (Jiang, Claramunt et al. 1999; Stahle, Marcus et al. 2007). In general terms the measure can be defined as:

$$A_i = \sum f(W_j, d_{ij})$$

Where $W_j$ is some index of the attraction of j and $d_{ij}$ is a measure of impedance, typically the distance of travel time of moving from *i* to *j*. Defining how to measure d*ij*, the 'distance', 'transport cost', or 'energy effort to move' from *i* to *j*, is then obviously a critical part of an accessibility measure. The most common distance units used within accessibility research are: Euclidian metric distance, travel time, travel cost and monetary charges (Stahle, Marcus et al. 2007, p.26).

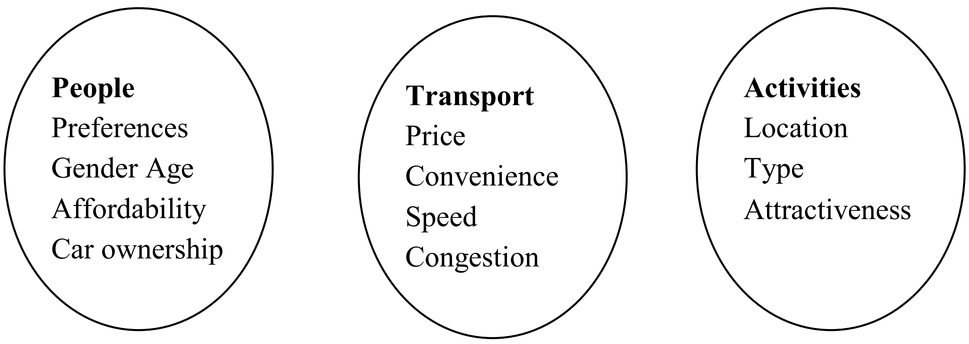



**Figure 2-1 Components of accessibility (Moseley 1979)**

Moseley (1979) framework (Figure 2-1) shows that the accessibility varies with the characteristics of the people, of the activity or opportunity and of the transportation infrastructure. Both the size and the composition of the population affect accessibility. Population determines the scale of demand or the need for public services. Activities reflect the spatial distribution of activities at distribution and attractiveness for activities. The links reflect the travel time, costs and effort to travel between origin and destination. Accessibility is the combined characteristics of these three components. As this theory of Moseley suggest, the accessibility is the results of relationship between socio-economic and the spatial dimension that existed in the real world.

According to Geurs and Ritsema Van Eck(2001) components of accessibility are identified as the outcome of four interrelated components as in Figure 2-2:

1. *Transport component*: travelling from origin to destinations
2. *Land use component (spatial):* spatial distribution of supplied destinations like location of schools
3. *Temporal component:* availability of opportunity and the time individual participate the activities
4. *Individual component:* reflects the needs, abilities and opportunities of individuals.

The purpose of transport component is to describe how people overcome the friction of distance that separates the point of demand from the point of supply. Spatial component generally refers to the consumption and production in space. In terms of education, it reflects the spatial arrangements of high schools provision in relation to spatial variation of education needs of the people. A temporal component of accessibility describes the availability of services at different moments of time. The individual components of accessibility measures refers to the characteristics of individual population under study using social, economic, and demographic characteristics (Geurs and Ritsema van Eck 2001; Amer, Ottens et al. 2007).

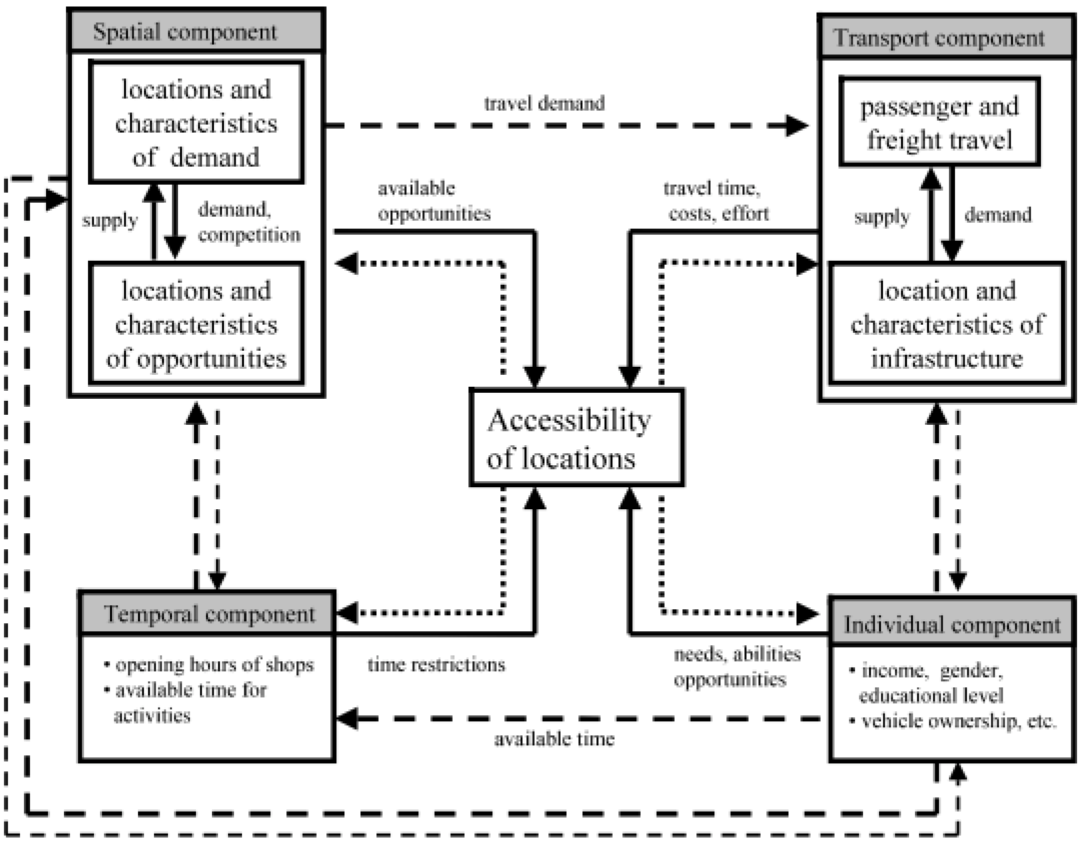



**Figure 2-2 Relationship between the components of Accessibility (Geurs and Ritsema van Eck 2001)**

### 2.3.2. Accessibility and Facilities planning

Accessibility can be applied between two places to show the relationship between the location of the service, and the location of the settlements where people that would use these services live; simply it is a relation between the supply and demand(Geurs and Ritsema van Eck 2001).

In general, the given aim of public facilities planning can be described in twofold.

1. Facilities are supply as near as possible to demand in order to reduce the transport cost.
2. The cost of establishing the facilities is keep low as possible by reducing the number of facilities to be established.

Educational facilities best illustrates the so called geographical approach which focuses on the geographical proximity of services as an important determinant of utilization behaviour. For instance for the purpose of school location planning at the local level, called the school mapping, use the concept of catchment areas. The catchment areas is the geographical area served by a school which is defined by the maximum acceptable distance a child can travel between home and school, the size of the school and the density of school age population.

### Accessibility measures

Accessibility measures can be categorized in several ways. The basic perspectives on measuring accessibility are as identified by (Geurs and Ritsema van Eck) (2001) includes: Infrastructure based accessibility measures, Activity based accessibility measures Utility based accessibility measures. Some of the key elements of these measures are highlighted in the following section:

**Infrastructure based accessibility measures**

These measures are used in transport based studies and infrastructure planning. The average speed of the road network, journey times, and operating system of the road network and congestion level provides the valuable insight of the service level of the infrastructure in an area. Improvements in accessibility as measured by infrastructure based accessibility measures is generally considered important for economic development of the regions or population.

**Activity based accessibility measures**

These measures used the travel impedance between the origins and destinations to analyze the range of available opportunities. Activity based can be further divided into two main categories as: first, geographical accessibility measures the number of opportunities within a specified travel period on a macro level (for example, the number of jobs available within 30 minutes of travel time); and second, time-space measures of the activities in which individuals can participate at a certain time at micro level (for example, whether individual or household activity programmes can be carried out given the location of activities and time restrictions). These activity based accessibility measures can be further categorized further as:

***Distance measures:*** A very simple measure counts the distance from one location to a given destination, for example the high school, the closer the destination the higher the accessibility. Measuring accessibility by average distance estimates either the average distance from departure points in the area or the opposite, the average distance to all destinations from one departure points or zone. The attraction of the destinations is not included in this measure.

***Contour measures:*** These measures indicate the number of opportunities reachable within a given travel time or distance. If more opportunities can be reached the accessibility will increase. They incorporate the transport impedance of travel time, cost and distance together with the land use component of location of facilities.

***Potential accessibility measures****:* These measured has been developed and used in the form of market potentials in location analysis. These measures describe the accessibility from one origin to the all opportunities in other words ‘the potential of opportunities for interaction’. It can be represented as:

$$A_i = \sum D_j \, d_{ij}^{-\alpha}$$

Where: A is the measures of accessibility at zone '*i*' to all opportunities D ate zone '*j*'. *dij* is the distance between *i* and *j* and $\alpha$ is the parameter reflecting distance friction.

***Accessibility measures from space-time geography**:* In these measure the time component and distance component is considered equally important. Several pattern for example; Model of Action Space in Time Intervals and Clusters (MASTIC) has been used to study the effects of time and transport policies on accessibility, different activities such as schools, jobs, shops etc.

**Utility based accessibility measures**

These approaches are used in measuring economic studies. These measures interpret accessibility as the outcome of set of transport choices. These accounts for the individual accessibility on users' characters such as travel costs and speed.

### 2.3.3. Comparison between measures

**Table 2-1: Types of accessibility measures and their comparisons**

| Measures | Major consideration | Weakness | Aggregation level |
|---|---|---|---|
| Infrastructure based accessibility measures | Considers travel speed, travel time, and congestion | Characteristics of individual are not considered | Transport and infrastructure planning |
| Distance measures | Calculates either straight-line or network distances | Cannot calculate the accurate description of reality, for example, may not consider congestion | Land use polity and geographical studies |
| Contour measures | Choice of cut-off travel distance and time | Generalize their travel time or cost for certain distance | Analysis of accessibility of jobs, facilities and services |
| Potential accessibility measures | Accounts the accessibility from one origin to all opportunities | Does not account the characteristics of individuals and spatial distribution of demand | Analysis of accessibility to jobs, facilities and services; market potentials |
| Utility based measures | Individual in the same location has same level of accessibility | Does not support relatively complex theory. | Access to spatially distributed activities |

Infrastructure-based accessibility measures may result in different conclusions on accessibility then activity based accessibility measures, which incorporate both transport and land use component of accessibility. Distance based accessibility measures simply combine the location of an activity with the transport system. This measure can be used if the destination is known. Contour measures describe the transport and land-use system from the user's point of view by estimating the travel time or cost to reach fixed number destinations. Potential accessibility measures denote the range of choice offered by the land-use transport systems though it doesn't account for possible capacity limitations of the supplied opportunities. Utility based measures has sound more theoretical base and it has better behavioural basis then basic potential accessibility measures.

### 2.3.4. Selection of accessibility measures for high school planning

From the literature of accessibility measures, it is clear that accessibility can be measured and evaluated in variety of ways. As the current focus is on the accessibility of high schools, it is important to choose the appropriate approach. The selection of approach can strongly influence the result of analysis. Therefore, the number of criteria for selection of appropriate methods of measuring accessibility has to be defined. Among them the most important are as follows:

1. Consideration of travel time or distance of student from home to school.
2. The measure which can incorporate the accessibility of origins (demands) and capacity of destinations (high schools).
3. Existing rules to attend the nearest in case of general public high school in study area (Turkey).
4. There are national/international socially accepted norms, in the case of high schools, the cut off distance of 1.6 - 2 km or 20 minutes of walking are applied especially in case of Canadian and Taiwanese cities (Pearce 2000; Ewing, Schroeer et al. 2004; Ministry_of_National_Education 2006-2007; Allen 2007; Sabean 2007; Müller, Tscharaktschiew et al. 2008).
5. Ethical framework that supports the spatial perspective on welfare maximization, equity and efficiency for distribution of high schools.
6. Existing availability of data has to be considered.

In fact, there is hardly any approach that measures the accessibility perfectly. Different situation and purposes demand different approaches. Among them contour measure is more appropriate for this case because of the following reasons:

1. In contrast with the potential measure, contour measure is more stable
2. The contour measure and its parameters, the distance range, are easily interpreted in real world terms.
3. The cut off distance fixed cost and fixed population can be applied in contour measure
4. It satisfied one of concept of accessibility, where three basic components of accessibility, people, activities and links, can be modeled with the available data in more realistic approach.

Again, the analysis is focused on the accessibility, distribution and capacity of high schools. The accessibility questions are: How much percent of population are within the serviced areas? What is the average travel distance in the current situation? How can accessibility be improved? All these questions can be answered based upon the contour measure. The characteristics and its data requirements are discussed in the following section.

### 2.3.5. Characteristics and requirements of contour measure

Contour measure also called *proximity distance or proximity count* is a measure that indicates the number of opportunities reachable within a given travel time or distance. This measure indicates that accessibility increased if more opportunities can be reached within a given travel time or distance. This increase can be the result of a change in the ease of reaching destinations and land use change. Basically three types of contour measures are identified as(Breheny 1978; Geurs and Ritsema van Eck 2001):

- *Fixed costs* : number of opportunities accessible within a fixed cost limit, the rationale of this measure is derived from the case of a business traveller who wishes to travel to a certain city, conduct business there and return on the same day for example the health services, retail services, education etc
- *Fixed opportunities*: The time or the cost required to access to certain numbers of origin activities reaching the specified levels of opportunities are measured and summarised to give a measure of accessibility. This method is adopted by most literatures and most popular.

- *Fixed population (origin activities constant)*: In this method the average number of opportunities, high school, available to all zones in costs band away from the zone is calculated. "The number of origin activities (population) is not specifically calculated and is, is effect, held constant at its total level whilst changes in opportunities and costs are observed" (Breheny 1978 pp 472).

According to three basic components of accessibility, people, activities and links (Moseley 1979), the corresponding data for this study can be fulfil in our research. The population with their ages is used to calculate numbers of potential students, which is called demand. The transport components of real road networks bridge the schools and the students. The activities components include the location and characteristics or capacity of schools, which is used to calculate the service area.

## 2.4. Concept of Connectivity

In this section, topological analysis of space syntax is described to analyze the pattern of high schools and it also analyzes the correlation between the transport network and high school locations.

### 2.4.1. Urban Topology

As stated by Hillier and Vaughan (2008), "The basic urban relation is that the configuration of the urban street network, which is the largest spatial pattern in the city, is in and of itself a key determinant of movement flows and so co-presence in space. This has a huge consequence for both form and functioning of the cities." The syntax approach take the predominantly linear nature of urban space seriously, and propose a representation of the street network based on the longest and fewest lines that could be drawn through the system (Hillier and Hanson 1984). We then treated the lines as the elements of a graph, with the junctions as links and we could then calculate the measures of integration and choice variable radii as we wanted. The decision to make the lines into elements, had the effect of internalizing the line structure into the graph, and so in effect capturing key features of the geometry of the street network in the graph (Hillier and Vaughan 2008).

### 2.4.2. Theory of Space Syntax

This theory has its origin as non discursive theory of architecture, which later found its application in many studies regarding movement in cities. Recently, it has been developed further with the integration on GIS and is being used by many researchers for studying many urban phenomena.

Space syntax study considers the spatial configuration as an independent variable in the analysis of social systems. Any spatial configuration that we see around us can be represented by axial lines. Axial lines show the line of visibility from the origin, or eye level, to the point of maximum vision. (In case of ArcGIS application, axial line is based on the principle of present road map (street network) and it can be used as an alternative of axial map). An axial map is defined as the least set of straight lines that pass through all the open space. Analysis of an axial map enables the computation of relative nearness or accessibility, in common terms.

The notion of relative nearness can be analyzed through variables of global integration and local integration. Thus the street having highest global integration means it has better connectivity to the whole street networks than all others. A street with a high local integration is better connected to its immediate neighbouring streets.

### 2.4.3. Space syntax parameters

In space syntax analysis, axial lines are the study object and the topological relations are reflected by parameters of the axial lines. These parameters include connectivity, control, depth and integration. These parameters are briefly discussed below.

**Connectivity, C*i***

The number of lines or axial lines (roadway, alley or trail) that are directly link to the particular given (axial) line is defined as connectivity. This variable reflects the relationship between one space and another space, which intersects it directly. It is supposed that all city roads are connected to each other, but the degree of connectivity is different. The more connected roads are considered as more central and the measure of connectivity reflects the importance of street in overall network and in actual mobility and use by the population. The minimum connectivity value equals one that means the road is lying in outskirts or the dead ends. For the particular axial line ($i$) the connectivity is defined as:

$C_i = k$

Where k is the number of direct connections

**Control value**

As like the connectivity, control measures the relationship of one space to the others. The spaces that have high control value mean that have a higher control over their immediate neighbourhood. Sometimes, control measure is defined as a modification of connectivity. It measures the degree to which a line controls access to its immediate neighbours taking into account the number of alternative connections that each of these neighbours has. Simply, control value represents the degree to which a line is important for accessing neighbouring lines. A high control value indicates the line is important, almost necessary, link of neighbouring lines (Baran, RodrÃguez et al. 2008). To better understand this concept, consider a straight street segment that is connected to three different dead-end streets and another street segment that is connected to three other non-dead end streets. The former street segment has higher control value, as access to any of the three dead-end streets is possible only through the segments. The later street segment has lower control, as there are alternative streets to access that three non-dead end streets. In addition, a street segment that has more connections potentially will have a higher control than a street segment that has fewer connections. Hence control can also be used as local connectivity. In other way, control value is defined as the sum of the reciprocal of the space being shared by the neighbours of a line.

$$Ctrl_i = \sum_{j=1}^{k} \frac{1}{C_j} \qquad \textbf{2-1}$$

Where '$k$' is the number of direct connections and C$j$ is the connect value of the directly linked line '$j$'

**Depth, D*ij***

To go from one line to all other lines, one has to pass through one or more intermediate lines. However, the shortest number of steps required to reach from one line to any other line is known as the distance between the two lines. If the number of steps required to pass from one line to all other is higher compared to other lines it implies that the particular line is deeper than other lines, where if the number of steps required is less than that line is shallower than other lines. If the depth in calculated at *s* = 3 then it is known as local depth and if it is calculated for s = m where m is the total number of steps to cover the graph then it is called total depth or global depth. Hence, depth is defined as the number of spaces being connected to the particular space after each increasing step as shown in the equation 2-2.

$$D_i = \sum_{s=1}^{m} s \times N_s \begin{Bmatrix} connectivity\ iff\ s = 1 \\ local\ depth\ iff\ s = 3 \\ global\ depth\ iff\ s = m \end{Bmatrix} \qquad \text{2-2}$$

Where s is shortest distance from a given axial lines to another and $N_s$ is number of connecting at step '*s*'.

The number of links that are being connected to the particular link with each other increasing step in the system gives an idea of the relative compactness of the graph. Again, if we closely look at the depth, for example, to reach from any line to a particular line there must be one or more intervening lines and a respective number of steps. The average number of steps to reach of the lines is the graph to that particular line is called the mean depth of that line. It is very useful to understand the grid structure of the system. It also suggests that the higher the mean depth of the space lesser the movement and lesser the depth high is the observed movement. Mathematically, mean depth is represented as:

$$(Mean\ depth)_i = \frac{global\ depth}{n-1} \qquad \text{2-3}$$

Where n is the total number of lines in the graph.

**Integration**

Integration is an indicator of how easily one can reach a specific line of the axial map. Mathematically, integration is an algebraic function of the number of axial lines that must be traversed if one were to move from every line or street to every other line or street in axial map. The higher the integration value of a line the lower the number of axial lines needed to reach that line. For a given line, integration can be computed in terms of access from all other lines, which is called global integration. Global integration value of one specific axial line reflects the route complexity from it to all others in the road network. Higher the global integration value represents the line is (relatively) easily reachable from all networks as compared to others lines. In terms of those lines that are accessible up to a given number of lines away is called the local integration. In syntactical analysis this is called the radii (Baran, RodrÃguez et al. 2008). Local integration can be a measure of local syntactical accessibility if the radius is small. If we limit the analysis to radius of 3, it means that the integration measure for a line will be calculated by considering only lines that are up to three turns away. These are the lines (spaces) that could be easily accessible from the surrounding areas with minimum efforts. Therefore, local integration can be a measure of local syntactical accessibility if the radius is small and global integration can be a measure of general accessibility if the radius considers all lines in the axial map. The axial lines with highest degree of global integration would be the one that could be accessed with the least number of turns from all other axial lines. By contrast, an axial line that requires many turns to get to it from all other lines in the system is considered to have low syntactical accessibility and will have a low global integration value. Similarly, an axial line with the highest local integration value is a line that is accessible with the least number of connections from all other lines in its surrounding.

The integration value is the number of relational asymmetry which represents the accessibility and penetrability of the certain road space. Considering different depth, the Integration constitutes Local Integration and Global Integration.

$$I_{(i)} = \frac{1}{RRA_i} \frac{n\,[log_2\left(\frac{n+2}{3}-1\right)+1]}{(n-1)|MD-1|} \quad \text{2-4}$$

$$MD = \frac{\sum_{s=1}^{m} S \times N_s}{n-1} \quad \text{2-5}$$

Where,

$I_i$: Integration value of the given axial line within i steps

*n*: the total number of axial lines within i steps

*MD*: Mean depth

*RRA*: Real Relative Asymmetry defined as the ratio between the theoretical depth and the actual depth

***Connectivity***: when i=1 the integration value is called connectivity

***Local Integration***: when i=3 the integration value is called Local Integration

***Global Integration***: when i=m the integration value is called Global Integration

The connectivity and local integration measures the degree of integration or segregation at the local level where as global integration measures the degree of integration at global level. Basically there is a correlation between these local and global parameters. This correlation is term as 'Intelligibility', which is discussed in the next section.

### 2.4.4. Intelligibility

Jiang, Claramunt et al.(2000) defines intelligibility, 'the coefficient of correlation between local and global parameters'. This shows that the intelligibility is a syntactic measurement obtained by the statistical correlation between the global integration and local integration. In fact intelligibility of a network indicates the relationship local and visible spaces located either one step or three steps away; for one step, the correlation of global integration and connectivity are used and for three steps correlation of global integration and local integration are used. (Lima 2001).

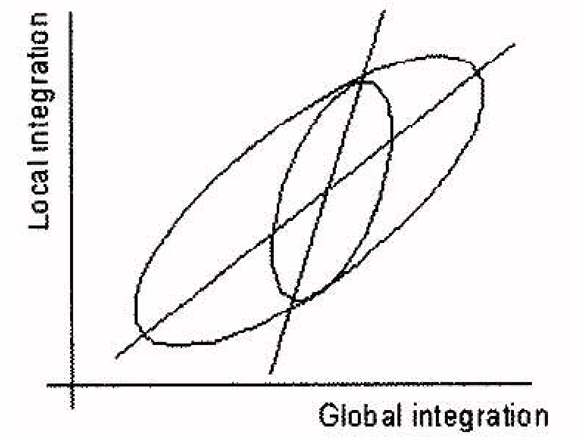



**Figure 2-3: Intelligibility (Jiang, Claramunt et al. 2000)**

As illustrated in Figure 2-3, the large oval represents the cluster of all spaces of a whole area, which means all lines in the system, while the small oval represents the cluster of selected local area, for example, small neighborhood or selected lines of existing school locations. A local area is considered intelligible if its coefficient value is higher than the one of global area.

## 2.5. Accessibility in contour measure and space syntax theory

From these theoretical sketches we can draw two conclusions separately for two theories, which can be correlated in the coming chapters for the planning of high schools. As identified, the first is the generic concept of accessibility- “which pertains to locational behavior where physical infrastructure is implicit and the definition is one of how proximate or ‘near’ an individual is to opportunities”(Batty 2009), here we called it proximity. The second type of accessibility measures the physical infrastructure but as it is still locational behavior, this “measures the shortest routes in a network which result from the underlying planar graph or physical connections, where segments defining the arches of planar graph are connected to one another if they intersect”(Batty 2009). This type of accessibility gives the accessibility of street rather than a fixed point or node. This method is used in space syntax. In this study, we called this the accessibility based on connectivity.

Accessibility based on proximity analyses provide enough background for urban facilities planning, for example, high schools. As specified in the previous sections, the selection of contour measure in high school planning follows the components of accessibility measure of people, link and Activities as origins, transport and destinations respectively as shown in the Table 2-2.

**Table 2-2: Components of accessibility and their representation**

| **Components of Accessibility** | **Accessibility using Contour measure** | | **Accessibility using Space syntax** | |
|---|---|---|---|---|
| | **Representation or Coverage** | **Notes** | **Representation or Coverage** | **Notes** |
| Activities | Explicit | Destinations (characteristics of high schools) | Implicit | |
| Transport | Explicit | Transport (Road network) | Explicit | Axial lines (centre lines of road networks can work as axial lines) |

| | | | | |
|---|---|---|---|---|
| People | Explicit | Origins (Potential students) | Implicit | |

Again, One of the most widely applied measures of accessibility is based on the theory of urban morphology which is called space syntax (Hillier and Hanson 1984). “However, space syntax defines the accessibility of streets, not nodes linking streets or defining locations along streets although the vertex-edge or node-arc representation is central to its conceptualization and operation” (Jiang, Claramunt et al. 1999, p. 132). Space syntax has evolved into a set of tool linked to a set of interpretative models for different socio-spatial models. Interpretative models are schemes of analysis which work for particular phenomena, for example, urban movement model or land use model or crime model and so on. These models show that by clarifying space in a particular way the social origins and consequences of the spatial patterns can be brought into clear view (Vaughan 2007, p. 208). It is clear that the configuration of urban street network, which is the largest spatial pattern in any city, is a key determinant of movement flows and hence co-presence in space. For example, consider a notional grid with a main street, cross street, side streets and back streets and imagine that these streets are lined with houses and people move between the houses by using more or less the direct routes. Then the flows of people through the main-street will be more than the side-street or back-street. The main street is easier to get to than other streets, hence it is more accessible. It shows that the spatial configuration of streets itself can represent the different social-spatial properties (Vaughan 2007, p. 215). The notion of space syntax captures these properties of space through the use of axial lines, which in many cases is represented by the urban networks and the different integration values for different axial lines indicate the importance of street segment measuring the local and global properties of street configurations. This study contributes the understanding of the syntactical properties of street design

Hence, unlike the contour measure (proximity measure), space syntax uses the properties of axial lines (or set of urban networks or transportation networks) to define the relative accessibility of the street segment. In this accessibility based on connectivity, directly associating the point locations, for example, the demand and supply points, is difficult and they are achieved with much higher level of abstraction as like associating the traffic flows as explain in the previous paragraph, these locations are implicit in set of networks having physical connections (Table 2-1). Positive relationships are expected between the centrality of space and the syntactical measures that can be useful in planning the facilities like high schools. As one have a close looks into the Table 2-2: Components of accessibility and their representation, the representation of activities transport and people has remarkable difference; the contour measure has the clear representation of all these three components.

Hence based on the theories of accessibility using contour measures and space syntax, the centrality of every location is determined parallelly and the results based on the centrality are compared for the locations of high schools. The centrality of locations could be higher in contour measure when the location can serve the large number of population or can have maximum number of facilities available. Likewise, the place is central when it is easily reachable, which represent the higher global and local integration values. These values of centrality can be assess and compared for the every location and the centrality of facility as well.

# 3. Data collection and preparation

This chapter brings describes and discuss the important aspects considered during data collection phase the chapter will introduce the data used in this research and their sources. In order to meet the objectives, the data for analyzing the spatial distribution of high schools, data on population (demand) and the high schools (supply) are required. These measures of supply and demand will be analyzed with the help of urban transportation networks modes of transportation.

## 3.1. Selection of the study area

### 3.1.1. A brief overview if Istanbul

Istanbul, a dynamic mega city with a population of more than 12.9 million (based on projection by the end of 2009) is Turkey's largest city. It shares the population 17.5% of the country's total population (Turkish_Statistical_Institute 2009). Istanbul is located on both the European and Asian sides of the Bosphorus Straits. It is bordered to the South by the Sea of Marmara and North by Black Sea. The European side of the city is further divided by the Golden Horn into Old Istanbul to the South and New Istanbul to north.

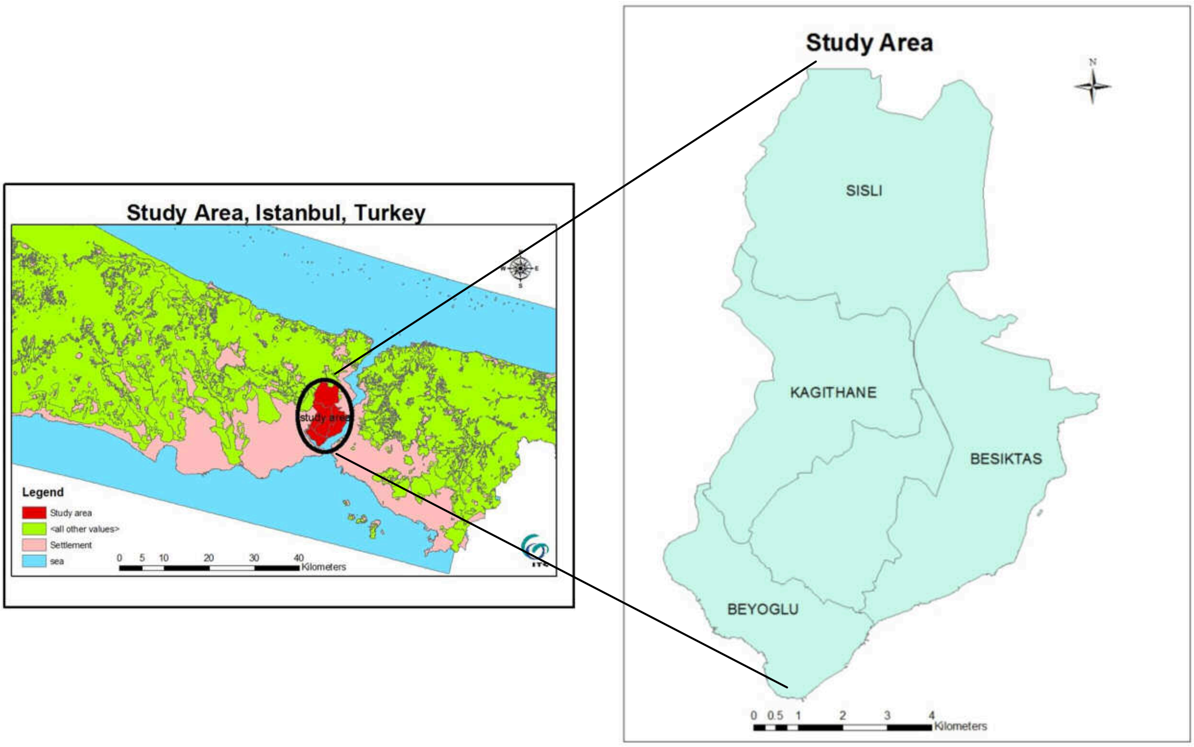



**Figure 3-1: Study area, Istanbul**

City of Istanbul, due to Mountains and water shed areas in the North, the city is growing rapidly in linear pattern along the Marmara Sea and also in the Bosphorus regions. The growth in the Bosphorus region is often marked as the addition of new bridge along Bosphorus. This growth of population as in

Figure 3-2,**Error! Reference source not found.** is marked as the heavily industrialization of the city. The existing two approved plans one existing from 2006 and other newly formed 2009 approved plans of the city aim to shift from the industrial to service metropolis in future (IMP 2006; IMP 2009). Two additional city centres one in each side of Bosphorus together with the existing CBD is planned to served this 150 kilo-meter long metropolis. Hence this city will shifts from mono centric to poly centric metropolis (IMP 2009). The addition of underground rail crossing along the Bosphorus and expansion of metro rails is intended to reduce the traffic problems.

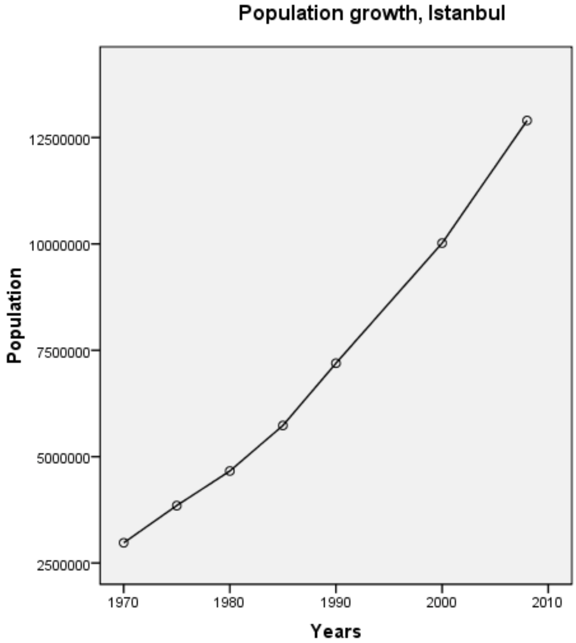



**Figure 3-2: Population growth, Istanbul (Turkish_Statistical_Institute 2009)**

## 3.2. The Education System

The overall structure of Turkish National Education system, determined by 'National Education Basic Act no 1739', consists of mainly two parts, called "formal education" and "non-formal education" (Ministry_of_National_Education 2008-2009). The National education basic act defines formal education as: "The regular education conducted within a school for individuals in a certain age group and at the same level, under programs develop in accordance with the purpose". Formal education includes pre-primary, primary, secondary and higher education institution. After the education reform, the primary education becomes the compulsory education in Turkey, and government has focused more in primary education in last decade. With the success in their plans, number of school students has been increased in recent years. This has also positive effects in secondary education too. Now the government has been focusing both on secondary and primary education.

Secondary education in Turkey includes all education institutions of a general or vocational and technical character with duration of at least four years following primary education. The objectives of secondary education are, "to give students a common minimum overall knowledge, to familiarize them with problems of the individual and society and seek solutions, to ensure that they gain awareness that shall contribute to the socio-economic and cultural development of the country and to prepare them for both education and profession or for life and employment, in line with their interests and aptitudes" (Ministry_of_National_Education 2008-2009).

Number of students per school in Istanbul for general secondary education is 535 and for vocational and technical school are 575. The average number student per teacher is 19 and 22 for general and vocational schools respectively. Class room per school is 31 and 48, general and vocational respectively.

There are more than 4000 education institutions in Istanbul metropolitan area. Among them, 600 pre-school education institute, 1500 compulsory education (primary education) institutes, 550 secondary education institute, 22 universities (more than 100 university units), more than 1200 public education institutes and 35 special education institutes, 4 police schools and 6 military schools (BIMTAS 2003; Ministry_of_National_Education 2008-2009).

The total demand of high schools is around seventy-seven thousands. This is calculated from the population categories between the 10-14 and 15-19 based on population pyramid (Figure 3-5). Since the opulation within the age of 14 to 17 years is assumed as the theoretical age group of populations for high school education, we calculate the population in two steps. First divide the total populations between age group 10-14 by 5 and for age group 15-19 divide it by 5 and multiply by 3. Then in second steps addition of these populations will give the aggregate population between the age group 14-17.

### 3.2.1. Secondary education in Istanbul

Table 3-1 shows the comparison of secondary institution Istanbul. It shows that there are 550 secondary education institutions in Istanbul metropolitan area (BIMTAS 2003; Greater_Instanbul_Municipility 2005; IMP and BIMTAS 2006; Metropolitan 2006; Ministry_of_National_Education 2008-2009). As like most of population live in European side, one can see, most of the schools are also in European side but the proportion of population to the school area is greater in Anatolian side of the city.

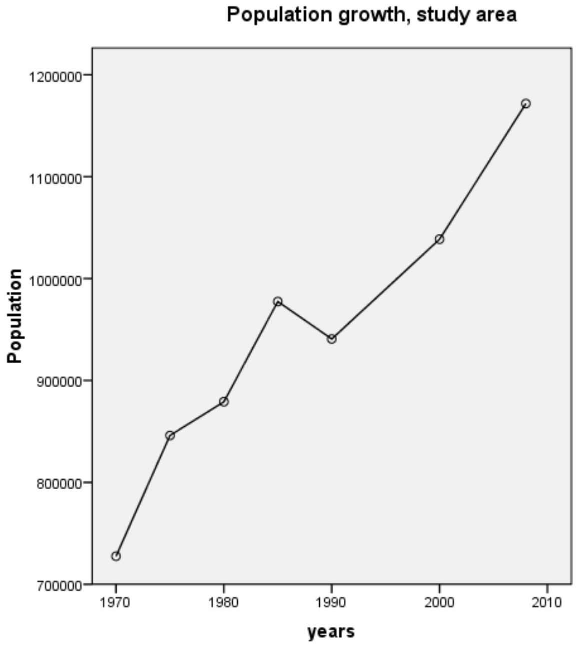
**Table 3-1: General distribution of secondary education institutions in Istanbul (Greater_Instanbul_Municipility 2005)**

| | **Population (2005)** | **Total no of High schools** | **% of high schools** | **Total parcel area of high school ($m^2$)** | **% share of high school area** | **Area Per capita for high schools ($m^2$/person)** |
|---|---|---|---|---|---|---|
| European side | 7233025 | 346 | 63 | 2111518 | 59 | 0.29 |
| Anatolian side | 3419753 | 204 | 37 | 1443091 | 41 | 0.42 |
| Total | 10652778 | 550 | 100 | 3554609 | 100 | 0.33 |

## 3.3. A profile of the study area

With the view of availability of useful data, and the period of field works in Istanbul, a part of city of Istanbul was selected for analysis. This study area consists of the four districts of Istanbul, Besiktas, Beyoglu, Kagithane and Sisli. It covers the area more than 76 sq km and population of more than 1.1 millions. The area has variety of population density from less than 8000 per sq km to more than 91000 per sq km (Turkish_Statistical_Institute 2009). This area is called New city area lies in North-East of Golden Horn and the West of Bosphorus (Figure 3-1). This area is characterised by the famous places and streets like Takshim Square, Shopping Street (Istiklal Caddesi). This area consists of high rise apartments, luxury offices, banks, hotels, consultants. Two major bridges which connect from Anatolian sides are the main traffic hub of this area. This area is also connected Galata Bridge Ferries and Bhosphorus Bridge Feries and is therefore a leading center of population, commerce, education and culture. It has variety of residential suburbs (old/ new, poor/ rich). With moderate population growth (Figure 3-3) and high to low density areas, most people live in the high rise apartments with no surrounding grounds.

From Figure 3-3 and Figure 3-4, one can distinguish the population growth rate in the study area and the rest of Istanbul; the former has uneven growth where as the later has steady growth in recent couple of decades. The composition of the population of the study area and rest of the Istanbul is shown in the Figure 3-5 and Figure 3-6, which essentially illustrates the biggest share of population are from the 15-29 years. The population age group containing 15-19 in both cases shares one of the biggest population categories; this is the majority of people who are attending the high schools in Turkey.



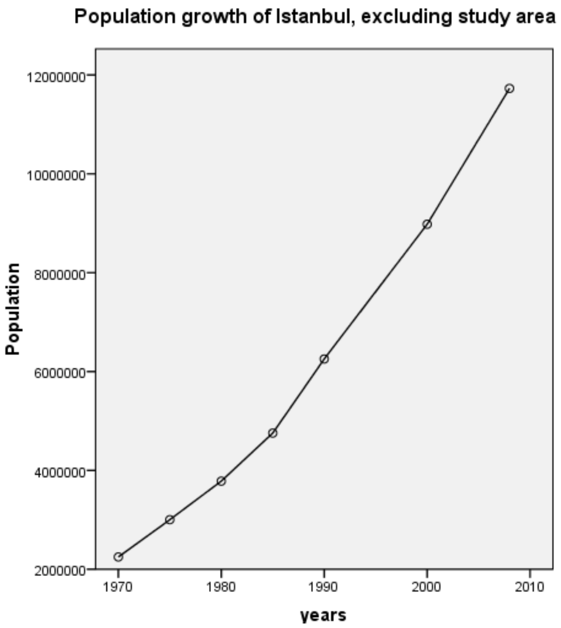
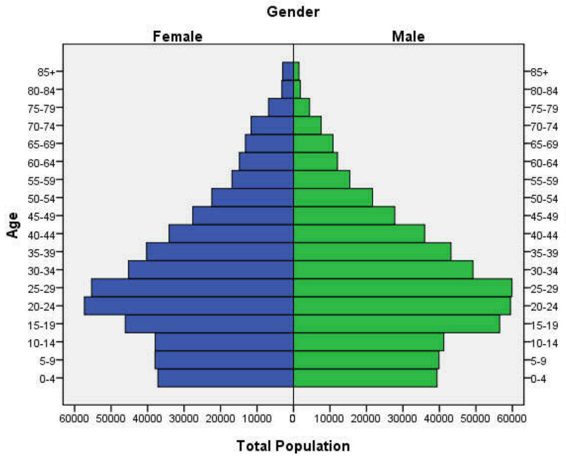




**Figure 3-3: Population growth, study area**
**Figure 3-4: Population growth in Istanbul excluding the study area**



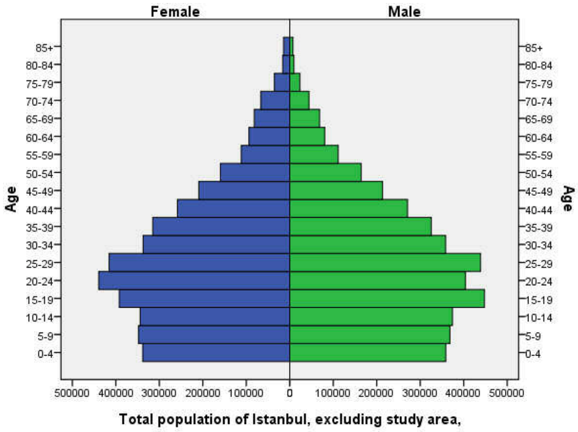




**Figure 3-5: Population pyramid of the study Area (based on year 2000)**
**Figure 3-6: Population pyramid of Istanbul excluding study area (based on year 2000)**

**High schools patterns**

According to the education policy of Turkish government there are basically two types of schools from the management point of view, namely private and government high schools. There are total 91 high schools in the study area among them the number of government high schools is 55 and the rest are private. Out of total those 27 are vocational in characters and rests are general high schools. From the study we can see that the domination of private schools till 1970. Figure 3-7 shows that the increase in number of high school in every five years starting from 1970. From this figure one can see the increase of high schools is higher after the implementation of new education law in 1996.

In general, government high schools are larger in size and distributed evenly in all areas as compared to the private high schools (Figure 3-8). Figure 3-9 shows that high schools are located around the 1st arterial and 2nd arterial roads.

Most of the students (more than 63%) in Istanbul walk to school (IMP and BIMTAS 2006). And those who use the motorized trips use service and public buses as shown in Figure 3-10. When we look at the hourly trips of the students from home to school and school to home, there is clear indication that school are running in more than one shifts. From Figure 3-10, at least two shifts of schools are seen one starting from early morning at six or seven and one from 12 noon.

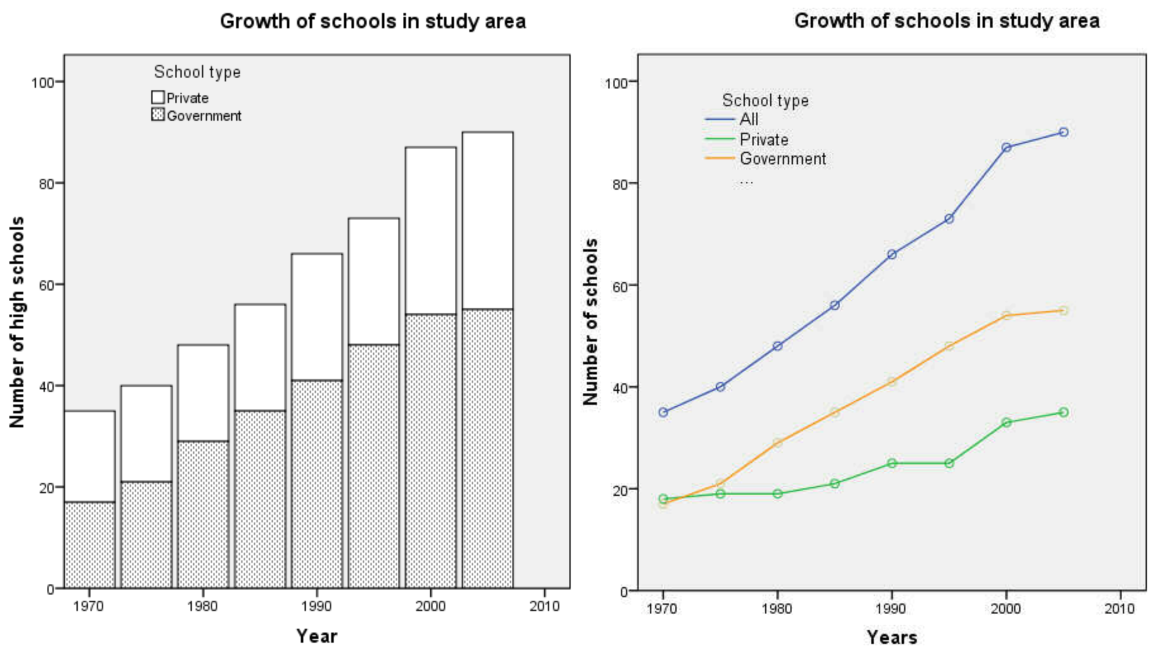
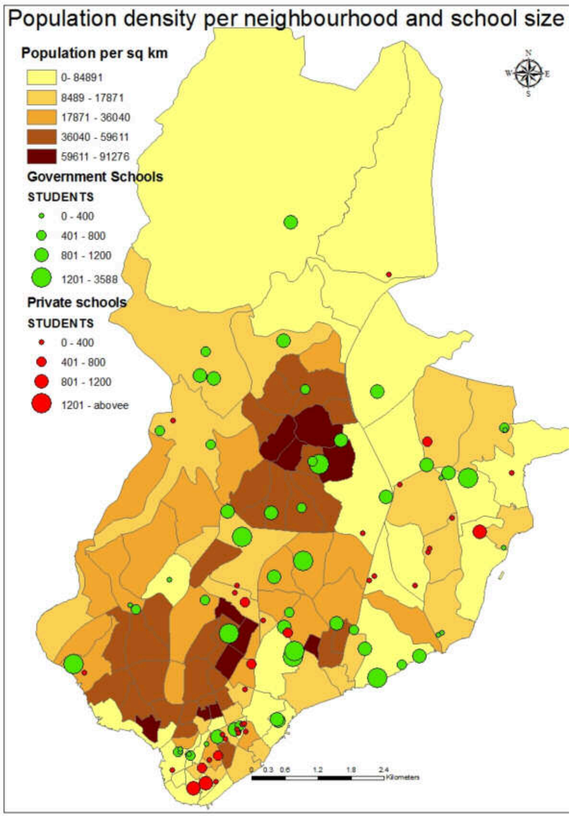



**Figure 3-7: Growth of high schools in the study area**



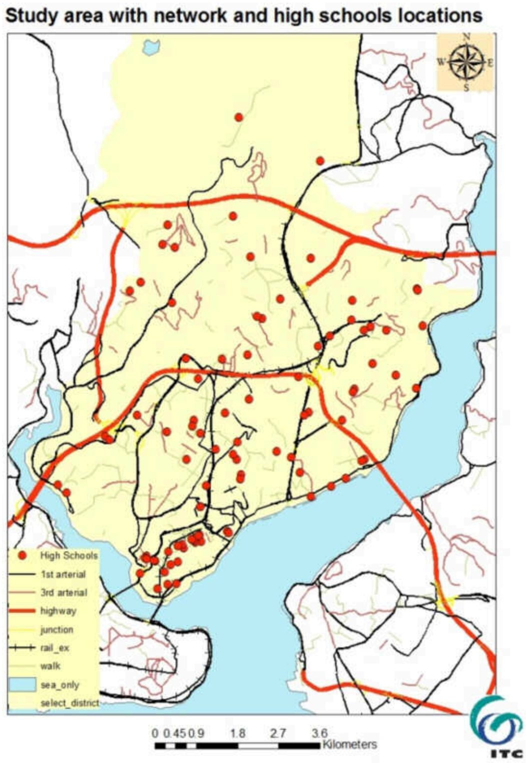




**Figure 3-8: Distribution of High schools**
**Figure 3-9: Urban network and high school locations**

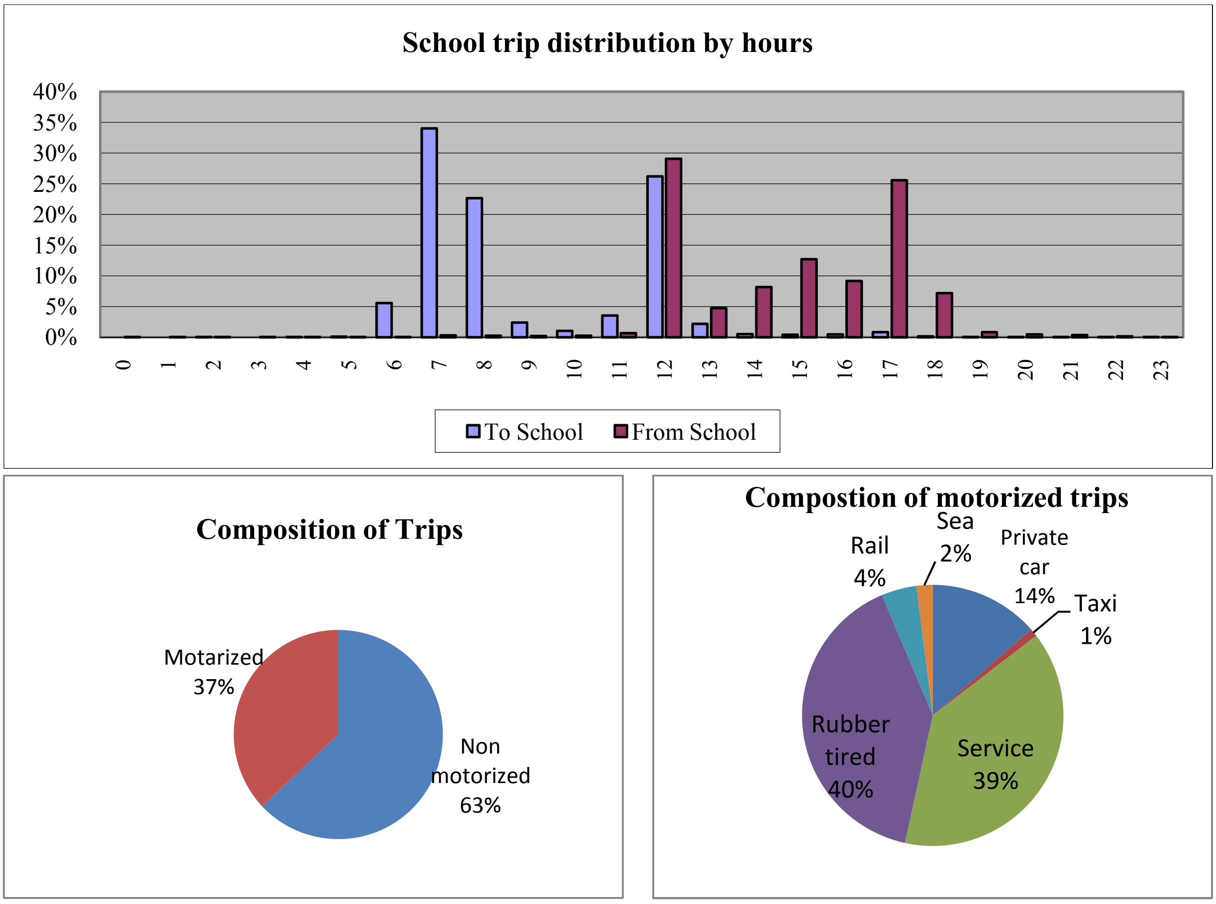



**Figure 3-10: School trip distributions and composition in Istanbul (week days) (IMP and BIMTAS 2006)**

## 3.4. Data Source and collection

This process basically involves two steps. One is the conceptualization of the data required and then the collection of data from the primary and secondary sources. In the second stage is basically visiting the concerned institutions and the consulting the expertises. Most data for the study was collected from secondary sources. The sources mainly include the IMP office in Istanbul, Department of Education Istanbul and in the Department of Education in the concerned districts. The list of data collected from different institutions is listed in Table 3-2.

### 3.4.1. Secondary data collection

**Table 3-2: Data Sources of secondary data**

| S No | Data | Source |
|---|---|---|
| 1 | **Maps** | |
| 1.1 | District, neighborhoods, boundaries with population | Department of Urban planning, IMP |
| 1.2 | Education shape files in (NetCAD format) | IMP |
| 1.3 | Road network (Istanbul): different modes | IMP |
| 1.4 | Land use maps indicating the residential properties | IMP |
| 1.5 | Traffic Analysis Zone (TAZ ) | Department of Transport, IMP |
| 2 | **Documents** | |
| 2.1 | Education data book (List of schools with area, and student-teacher numbers) | Department of Education, Istanbul |
| 2.2 | Report: facilities distribution report | Istanbul Municipility |
| 2.3 | Education Statistical Report | Department of Education |
| 2.4 | Rules/regulations: school catchment area, | Websites of Turkish government and Urban Planning Department |
| 2.5 | Population statistics with different age categories | Turkish Statistical Institution (census data) |
| 2.6 | JICA Report on Transportation master planning | Department of Transport, IMP |

### 3.4.2. Primary data collection

To capture the catchment area of selected schools, interview with school administrations were conducted with the help of two enumerators /translators for Turkish to English. The questionnaires include the number of students from different districts, total population of students and teachers in the school, total area of school and the admission pressure (ratio of number entry possible to number of application filed). This data was then used to verify the secondary data. For primary data collection, stratified random sampling was adopted, so as to get the data from at least a government and private high schools from each district are included. From the total 20 schools that were visited.

**Figure 3-11: Interview with school principal and Meeting in IMP**


**Figure 3-12: A high school and the IMP office, Istanbul**

## 3.5. Preparation of data for analysis

Many data need to be prepared, via data edit, statistics, calculation ad attribute input, change the format of data etc. Since majority of data related to high schools are in Net CAD 4 GIS format, which is hard to process in the ArcGIS software, necessary refining and converting are conducted to .dwg format first and then to ArcGIS format. The distribution of high schools includes the boundaries of schools. So, translation of polygons into their centroids by using the convert shapes to centroids in ArcMap is needed in to prepare for network analysis. Using the selection in location function with land use data in the ArcMap, the area of each school was calculated. Then the tables of which contains the information about the number of students, teachers, classes, areas, and types of high schools were joined. Now, the school data can be used for analyzing capacity, service area, and optimum location.

The density of population is calculated by dividing the population per neighbourhood by its residential area. This is based on the assumption that population density is uniform over over the residential area of each neighbourhood. The number of population is between the age 14-17 was estimated (see section 3.2).

All Network including main roads, express roads and other types of roads were aggregated together All roads segments are connected in road network. The road network coverage was also converted to FlowMap format and they were also prepared as axial lines to work in Axwoman as described below.

To support for the FlowMap the shape file in ArcMap should not have Z and M coordinates. Use 'copy features' of the shape files, disabled the M and Z coordinate and save the file. This can be used in FlowMap.

To use data in Axwoman, we have to prepare the axial lines. As described in the chapter 2.4, axial lines are set of longest possible lines of sight. Here we are considering the centre line of each road segment as an axial line. For some roads like highways and 1st arterial, there are more than one lines to represent the different types of lanes like, one way tract, pathways, high-speed lanes, road crossing, and complex junctions. These all lines have to be simplified, and replaced by a single line to represent the single road with single line. These lines are assumed as axial lines.

### 3.5.1. Subdivision of residential areas with hexagons

In data preparation, the densities of population and students were obtained. This is available in every residential area to calculate the number of students, but the size and shape of each residential area is different. As this is not suitable for analysis, residential areas were divided into hexagons to be better able to estimate the spatial distribution of demand. This process creates a uniform structure that is more accurate for the demand analysis. The population of study area is more than one million. Normally, there are two ways to subdivide the neighbourhood, a regular tessellation such as squares or hexagons or using irregular structure such as street blocks. The selection of the form depends on the size of total area; the precision required and need for spatial uniformity. In order to get more accurate results, the process of dividing the area into regular tessellations using hexagons are selected (Amer, Ottens et al. 2007p. 15).

### 3.5.2. Disaggregating population into hexagons

Since hexagons are created there is still need to relate the information the information such as the population and schools with the hexagons. The population data on neighbourhood level are distributed to the overlapping hexagons by taking residential land area each hexagon as weight, based on the assumption that the population is distributed evenly so density is uniform within the neighbourhood. The partial hexagon will be assigned population by calculation the area on the basis of area percentage. The proportion of any residential land area falling within a neighbourhood is computed after the intersect operation. This proportion is then multiplied by the population density in this neighbourhood and the product sub-divided by the hexagons. Similarly population of each hexagon can be calculated. All demand is assumed to be located at the centre point of each hexagon. Better accuracy may be achieved by using the extract demand location, as population address as point in the network analysis. If the centre points are located within a user-specified distance, they are captured to represent the population attribute of the hexagon. The process of disaggregating students is showed Figure 3-13.

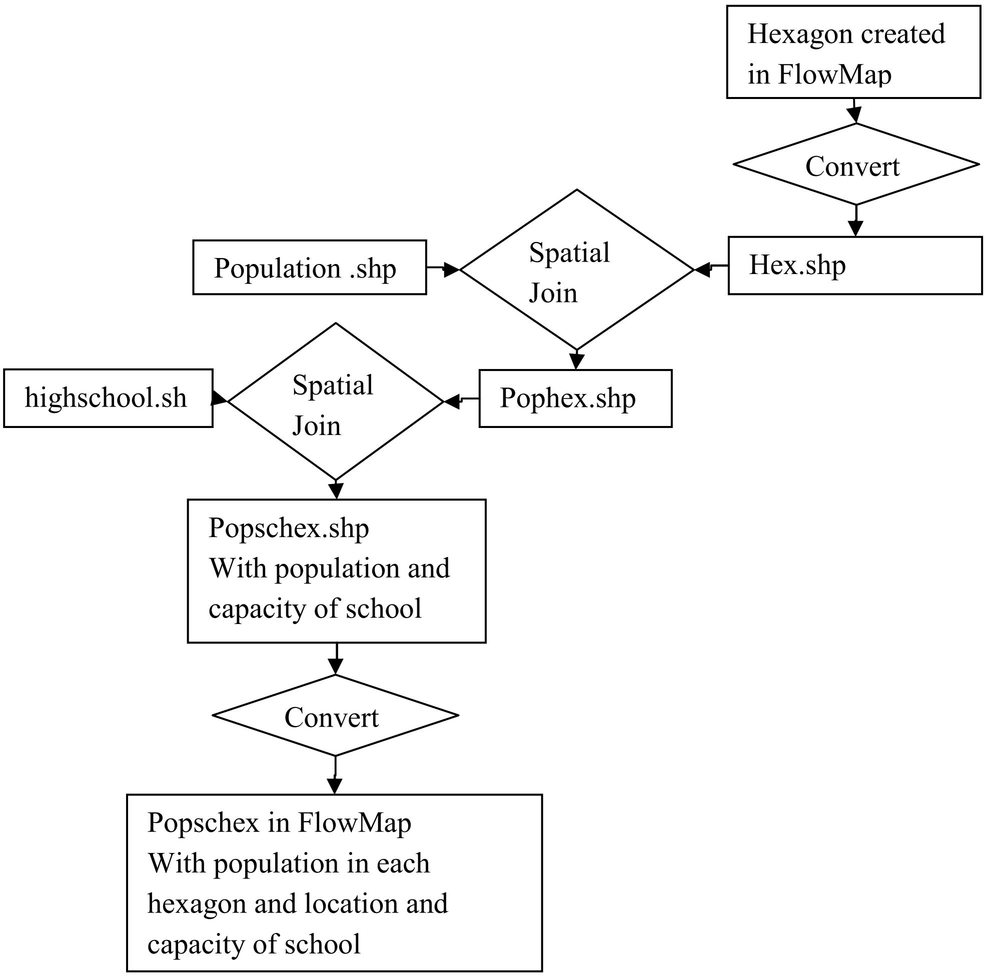



**Figure 3-13: Process of allocation demand into hexagons**

## 3.6. Data preparation for space syntax analysis

Urban topological analysis examines the urban structure by exploring the spatial relationships between the points, lines and blocks that together form urban space. With the similar principle, Space Syntax is used to examine the urban topology. In space syntax, the urban space is extracted as an axial network comprised by axial lines and junctions based on the road network. Through calculation, various measures of each axial space will be calculated (i. e. connectivity, depth and integration) giving insight into the structure and diversity of urban space.

### 3.6.1. Space Syntax elements

The relative proximity of space from all other spaces in the system where the impedance to move between the two points can be a function of costs, benefits, distance, time etc. To calculate the accessibility between two points, it is treated as graph and the elements of such graph consists mainly sets of lines and nodes.

**Axial line**

The road is a primary spatial element of the city. The structure of the road network is a fundamental determinant of the urban movement pattern, so the road contains both spatial and social attributes, with the social assumed to be dependent upon the spatial. Space syntax takes the linear space along the road as major research object and the axial lines are created based on the urban road network.

**Node**
The node includes the natural road junctions and the turning points of the road.

**Network**
The network consists of the least number of longest axial lines, the nodes and the attributes of each axial space.

**Axial centre**
The axial centre correspond the actual urban space with high value of syntax integration. The question to be examined is whether the functional centres are related to the syntax based central location.

The network, which consists of set of road networks of are used with simple modifications in space syntax analysis. Some roads represented by multiple centre lines, for example highways, or two ways roads or roads where different lanes representing different modes of transportation, were represented as a single line so as to give the effect of axial line. This is necessary to avoid the unnecessary connection of axial lines in road network which may mislead the result. Again this road network can be easily compared with the full network since the whole network represents the same location.

# 4. Proximity and locations of High Schools in Istanbul, Turkey

*This chapter is to apply the accessibility measures for the current distribution of high schools in order to develop a methodology to describe the accessibility. In this case study, accessibility measure used is contour measure. The distances between the origin and destinations are measures as the shortest road network. Origins also called the population or demand are disaggregated into regular hexagons with 100 meters radius. Destination or supplies (high schools) are measured in their nearest centre point of hexagons. Links are the real road networks.*

## 4.1. Proximity

The main aim of this section is to take a spatial analytical perspective to analyze the accessibility in terms of the shortest distance to the facility (high school). In this study we will focus on distance of the school form the demand area called population. The surrounding catchment area of schools has to be defined from the contour measures as discussed in previous chapter(s) 2.3.5. We can calculate the distance between the school and the students living in the residential land. The students living in residential areas are demand and schools are supply. The road networks are represented in the network as linear features to connect the demand and supply. Then the shortest travel distance along road network is computed in order to give an accurate picture of the distance between the destinations and demands.

To study the proximity we need to access the current situation of high schools and their distribution.

## 4.2. Procedure

This section presents the analysis and study of high school supply and demand (potential accessibility) in the study area and the actual service use of these facilities. The evaluation of provision of high schools and their use was based on the GIS database specifically developed for this research using both primary and secondary data. This consists of the maps containing the basic information types pertaining to the spatial structure of the city such as neighbourhood, public transport network, and population data based on neighbourhood and high schools locations. The discussion of this section proceeds from the characterization of the present high school supply and its relationship to the distribution for use as basis in describing its potential accessibility.

In this case study, contour measure is applied to measure accessibility of destination or supply (high school). To achieve the (sub) objectives, the research is carried out from two perspectives: accessibility analysis mainly run in the flow map as described in the framework Figure 4-1.

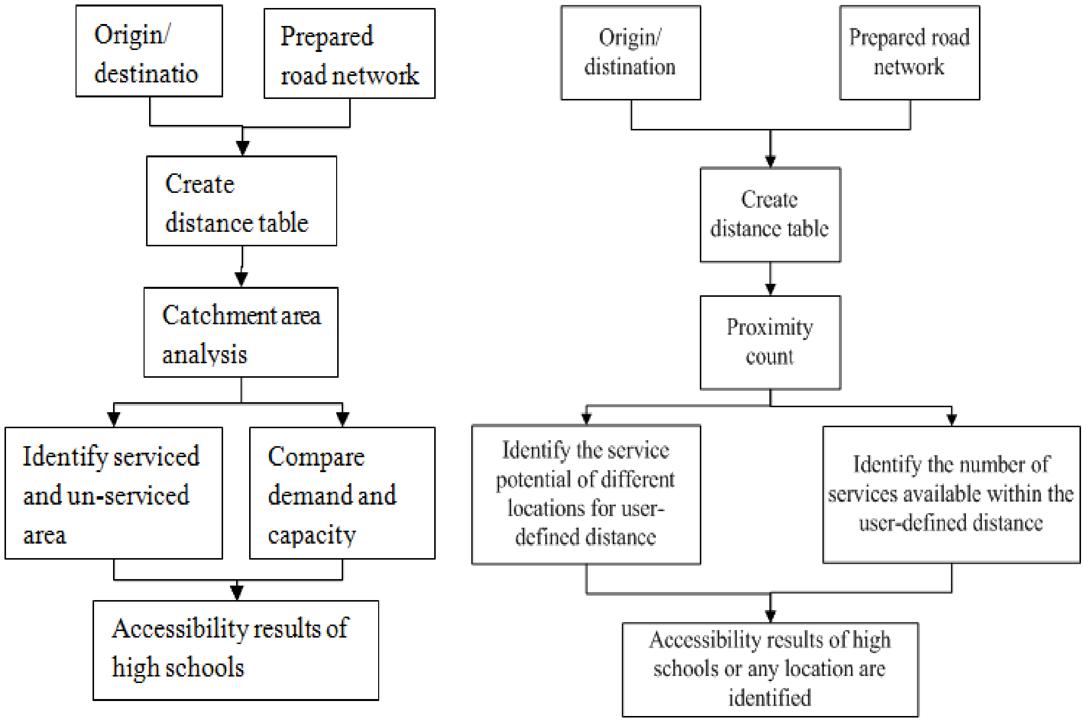



**Figure 4-1: Framework of analyzing the accessibility**

After data preparation, calculation of demand and supply of schools is analyzed. Demand is the number of school children (of particular age between 14 and 17) living in the residential land. The road networks represented in the network as linear features and schools are supplies represented as points. Then the shortest travel distance along the road network is computed in order to give an accurate picture of the between the demand and supply. Therefore, in this research, preference is given to the distance based on network distance over the straight line distance.

The distance between the centre and target location is calculated as sum of distances: First the distance from centre to nearest point /node on road network; second network distance from the node nearest to the centre to node nearest to the target location; and finally the distance to the target location from the nearest node on network.

In case of using the public transportation facilities, we can take the nearest nodes, which represent the limited number of bus/train stops along the transport lines.

The key element of contour measure is to choose a cut-off travel distance or time. Impedance is the cost associated with utilization of supplied resource through a network. In this research, the distance to the school is the impedance to the utilization of the destination. Since Turkey lacks the fixed distance service radius for high schools (though many literatures as discussed in chapter 2.3.4, uses 20 minutes travel time is regarded as cut-off), for this study, different cut off distances as 10, 20, 30, 40 and 50 minutes of walking are considered. Serviced area is defined as the area within a specified distance to facilities while un-serviced area defines as the area where people must travel more than specified distance from their location to the facility. As we looked on the serviced population of high schools for user-defined cut off distances, the numbers of students staying within these user-defined distances were counted as serviced population. Within the fixed distance, one origin location could have more than one option for their destinations (high schools) or the two or more destination could have the same origin location within the fixed user-user defined distance. Competition between the various destinations does not matter in proximity count. Hence the origin in our case number of potential population or students located within the defined distance of, for example two high schools, different destinations, was included in the count of both high schools (destinations).

### 4.2.1. Catchment area analysis

To analyse the accessibility in an existing situation, we started with application of catchment area analysis in FlowMap. In catchment area analysis: origins were allocated to the nearest and single destination. Assumption was made that destinations were in maximum capacity. Again those destinations were within the maximum reach from origins.

In the current service location, the capacity variable was only used in the on/off sense that means that a location either has no capacity or an unlimited capacity of service available. This was based on the idea that new locations can be tailor-made to demand and that in many cases the presence of location was regarded as much more important than its capacity.

In our case, every demand location was allocated to its nearest supply location. To make sure "count" was used as weight variable per origin/destination and unlimited for capacity variable (say 200000 per high school). As a result, in Figure 4-2: Theoretical catchment area of high schoolsit was noticed that large area were covered by Northern high schools. Again, some schools in centre, due to their strategic positions with regard to the road network, their catchment area differ accordingly. The longest distances (red) occur in the extreme north section of the study area. From the result of the catchment area analysis as displayed in the Figure 4-5, there are no demands in this (North) part.

If we look the catchment profile of the current distribution of high schools in Figure 4-4, the profile is convex, which shows many origins were relatively near to nearest destinations. Here, more than 90% of total population are with the 20 minutes of walking distance range (walking speed is taken 5.4 km/ hour). It is the reflection of central locations of high schools.

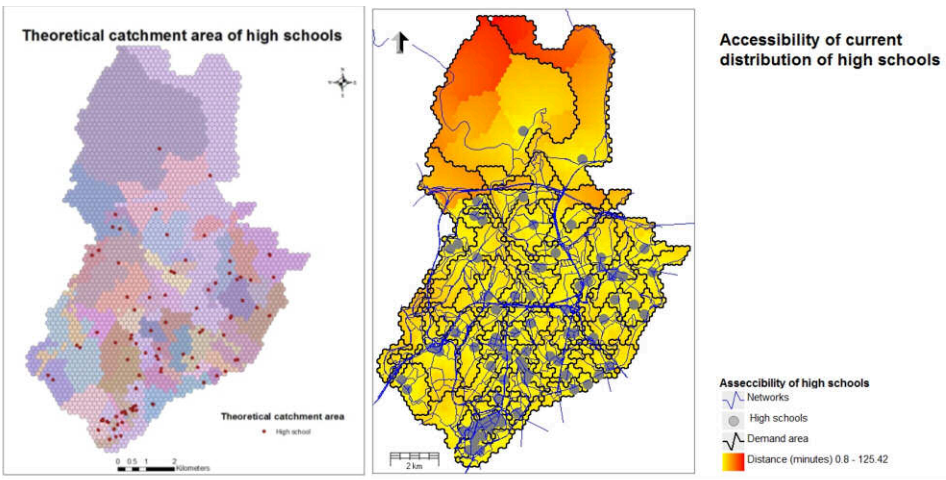
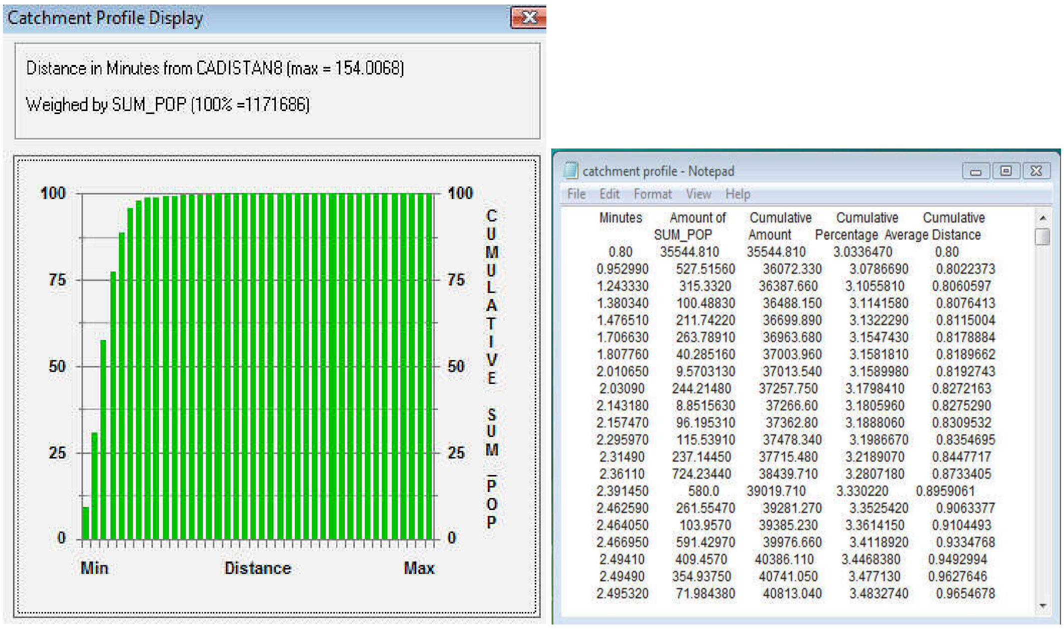



**Figure 4-2: Theoretical catchment area of high schools**
**Figure 4-3: Spatial distribution of high schools**




| Minutes | Amount of SUM_POP | Cumulative Amount | Cumulative Percentage | Cumulative Average Distance |
|---|---|---|---|---|
| 0.80 | 35544.810 | 35544.810 | 3.0336470 | 0.80 |
| 0.952990 | 527.51560 | 36072.330 | 3.0786690 | 0.8022373 |
| 1.243330 | 315.3320 | 36387.660 | 3.1055810 | 0.8060597 |
| 1.380340 | 100.48830 | 36488.150 | 3.1141580 | 0.8076413 |
| 1.476510 | 211.74220 | 36699.890 | 3.1322290 | 0.8115004 |
| 1.706630 | 263.78910 | 36963.680 | 3.1547430 | 0.8178884 |
| 1.807760 | 40.285160 | 37003.960 | 3.1581810 | 0.8189662 |
| 2.010650 | 9.5703130 | 37013.540 | 3.1589980 | 0.8192743 |
| 2.03090 | 244.21480 | 37257.750 | 3.1798410 | 0.8272163 |
| 2.143180 | 8.8515630 | 37266.60 | 3.1805960 | 0.8275290 |
| 2.157470 | 96.195310 | 37362.80 | 3.1888060 | 0.8309532 |
| 2.295970 | 115.53910 | 37478.340 | 3.1986670 | 0.8354695 |
| 2.31490 | 237.14450 | 37715.480 | 3.2189070 | 0.8447717 |
| 2.36110 | 724.23440 | 38439.710 | 3.2807180 | 0.8733405 |
| 2.391450 | 580.0 | 39019.710 | 3.330220 | 0.8959061 |
| 2.462590 | 261.55470 | 39281.270 | 3.3525420 | 0.9063377 |
| 2.464050 | 103.9570 | 39385.230 | 3.3614150 | 0.9104493 |
| 2.466950 | 591.42970 | 39976.660 | 3.4118920 | 0.9334768 |
| 2.49410 | 409.4570 | 40386.110 | 3.4468380 | 0.9492994 |
| 2.49490 | 354.93750 | 40741.050 | 3.477130 | 0.9627646 |
| 2.495320 | 71.984380 | 40813.040 | 3.4832740 | 0.9654678 |

**Figure 4-4: Catchment profile display**

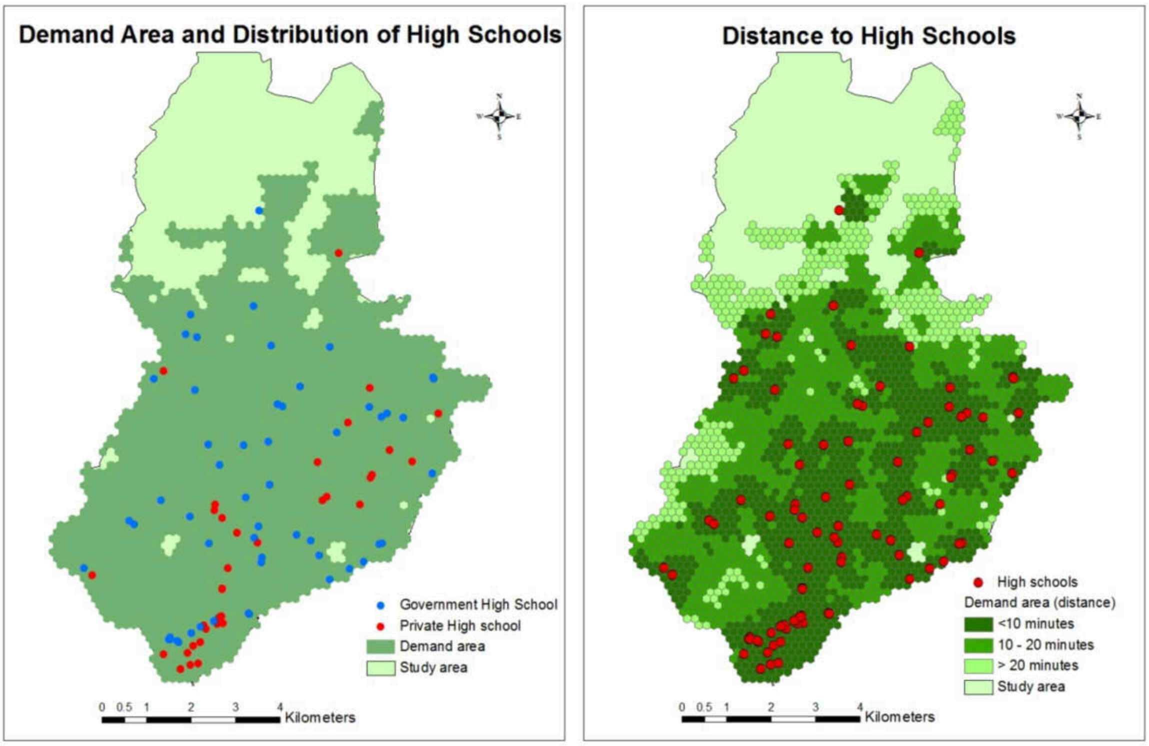



**Figure 4-5: Demand and Distribution of High schools**
**Figure 4-6: Distance to High School**

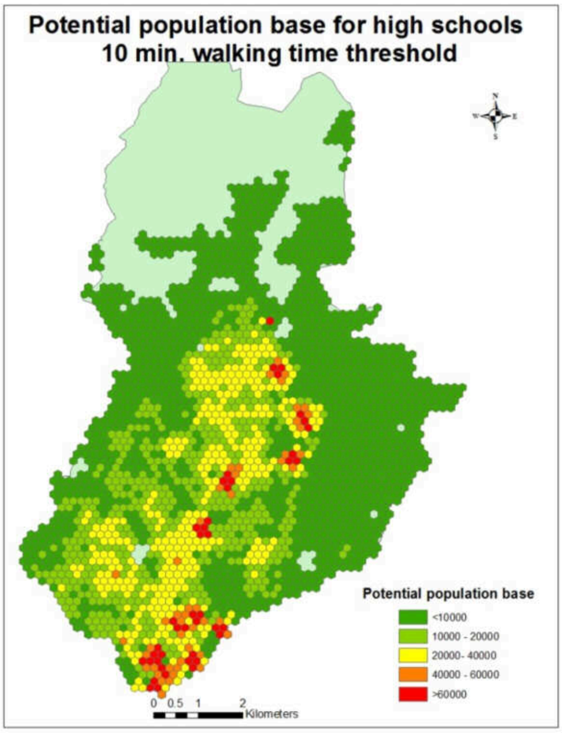
## Limitations of Catchment area analysis

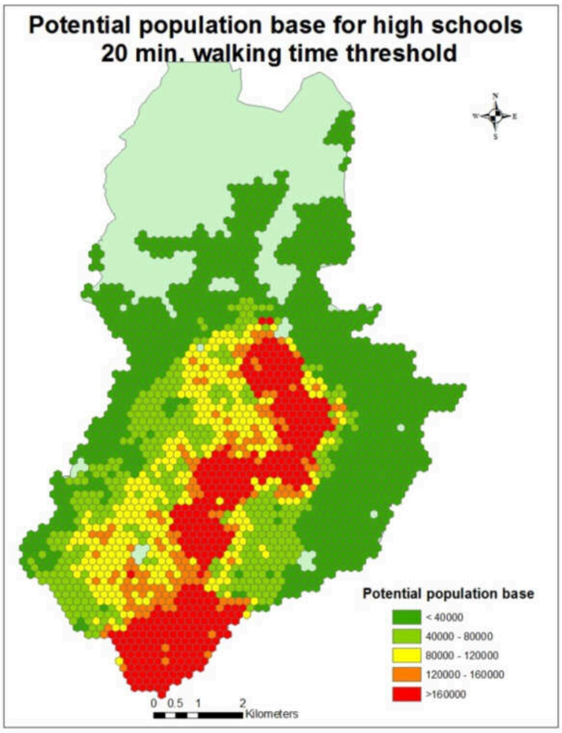
The spatial distribution of high schools is shown in Figure 4-5. A closer looks at the map revels the following. First, the high schools both private and government are distributed unevenly. Though they are distributed over the large part of the built area, the density of schools in the Eastern part of the study area is much higher. In Eastern part the service area of schools are overlapped. In Fact we can see the quite large numbers of schools are located near to each other overlapping the service area. Catchment area analysis identified the services and un-serviced areas rather than centrality of the area, hence, it is mostly used to analyze demand and supply of facilities and its efficiency. So to measure the centrality of location of high school we analyze rather by Proximity counts.

### 4.2.2. Proximity counts

"A proximity count is a measure representing the number of origins within a use-defined distance of each destination" (Jong, Wel et al. 2007, P. 77). The origins represent the potential population for the destination in this case high schools. Then the total population for potential for each destination was counted for the particular cost, which we called cut-off (use-defined) distance. In this case we use the distance of threshold of 10, 20 30, 40 and 50 minutes of walking. The proximity count effectively counted the additional population in reach for every potential new location. The different cut-distance was chosen depending upon the socially accepted threshold. In cities like Istanbul, 10 minutes walking is no more than the one or two streets away from the destination called schools (As one looked at the average length of streets in study area of Istanbul was about 270 meters). Likewise 20 minutes of walking can represent three to four streets away from the destinations (schools) and in 50 minutes one can (approximately) crossed the either East or West border of the study area from the centre of the selected area.

For the analysis of current location of high schools, one can examine the existing location of high schools (private and government) and calculate the centrality index of each location of high schools whether government of private in relation to the rest of locations. As we look at Figure 4-7, potential population for different threshold of walking distance are visualized. With the smaller threshold of 10 minutes of walking, only limited population has potentiality to access to the location where as with greater threshold distance of 50 minutes of walking majority of the area has fairly large potentiality for population base.



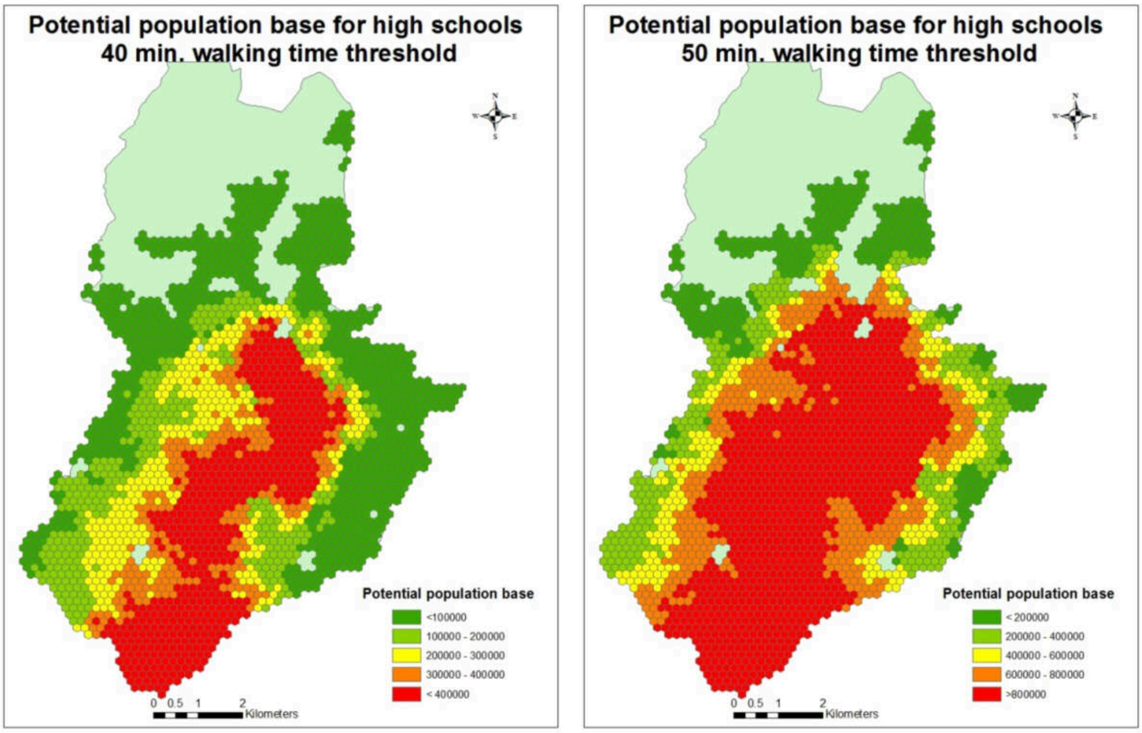



**Figure 4-7: Potential population base for high schools with different thresholds**

### 4.2.3. Interpretation of results for comparison and conclusion

After calculating the population base for every location in the study area, the centrality index of every location is calculated. Calculation of Centrality index is also called normalization of potential population base for every location and this was calculated as like the Z-score in statistics shown below:

$$Centrality\ Index\ of\ Proximity\ count\ for\ user\ defided\ distance = \frac{\text{Potential population base of the location for user defined cost} - \text{mean}}{\text{standard deviation (SD)}} \times 100$$

Hence after calculation the population base for every cut off (user defined) distance, mean and standard deviation of every location for that particular distance is calculated and finally the centrality Index of 10, 20, 30, 40 and 50 minutes of walking are calculated. For the comparison of results, the centralities Index of locations, where high schools are located are shown in **Appendix 1**. Since there are total 91 high schools in study area including the private and government, these are located within 78 different hexagons of 100 meters radius that we created for analysis of the data.
From this table Appendix 1, we can calculation the centrality of location of schools, for example, which values are less than |± 25| lies above or below 10% of the mean value, likewise the values lies between |±25 and ±52| deviates 20 % from the mean, the values between |±52 and ±84| deviates 30% from the mean, the value lies between the |±84 and ±128| deviates 40% from the mean and finally values greater than |±128| lies either top 10% or lower 10% in the index, that is, they deviate more than 40% from the mean (Adopted from the Discovering statistics using SPSS (Field 2005)). The negative sign indicates that the values are lying below the mean, such that the centrality index of such locations are lower than the average. After these parameters are calibrated these results are ready to compare with the results in connectivity analysis.

# 5. Syntax analysis of urban networks

In general this chapter contains the principles of deriving the axial lines and the process of deriving the most connected locations in the study area. The first part of the chapter includes the syntax analysis and the later part illustrates the results and subsequent section displays the interpretation of the.

## 5.1. Space syntax analysis

Space syntax theory describes and measures quantitatively the relational properties of urban space (Hillier and Hanson 1984; Hillier 1996). Such relational properties rest on assumptions that longer lines of sight fewer turns, higher connectivity and a high ability to reach points from every other point in space are desirable (Baran, RodrÃguez et al. 2008). The evidence, reviewed below in detail, has shown a positive relationship between the occurrence of activity and spaces that exhibit these desirable properties.

In developing the quantitative syntactical measures, street layouts are first transcribed into appropriate representations of their spatial structure called "axial maps", for this research the streets themselves are consider as axial lines and set of street networks formed the axial map. The axial map is a network of intersecting lines that consists of the longest sets of lines of sight that pass through all the open spaces in a study. However, it is practically difficult to draw axial lines manually, since it consumes lot of efforts: firstly it is too much time consuming and secondly it is difficult to draw the exact longest line of sight in each section of streets within a limited period of time. So, in this case study the set of road networks are supposed as having the same property of axial lines. This axial lines are used to calculate a set of measurements of syntactical properties of space (Hillier and Hanson 1984). Each measure is assigned to each axial line on the map. The common syntactical measures in space syntax include the connectivity, control, integration (local and global), and depth as described in section 2.4.3.

### 5.1.1. Procedure of space syntax analysis

The space syntax analysis can be implemented through following the sequential steps. First create a principle for deriving axial lines from the transportation (road) network and public transportation networks. Then draw axial lines in ArcGIS based on principle e of and present the road map (In principle axial lines are created from visual distance such that the lengths of these lines are long possible and numbers are as least as possible). The Arc GIS extension called Axwoman 4.0 was used to calculate the space syntax values and generate the connectivity or accessibility maps. The various space syntax measures are then analysed and interpreted with respect to high school locations as shown in Figure 5-1.

The data collected about the high schools including their spatial and non spatial properties are stored as point features in ArcGIS. Identify the road section that connected to the entrance of the high school and the nearest bus or rail stops (public transport stops). Then according to the distribution map of high schools describe the pattern of high schools location.

Then combine the results of space syntax and location pattern of high school analysis. This output is used to study the correlations between the distributions pattern of high schools and the connectivity or integration measures. The procedure of this process is carried as per the frame work illustrated in Figure 5-2.

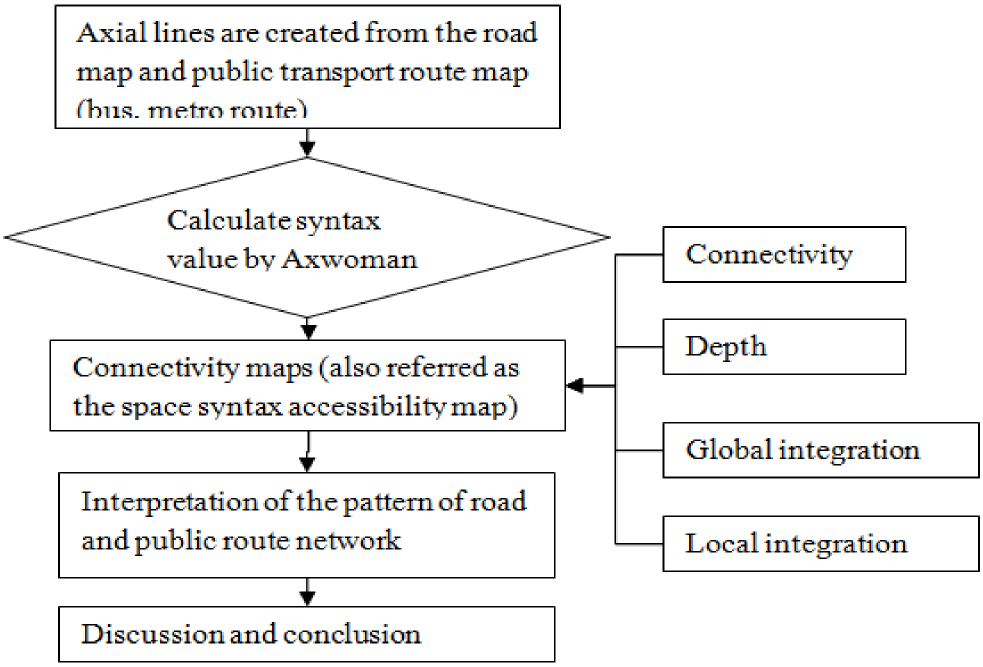



**Figure 5-1: Basic framework of space syntax (connectivity) analysis**

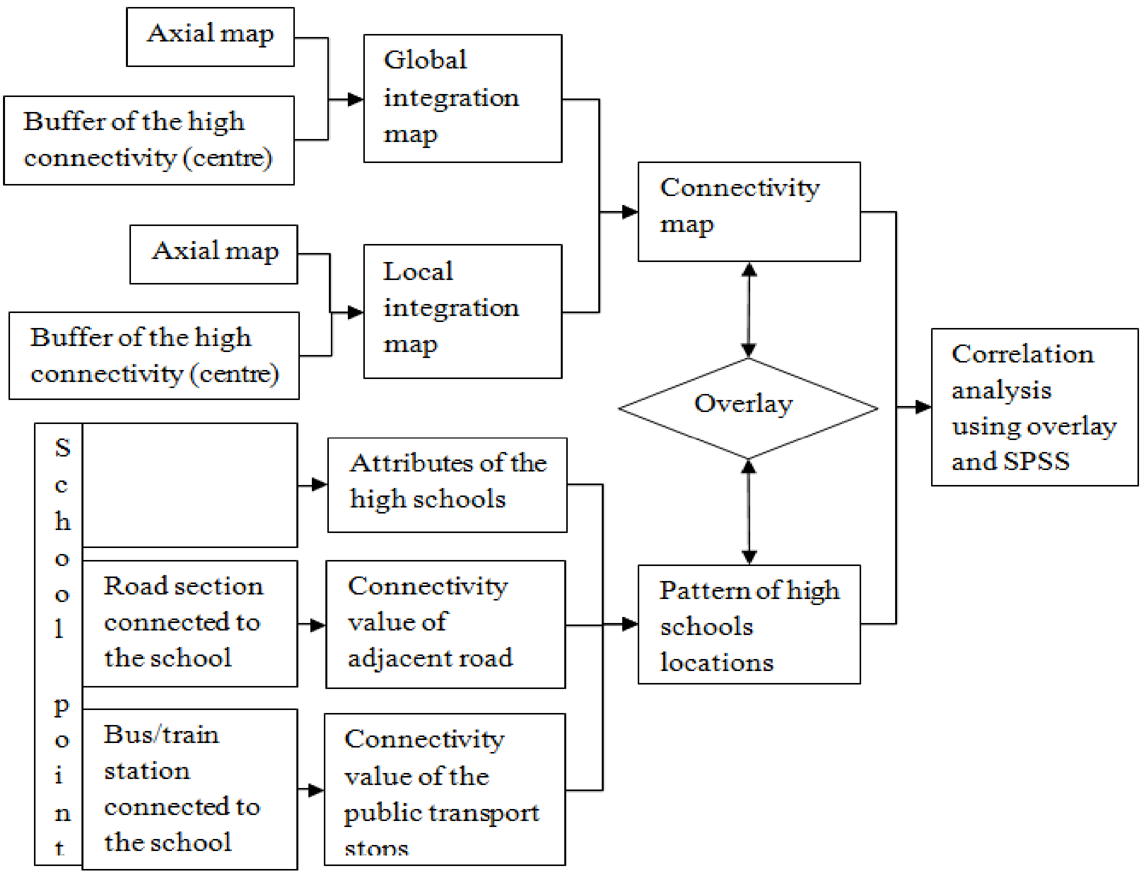



**Figure 5-2: The framework of correlation analysis of high schools pattern with connectivity**

### 5.1.2. Deriving axial lines and syntactical analysis

The process of space syntax analysis consists two phases. The first is the digitization, which includes the preparation of axial lines. To prepare this, AXWOMAN 4.0 the extension for ArcGIS was used. Once the axial map was ready, it was checked for existence of unconnected lines called 'isolate lines' in the network. Once the digitization work is finished, we highlighted the poly-line layer on editing status, and highlighted the corresponding layer on the table of contents and finally calculate the space syntax measures using Axwoman toolbar. All syntactical parameters for axial lines are seen in the attribute table in ArcGIS.

Here, syntactical analysis is carried in two distinct ways in street networks. The first analysis limits the axial line generation within the boundary of selected four districts of Istanbul and computes the syntax measures. The second methods consider the whole streets networks of Istanbul and calculate the syntax measures. Then select the networks in study area by location in ArcGIS. Since, the ability of space syntax to describe global configuration properties of streets and their relationships, the impact of neighbouring networks over the networks of the study area is obviously significant. Hence, considering the second method demonstrate more precision.

### 5.1.3. Interpretation of different outputs of syntactical analysis

The value of each space-syntax parameters were calculated in Axwoman 4.0 as describe above. Maps were plotted for each parameter to show the variations within the city. Histograms were plotted and normal curve was fitted for each parameter to see the spread of the data (Figure 5-3). This provided better understanding for classification of data used in the maps. Each class for different parameters is colour coded from blue to red, which represents low to high integration of spaces within the city(Jiang, Claramunt et al. 1999). The results of the commonly calculated syntactical measures that include connectivity, control and integration are discussed next.

**Connectivity**

In this case, the minimum value for connectivity is 1. This is due to selection of case study area after the space syntax measures are calibrated and the area lies relatively in the centre of the Istanbul. Again consideration of small sized roads like cul-de-sac is difficult during the generation of axial lines. In the analysis average connections in the network is 5.49 and maximum connection is 31 as shown in Figure 5-4.

**Control**

The road, which runs North/South passing through '*Istiklal street'* has and other highways which are using multi model transport system have higher control values (Figure 5-5). Control value represents the degree to which the line is important for accessing neighbouring lines.

**Global Integration**

Integration is an indicator of how easily one can reach a specific line of the axial map. Global integration value of one specific axial line reflects the route complexity from it to all others in the road network. Higher the global integration value represents the line is (relatively) easily reachable from all networks as compared to others lines.

As we can see that different transportation modes are used especially for the schools trips, we can considers all types of transportation networks, which includes roads (vehicular, walking), rail, ship (especially transportation from Anatolian to European students these ferry are popular among students). From these results Figure 5-6 we find the roads, which have higher integration values include highways, first arterial roads and the roads along the metro/rail lines.

**Local Integration**

Local integration can be a measure of local syntactical accessibility if the radius is small (in our case 3). These are the lines (spaces) that could be easily accessible from the surrounding areas with minimum efforts. The value of local integration is dispersed in all directions as shown in Figure 5-3 and Figure 5-7 and as compared to global integration.

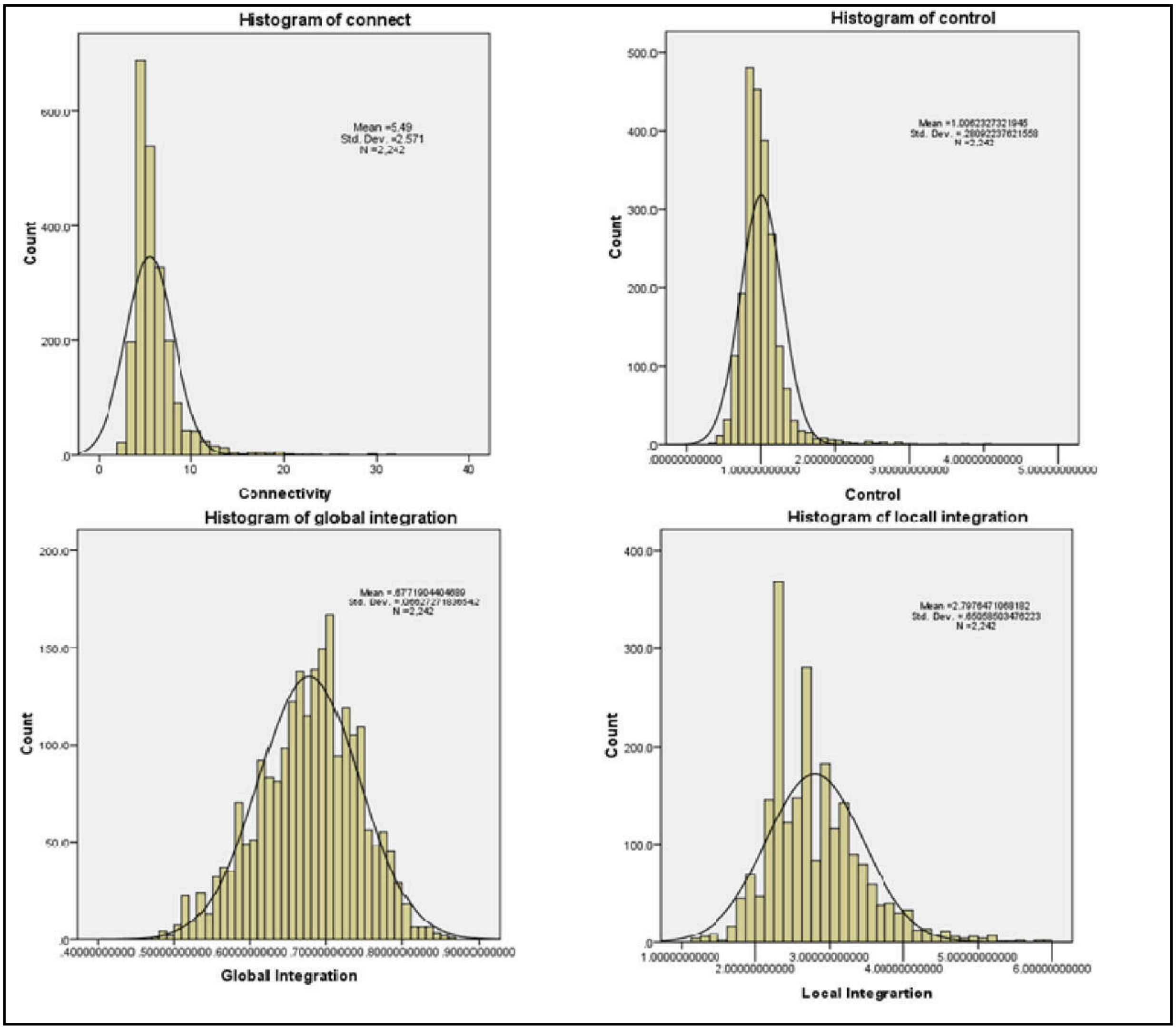
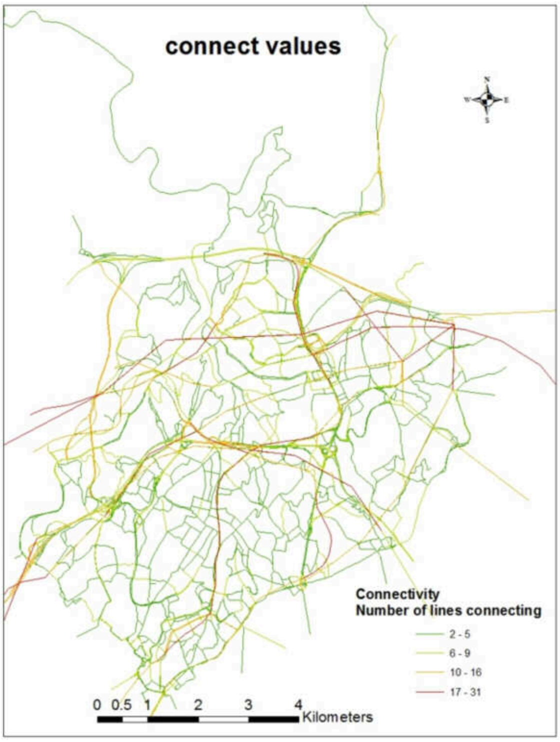



**Figure 5-3: Histogram of syntactic (space syntax) measures**



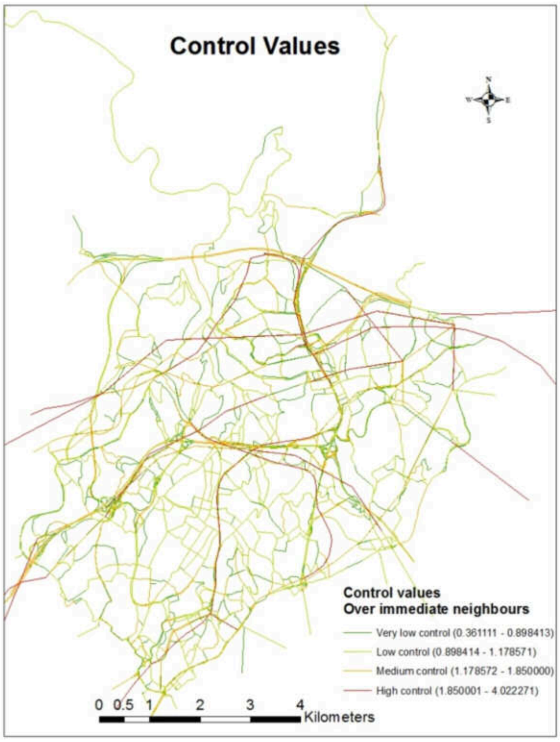
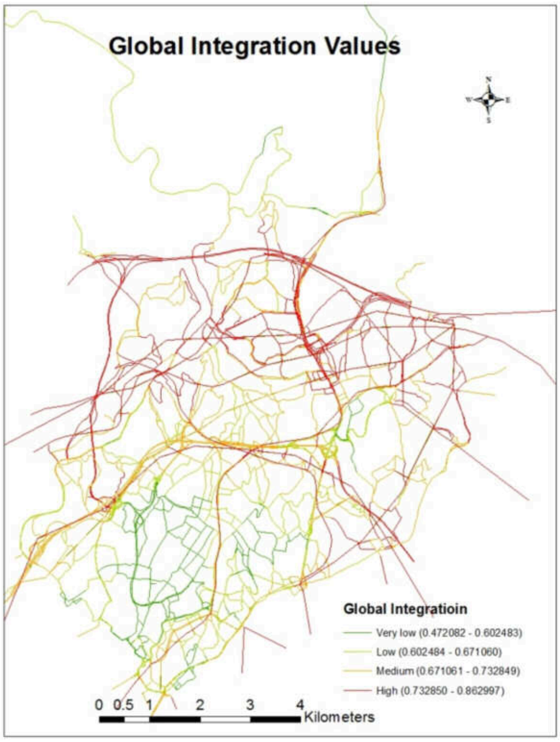




**Figure 5-4: Connectivity of all networks**
**Figure 5-5: Control Values of all networks**



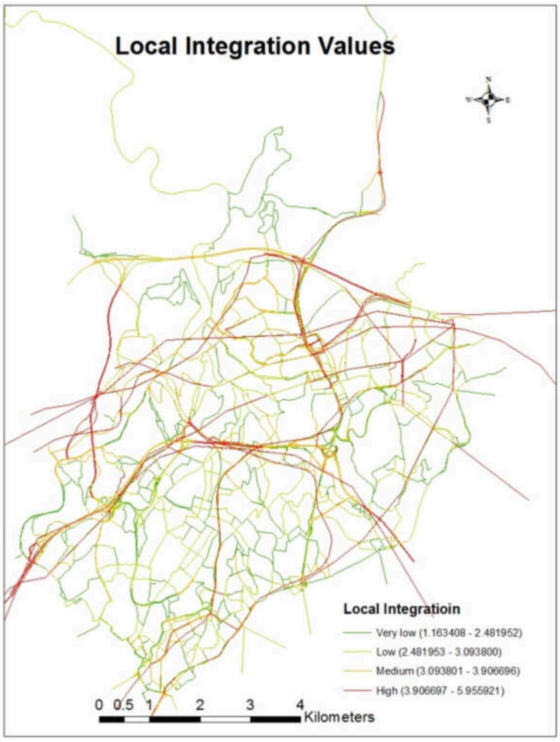




**Figure 5-6: Global integration of all networks**
**Figure 5-7: local Integration of all networks**

### 5.1.4. The centre of traditional axis network and high schools

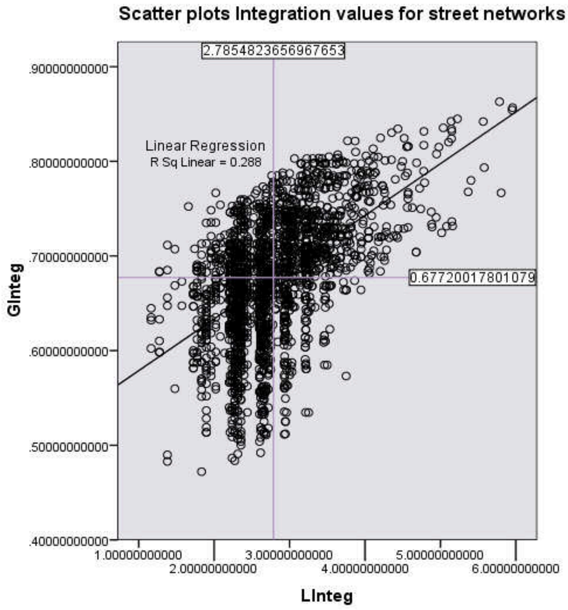
Since we have the location of school in shape file, we can overlay the school location with space syntax output map. We can see that the most of the schools are corresponding to the networks with high integration values. Especially the schools in the Beyoglu (south part of study area) are concentrated around the integrated networks of Istiklal Street, a famous walking street in Istanbul.

This study area lies in between the Golden horn and the Bosphorus region. There are two major ferry connections in this region especially joining the Anatolian side of Istanbul and also the Marmora area. This area also holds two existing connection road network between the Asia and European sides of Istanbul, which are followed with the highways. Apart from these rail connection from north south and some from east to west part of the region also plays a vital role in connection. This area also posses the famous square called Taskin and the CBD area.  There are total 91 high schools in this area, among them 27 are vocational in character and rest are general high schools. The Anatolian and minorities high schools (American, Italian etc) are considered as general high schools. Out of total 91 high schools 55 of them are government and rest are run in private levels.

In overlaying the distribution map of schools' area (polygon) with the syntactical map, it is found that majority of high schools are directly located within the high integrated roads or nearby to these roads. For the analysis, buffer of 400 m for the school polygon are created. Since the 400 m radius is considered as the maximum 5 minutes walking, which (almost) equal to two fold of the diameter of 100 m radius hexagon which are created in proximity analysis in the previous chapter. The spatial join of this buffer with the syntax map, added the attributes of the axial lines to the school locations or vice versa. In some cases, in fact many cases, the schools will have multiple values of integration, when the school is facing with the multiple networks or nearby the networks. In this case we summarize per school to get the summary statistics of syntax values (integration, connect, control as highest field and depth as lowest field values).

As we compare the graphs of Figure 5-8, and Figure 5-9, the mean local integration value of all road segments is 2.78548 while the mean vale of high schools (buffer) is 4.659. We cannot expect every schools are directly located to road sections of high integrated value. Since the sizes of schools are relatively large and the consideration of user's in entry together with the noise factor, direct measurement of integration value based on school's entrance is illogical. So we depend on the buffers of the highest value available within the range.

Similarly the mean of the global integration value of the whole networks is 0.677 and the school buffer is 0.754. Almost all schools have higher integration value (400 m) buffer, the accessibility to these schools from the neighbourhood is better.



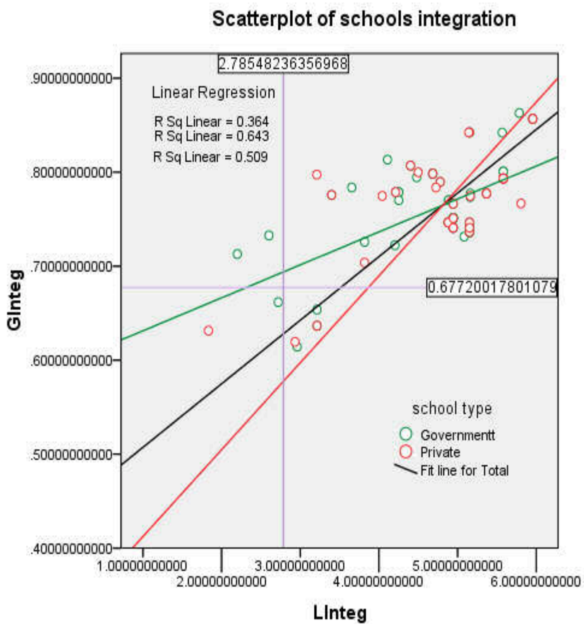




**Figure 5-8: Scatter plot of syntax accessibility of Istanbul networks**
**Figure 5-9: Scatter plot of syntax accessibility of High schools (government and private)**

The scatter plots provided by the SPSS are the summary of the global and local integration values plotted against each other (Figure 5-8 and Figure 5-9). These have provided the value of R2 (linear). The value of R2 is 0.288 for the whole networks in the study area (selected districts of Istanbul) and 0.509 for the all school locations. For private schools R2 is bit greater, which equals to 0.643 and for government schools its value is 0.364. Increase in R2 for location of schools shows the more dependency of Global Integration over the local integration. This shows that the private schools are located in and around the local and global centres where the dependency of global integration is more over local integration values.

### 5.1.5. Interpretation of the results for comparison and conclusion

There are clear distinctions that the locations of high schools (and its buffer) have correlations with the syntactic accessibility. The areas which are well connected don't mean that it should have high school locations. Such types of areas include the highways. The clustering of high schools is seen in the highly globally and locally integrated areas. The chance of locations the private schools in such locally and globally integrated area is high.

As like the results in section 4.2.3, the centrality index for every segment of streets (axial lines) was calculated. This includes the centrality index of high schools based on Global integration, Local integration, and connectivity and control values as shown in table in **Appendix 1**. These values are then ready for comparisons with the results in chapter 4.

# 6. Comparison between the proximity and connectivity

This chapter compares the output of the results from proximity (chapter 4) and connectivity (chapter 5) that can be useful for joining the results in future to form a unified theory of accessibility.

## 6.1. Results and discussion

### 6.1.1. Proximity measures

As discussed in the section 4.2.2, the different threshold of distance or cost were considered, obviously, the short distance of 10 minutes of walking gives the localized parameter and the long distance travel of 50 minutes of walk was more generalized parameter. In between them, the 20, 30 and 40 minutes of walk were moderate to higher parameters that were available for comparisons. Some of primary observations that were noted from the centrality of location of high schools (see appendix 1) are listed below:

- For 10 minutes of walking: 21 % of high schools locations (where 26% private high schools and 18% government high schools) were located in the top 10 % central places from the potential population base point of view.
- For 20 minutes of walking: Total 31% of high schools (18% government and 52% private) were located in the top 10% central location.
- For 50 minutes of walking: None of the high schools were located in top 10% of central locations.

### 6.1.2. Connectivity measures

Among the parameters of space syntax, those readily available for comparisons are Connectivity, Local and Global Integration All three of them are algebraic function of the number of axial lines that must be traversed if one were to move from every other line or street to street in axial map, only difference in between them is the degree or radii. Here the global integration value of one specific axial line reflects the route completely from it to all others in the road network; hence this can be compared with relatively larger or global measures like 50 minutes of walking in Proximity counts. The local measures like connectivity and local integration covered only one two three steps away respectively, and they can be better compared with the smaller distance like 10 minutes or 20 minutes of walking time in proximity. Other measures of connectivity like depth and intelligibility are either the reciprocal of the integration or the combined results of global or local measures of integration.

As discussed in previous chapter, space syntax also measures the centrality of the street segment in reference to the rest of the segments in the network. In other words, it captures the relative accessibility of the street segments in question. For this study of high schools, one had calculated the relative centrality of every street segment based on the connectivity, local integration and global integration. Then the centralities of street segment, where the high school are located are then estimated. Since, it was difficult to find the exact locations of high school, the buffer of 400 meters for every high school were created and the highest values of connectivity, local integration and global integration are assigned for the location of high schools. The buffer of 400 meter buffer is to match twice the diameter of the hexagon chosen in the proximity counts (chapter 4). The centrality of location (of street segment) consisting or within the buffer 400 meters of high school in respect to all street networks is then estimated. If have a close look at the results some observations are listed below as:

- Connectivity measure: 77 Out of 91 (70%) high schools locations were located on top 10% central locations. Thant means the majority of high schools (80% government and 91% private) were located in and around the areas where the connectivity value of street segment is higher or lies within top 10% in overall network.
- Local Integration: Most (94%) of the high schools (both private and government) were located in and around top 10% central locations of the overall network.
- Global Integration: About (54%) 49 high schools -47% governments and 63% private- were located around top 10% central location from global integration point of view.

## 6.2. Comparison

To compare, the measures of proximity and connectivity, we begin with the descriptions of two methods. Both of them are GIS based accessibility measures. The proximity measure which is also called generic concept of accessibility defines how near the facility is to the individual. Hence the Proximity measure is basically based on the three components of supply, demand the links in between them. The relatively new measure of connectivity based on space syntax theory defines how easy is to move from one segment of street network to the rest of other segments- that is relative accessibility of network.

**Table 6-1 Indicator for comparison**

| Comparisons | Proximity | Connectivity |
|---|---|---|
| Software | ArcGIS /Flowmap | ArcGIS (Axwomen extension) |
| Approach /(process) | Grid based, use of hexagons for disaggregation of population (demand/supply) | Axial lines and their syntactic values were used as accessibility indicator |
| Components of accessibility | Explicit covers the Activities (high schools), Transport (road network) and origin or demand as population | Consider only the links-that is transportation-explicitly (even sometime modified to make the set of axial lines) |
| Analysis based on: | network | Network (axial lines) |
| measures | Different user-defined cut of distance radius (10, 20, 30, 40 and 50 minutes of walking) were used to count potential numbers of inhabitants | Integration both local and global, depth, connectivity etc were used as measures of space syntax to measure the accessibility of street network |
| Centrality index | Centrality of location for cost interval of 10, 20, 30, 40 and 50 minutes of walking to calculate the number of population (origin activities) available for every activity and centrality index of every location are referred to define the centrality of high school locations. | Index of the location of high schools (government and private) as compared to the overall centrality of the system calculated from connectivity, Local integration, global Integration, Depth etc |

Since both measures are GIS based, Flowmap/ArcGIS was used to analyze the proximity measure, and Axwomen extension in ArcGIS was used for calculation of accessibility of high schools as discussed in chapter 4 and 5 respectively and is summarized in Table 6-1. And finally the variations in results produced by two methods were analyzed.

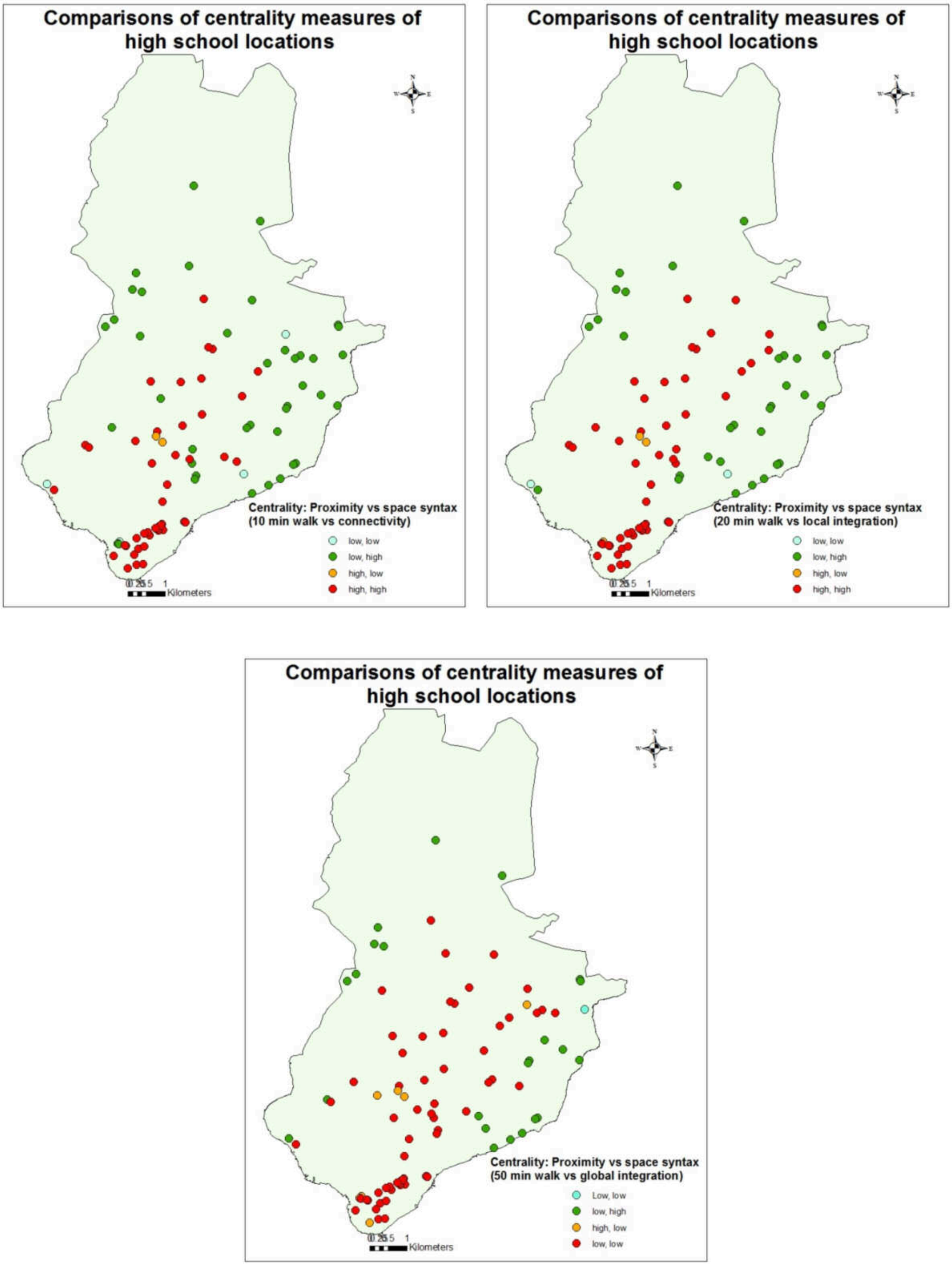



**Figure 6-1: comparisons of centrality measures of high school location based on the proximity and space syntax accessibility**

The values of centrality index for both proximity and space syntax methods were classified into two class: one was below average called low and the one above average called high. Similar results were observed in south part of the study area in all three cases, whereas more similarities were for whole study area wad identified in the global context (Figure 6-1). The higher values of 50 minutes walking and global integration has much more similarities. But the values around the periphery of the study area, the proximity count is low where as the global integration is above average (here term as high).

## 6.3. Added value of space syntax

The generic concept of acceptability based on proximity has been the key in planning the facilities from the long run. Though it is also suffering number of limitations, for example, competition between different high schools and the number of services (in this case high schools) available in one single location. The proximity count couldn't deal much about these problems. Whereas, the space syntax alone doesn't fixed the location of opportunities, since the location its values are rather spread along the street segment rather than the fixed point. But the centrality of location articulated from the space syntax could have added value in defining the location of services, with much more competitive way. The higher the values of connectivity, local integration and global integration, the place is important and more competition among facilities is expected. This could be the added value in planning the facilities. .

Hence, further improvements for accessibility based on proximity may be possible. A simple count of population cannot reflect the true capacity that meet the demand. In addition to refinements of the supply or destination for better accessibility measure, the demand or origin population should be refined as well. The measure based on the user defined distance can be hold for convenience. Though space syntax theory explicitly covers only the network, its essence to represents the people's activities implicitly makes it much easier to handle.

# 7. Conclusions and Recommendation

This chapter gives an overview on the main findings and conclusions of the research and provide some recommendations for supporting the urban spatial planning, in the path of combining the multiple theories of accessibility in future.

## 7.1. Main conclusions

As we define the generic concept of accessibility and more abstract measure of space syntax, it is a complex task to compare them and combine for added value of benefit. From the research we can draw several conclusions as:

- Proximity is a generic concept of accessibility that defines the nearness of an individual to the opportunities, whereas, the space syntax define the relative accessibility of streets segments.
- By quantifying and measuring the number of high schools in study area of Istanbul, it is distinct that facilities (high schools) are spread all over the study area and agglomerated more in and around the Istiklal Street (South East part of study area). The accessibility of every location for every possible demand was studied. The centrality of every location was then compared with the centrality of high schools location, so, to have an idea of accessibility of location of high schools on the basis of different user-defined cut off distance, to calculate the possible demand.
- As an abstract idea of composite physical object such as streets, relates to one another, the accessibility of different streets are studied and their centrality indices were measured using different measures of space syntax like connectivity, local and global integration.
- Though there were some clear distinctions between the results of proximity and space syntax measure for extreme cases like top ten percent, many similar results were observed in centrality of location of high schools especially in the central areas of the study areas for global parameters of both types of accessibilities.

## 7.2. Limitations

- Travel behaviour of students was not captured in the study
- In practice such kind of island formation for accessibility of services are rare, with the addition of new area on all four sides of study area, the results could be different.
- The value for space syntax is considered on buffer of 400 meters; this value is taken as the double the diameter of the hexagon in proximity analysis, but the travel from neighbour hexagon from one hexagon to next could be bit smaller than this. This could be managed more scientifically.

## 7.3. Recommendations

- We are capturing only two types of accessibility, the third type of accessibility, which is directly based on graph theory relates these two theories in some sort and in future if accessibility is studied we can incorporate the third type of accessibility to produce the combined effect.

- Study of not only the street segments but also incorporation of public transportation facilities could produce the different results

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# 9. Appendix 1

Table: showing the Centrality Index of Proximity count for different walking distance threshold

| | | | | Proximity based centrality index walking distance | | | | | Space syntax based centrality index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| objectid | Type | Name of School | label | 10 min | 20 min | 30 min | 40 min | 50 min | GI | LI | conn | ctrl |
| 1580 | | | | 0 | 0 | 0 | 0 | 0 | 170.01 | 4006.37 | 603.29 | 538.72 |
| 1321 | Govt | Kaºìthane Gültepe Endüstri Meslek Lisesi | 12923 | 59.81 | 20.56 | 73 | 82.41 | 72.36 | 155.51 | 3205.27 | 447.73 | 549.79 |
| 1328 | Govt | Cengizhan Lisesi | 13118 | -54.41 | 76.73 | 126 | 118.11 | 100.17 | 126.65 | 3298.22 | 486.62 | 437.87 |
| 1348 | Govt | Beyoºlu Anadolu Lisesi | 11737 | 11.2 | 108.04 | 137 | 124.3 | 103.84 | 126.65 | 3298.22 | 486.62 | 437.87 |
| 1359 | Govt | Bingül Erdem Lisesi | 13000 | 46.22 | -11.01 | -39 | -7.98 | 15.92 | 155.51 | 3205.27 | 447.73 | 549.79 |
| 1360 | Govt | Profilo Anadolu Teknik Lisesi (Erkek Tekni | 11773 | -21.7 | -21.73 | -14 | -5.36 | 15.33 | 119.8 | 3198.04 | 447.73 | 591.45 |
| 1376 | Govt | Ziya Kalkavan Anadolu Denizcilik Meslek Li | 13666 | -71.76 | -69.8 | -84 | -89.78 | -56.98 | 263.94 | 4255.59 | 681.07 | 638.87 |
| 1391 | Govt | Ortaköy Zübeyde Hanìm Anadolu Meslek Lises | 14054 | -20.37 | -67.3 | -88 | -107.7 | -88.75 | 168.49 | 2172.82 | 253.28 | 383.24 |
| 1393 | Govt | ÿstanbul Atatürk Lisesi | 12027 | 350.92 | 294.05 | 215 | 157.99 | 121.32 | 111.07 | 3298.22 | 486.62 | 437.87 |
| 1402 | Govt | Kaºìthane ÿmam Hatip Lisesi | 12740 | 135.38 | 55.68 | 82 | 96.1 | 85.97 | 168.24 | 2234.42 | 253.28 | 338.74 |
| 1416 | Govt | Kaºìthane Ticaret Meslek Lisesi | 10890 | 86.45 | 16.17 | -4 | -17.03 | -6.52 | 166.4 | 3631.02 | 564.4 | 662.31 |
| 1418 | Govt | Piƒli Anadolu Lisesi | 11658 | 64.09 | 24.5 | 93 | 113.04 | 108.45 | -20.22 | 637.03 | 58.83 | 199.29 |
| 1474 | Govt | Gültepe Lisesi | 12827 | 80.65 | 13.24 | 36 | 56.53 | 60.52 | 192.26 | 2584.31 | 253.28 | 282.12 |
| 1485 | Govt | Kaºìthane Lisesi | 11295 | -53.47 | -69.31 | -89 | -96.32 | -94.78 | 126.65 | 3298.22 | 486.62 | 437.87 |
| 1486 | Govt | Kaºìthane Ekrem Cevahir Çok Programlì Lise | 11686 | -16.25 | -70.12 | -99 | -122.02 | -130.2 | 126.65 | 3298.22 | 486.62 | 437.87 |
| 1493 | Govt | Halit Rìfat Paƒa Lisesi | 11373 | -9.09 | 2.81 | 16 | 71.31 | 81.69 | 175.99 | 1316.16 | 97.72 | 129.55 |
| 1545 | Govt | Güner Akìn Lisesi | 10403 | -13.78 | -30.13 | -53 | -74.08 | -45.58 | 69.04 | -919.19 | -57.84 | 56.99 |
| 1557 | Govt | Arnavutköy Korkmaz Yiºit Lisesi | 14737 | -73.94 | -81.67 | -100 | -126.12 | -158.23 | 168.24 | 2234.42 | 253.28 | 338.74 |
| 1559 | Govt | Ortaköy Zübeyde Hanìm Kìz Meslek Lisesi | 14054 | -20.37 | -67.3 | -88 | -107.7 | -88.75 | 286.09 | 4852.5 | 914.41 | 1072.85 |
| 1563 | Govt | Mehmet Ali Büyükhanlì Ticaret Meslek Lises | 14361 | -63.11 | -70.33 | -64 | -8.47 | 28.59 | 286.09 | 4852.5 | 914.41 | 1072.85 |
| 1575 | Govt | Piƒli Endüstri Meslek Lisesi | 12050 | -39.44 | 36.17 | 113 | 115.96 | 105.28 | 198.08 | 2898.32 | 369.95 | 286.32 |
| 1576 | Govt | Çaºlayan Lisesi | 11957 | 74.41 | 28.52 | 44 | 93.68 | 106.67 | 163.91 | 922.54 | 58.83 | 56.99 |
| 1578 | Govt | ÿ.T.O. Anadolu Meslek ve Terzilik Meslek L | 11544 | 318.58 | 281 | 209 | 157.84 | 119.35 | 96.98 | 3509.77 | 525.51 | 380 |
| 1583 | Govt | Ahi Evran Ticaret Meslek Lisesi | 12719 | 46.95 | 154.07 | 161 | 127.11 | 105.12 | 198.08 | 2898.32 | 369.95 | 286.32 |
| 1590 | Govt | Kasìmpaƒa Çok Programlì Lise (Ticaret ve T | 11448 | -24.35 | 120.51 | 141 | 133.56 | 107.15 | -8.33 | -122.5 | -18.95 | 92.56 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1591 | Govt | Ayƒe Ege Anadolu Kìz Meslek Lisesi | 11448 | -24.35 | 120.51 | 141 | 133.56 | 107.15 | -46.15 | 637.03 | 58.83 | 199.29 |
| 1592 | Govt | Kasìmpaƒa Çok Programlì Lise (Ortaögretim) | 11448 | -24.35 | 120.51 | 141 | 133.56 | 107.15 | 104.44 | 3616.81 | 564.4 | 686.08 |
| 1597 | Govt | Niƒantaƒì Anadolu Lisesi | 12617 | -2.64 | 106.23 | 125 | 109.95 | 96.2 | 111.07 | 3616.81 | 564.4 | 686.08 |
| 1602 | Govt | Beyoºlu Teknik Lise ve Endüstri Meslek Lis | 11544 | 318.58 | 281 | 209 | 157.84 | 119.35 | 201.52 | 4276.49 | 758.85 | 860.22 |
| 1603 | Govt | Mehmet Rìfat Evyap Endüstri Meslek Lisesi | 12568 | -45.04 | -74.74 | -101 | - 132.86 | -176.3 | 201.52 | 4276.49 | 758.85 | 860.22 |
| 1609 | Govt | Fìndìklì Lisesi | 12412 | 196.32 | 254.89 | 199 | 151.44 | 116.91 | 220.61 | 2012.81 | 175.5 | 157.78 |
| 1610 | Govt | Kabataƒ Ticaret Meslek Lisesi | 12412 | 196.32 | 254.89 | 199 | 151.44 | 116.91 | 264.31 | 3616.05 | 525.51 | 497.43 |
| 1615 | Govt | ÿSOV Yapì Meslek Lisesi | 13591 | 22.37 | 166.78 | 170 | 139.71 | 109.93 | 119.8 | 3616.81 | 564.4 | 686.08 |
| 1619 | Govt | Mecidiyeköy Lisesi | 12725 | 47.8 | 31.82 | 74 | 90.12 | 75.51 | 88.53 | 1567.29 | 136.61 | 259.17 |
| 1620 | Govt | Kurtuluƒ Lisesi | 11942 | 167.84 | 39.95 | 71 | 90.98 | 90.9 | 111.07 | 3616.81 | 564.4 | 686.08 |
| 1622 | Govt | Taksim Ticaret Meslek Lisesi | 12027 | 350.92 | 294.05 | 215 | 157.99 | 121.32 | 126.65 | 3298.22 | 486.62 | 437.87 |
| 1626 | Govt | Yeni Levent Lisesi | 13412 | -74.82 | 59.06 | 113 | 113.12 | 98.4 | 295.57 | 4587.9 | 797.74 | 656.1 |
| 1630 | Govt | Galatasaray Anadolu Lisesi | 11834 | 8.36 | 113.26 | 141 | 124.95 | 104.48 | 155.51 | 2234.42 | 253.28 | 237.12 |
| 1634 | Govt | Anadolu Otelcilik veTurizm Meslek Lisesi | 13979 | -37.52 | 23.49 | 95 | 107.76 | 93 | -79.9 | 249.81 | 19.94 | 110.35 |
| 1643 | Govt | Etiler Lisesi | 14170 | -26.92 | -51.83 | -3 | 44.05 | 61.35 | 184.85 | 3042.74 | 408.84 | 404.1 |
| 1646 | Govt | Rüƒtü Akìn Anadolu Meslek Lisesi | 14751 | -60.3 | -73.58 | -96 | -117.3 | -89.4 | 211.16 | 2464.04 | 292.17 | 297.27 |
| 1647 | Govt | Levent Kìz Meslek Lisesi | 14169 | -17.97 | -38.11 | 27 | 66.14 | 72.53 | 160.86 | 3631.02 | 564.4 | 662.31 |
| 1652 | Govt | Rüƒtü Akìn Kiz Meslek Lisesi | 14751 | -60.3 | -73.58 | -96 | -117.3 | -89.4 | 111.07 | 3616.81 | 564.4 | 686.08 |
| 1669 | Govt | ÿTO Anadolu Ticaret Meslek Lisesi | 11081 | 150.54 | 54.32 | 11 | 2.58 | 8.19 | 166.4 | 3948.47 | 642.18 | 492.31 |
| 1670 | Govt | Yunus Emre Lisesi | 12437 | 98.95 | 93.58 | 131 | 122.73 | 104.02 | 126.65 | 3298.22 | 486.62 | 437.87 |
| 1678 | Govt | Beƒiktaƒ Lisesi | 13473 | -56.74 | -59.28 | -71 | -41.38 | -3.99 | 190.49 | 4276.49 | 758.85 | 860.22 |
| 1696 | Govt | Atatürk Anadolu Lisesi | 13284 | -52.49 | -61.48 | -70 | -70.72 | -39.36 | 98.93 | -302.49 | -18.95 | 86.63 |
| 1730 | Govt | Sakìp Sabancì Anadolu Lisesi | 13191 | 25.01 | -12.75 | -52 | -32.37 | -1.55 | 111.07 | 3616.81 | 564.4 | 686.08 |
| 1734 | Govt | Kabataƒ Erkek Lisesi | 13860 | -64.48 | -71.58 | -88 | - 106.21 | -86.08 | 83.16 | 2159.07 | 253.28 | 240.51 |
| 1743 | Govt | Maçka Akif Tuncel Endüstri Meslek Lisesi | 12612 | -50.03 | -8.87 | 58 | 71.73 | 73.05 | 111.07 | 3616.81 | 564.4 | 686.08 |
| 1758 | Govt | Piƒli Lisesi | 12429 | 18.39 | 134.45 | 163 | 130.85 | 109.75 | 111.07 | 3616.81 | 564.4 | 686.08 |
| 1761 | Govt | Rüƒtü Uzel Kìz Meslek Lisesi | 12519 | 15.01 | 156.48 | 157 | 124.07 | 105.4 | 149.73 | 3298.22 | 486.62 | 437.87 |
| 1769 | Govt | Vali Hayri Kozakçìoºlu Ticaret Meslek Lise | 11877 | -53.68 | -74.17 | -103 | - 130.95 | - 156.27 | 104.44 | 3616.81 | 564.4 | 686.08 |
| 1774 | Govt | Kaºìthane Anadolu Lisesi | 11785 | -57.06 | -72.6 | -102 | - 126.44 | -138.5 | 104.44 | 3616.81 | 564.4 | 686.08 |
| 1781 | Govt | Dr. Sadìk Ahmet Lisesi | 12554 | -35.69 | -55.71 | -62 | -28.23 | 21.82 | 111.07 | 3298.22 | 486.62 | 437.87 |
| 1790 | Govt | Niƒantaƒì Nuri Akìn Lisesi | 12611 | -46.03 | -28.72 | 35 | 58.22 | 61.89 | 111.07 | 3298.22 | 486.62 | 437.87 |
| 1297 | Private | Özel Beyoºlu Yabancì Lise (Italyan) | 11929 | 104.11 | 167.03 | 166 | 137.69 | 108.49 | 190.49 | 4276.49 | 758.85 | 860.22 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 1301 | Private | Özel BJK Türk Anadolu Lisesi | 13772 | -79.03 | -87.37 | -58 | 4.1 | 26.63 | 184.85 | 3042.74 | 408.84 | 404.1 |
| 1311 | Private | Robert Yabancì Lise (Amerikan) | 14547 | -81.15 | -85.98 | -104 | -130.93 | -169.98 | 162.34 | 1911.23 | 214.39 | 513.52 |
| 1336 | Private | Mavi Haliç Özel Türk Lisesi | 10497 | 62 | -17.34 | -43 | -43.02 | 3.64 | 111.07 | 3298.22 | 486.62 | 437.87 |
| 1366 | Private | Özel Zapyon Azìnlìk (Rum) Lisesi | 12123 | 296.1 | 281.6 | 209 | 155.79 | 119.72 | 55.22 | 1567.29 | 136.61 | 259.17 |
| 1372 | Private | Tarhan Özel Türk Anadolu Lisesi | 11735 | 473.08 | 323.18 | 226 | 165.18 | 122.42 | 200.42 | 2613.76 | 292.17 | 328.4 |
| 1380 | Private | Özel Zografyon Azìnlìk (Rum) Lisesi | 11834 | 8.36 | 113.26 | 141 | 124.95 | 104.48 | 175.99 | 2959.72 | 408.84 | 393.86 |
| 1381 | Private | Opera Güzel Sanatlar Özel Türk Anadolu Lis | 12122 | 50.93 | 162.27 | 167 | 136.08 | 109.61 | 198.08 | 2898.32 | 369.95 | 286.32 |
| 1389 | Private | Özel Merkez Azìnlìk (Rum) Lisesi | 12026 | 115.4 | 172.4 | 169 | 137.12 | 110.28 | 119.8 | 3198.04 | 447.73 | 591.45 |
| 1410 | Private | Notre Dame De Sion Yabancì Lise (Fransìz) | 12227 | 43.44 | 80.5 | 106 | 104.24 | 91.9 | 150.29 | 4623.01 | 914.41 | 716.32 |
| 1484 | Private | Özel Sadabad Özel Türk Lise (Klasik) | 11392 | -61.87 | -70.32 | -83 | -87.07 | -86.31 | 168.49 | 2172.82 | 253.28 | 383.24 |
| 1561 | Private | Özel Azìnlìk (Musevi) Lisesi | 14164 | -52.27 | -68.41 | -88 | -57.85 | -12.13 | 162.18 | 3631.02 | 564.4 | 662.31 |
| 1564 | Private | Yeni Yìldìz Özel Türk Anadolu Lisesi | 14842 | -63.5 | -76.55 | -95 | -115.16 | -79.32 | -72.03 | 207.54 | 19.94 | 68.85 |
| 1579 | Private | Özel Sankt Georg Avusturya Lisesi ve Ticar | 11540 | 7.31 | 165.91 | 166 | 139.29 | 110.41 | -46.15 | 637.03 | 58.83 | 199.29 |
| 1582 | Private | Pangaltì Azìnlìk (Ermeni) Lisesi | 12232 | 153.04 | 248.63 | 182 | 149.18 | 114.65 | 163.91 | 922.54 | 58.83 | 56.99 |
| 1584 | Private | Saint Michel Yabancì Lise (Fransìz) | 12138 | 360.12 | 322.71 | 211 | 163.89 | 123.1 | -54.04 | -1482.64 | -96.73 | -20.09 |
| 1589 | Private | Iƒik Özel Türk Anadolu Lisesi | 12518 | -37.23 | 18.52 | 85 | 82.45 | 83.48 | 190.49 | 4276.49 | 758.85 | 860.22 |
| 1606 | Private | Özel Sainte Pulchérie Fransìz Yabancì Lise | 12027 | 350.92 | 294.05 | 215 | 157.99 | 121.32 | 119.8 | 3616.81 | 564.4 | 686.08 |
| 1607 | Private | Özel Saint Benoit Yabancì Lise (Fransìz) | 11636 | 273.6 | 282.06 | 210 | 155.85 | 119.97 | 286.09 | 4852.5 | 914.41 | 1072.85 |
| 1612 | Private | Özel Esayan Azìnlìk (Ermeni) Lisesi | 12123 | 296.1 | 281.6 | 209 | 155.79 | 119.72 | 264.31 | 3616.05 | 525.51 | 497.43 |
| 1613 | Private | Özel Alman Yabancì Lise (Alman) | 11638 | 369.02 | 308.5 | 219 | 161.59 | 121.62 | 104.44 | 3616.81 | 564.4 | 686.08 |
| 1623 | Private | Piƒli Terakki Lisesi Özel Türk Lise (Klasi | 13981 | -32.89 | 29.3 | 97 | 109.09 | 93.17 | 196.75 | 632.46 | -57.84 | 56.99 |
| 1627 | Private | Özel Tudem Özel And. Otelcilik ve Turizm M | 12127 | 85.25 | 222.21 | 173 | 139.77 | 111.42 | 264.31 | 3600.65 | 525.51 | 497.43 |
| 1628 | Private | MEF Uluslararasì Lise | 13968 | -45.06 | -69.98 | -93 | -115.54 | -89.69 | 166.4 | 3948.47 | 642.18 | 492.31 |
| 1629 | Private | Özel ÿtalyan Yabancì Lise (Italyan) | 11831 | 6.9 | 116.48 | 141 | 123.6 | 105.29 | 211.16 | 2464.04 | 292.17 | 297.27 |
| 1636 | Private | Özel Getronagan Ermeni Lisesi Azìnlìk (Erm | 11732 | 742.21 | 388.2 | 253 | 175.25 | 126.16 | 166.4 | 3948.47 | 642.18 | 492.31 |
| 1637 | Private | Yìldìz Özel Türk Anadolu Lisesi | 13688 | -31.58 | 109.29 | 141 | 132.41 | 105.65 | 119.8 | 3198.04 | 447.73 | 591.45 |
| 1644 | Private | ÿstek Atanur Oºuz Özel Türk Anadolu Lisesi | 13485 | -23.41 | -21.77 | 61 | 79.65 | 74.74 | 126.65 | 3298.22 | 486.62 | 437.87 |
| 1658 | Private | Nilgün Doºay Özel Türk Lise (Klasik) | 13298 | 29.11 | 163.45 | 171 | 135.86 | 107.36 | 190.49 | 4276.49 | 758.85 | 860.22 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1707 | Private | Mef Lisesi Özel Türk Anadolu Lisesi | 13968 | -45.06 | -69.98 | -93 | -115.54 | -89.69 | 190.49 | 4276.49 | 758.85 | 860.22 |
| 1728 | Private | Özel Ata Anadolu Lisesi | 13389 | -14.19 | -14.97 | 60 | 76.74 | 71.96 | 111.07 | 3298.22 | 486.62 | 437.87 |
| 1751 | Private | Boºaziçi Özel Türk Anadolu Lisesi | 13618 | -82.96 | -88.16 | -110 | -133.34 | -121.77 | 286.09 | 4852.5 | 914.41 | 1072.85 |
| 1752 | Private | Bilgi Özel Türk Anadolu Lisesi | 12044 | 98.45 | 219.21 | 190 | 154.51 | 119.62 | 149.73 | 3298.22 | 486.62 | 437.87 |
| 1777 | Private | Özel Tudem Akƒam Anadolu Otelcilik ve Turi | 12127 | 85.25 | 222.21 | 173 | 139.77 | 111.42 | 111.07 | 3616.81 | 564.4 | 686.08 |
| 1793 | Private | Evrim Özel Türk Lise (Klasik) | 12043 | 140.16 | 228.01 | 188 | 155.83 | 119.87 | -1007.17 | -4299.91 | -213.4 | -358.04 |