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## Spatial Characteristics of Labor Mobility and Innovation inside an Industrial Cluster: Some Reflections from Siteler in Ankara

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**50th Anniversary European Congress of the Regional  
Science Association International**

**“Sustainable Regional Growth and Development in the Creative  
Knowledge Economy”**

**Socio-Spatial Characteristics of Labor Mobility and Innovation inside an  
Industrial Cluster: Some Reflections from Siteler in Ankara**

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**19 - 23 August 2010 - Jonkoping, Sweden**

# **Socio-Spatial Characteristics of Labor Mobility and Innovation inside an Industrial Cluster: Some Reflections from Siteler in Ankara**

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Although the literature on industrial clusters and districts emphasizes the role of labor mobility in the diffusion of innovation and tacit knowledge, relatively little academic effort supported by strong empirical evidences has been made in order to reveal the association between labor mobility and innovation in an appealing way. Likewise, the experimental studies outlining the spatial characteristics of labor mobility and innovation inside a cluster are nearly absent. In terms of its inner spatial configuration, the cluster itself is a black box for not only economists but also geographers and planners especially when the interplay of labor mobility and innovation is considered. Most of the studies either tend to concentrate on a single cluster without informing us about the actual relevance of space inside the cluster or compare the clusters in a region (or country) again without developing a proper measure for the comparisons of the respective clusters in terms of the socio-spatial characteristics of the labor mobility and innovation inside them. In this regard, the basic pursuit of this paper is both to develop and utilize simple measures in order to account for the relevance of space in different configurations of innovation and labor mobility inside an industrial cluster by making use of the parameters and techniques developed for Social Network Analysis (SNA), Space Syntax (SS) and Geographic Information Systems (GIS). What is especially remarkable in this study is the preference for free and open source software and establishment of author's own algorithms. In an attempt to reveal the socio-spatial contexts of the labor mobility and innovation occurring inside a cluster, firstly streets involved in Siteler, an industrial cluster in Ankara and specialized in furniture production, are divided into segments according to some intuitive criteria. Subsequently, a series of analysis is conducted by employing parameters of SNA, SS and GIS. What is evident from this paper is that labor mobility and innovation inside Siteler is strongly imprinted with the spatial configuration of streets in the cluster.

## 1. Introduction

The role of labor mobility in the diffusion of innovation and tacit knowledge is well documented. As Hodgson (1988: 142) argues, “the **skills** learned by a worker in a given firm become partially **embedded in** his or her **habits**, and these will **survive if the person changes employer**, or if they are ‘taught’, explicitly or by imitation, to a colleague” [emphasis added]. The literature on especially high-tech industrial districts, learning regions, innovative milieu and local innovations systems (Steed, 1987; Saxenian, 1990; Angel, 1991; Camagni, 1991; Harrison, 1994; Maillat, et al., 1995; Garnsey, 1998; Henry and Pinch, 2000; Breschi and Lissoni, 2001; Beyhan, 2006) is absolutely complementary to this account, though with some reservations, as explained by Beyhan (1999), for the employment of ‘learning-by-moving’ as a tool of economic development. Although circulation of habits and routines through tacit conducts of knowledge is not limited to formal labour mobility as part of an economic point of view, labor mobility is very central to the formation of cognitive architecture in a functional region (Beyhan, 2006, 2008 and 2010). In fact, the learning process triggered by labor mobility can be described as a different category (such as the one defined by Beyhan (1999 and 2001) with reference to the motivations behind ‘learning-by-moving’ and ‘earning-by-moving’). Even some of the new growth theorists such as Grossman and Helpman (1994) admit this fact as an integral part of the economic growth and development process.

Although there is an ever growing literature acknowledging the role of the cluster as a medium for labor mobility and innovation (or more generally firm performance), in terms of its inner spatial configuration, the cluster itself is a black box for not only economists but also geographers and planners. Especially, in recent years the number of studies employing Social Network Analysis (SNA) has dramatically increased. Yet, as it is discussed by Beyhan (2008), there are certain biases in the respective literature. One of the remarkable biases of the literature is the exclusive focus on modern high-tech sectors at the expense of low-tech and traditional sectors. Indeed, although there is a number of studies employing SNA and concerning labor mobility in connection with innovation (see for example Breschi and Lissoni (2003), Cantner and Graf (2006), Casper (2007) and Graf and Henning (2009)), respective studies having a concern in the application of SNA on labor mobility and innovation mostly do it by tracking the career paths of scientists or senior managers. Actually, regardless of an interest in the employment of SNA, one can argue that this is a general trend in the studies

discovering the interconnections between labor mobility, innovation and diffusion of ideas (see for example Crespi, Geuna and Nesta (2007), and Miguélez and Moreno (2010)).

But, there is no doubt that learning and innovation is an activity going on in all parts of the economy including both traditional sectors such as manufacture of furniture and textile products, and other sectors that are not characterized by high-tech. Some of the new studies seem to overcome this problem by focusing on relatively more traditional or non-high-tech sectors of the economy (see for example Møen (2000), Lam and Lundval (2004), Frederiksen and Sedita (2005), and Vinodrai (2005)). Yet, it is observed that they did not employ the potential of SNA for the exploration of the social contexts revealed by the mobile laborers. Nevertheless, it is important to note that the first half of the 2000s has witnessed, though limited, a growing number of studies focusing on or accounting for the interconnections between labor mobility and dissemination of innovation and (tacit) knowledge. Among them Møen (2000), Dahl (2002 and 2004), Power and Lundmark (2003), Aslesen, Isaksen and Stambøl (2004), Frederiksen and Sedita (2005) and also Vinodrai (2005) especially deserve attention.

Another bias of the labor mobility studies having a concern both in SNA and in innovation and knowledge spillover is the employment of relatively small databases (Beyhan, 2008). Indeed, in spite of the availability of large databases and the computation power provided by modern computer technology, bulk of the labor mobility studies having a concern in the application of SNA still concentrates on small networks. Fortunately and interestingly, in recent years the role of labor mobility and interactions in knowledge dissemination and economic performance has been seriously investigated by drawing on relatively large databases (see for example Møen (2000 and 2007), Dahl (2002 and 2004), Power and Lundmark (2003), Aslesen, Isaksen and Stambøl (2004), Eriksson and Lindgren (2009), also Castillo et al. (2006), Destré, Lévy-Garboua and Sollogoub (2008)). Yet, it is again observed that these studies do not develop a concern for the application of SNA to study of relationships between labor mobility and innovation.

As it is discussed in Beyhan (2008), as part of a wider research program, the database employed in his study is specifically designated in order to overcome the biases discussed above. Following the research program offered by Granovetter (1973), Beyhan's (2008) recent study is an attempt in order to show the merits of SNA in outlining the cognitive

architecture of a region by uncovering the inter-firm social networks created by mobile laborers. Although the database employed in this study is the same with the one used in Beyhan (2008), the primary concern of this paper is a blend of concerns motivated by the application of graph theoretical framework and parameters to not only the analysis of social networks but also the spatial configurations of basic spatial units (BSU) in Siteler. In this respect, application of SNA to the examination of the inter-firm social networks created by mobile laborers constitute only one dimension of the story. In this paper, it is rather intended to fill the missing parts in the respective story by extending the application of graph theoretical framework to the co-examination of the relationships and interconnections between spatial configurations, the inter-firm social networks created by labor mobility, innovativeness and some other attributes available for both firms and employees.

Having given these introductory remarks presented above, the rest of the paper is organized as following: Firstly, a juxtaposition of SS to SNA is presented with some reservations for the historical precursors and methodological clarity. Subsequently, construction of the spatial database is discussed as an ontological and methodological appeal by drawing on the semantics and ontological qualities of the line networks employed in this study. After elaborating some of the parameters of both SNA and SS by re-exploring the interconnections between the respective graph theoretic endeavors, the analysis conducted by employing the graph theoretical parameters of SNA and SS are presented in a step wise fashion. Last section of the paper re-elaborates the findings emerging from both the discussion of the methods and the analysis conducted in this study by drawing on some concluding remarks.

## **2. A Juxtaposition of SS and SNA with Some Reservations for the Historical Precursors and Methodological Clarity**

Although Space Syntax (SS) parameters were first developed by Bill Hillier and Julienne Hanson (Hillier and Hanson, 1984) at the University College London (UCL) during the late 1970s and the early 1980s in order to analyze the spatial configurations, some of the parameters (such as connectivity, total depth and mean depth) employed in SS have already been used by those social scientists developing or employing social network analysis (formerly known as sociometrics) in their studies, though under different and maybe more proper names (see especially Freeman (1977 and 1978) for an elaboration of the concept of

centrality in the respective studies). It should be emphasized that both Social Network Analysis (SNA) and SS heavily draw on the graph theory borrowed from mathematics.

In this respect, some of the recent studies that have successfully employed SNA for the analysis of the relationships between social networks and innovation deserve attention and reveal the need for the inclusion of a spatial perspective into analysis of the respective relationships. One of the successful application of SNA to the analysis of the interconnections between social networks and innovation is Ter Wal's (2009) study, though he does not focus on the role of labor mobility in the dissemination of knowledge. Although Ter Wal (2009) claims "to introduce a spatial dimension into the dynamic analysis of innovation networks", he only reveals the fact that "proximity between inventors is mostly relevant in a situation of knowledge exploration" without informing us about the actual spatial processes inside an agglomeration or cluster. Nevertheless, his focus on **triadic closure** (clique) as an ingredient of innovation deserve attention despite the fact that he does not provide us with the geographical extent of the respective cliques.

In fact, Ter Wall's (2009) attempt to cast the cliques against the geographical proximity leads us to a confusion because of his fallacy in the conceptualization of the relationships between social networks and spatial configurations. It is clear that clique formations can be operative both inside a cluster and between the clusters. Thus, a spatial quest for SNA and innovation should be sensitive to the spatial characteristics of the clique formations and their association with innovation. That's why in this study the respective measure have been developed and employed by drawing on both SNA and SS also utilizing Free and Open Source Software (FOSS) programs for Geographic Information Systems (GIS).

In another paper, Ter Wal and Boschma (2009) try to present 'key analytic issues' for the application of SNA in economic geography without any reference to the earlier interactions between the respective fields of geography and sociometry. It is within this context that Hägerstrand's study on diffusion of innovation as a spatial process gains critical importance and deserves to be presented as a historical precursor despite the fact that he did not overcome his metric of conception of distance. Another important issue which is completely omitted in Ter Wal and Boschma (2009) is the possibility of employment of employer-to-employee databases in the construction of large social networks. As discussed in introduction, it is important to note that respective databases have been already investigated by many scholars,

though, without a concern on the application of SNA for the exploration of the social structures embedded in these large databases.

Beyhan's (2008) recent study is also illustrative for the employment of SNA in the analysis of social networks created by mobile laborers in order to shed some light on the formation of social sub-groups, diffusion of innovation and tacit knowledge within and through an industrial cluster. Although in his study Beyhan (2008) does not explore the spatial configuration of the cluster, he suggests it as an area of future research in the form of exploration and explanation of the interactions between spatial and network dynamics in industrial clusters by developing co-evolving perspective between SNA and Geographic Information Systems (GIS). It is partly within this context that the aim of this paper is designated to uncover the socio-spatial configurations and relationships behind the respective network outlined in Beyhan (2008) by drawing not only SNA but also SS parameters in combination with opportunities provided by available 'FOSS for GIS programs'<sup>1</sup>.

In fact, in terms of employment of SS and SNA, a co-elaboration of social networks and spatial configurations in relation to innovation can be observed in two remarkable articles published by Peponis et al. (2007) and Wineman, Kabo and Davis (2009) in *Environment and Behavior*. Nevertheless, respective studies focus on the interconnections between innovation, spatial configuration and social networks by drawing on only 'innovative organizations and buildings' without developing a concern for the larger spatial configurations and labor mobility. It is interesting to note that some earlier attempts (such as the one made by Hägerstrand) seem to be more successful in this respect.

## **2.1. Some Earlier Attempts: The Historical Precursors**

It can be argued that one of the earlier applications of graph theory to the analysis of spatial configurations of BSUs can be observed within the field of regional science and geography in order to delimit the planning regions by drawing on functional regions (Beyhan, 2010). It is no accident that nodal region as a derivative of functional region, as explained below, also attracted Hägerstrand's interest when he launched the concept of 'private information field'.

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<sup>1</sup> See Steiniger and Bocher (2009) and Beyhan, Belge and Zorlu (2010) for comparisons of different FOSS for GIS (FOSS4GIS). In this study, all of the space syntax parameters have been calculated by producing and employing a set of plugin scripts that can be run in a series of FOSS4GIS. The respective plugins will be presented in another paper by focusing on the scripting facilities available in FOSS4GIS.

Yet, it should be noted that a rough spatial representation of social networks can actually be first observed during the 1930s in a study conducted by Loomis and Davidson (1939) who display the social relations among the members of a rural community on a cartographic map (see Figure 1). Nevertheless, one may find the earlier considerations or implications of the employment of SNA for the analysis of spatial processes in the innovation diffusion studies of Hägerstrand, though it was not employed by him in an exhaustive way.

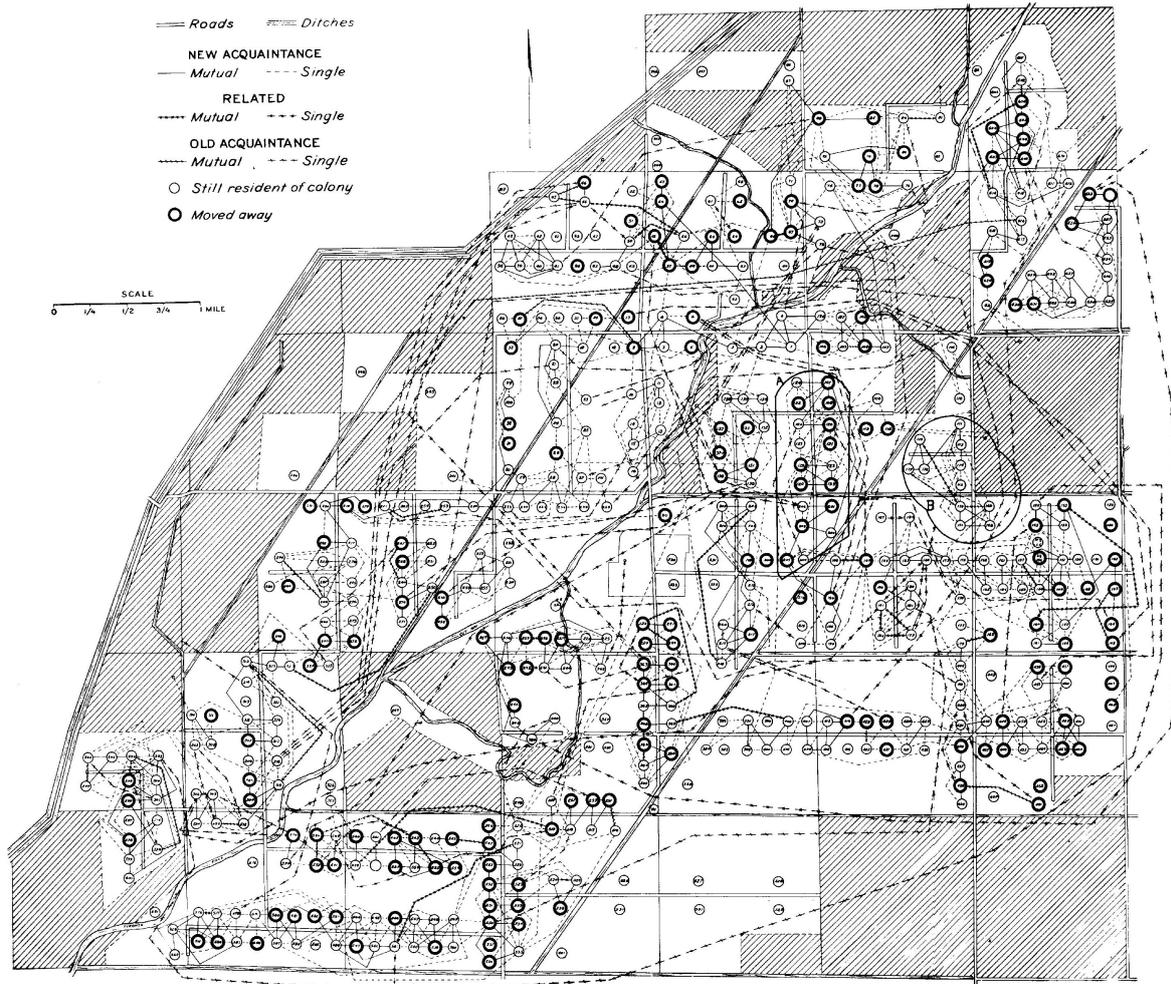


Figure 1 Visiting relationships of Families Residing on Dyess Colony, Arkansas, May 1936 (Loomis and Davidson (1939)).

It is not difficult to infer from his book on “Innovation Diffusion as a Spatial Process” that Hägerstrand was very much influenced by Moreno, founder father of sociometric studies that has in later years become known as SNA. The private information field, one of the most important concepts of Hägerstrand ([1953] 1967: 166-167), is actually based on the sociometric concept of “the social atom suggested by Moreno”. Social atom refers to “[t]he smallest constellation of psychological relations which can be said to make up the individual

cells in the social universe” (Moreno, 1934: 432 quoted in Hägerstrand, [1953] 1967: 166). As the construction of structural ties even for a moderate geographical region would be very difficult, Hägerstrand ([1953] 1967: 167) found it “feasible to derive at least the approximate values and types of private information fields” which is actually “a spatial substitute for the psychological concepts of social atoms”. Hägerstrand adds that “the concept is [also] compatible with other closely related ideas which have been developed in connection with research on “the centered nodal region”. In this respect, private information fields “can be considered as centered regions where single individuals, rather than places, establishments, or institutions, act as centers” (Hägerstrand, [1953] 1967: 167).

Considering these early contacts between Hägerstrand and sociometrics, it is no accident that he is well acknowledged by Freeman, White and Romney (1992) in their book titled as “*Research methods in social network analysis*”. As Freeman, White and Romney (1992: 167) reveal the basic contribution of Hägerstrand to the social network models is the introduction of the **geographic propinquity** as a major factor in diffusion of innovations. Although, Hägerstrand successfully identified the opportunities provided by sociometric conception of relationships between the actors and partly implemented them in the analysis of innovation diffusion as a spatial process, he could not foresee the possibility of implementing the same method for the elaboration of the spatial configurations themselves and based his analysis on the metric conception of the distance and space as it was the case for majority of studies during the ‘quantitative revolution in geography’ experienced in the 1950s and the 1960s. Reduction of space to distance and probability functions were the inevitable consequences of this revolution.

During the 1970s, it was Hillier and his colleagues who proposed the employment of graph theory as a method to uncover the spatial configurations themselves. Today, SNA, SS and GIS have been actively employed for the analysis of both social networks and spatial configurations. Nevertheless, the number of studies exploring the interconnections between the respective tools and methods of analysis is very limited. In terms of co-elaboration of social networks and spatial configuration in relation to the concepts of innovation and diffusion of knowledge, as noted above, those studies conducted by Peponis et al. (2007) and Wineman, Kabo and Davis (2009) especially deserve attention, though they do not explore the interconnections between spatial layout, social networks and innovation in a wider spatial context composed of streets in a city or industrial cluster. Another study focusing on the co-

elaboration of spatial configurations and social networks, though without a concern in innovation, is conducted by Radil, Flint and Tita (2010) employing SNA to investigate the geographies of gang rivalry, territoriality, and violence in Los Angeles.

Radil, Flint and Tita (2010: 308) is especially successful in arguing for reduction of “the possibility of privileging space over social process” by employing social network analysis in spatializing social networks. According to them, employment of SNA “operationalizes relational data in a way that allows simultaneous systematic evaluation of the way in which social actors’ positionality in network relationships and spatial settings provide constraints and possibilities on their behavior” (Radil, Flint and Tita, 2010: 309). For Radil, Flint and Tita (2010: 311), “space is socially constructed” and “part of the construction process relates to the simultaneous geographic embeddedness and network position of actors”. This point of view seems to be problematic for Hillier (2008) in his conception of the methodological standing that is most appropriate for ‘Space Syntax’ studies, which also constitutes the underlying theme for the subsequent sub-section before proceeding into the next section dealing with the construction of the spatial database as an ontological and methodological appeal.

## **2.2. Methodological Disputes Raised for the Employment of SS and the Need for a Methodological Clarity**

As it is partly revealed above, methodological standing offered for SS by its originators and subsequently favored by those employing the respective methods of spatial analysis seems to be problematic. This is especially evident in Hillier (2008) and subsequently in SS studies conducted by some followers (see for an example Vaughan, et al. (2005)). According to Hillier (2008), in the fields of social study on ‘urban sociology’ and ‘society and space’, the relationship between society and environment is examined by assigning a priority to society (in his words ‘society first’). Consequently, he argues that in the respective fields “the form of the environment is sought as the product of the spatial aspects of social processes”, which is called by him as the spatiality paradigm. For Hillier (2008: 218), “such approaches have never reached, and probably can never reach, the level of precision about the built environment which would be needed to find testable propositions at the design level”. Subsequently, he suggests that one can follow “the other way round and through ‘environment-first’ studies look for evidence of social processes in the form of the built environment” (2008: 218). In

order to illustrate the merits of this approach, what he calls as ‘space syntax’ paradigm, he tries to undertake a deconstructive critique of spatiality paradigm.

Although Hillier (2008: 224) favors a methodological position prioritizing space over social in arguing that “there must in the first instance be a some kind of logic of space on which [a social logic of space] can be built”, he dismiss one of the central dimensions of socio-spatial processes, time, for which that’s why Hägerstrand’s time-geography is much valuable (though Hägerstrand himself can also be listed, according to the narrative of Hillier, among the opponents of spatiality paradigm). By assigning an implicit and unresolved arbitrariness to spatiality paradigm’s conception of space, Hillier (2008: 224) claims that “it is not clear that it would be possible to argue in a coherent way that space was being shaped by society”. Shortly, Hillier (2008: 224) calls for a space for the study of ‘space of space’ by arguing that rejection of such kind of a line of research “deter engagement between social theory and those who create the built environment” and excludes “the possible agency of spatial transformation in social morphology”. Although much of the methodological standing favored by Hillier (2008) is not acceptable from the point of view favored in this study, his following remark for the spatiality paradigm deserves consideration in that it partly reflects the underlying causal mechanisms through which the proponents of the spatiality paradigm do not develop a strong concern for the application of the relatively less known yet powerful mathematical methods of analysis (such as graph theory) to the examination of socio-spatial processes:

In this context, attention to spatial patterns without reference to the social processes creating those patterns is to turn away from the reasons for studying space. ... Studying the forms of the material world other than in the light of their social causes seems to be to take a step back into the western darkness. ... For these authors, the idea that space in itself is a worthwhile object of study then risks a repetition of what these authors had come to see as the intellectual error of the 1960s[, the ‘quantitative revolution’]. (Hillier, 2008: 223)

Methodologically this paper does not favor the meta-theoretical position proposed by Hillier (2008) for SS. In this study, it is rather claimed that causation is neither unidirectional nor unilevel from a predefined unique socio-spatial order to predefined indivisible socio-spatial agents. It is both multi-directional and multi-level without any analytical priority assigned to either the respective agents and order, or the time and space. In this respect, this study’s preoccupation with space syntax is restricted with the graph theoretical infrastructure of SS. It

should also be reminded that it is through the same infrastructure, parallel to Radil, Flint and Tita (2010), Hanneman and Riddle (2005) emphasize the following:

One of the major continuing themes of social network analysis is the way in which individual actors ‘make’ larger social structures by their patterns of interaction while, at the same time, institutional patterns shape the choices made by the individuals who are embedded within structures. Hanneman and Riddle (2005)

### **3. Construction of the Spatial Database: An Ontological and Methodological Appeal for the Determination of the Basic Spatial Units**

In the application of graph theory to a spatial configuration composed of streets, as it is the case with SS studies, there are basically three options available for the construction of line networks that will be used in order to produce an adjusted graph representing adjacency between the basic spatial units (BSU).<sup>2</sup> The first one is to divide streets into their constituent parts by producing different nodes for each segment involved in any street. Respective segments are defined according to the intersection between the streets such that each segment can be distinguished by its end points that are either connected to other segments or dead ends without any connection to other segments. This option can be called as ‘segment approach’. In this way, each segment is treated separately in the space syntax analysis (for an example see Demšar, Špatenková and Virrantaus (2007) who take “the original vertices and edges of the street network as the basic spatial elements in the calculation of the line graph”). The second option which employs axial lines is more traditional in SS studies and actually based on the visibility pattern of the streets. In this option, line network is constructed upon the vistas. Accordingly, streets are partitioned into axial lines in such a way that as long as possible each street is represented by a set of longest but fewest lines along which one can easily see both ends of the respective lines. The concept of axial line was first introduced by Hillier and Hanson (1984).

The third and last option takes the streets themselves as the basic spatial unit of analysis without disaggregating them into segments or axial lines. For the first experiments in this direction see Jiang and Claramunt (2004), who employ the streets as the BSUs in the construction of adjusted graph. According to the third option, for each separate street in a

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<sup>2</sup> In SS, adjusted graphs can also be produced for the network of convex spaces (polygons).

given area a node is created in the adjusted graph according to the names of the respective streets. In a recent study (Tomko et al., 2008: 44), this approach is labeled as ‘named streets’ approach. Named streets approach puts its emphasis on the fact that in daily life people usually refer to streets by only employing their names not the particular segments that actually constitute the respective streets. Although it can be argued that this reflects some part of the reality, there is no doubt that under certain circumstances street names can not be taken as the building block of a space syntax analysis. Especially, in an area where the length of streets are longer than as usual or expected, one can not refer to a specific point placed along a very long street by simply providing the name of the respective street, which is also the case in Siteler where there are many streets whose length are more than 500 meters (see Table 1 and 2).

Table 1 – Streets in ‘grid’ of Siteler according to their length.

Length (meters)	count
042-049	1
050-099	22
100-149	29
150-199	31
200-249	14
250-299	4
300-349	7
350-399	13
400-449	6
450-499	3
500-549	3
550-599	8
600-2091	19
Total	160
Average	319.48
Mean	197.05



The thickness of the lines represent the length of streets (it is scaled at a factor of 0.01 in GRASS GIS).

Thus, in contrast to Tomko et al. (2008: 44) who argue that “[a] street name is often the only characteristic of a street that is part of common knowledge”, in this paper it is argued that segments of the streets are also part of the common knowledge if it is practical to name them according to their position in the main street (such as middle, north, south, east or west part of a very long street). Indeed, in route directions although majority of the people usually refer to the street as a whole, one can also encounter cases in which not the street itself but a set of individual segments inside it is referred. For example, Liu (2007: 9) notes that “[i]n reality, a named street usually is separated into several parts, for example, [Bauhinia Road North] and [Bauhinia Road South], and these two parts should be semantically aggregated in named

street model”. As Liu (2007: 9-10) argues, named street model of Jiang and Claramunt (2004) can be employed in order “to do topological analysis of large urban street networks based on its connectivity graph”. The respective graph representation can be used to calculate “several topological measures” in order “to evaluate the importance of each named street and the properties of whole street network” in a big city (Liu, 2007: 10).

Table 2 – Longest streets in ‘grid’ of the cluster and segments in ‘extent’ of the cluster according to their length.

Grid of the Cluster				Extent of the Cluster			
Longest Streets		Extended List		Segments			
Name of Street	Length	Lenght	count	Lenght	count	550-599	15
Çamlitepe Sokak	2091	2050-2091	1	028-049	19	600-649	7
Demir Hendek Caddesi	1896	1850-1899	1	050-099	144	650-699	5
Karacakaya Caddesi	1843	1800-1849	1	100-149	177	700-749	2
Taşdelen Caddesi	1226	1200-1249	1	150-199	268	750-799	5
Ereğli Sokak	1163	1150-1199	1	200-249	178	800-849	7
Koçak Sokak	998	950-999	2	250-299	139	850-899	3
Altınay Caddesi	902	900-949	1	300-349	73	900-949	1
Çamlık Sokak	794	750-799	2	350-399	80	1000-1049	3
Karpuzlu 1. Sokak	788	700-749	3	400-449	55	1150-1199	1
Sırma Sokak	747	650-699	4	450-499	35	1600-1649	1
Sarıçam Sokak	728	600-649	2	500-549	23	Grand Total	1241

Nevertheless, in relatively small areas such as Siteler, named street model do not offer any useful insights. This is not only, as discussed above, because of the inadequacy of the names assigned to the streets in representing the semantic qualities of the streets but also due to the fact that very long streets may involve sub-social formations with different socio-cultural and economic characteristics. In other words, in this paper it is argued that semantic properties of the street network can not be reduced to the names of the respective streets. Named streets approach may “allow an integration of the semantic properties of the street network”, but it is clear that semantic and ontological qualities of the streets go beyond the definitional boundaries. Thus, beyond the considerations devoted to the visibility (axial), directional continuity (stroke) and semantic qualities of the streets, segments or group of contiguous segments should be considered as a socio-spatial unit of analysis because of the association between social groups and the respective BSUs which are the actual medium through which people see each other and a social atmosphere is created by virtue of everyday life practice. In other words, streets and segments have an ontological quality with respect to their capacity to represent a socio-spatial identity.

Under the light of the critical review given above for the options that can be used in the construction of line networks, in this study a hybrid approach is developed and employed in order to analyze the socio-spatial relationships between labor mobility, innovation and other available variables. In accordance with the respective approach, each node in the adjusted graphs analyzed in this paper may correspond to a segment, group of contiguous segments or a street as a whole in Siteler (Table 3). Some socio-visual criteria such as good directional continuity and formation of relatively closed areas were imperative factors in the determination of BSUs in the cluster. In fact, Liu’s (2007) stroke model is similar to the segment based model employed in this study. Nevertheless, BSUs in this study are defined not only in accordance with some socio-visual criteria (such as good directional continuity between the consecutive segments) but also according to the the possibility of the assignment of the building numbers to the respective BSUs. In practical terms one may call the model employed in this study as the address based segment model.

Table 3 – BSUs in ‘grid’ of Siteler according to their length.

Length (meters)	count
028-049	6
050-099	28
100-149	35
150-199	80
200-249	31
250-299	17
300-349	17
350-399	19
400-449	9
450-499	3
500-549	6
550-599	2
900-902	1
Total	254
Average	219.19
Median	189.92



The thickness of the lines represent the length of BSUs (it is scaled at a factor of 0.01 in GRASS GIS).

Within the framework drawn above, in order to define BSUs in Siteler, firstly, segments or group of contiguous segments were identified according to some socio-visual criteria (such as the continuity of lines, the formation of relatively closed areas and their mutual exclusion of each other). The assignment of the individual firms to the already defined BSUs was realized

according to the postal numbers of the buildings indicated in the street map of Siteler. For this purpose, for each segment the odd and the even numbered first and last buildings were identified and registered to the databases in order to define the range of the buildings located along the respective segment. Subsequently, a small formula based script was produced in Open Office in order to automatically assign the firms to the identity numbers representing BSUs along which the respective firms are located. Finally, by employing the proper GIS procedures, the respective tabular data was linked to the map of Siteler composed of BSUs.

#### **4. On Some of the Parameters Employed in SNA and SS: Re-exploring the Interconnections Between Two Graph Theoretic Endeavors**

In SNA, as Moody (2000) notes, “a social network is an analogy relating actors and relations to points and lines”. In this analogy, graph theory is used to analyze social systems. Any graph in SNA is composed of nodes corresponding to actors in the network and lines (or edges) corresponding to relations between the respective actors. Thus, a graph in SNA, if appropriate, actually represents the social structure as a set of persistent relationships between the individuals for the time period for which the respective graph is produced. In similar veins, in SS the urban space is described by using an adjusted graph in which streets are represented as nodes, and the interconnections between them are shown as edges linking nodes as it is discussed in the previous section. It should be noted that as they employ the same mathematical infrastructure, graph theory, most of the parameters developed for SNA and SS actually overlap with each other.

For example, degree centrality which is based on the simple counting of the ties incoming or outgoing from a node in a network is called connectivity in SS studies (see Equation 1). Since it is a local measure, as Tomko et al. (2008: 44) emphasize, degree centrality does not seem to be a prominent measure for large areas. Although, other forms of centrality measures used in SNA are not formally available in standard space syntax software programs provided by various research centers, a closer examination unveils that ‘mean depth’ (see Equation 4) in SS actually corresponds to ‘closeness centrality’ in SNA.<sup>3</sup> One can easily discover that ‘closeness centrality’ of a node can be defined as the reciprocal of ‘mean depth’ which is the average length of the shortest paths between the respective node and every other node. In this

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<sup>3</sup> See Freeman (1978) for an elaboration of different centrality measures including closeness centrality in SNA.

respect, as Kalamaras (2010) notes, ‘closeness centrality’ can be “interpreted as the ability to access information through the ‘grapevine’ of network members” because nodes characterized with high closeness centrality have low average length of the path to all the other nodes in the network. The formulas for the graph theoretic parameters of SS and SNA employed in this study can given as below;

$$c_i = k \quad (1)$$

where  $c_i$  is the connectivity value (degree centrality) for basic spatial unit (BSU)  $i$ ,  $k$  is the number of other BSUs connected to BSU  $i$ ;

$$ctr_i = \sum_{j=1}^m \frac{1}{c_j} \quad (2)$$

where  $ctr_i$  is the control value for BSU  $i$ ,  $m$  is the number of neighbors of BSU  $i$ , and  $c_j$  is the connectivity value of BSU  $j$ ;

$$td_i = \sum_{j=1}^n d_{ij} \quad (3)$$

where  $td_i$  is the total depth (farness) value for BSU  $i$ ,  $d_{ij}$  is the geodesic distance (shortest distance) between BSU  $i$  and BSU  $j$ , and  $n$  is the total number of BSUs;

$$md_i = \frac{td_i}{n-1} \quad (4)$$

where  $md_i$  is the mean depth value (reciprocal value of ‘closeness centrality’) for BSU  $i$ ,  $n$  is the total number of BSUs;

$$g_i = \left( \frac{\frac{2(md_i - 1)}{n - 2}}{\frac{2(n(\log_2((n + 2)/3) - 1) + 1)}{(n - 1)(n - 2)}} \right)^{-1} \quad (5)$$

where  $g_i$  is the global integration value for BSU  $i$ ,  $md_i$  is the mean depth value for BSU  $i$ .

Although SS parameters such as connectivity, ‘total depth’<sup>4</sup> (see Equation 3), and mean depth directly correspond to some of the parameters already available in SNA, this is not the case for all the parameters developed for SS studies. Nevertheless, the same or some other parameters developed for SNA provide approximate measures for the respective parameters used in SS studies. For example, in spite of the more complicated formula given above for global integration value (see Equation 5), it is well documented in some studies that ‘closeness centrality’ highly correlates with the global integration values, which is also confirmed in this study by drawing on the correlations between the innovativeness of BSUs and the graph theoretical parameters calculated for the respective BSUs (see Table 10). Theoretically, BSUs associated with high ‘closeness centrality’ and ‘global integration’ values reveal the core of the network.

In SS, two other important parameters are ‘local depth’ and ‘local integration’ values calculated for each BSU by taking into account the network within a range of generally three closest BSUs. Local integration is basically employed to unveil the variation of integration across the network within a given radius. Actually, both ‘local depth’ and ‘local integration’ values reflect the average length of pedestrian walks, which has been proven empirically by many SS studies (among many others see Liu (2007) and Hillier et al. (1993)). Although Tomko et al. (2008: 44) consider local integration as “a measure designed to be applied to axial map analysis, as opposed to named streets”, it is clear that in areas with relatively short named streets, the respective parameter can be employed in order to observe the relationship between the pedestrian circulation and the spatial configuration of BSUs. In this paper, local parameters of SS (‘local depth’ and ‘local integration’) were also calculated for both ‘grid’ and geographical ‘extent’ of the cluster (Figure 4 and Figure 5).

It is notable that there is no direct corresponding parameter for local integration value in SNA. Nevertheless, it is also important to note that some of the critical parameters (such as ‘betweenness centrality’) available in SNA is not available in a standard SS software program. It is within context that ‘betweenness centrality’ is designated to be employed in this paper. Betweenness centrality (Equation 6) of a node is the ratio of all geodesics between pairs of nodes which run through the respective node. As Kalamaras (2010) notes, it reflects

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<sup>4</sup> Total depth in SS actually corresponds to farness parameter calculated for closeness centrality in SNA. Closeness centrality of a node in SNA is the reciprocal of the value calculated by dividing the farness value with the total number of other nodes in the graph. Farness parameter and closeness centrality can be separately calculated in AGNA (Applied Graph and Network Analysis) developed by Benta (2005).

how often a node lies on the geodesics between the other nodes of the network. As betweenness centrality “provides the means to quantify the likelihood a graph node will lie on a shortest path between two other nodes of the graph”, it actually “provides a global value for a specific network element” such as segments in a street (Tomko et al., 2008: 44). As Tomko et al. (2008: 44) argue betweenness centrality can be “expected to reflect the probability of being selected by a frequent wayfinder”. The respective parameter was also calculated in order to analyze the relationship between spatial configurations of BSUs and innovation in Siteler. Betweenness centrality of a node  $i$ ,  $C_i^B$ , is defined by Tomko et al. (2008: 45) with reference to Freeman (1977) as below:

$$C_i^B = \sum_{i \neq j \neq k} \frac{n_{jk(i)}}{n_{jk}} \quad (6)$$

where  $i, j$  and  $k$  are distinct BSUs,  $n_{jk}$  shows the number of shortest paths between BSU  $j$  and BSU  $k$ ,  $n_{jk(i)}$  denotes the number of such paths leading through BSU  $i$ .

After elaboration of the spatial database and parameters employed in this study, the next section is devoted to the presentation and discussion of the findings emerging from the application of SS and SNA to the analysis of the interconnections and relationships between labor mobility, innovation, social networks and spatial configuration of BSUs in Siteler.

## **5. Application of Graph Theoretical Framework and Parameters to the Analysis of Socio-Spatial Configuration of BSUs in Siteler**

Analysis conducted for this study can be grouped under two headings; (1) cross tabulations produced by employing the number of moves (NoM) and the average geodesic distance (AGD) between origin and destination firms; (2) examination of the correlation between the innovativeness and graph theoretic parameters of SS and SNA;

### **5.1. Cross Tabulations for NoM and AGD between Origin and Destination Firms with Respect to Innovativeness and some other Attributes**

It is important to note that geodesic distance (GD) is one of the critical parameters in graph theory. Actually, both SNA and SS heavily draw on the respective parameter in order to construct a series of both centrality and depth parameters. Thus, before proceeding directly into the examination of the spatial configurations of BSUs in connectin with their correlation

with innovativeness according to the parameters of SS and SNA, it would be wise to employ the building blocks in rather a different yet innovative way by creating cross tabulations based on the average geodesic distance. For this purpose, in this sub-section a series of tables (see Table 4, 5, 6, 7, 8 and 9) were produced in order to uncover the spatial relationships between innovativeness and some other variables available for both firms and employees.

What is evident from Table 4 is that average geodesic distance (AGD) between the innovative firms is shorter than AGD between the non-innovative firms. Additional, one can observe that AGD between innovative and non-innovative ('12') firms is shorter than AGP between non-innovative and innovative ('21') firms. Although the scale of available information prevents any strick generalization (even sometimes for the cluster itself), one can easily infer that not only innovative firms tend to locate close to each other but also they are rather difficult destinations for mobile laborers in terms of the distance to overcome. This generalization can be validated for both five-year periods examined and different geographical coverages of the cluster (one covering only the regular grid pattern of the cluster (henceforth 'grid of the cluster' or simply 'grid' if not otherwise stated) (Figure 4) and the other one organically penetrating into the squatter housing areas surrounding 'grid of the cluster' (henceforth 'extent of the cluster' or simply 'extent' if not otherwise stated) (Figure 5)).

Table 4 – NoM and AGD between origin and destination firms according to the couplings of the respective firms with respect to their innovativeness over time and for different geographical coverages of the cluster.

Col	inside grid						inside extent					
	1995-1999		2000-2005		Total		1995-1999		2000-2005		Total	
	AGD	NoM	AGD	NoM	AGD	NoM	AGD	NoM	AGD	NoM	AGD	NoM
11	2.35	26	2.15	79	2.20	105	2.86	28	2.15	79	2.34	107
12	3.30	213	3.24	345	3.27	558	3.47	222	3.32	355	3.38	577
21	3.44	<b>299</b>	3.26	<b>424</b>	3.34	<b>723</b>	3.71	<b>316</b>	3.39	<b>439</b>	3.52	<b>755</b>
22	2.91	7568	2.80	4680	2.87	12248	2.98	7829	2.89	4809	2.94	12638
Total	2.93	8106	2.86	5528	2.90	13634	3.02	8395	2.94	5682	2.99	14077

Note: Col: couplings of firms with respect to their innovativeness ('0' and '1' stand for respectively non-innovative and innovative firms); AGD: average geodesic distance; NoM: number of moves;

Another interesting finding emerging from the comparison of AGD and NoM in Table 4 for '12' and '21' types of moves is that innovative firms are predominantly destination places and they attract more laborers from a wider area compared with non-innovative firms. Indeed, although for each period and geographical coverage, '21' type of moves is more than '12' type of moves, average geodesic distance between the innovative and non-innovative firms is

less than AGD between non-innovative and innovative firms, which reveal the fact that the move from non-innovative firm to innovative firm is much more difficult compared with the move from innovative firm to non-innovative firm in terms of the distance to be overcome.

Analysis of Table 5 also reveals similar findings. Table 5 is actually a reinterpretation of Table 4 in a more detailed context where one can see the distribution of moves according to both geodesic distance between and innovativeness of the origin and destination firms. What is evident from Table 5 is that both majority of the moves and association of innovativeness with the moves are realized at most within a geodesic distance of 3 BSUs, which reveals that pedestrian circulation and face-to-face relationships are important within the cluster. The same result is also confirmed by the findings elaborated in the subsequent sub-section and emerging out of the correlation of the parameters of SS and SNA with the innovativeness of BSUs. The reciprocal of distance is positively and remarkably correlated with the number of moves (NoM). The highest Pearson's correlation between the reciprocal of distance and the types of move defined according to the innovativeness of the origin and destination firms is observed for '11' moves, which reveals that innovative firms tend to be located close to each other compared with the others.

Another striking findings emerges from Table 5 when Pearson's correlation values for '12' and '21' moves are compared with each other. It is notable that the reciprocal of geodesic distance correlates with '12' moves more than it correlates with '21' moves, which suggests that innovative firms mostly spill over to the firms in close vicinity to themselves. This finding is in line with Hägerstrand's theory for the diffusion of innovation as a spatial process.

It is observed that the Pearson's correlation between innovativeness (for both CTD and STD) measured as the number of applications for industrial designs and labor mobility (NoM) is remarkably high for both 'grid' and geographical 'extent' of the cluster (see Table 6 and Table 7). Both Table 5 and Table 6 show that both innovativeness (in terms of both CTD and STD) and the number of moves decrease with the increasing geodesic distance (see also Figure 2 and Figure 3). Yet, one can observe that there is a major exception to this relationship. If the geodesic distance between origin and destination firms is equal to 1 BSU, the rate of innovativeness and NoM radically decreases, which seems to stem from the spatial configuration of the streets in the cluster. Indeed, one can easily notice that although the cluster has a grid-iron plan, the width of the building lots is generally much shorter than the

length of the building lots. As it is discussed in the section devoted to the specification of the basic spatial unit of analysis, nodes in the adjusted graphs produced in this study are created for the segments or group of contiguous segments of the streets according to some socio-visual criteria and in accordance with the availability of the address information for the buildings located along the respective segments or groups of contiguous segments.

Table 5 – The number of moves according to the geodesic distance between origin and destination firms, and the couplings of the respective firms with respect to their innovativeness over time and for different geographical coverages of Siteler.

P	GD	Col inside grid						Col inside extent					
		11	12	21	22	-1-	NoM	11	12	21	22	-1-	NoM
1995-1999	0	10	37	36	1537	83	1620	10	37	36	1554	83	1637
	1	3	15	27	637	45	682	3	15	27	639	45	684
	2	2	33	51	1413	86	1499	2	33	51	1427	86	1513
	3	4	37	50	1192	91	1283	4	38	50	1217	92	1309
	4	2	22	38	1011	62	1073	2	23	38	1058	63	1121
	5	2	25	38	713	65	778	2	26	43	767	71	838
	6		24	29	542	53	595	0	25	30	585	55	640
	7	2	12	16	283	30	313	3	12	17	310	32	342
	8		5	5	125	10	135	0	5	6	143	11	154
	9		1	8	63	9	72	0	3	10	67	13	80
	10	1	1		35	2	37	1	2	2	40	5	45
	11		1	1	9	2	11	0	3	3	12	6	18
	12				6	0	6	1	0	3	7	4	11
	13				2	0	2	0	0	0	3	0	3
	Total	26	213	299	7568	538	8106	28	222	316	7829	566	8395
C-1	-0.65	-0.85	-0.81	-0.90	-0.90	-0.90	-0.71	-0.87	-0.86	-0.90	-0.89	-0.90	
C-2	<b>0.93</b>	<b>0.60</b>	<b>0.39</b>	<b>0.73</b>	<b>0.60</b>	<b>0.72</b>	<b>0.91</b>	<b>0.62</b>	<b>0.47</b>	<b>0.72</b>	<b>0.59</b>	<b>0.71</b>	
2000-2005	0	25	56	59	1134	140	1274	25	56	59	1144	140	1284
	1	6	23	26	315	55	370	6	24	26	316	56	372
	2	20	63	84	865	167	1032	20	63	84	868	167	1035
	3	9	61	86	678	156	834	9	61	87	685	157	842
	4	9	39	68	620	116	736	9	39	70	635	118	753
	5	2	30	36	471	68	539	2	33	39	488	74	562
	6	5	44	23	276	72	348	5	46	23	301	74	375
	7	3	21	17	163	41	204	3	23	21	178	47	225
	8		4	14	77	18	95	0	5	15	93	20	113
	9		2	4	36	6	42	0	2	4	46	6	52
	10		2	4	32	6	38	0	2	4	38	6	44
	11			3	7	3	10	0	1	6	8	7	15
	12				4	0	4	0	0	1	7	1	8
	13				2	0	2	0	0	0	2	0	2
	Total	79	345	424	4680	848	5528	79	355	439	4809	873	5682
C-1	-0.80	-0.85	-0.81	-0.87	-0.85	-0.87	-0.80	-0.85	-0.80	-0.87	-0.85	-0.87	
C-2	<b>0.84</b>	<b>0.58</b>	<b>0.49</b>	<b>0.79</b>	<b>0.59</b>	<b>0.76</b>	<b>0.84</b>	<b>0.57</b>	<b>0.48</b>	<b>0.78</b>	<b>0.58</b>	<b>0.76</b>	

Note: GD: geodesic distance, C-1: correlation between GD and the respective column; C-2: correlation between  $1/(GD+1)$  and the respective column; NoM: number of moves; P: periods

Table 6 – Association of the moves with the innovativeness of the firms (CTD and STD) and NoM according to the geodesic distance between origin and destination firms over time.

GC	GD	1995-1999				2000-2005				Total			
		CTD	STD	NoM	%	CTD	STD	NoM	%	CTD	STD	NoM	%
Grid of the Cluster	0	83	93	1620	5.12	140	165	1274	10.99	223	258	2894	7.71
	1	45	48	682	6.60	55	61	370	14.86	100	109	1052	9.51
	2	86	88	1499	5.74	167	187	1032	16.18	253	275	2531	10.00
	3	91	95	1283	7.09	156	165	834	18.71	247	260	2117	11.67
	4	62	64	1073	5.78	116	125	736	15.76	178	189	1809	9.84
	5	65	67	778	8.35	68	70	539	12.62	133	137	1317	10.10
	6	53	53	595	8.91	72	77	348	20.69	125	130	943	13.26
	7	30	32	313	9.58	41	44	204	20.10	71	76	517	13.73
	8	10	10	135	7.41	18	18	95	18.95	28	28	230	12.17
	9	9	9	72	12.50	6	6	42	14.29	15	15	114	13.16
	10	2	3	37	5.41	6	6	38	15.79	8	9	75	10.67
	11	2	2	11	18.18	3	3	10	30.00	5	5	21	23.81
	12	0	0	6	0.00	0	0	4	0.00	0	0	10	0.00
	13	0	0	2	0.00	0	0	2	0.00	0	0	4	0.00
Total		538	564	8106	6.64	848	927	5528	15.34	1386	1491	13634	10.17
Geographical Extent of the Cluster	0	83	93	1637	5.07	140	165	1284	10.90	223	258	2921	7.63
	1	45	48	684	6.58	56	62	372	15.05	101	110	1056	9.56
	2	86	88	1513	5.68	167	187	1035	16.14	253	275	2548	9.93
	3	92	96	1309	7.03	157	166	842	18.65	249	262	2151	11.58
	4	63	65	1121	5.62	118	127	753	15.67	181	192	1874	9.66
	5	71	73	838	8.47	74	76	562	13.17	145	149	1400	10.36
	6	55	55	640	8.59	74	79	375	19.73	129	134	1015	12.71
	7	32	35	342	9.36	47	50	225	20.89	79	85	567	13.93
	8	11	11	154	7.14	20	20	113	17.70	31	31	267	11.61
	9	13	13	80	16.25	6	6	52	11.54	19	19	132	14.39
	10	5	6	45	11.11	6	6	44	13.64	11	12	89	12.36
	11	6	6	18	33.33	7	7	15	46.67	13	13	33	39.39
	12	4	5	11	36.36	1	1	8	12.50	5	6	19	26.32
	13	0	0	3	0.00	0	0	2	0.00	0	0	5	0.00
Total		566	594	8395	6.74	873	952	5682	15.36	1439	1546	14077	10.22

Note: CTD: count of total design, STD: sum of total design, NoM: number of moves, GD: geodesic distance; GC: geographical coverage; ‘%’ indicates CTD as percentage of NoM.

The inevitable consequence of the spatial configuration of BSUs defined according to the procedure described above is that majority of the work places are located along BSUs that are situated parallel to each other. The respective horizontal BSUs (about 200) are connected to each other via a much more limited number of perpendicular BSUs (about 50), which reveals that the geodesic distance between the parallel BSUs is actually equal to 2. As the number of workplaces located along the perpendicular BSUs is quite small compared with the one located along the parallel BSUs, the number of moves that occurred among the BSUs between which the geodesic distance is equal to one is naturally much less than the number of moves that occurred both inside the same BSU and among the BSUs connected to each other at least

at a geodesic distance of two BSU. Although spatial configurations of BSUs seem to account for bulk of the change in the number of moves and associated innovativeness, one can easily note that the number of moves inside the same BSU is less than the one between the BSUs connected to each other via at least two or three BSUs. It is pretty clear that if a laborer decides or is forced to move, he or she tends to find a job in a workplace at a 2 BSU distance from the origin firm. In other words, rather than working along the same BSU, mobile laborers tend prefer to find a new job beyond it. Nevertheless, in general workers tend to move between the firms located close to each other in terms of the geodesic distance between the respective firms.

Table 7 – The correlation of the innovativeness of the firms (CTD and STD)<sup>5</sup> with both NoM and geodesic distance over time and for different geographical coverages of the cluster.

GC		TD	1995-1999		2000-2005		Total	
TD-NoM	grid	Count (CTD)	0.9679		0.9574		0.9738	
		Sum (STD)	0.9748		0.9688		0.9834	
	extent	Count (CTD)	0,9653		0,9568		0,9735	
		Sum (STD)	0,9721		0,9686		0,9834	
TD-GD	grid	Count (CTD)	for d	for 1/(d+1)	for d	for 1/(d+1)	for d	for 1/(d+1)
		Sum (STD)	-0.8959	0.6032	-0.8523	0.5921	-0.8745	0.6006
	extent	Count (CTD)	-0.9047	0.6411	-0.8580	0.6295	-0.8815	0.6388
		Sum (STD)	-0,8871	0,5867	-0,8541	0,5846	-0,8731	0,5901
		Sum (STD)	-0,8965	0,6259	-0,8603	0,6233	-0,8807	0,6299

Another factor leading to a low number of moves between the consecutive BSUs compared with the moves occurring within the same BSU or between the BSUs located from each other at most at a geodesic distance of 5 BSUs may be the treatment of some long perpendicular streets as single BSUs in the spatial database without disaggregating them into relatively shorter BSUs according to the available address information. Although, this issue is discussed at length in the section devoted to the presentation of the spatial database employed in this study, it should be emphasized that total effect of these long perpendicular streets on the calculation of ‘geodesic distance’ between BSUs is considered to be low because each of the respective BSUs could be at most divided into two BSUs if the building numbers were available for all the buildings located along the respective perpendicular streets. Nevertheless,

<sup>5</sup> Application for industrial designs in Turkey is usually made by the firms for a bundle of products and each item in the bundle is listed as a separate industrial design. For example think of a dining room set including dining table, dining chair and dining accent furniture (such as buffets and sideboards), each item in the bundle is treated as a separate industrial design. Although this can be considered as a positive factor in the determination of the extent of innovation, it creates problems when one attempts to compare the innovativeness of the firms specialized in the manufacture of different furniture products. Thus, in this study industrial design application for both bundles of products (CTD) and individual products (STD) were taken into consideration.

the fact that respective streets are perpendicular to most of the other streets constitute a drawback to the previous assumption, which is, as noted above, elaborated in the section of the paper devoted to the presentation and discussion of the construction of the spatial database employed in this study.

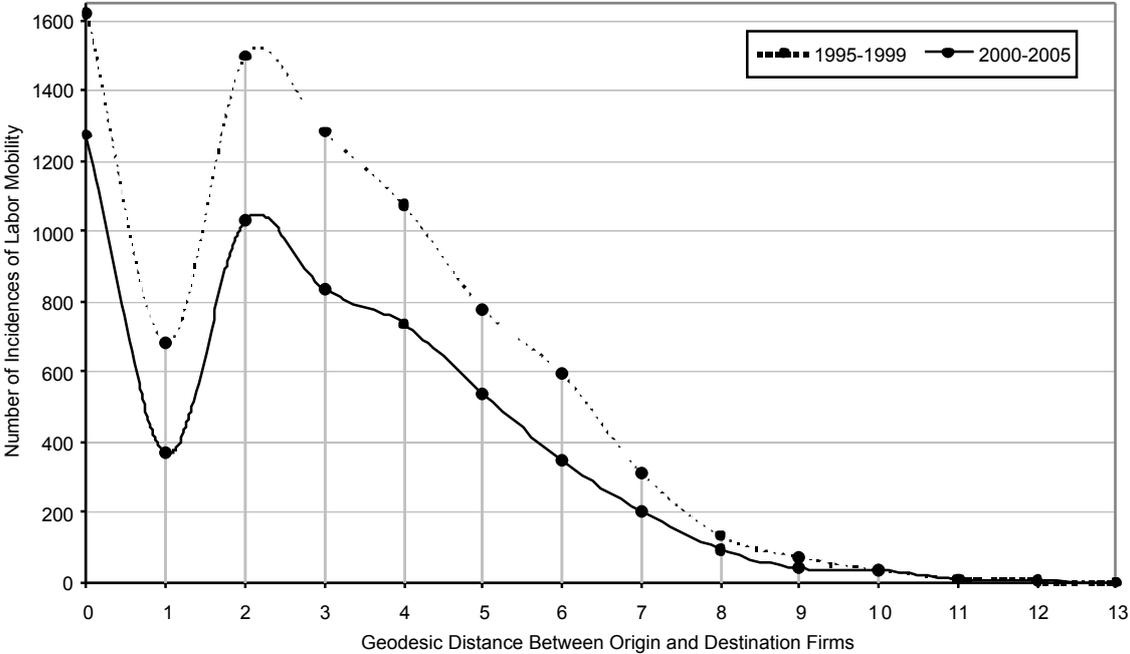


Figure 2 – The relationship between labor mobility and GD over time and inside ‘grid’.

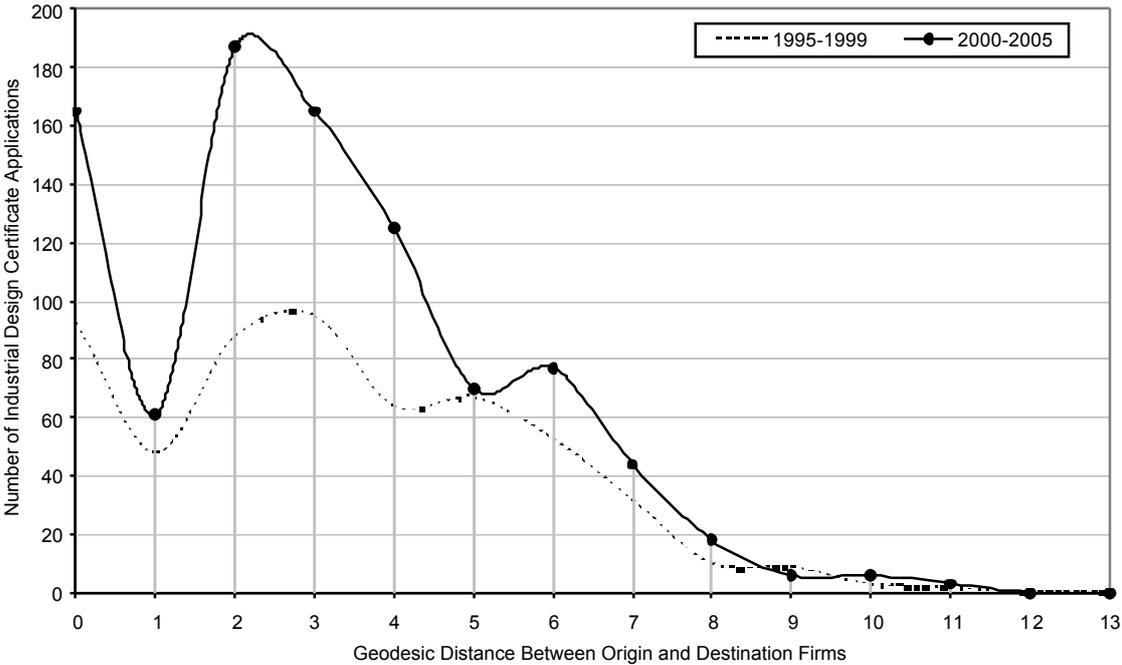


Figure 3 – The relationship between innovativeness and GD over time and inside ‘grid’.

Another interesting finding emerges from Table 8 illustrating AGD and NoM between the firms in terms of coupling of them with reference to the length of the stay of the mobile laborers in origin and destination firms. It is interesting to note that AGD is shorter between the firms where laborers tend to stay for longer periods of time compared with the other couplings. This reveals the fact that laborers are embedded not only in the cluster itself but also in the niche zones inside it. It seems that the longer a laborer works for both origin and destination firms, the shorter will be the distance between the respective firms. Although this may stem from a number of factors well documented in the literature by drawing on the anecdotal evidences such as establishment of trust based relations, it is clear from Table 8 that the degree of the embeddedness of the laborers in the specific parts of the cluster is a function of the length of his or her stay in origin and destination firms.

Table 8 – NoM and AGD between the origin and destination firms according to the couplings of the respective firms with respect to both their innovativeness and the length of stays of mobile laborers over time and for different geographical coverages of Siteler.

		1995-1999					2000-2005					
		CoI				Total	CoI				Total	
		CoLoS	11	12	21	22	Total	11	12	21	22	Total
Inside grid	Count	1-1	10	117	141	3801	4069	38	186	224	2474	2922
		1-2	8	51	76	1562	1697	21	45	60	593	719
		2-1	3	31	45	1196	1275	15	82	87	1155	1339
		2-2	5	14	37	1009	1065	5	32	53	458	548
		Total	26	213	299	7568	8106	79	345	424	4680	5528
	AGD	1-1	<b>4.30</b>	3.39	3.55	3.19	<b>3.21</b>	<b>2.58</b>	3.23	3.30	3.09	<b>3.11</b>
		1-2	1.50	3.20	3.33	2.74	2.77	1.81	4.00	3.32	2.80	2.89
		2-1	1.00	3.55	3.49	2.85	2.89	1.47	2.99	3.23	2.42	2.49
		2-2	<b>0.60</b>	2.36	3.24	2.17	<b>2.20</b>	2.40	2.91	3.06	2.24	<b>2.36</b>
		Total	2.35	3.30	3.44	2.91	2.93	<b>2.15</b>	3.24	3.26	2.80	<b>2.86</b>
Inside extent	Count	1-1	12	122	150	3936	4220	38	192	229	2547	3006
		1-2	8	52	81	1608	1749	21	46	64	608	739
		2-1	3	33	47	1243	1326	15	85	91	1188	1379
		2-2	5	15	38	1042	1100	5	32	55	466	558
		Total	28	222	316	7829	8395	79	355	439	4809	5682
	AGD	1-1	<b>5.17</b>	3.52	3.84	3.27	3.30	<b>2.58</b>	3.32	3.41	3.17	3.19
		1-2	1.50	3.33	3.67	2.78	2.83	1.81	4.07	3.53	2.87	2.97
		2-1	1.00	3.76	3.55	2.92	2.96	1.47	3.08	3.35	2.52	2.60
		2-2	<b>0.60</b>	2.93	3.47	2.23	2.28	<b>2.40</b>	2.91	3.20	2.29	2.41
		Total	2.86	3.47	3.71	2.98	3.02	2.15	3.32	3.39	2.89	2.94

Note: CoLoS: couplings of length of stays; in origin-destination couplings, 1 stands for the stays less than 500 days and 2 stands for the stays more than 499; AGD: average geodesic distance; NoM: number of moves.

If length of stay of a worker is taken as a proxy for the amount of tacit knowledge he or she acquired and accumulated in the origin and destination firms, one can also easily argue that spatial relationships between innovativeness and the amount of tacit knowledge accumulation should be discernible. Indeed, among the innovative firms ('11') the shortest AGD for 'within group' moves ('1-1' and '2-2') is observed for the moves occurring between the firms where the mobile laborers tend to stay more ('2-2'). Nevertheless, it is notable that respective observation seems to be true for also other couplings of firms with respect to their innovativeness. In other words, as noted above, the longer a laborer works for both origin and destination firms, the shorter will be the distance between the respective firms. Another important finding emerging from Table 8 is the fact that except for '11' and '1-1' type of moves during 1995-1999, and '11' and '2-2' type of moves during 2000-2005, AGD for '11' moves is remarkably shorter than AGD for other couplings of firms with respect to their innovativeness.

Lastly, in an attempt to uncover the socio-spatial characteristics of the interconnections between inter-firm social networks created by labor mobility and innovation inside the cluster, a final cross-table is created according to the couplings of the firms with respect to both their innovativeness and involvement in a clique formation. For this purpose, firstly each firm is checked whether or not it is involved in a clique formation. If the respective firm is involved in at least one clique formation it is marked with 'clique', if not, it is marked with 'dyad'. After classifying each firm according to their involvement in clique formations or dyadic relations, each incidence of labor mobility is checked whether or not it is a move within a clique formation of firms connected to each other by way of mobile labor. If it is a move within a clique formation, the respective move is labeled as 'inside clique'. If the respective labor mobility is not a move within a clique formation, it is marked with 'outside clique' and further classified according to the coupling of the origin and destination firms with respect to the involvement of the respective firms in clique formations or simple dyadic relationships. Accordingly, moves labeled as 'outside clique' are further classified into 'clique-clique', 'clique-dyad', 'dyad-clique' and 'dyad-dyad' moves. Table 9 shows the distribution of the moves according to the classification of the moves described above and the innovativeness of the origin and destination firms ('0' and '1' stand for non-innovative and innovative firms, respectively).

Table 9 – AGD between the firms according to the innovativeness of the firms and the couplings of origin and destination firms with respect to the type of the move for different geographical coverage of the cluster over time.

		1995-1999				2000-2005						
		Couplings of Firms				Total	Couplings of Firms				Total	
		11	12	21	22		11	12	21	22		
Inside Grid	Count	Type of Move	11	12	21	22						
		within clique	6	58	73	1191	1328	19	116	80	923	1138
		clique-clique	1	13	19	232	265	3	16	17	164	200
		clique-dyad	1	43	19	756	819	10	64	48	585	707
		dyad-clique	6	21	71	1025	1123	8	44	80	662	794
		dyad-dyad	12	78	117	4364	4571	39	105	199	2346	2689
		outside clique	20	155	226	6377	6778	60	229	344	3757	4390
	total	26	213	299	7568	8106	79	345	424	4680	5528	
	AGD	within clique	3.83	3.47	3.32	2.85	<b>2.90</b>	<b>1.79</b>	3.50	3.43	2.30	<b>2.49</b>
		clique-clique	7.00	4.08	3.37	3.74	3.74	1.67	3.50	3.82	3.49	3.49
		clique-dyad	0.00	2.72	3.89	3.32	3.30	2.50	2.30	2.94	2.74	2.71
		dyad-clique	2.33	3.67	3.83	3.44	3.46	2.13	3.45	3.20	3.46	3.42
		dyad-dyad	1.42	3.27	3.23	2.68	2.70	2.28	3.41	3.25	2.78	2.84
		outside clique	1.90	3.24	3.49	2.92	<b>2.94</b>	<b>2.27</b>	3.11	3.22	2.93	<b>2.95</b>
total		2.35	3.30	3.44	2.91	2.93	2.15	3.24	3.26	2.80	2.86	
Inside Extent	Count	within clique	6	63	79	1210	1358	19	120	85	932	1156
		clique-clique	2	13	20	237	272	3	16	18	167	204
		clique-dyad	2	44	21	774	841	10	68	49	600	727
		dyad-clique	6	21	75	1064	1166	8	45	84	678	815
		dyad-dyad	12	81	121	4544	4758	39	106	203	2432	2780
		outside clique	22	159	237	6619	7037	60	235	354	3877	4526
		total	28	222	316	7829	8395	79	355	439	4809	5682
	AGD	within clique	3.83	3.94	3.86	2.88	<b>2.99</b>	<b>1.79</b>	3.58	3.84	<b>2.34</b>	<b>2.57</b>
		clique-clique	7.00	4.08	3.70	3.75	3.78	1.67	3.50	3.89	3.59	3.58
		clique-dyad	6.00	2.86	4.19	3.36	3.36	2.50	2.54	3.02	2.83	2.81
		dyad-clique	2.33	3.67	4.09	3.49	3.53	2.13	3.53	3.32	3.53	3.50
		dyad-dyad	1.42	3.30	3.29	2.77	2.79	2.28	3.42	3.28	2.88	2.92
		outside clique	2.59	3.29	3.66	2.99	<b>3.02</b>	<b>2.27</b>	3.20	3.29	<b>3.02</b>	<b>3.04</b>
		total	2.86	3.47	3.71	2.98	3.02	2.15	3.32	3.39	2.89	2.94

Examination of Table 9 reveals that for both time periods and geographical coverage of the cluster, overall AGD between the firms involved in ‘within clique’ moves is shorter than the one between the firms involved in ‘outside clique’ moves (though it is much more slight for the period between 1995 and 1999), which unveils that members of the same clique formations tend to locate close to each other. Further examination of Table 9 divulges that again for both time periods and geographical coverage of the cluster, overall AGD between the firms involved in ‘clique-clique’ moves is longer than the one between the firms involved in any other classified group of moves, which, in connection with the above findings, unveils that the cluster is fragmented into different socio-spatial domains each of which dominated by a certain clique or group of cliques (it may be a sectoral fragmentation or any other kind of fragmentation that can be easily justified, but in any respect there seems to exist a ‘socio-

spatial fragmentation'). It is notable that among 'outside clique' moves, except for the period between 2000 and 2005, the shortest AGD between the firms belongs to the type of move labeled with 'dyad-dyad' for which AGD during the period between 2000 and 2005 is longer than AGD between the firms involved in 'clique-dyad' moves, which signals the tendency for the spatial dissolution of the clique formations during the first half of the 2000s that witnessed the one of the deep financial crises experienced in Turkey. Indeed, for the period between 1995 and 1999, it is observed that AGD for 'clique-dyad' moves is longer than the one for the period between 2000 and 2005. Again, it is interesting to note that AGD for 'within clique' moves noticeably decreased between two consecutive periods, which reveals a spatial shrinking in the interconnections between clique members.

Another important characteristic of 'outside clique' moves is the fact that AGD between the firms involved in 'clique-dyad' moves is always shorter than the one between the firms involved in 'dyad-clique' moves, which, in connection with the above findings, reveals that not only clique formations but also naturally clique members are more centrally located in the cluster than the ordinary dyad members. In terms of innovativeness, except for the period between 1995 and 1999 for which the information regarding innovativeness is less reliable because of the infancy of Turkish Patent Institute at that time, it is no accident that shortest AGD between the firms both of which are characterized as being innovative is observed for either 'within clique' or 'clique-clique' moves, which suggests that both innovative clique formations and clique members are much more spatially agglomerated and embedded in certain small zones inside the cluster compared with the other firms and clique formations. Also one can easily speculate for the following finding: Although overall AGD between the firms involved in 'clique-clique' moves is longer than the one between the firms involved in 'within clique' moves, for '11' kind of moves AGD between the firms involved in 'clique-clique' moves is shorter than the one between the firms involved in 'within clique' moves, which suggests that **cognitive distance** required for innovation is in operation in the cluster. Indeed, if it is assumed that innovation does rather require an overlapping of cognitive and social domains than telescoping of the respective domains, which is a theoretical suggestion of the studies focusing on the source of innovation, then the above finding can be easily explained by arguing that **structural holes** are accommodated by those connecting different cliques to each other but at the same time occupying a space in the network as a clique member.

## **5.2. Examination of the Correlations between the Innovativeness and the Graph Theoretic Parameters of Space Syntax and Social Network Analysis**

Not only geodesic distance but also other parameters of both SS and SNA (such as degree, closeness and betweenness centrality) have been checked against whether there is a correlation between the innovativeness of BSUs and the respective parameters calculated for each BSU in the cluster (see Table 10). What is evident from Table 10 is that for both time periods and geographical coverages, the highest Pearson's correlation between the innovativeness and space syntax parameters belong to local depth signalling the importance of pedestrian circulation in the cluster. The fact that an important segment of the labor mobility associated with innovativeness remains within a radius of mainly 3 BSUs can also be easily seen in Table 5 where one can also see the breakdown for the couplings of the firms with respect to their innovativeness. What is remarkable from this breakdown is that the highest correlation between GD and couplings of the firms with respect to their innovativeness is observed for '11' moves standing for the contexts in which both origin and destination firms are innovative as discussed above.

Following local depth, the highest correlations between the innovativeness and the graph theoretic parameters are observed, in order of magnitude, for 'closeness centrality', 'global integration' and subsequently 'local integration' (Figure 4 and Figure 5). As it is evident from the elaboration of the parameters available in SS and SNA, 'closeness centrality' actually corresponds to the reciprocal value of 'mean depth'. That's why it is observed that while 'closeness centrality' positively correlates with innovativeness, both 'total depth' and 'mean depth' negatively correlate with innovativeness. Although the third highest correlation for the graph theoretic parameters is observed for the relationship between innovativeness and 'global integration' which is also known to be highly correlating with 'closeness centrality' in SNA, for especially 'grid of the cluster' the correlation between betweenness centrality and innovativeness is also remarkable. One can easily notice that the magnitude of the correlations decrease when the geographical 'extent' of the cluster is taken into account, which reveals the fact that the cluster is heavily bounded within the planned and regular 'grid' pattern in spite of its extension into the squatter housing areas surrounding 'grid of the cluster' in the environs. It is also noticeable that the correlation between innovativeness and 'betweenness centrality' is much worse affected by the enlargement of the geographical 'extent' of the cluster than the correlation between innovativeness and 'local depth' (also 'global integration').

Table 10 – The correlation between innovativeness of BSUs (CTD and STD) and the important parameters of SNA and SS over time and for the different geographical coverages of the cluster.

Graph Theoretic Parameters in SS and SNA	Only Innovative Cases		All Cases			
	STD		STD		CTD	
	1995-1999	2000-2005	1995-1999	2000-2005	1995-1999	2000-2005
Segments	66	97	254	254	254	254
Connectivity	0.0672	0.0390	0.1668	0.1307	0.2796	0.2534
Totaldepth	-0.1165	-0.2018	-0.1777	-0.2769	-0.2695	-0.4302
Meandepth	-0.1165	-0.2018	-0.1777	-0.2769	-0.2695	-0.4302
Globalinteg	0.1645	0.2354	0.2282	0.3241	0.3145	0.4644
Localdepth(3)	0.2603	0.3436	0.3429	0.4183	0.4392	0.4716
Localinteg	0.1187	0.1774	0.2123	0.2388	0.3469	0.3446
Control	-0.0646	-0.1435	0.0131	-0.048	0.0923	0.0646
Degree	0.0672	0.0390	0.1668	0.1307	0.2796	0.2534
Closeness	0.1548	0.2295	0.2186	0.3161	0.3076	0.4608
Betweenness	0.2836	0.2264	0.3151	0.2673	0.2675	0.2299
Segments	69	100	1241	1241	1241	1241
Connectivity	0.0936	0.0252	0.0609	0.0413	0.0845	0.0728
Totaldepth	-0.2074	-0.1316	-0.1278	-0.1512	-0.1908	-0.2644
Meandepth	-0.2074	-0.1316	-0.1278	-0.1512	-0.1908	-0.2644
Globalinteg	0.2152	0.1289	0.1504	0.1749	0.2136	0.2985
Localdepth (3)	0.2900	0.2736	0.1039	0.1185	0.0986	0.1096
Localinteg	0.1726	0.1492	0.0863	0.0838	0.1135	0.1080
Control	-0.0351	-0.1245	0.0102	-0.0159	0.0314	0.0150
Degree	0.0936	0.0252	0.0609	0.0413	0.0845	0.0726
Closeness	0.2143	0.1295	0.1480	0.1725	0.2114	0.2953
Betweenness	0.2097	0.0191	0.1321	0.0691	0.1068	0.1226

As it is discussed in the previous section, the high degree of correlation between local parameters (depth and integration) and pedestrian circulation (within walking distance) has been already shown in a number of studies conducted by those studying space syntax (see for example Liu (2007) and Hillier et al. (1993)). It should be noted that definitionally ‘local depth’ is actually developed especially for such kind of a test designed to account for the role of pedestrian circulation in spatial configurations. Within this context, it is no accident that also in this study the highest correlations between innovativeness and the graph theoretical parameters of SNA and SS are especially observed for the parameters indicating the importance of the pedestrian circulation in spatial configurations, which parallel to the findings presented in the previous sub-sections suggests that spatial configuration of BSUs in Siteler favors the formation of small socio-spatial niches inside the cluster.



Figure 4 – The local integration of BSUs in ‘grid’ of Siteler.



Figure 5 – The local integration of BSUs in ‘extent’ of Siteler.

**6. Concluding Remarks**

In this paper, socio-spatial characteristics of labor mobility and innovation inside Siteler have been analysed by employing a graph theoretical framework that seems to provide us with an oppourtunity to balance the analytical priorities of not only agents and structure (as it is argued by Hanneman and Riddle (2005)), but also both society-space and time-space.

Although those favoring the employment of SNA heavily draw on the role of the graph theory as a tool to balance the analytical priorities assigned to individuals and society, originators of SS employ the same infrastructure to prioritize space over social in spite of their significant contribution to overcome the restrictions imposed by the metric conception of the distance, which overall leads us in this paper to focus on the interconnections between these two graph theoretic endover and reveal that methodological biases can be overcome by employing the same mathematical infrastructure.

Apart from the methodological biases observed at the meta-theoretical level, it has been also shown that the literature focusing on the relationships between social networks, innovation, labor mobility and spatial configurations has been imprinted with some other thematic or scale based biases. On the one hand, those trying to uncover the relationships between labor mobility and innovation tend to focus on high-tech sectors at the expense of low-tech or non-high-tech sectors (though they successfully employ SNA in their studies). On the other hand, those trying to expose the interconnections between innovation, social networks and spatial configurations concentrate on the spatial layout of individual buildings and organizations without developing any concern for the larger socio-spatial whole and the labor mobility (though they successfully employ both SNA and SS in their studies). The scale based bias observed for this latter group of studies can also be seen in the former group in the form of the choice for the employment of large or small databases.

In any respect, this paper is partly an attempt to balance these (meta-)theoretical, thematic and scale-based biases by filling the missing parts in the story told for the relationships between social networks, spatial configurations, innovation and labor mobility. This is accomplished by extending the application of graph theoretical framework to the co-examination of the relationships and interconnections between spatial configurations, the inter-firm social networks created by mobile laborers, innovativeness and some other attributes available for both firms and employees. In this attempt, the paper is designed to be sensitive to two critical issues that are usually bypassed by the literature. The first one is the identification of the historical precursors and the second one is the elaboration of the unit of analysis with particular reference to the ontological qualities of the respective building blocks. It is within this context that, on the one hand, the interconnections between SNA and spatial studies (even in terms of a narrow focus on the diffusion of innovation) has been traced back to Hägerstrand's pioneering studies, and on the other hand, streets or contiguous groups of

segments are shown to be associated with not only some semantic properties but also ontological quality with respect to their capacity to represent a socio-spatial identity. It is for this second consideration that a great deal of attention is paid to the construction of the database employed in this study.

In terms of the results of the analysis conducted in this study, it has been shown that even in its simplest form, employment of average geodesic distance in the production of cross-tabulations provides us with significant explanatory material for the elaborations of the relationships between innovativeness, labor mobility and spatial configuration of BSUs. Indeed, it has been successfully shown that AGD between the innovative firms is shorter than the one between the non-innovative firms, which reveals the fact that innovative firms tend to locate close to each other in the cluster. Examination of the socio-spatial characteristics of the inter-firm cliques created by mobile laborers further divulges that members of the same clique formation tend to locate in close proximity to each other. Additionally, by drawing on the length of stay of workers in origin and destination firms, it has been indicated that not only firms but also employees are embedded in the small niche zones in the cluster. Some other findings emerging from the analysis of clique formations have also led us to suggest that the “cluster is fragmented into different socio-spatial domains each of which dominated by a certain clique or group of cliques”.

Apart from these findings obtained by producing cross-tabulations, examination of Pearson’s correlations between innovativeness and the graph theoretical parameters has further illustrated the fact that pedestrian circulation and face-to-face relationships are important inside the cluster. Indeed, the highest Pearson’s correlation between the innovativeness and space syntax parameters belong to local depth signalling the importance of pedestrian circulation in the cluster. The fact that an important segment of the labor mobility associated with innovativeness remains within a radius of mainly 3 BSUs can also be easily seen from the cross tabulations produced by using GD. There is no doubt application of a graph theoretical framework to the analysis of the interconnections and relationships between innovation, inter-firm social networks created by mobile labor and spatial configuration of BSUs enhance our understanding of what is happening inside the cluster. Future studies can employ other SNA based graph theoretic parameters (such as the procedure for the identification of bi-components, authority centrality, hub centrality and eigenvector centrality) for the analysis of socio-spatial configurations by drawing on different themes.

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