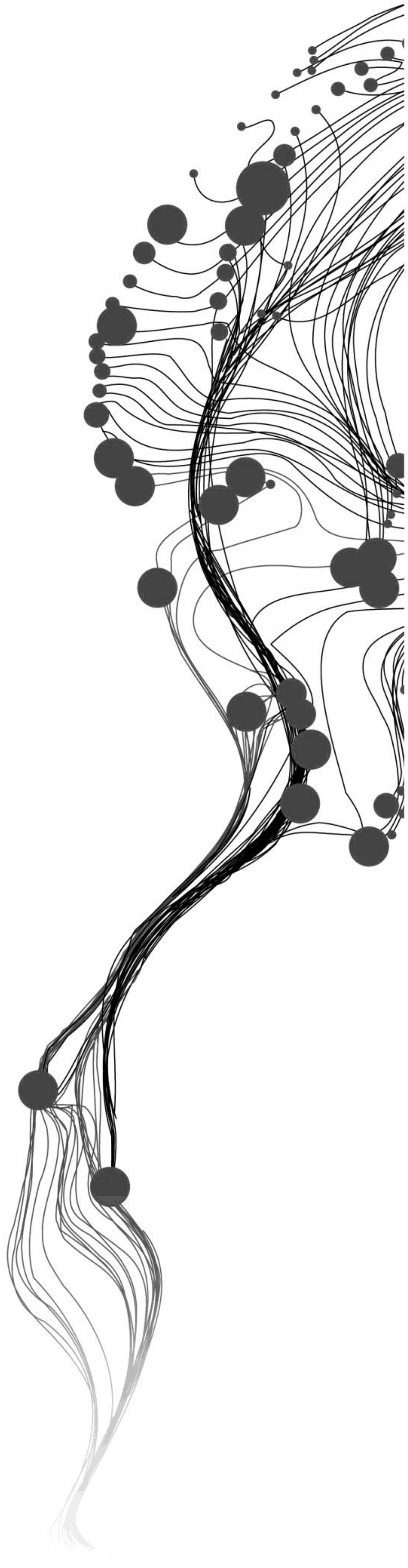
SUB – CENTRALITY ASSESSMENT USING SPACE SYNTAX THEORY IN GUATEMATALA CITY

KASIRAJAN MAHALINGAM
February, 2015

SUPERVISORS:
Dr. J.F., Johannes Flacke
Ing. F.H.M., Frans van den Bosch



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KASIRAJAN MAHALINGAM
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SUPERVISORS:
Dr. J.F., Johannes Flacke
Ing. F.H.M., Frans van den Bosch

THESIS ASSESSMENT BOARD:
Prof. Dr. J.A. Zevenbergen (Chair)
Dr. J.M. Morales Guarin, (External Examiner, University of Twente)
Dr. J.F., Johannes Flacke
Ing. F.H.M., Frans van den Bosch

ABSTRACT

The concept of polycentricism accompanied by sub – centrality and it's implication on urban space has been on the rise in recent research. Many recent studies have attributed such centrality characteristics to human development and movement. The case area – Guatemala City features as a mono – centric urban system with a central business district (CBD), thus a study of sub – centrality will naturally shed light on potential centres on the rise along with existent centres if any. Sub – centres tend to exhibit a structural element of an urban sub – system at a local scale, and these centres have their very own behavioural trait in terms of being active in nature. Hence, this research has chosen space syntax analysis to unravel the network configuration through a study of syntactic accessibility measure of the urban system. Space syntax studies have also been accounted for evaluation of centrality to conceive their active behaviour. This thesis began with the objective of identifying sub – centrality by conceptualizing syntactic measurements for all the traffic analysis zones (TAZ), and then these syntactic (topological (R3) and topo – geometric) values were correlated alongside the incoming trip data of the zones. Sub – centres were identified on both metric and topological scale.

The evaluation of this sub – centres took place in the form of axial intelligibility. Axial intelligibility is carried out in the form of a regression analysis in between integration (to – movement) and choice (through – movement), thus summarizing an overlap of integration and choice values to define converging movements. The results indicated the zones with highest trip volume exhibited the aforementioned overlap, suggesting that these zones were host to movement-oriented use of land. An in depth analysis of the land use composition belonging to the active centres were carried out to determine the driving force behind such movement attraction. Land use composition in these active centres unveiled that major proportion of these area included non – domestic (other than residential) use and more than half of these non – domestic use were dominated by commercial sector followed by industries, public building and institutions to name a few. An examination of the linear relation between zonal land use composition and their integration (R3) value revealed highly integrated networks being occupied by higher proportion of non –domestic use. On the other hand, composition of domestic (residential) use was largely restricted to poorly integrated (accessible) networks.

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1. INTRODUCTION

Accessibility has been a prime factor of urban fragmentation and residential dislocation in many cities. Concentration of activities at different scales of urban environment lead to an unbalanced level of accessibility, particularly towards residential neighbourhoods in Latin America (Rodriguez & Griffiths, 2012). Activities such as retail, markets, catering and entertainment are found to be operating as catalysts for the growth of hierarchy of centres and sub – centres. These concentrated activities act as a focal point, which range from large local centres to a rival that competes with main centre in level of activity (B Hillier, 1999). The research aims to identify and evaluate such hierarchy of sub – centres in terms of accessibility measures.

In this context, accessibility acts as not only a measure of distance but also as a resource, it becomes an added value in the spatial configuration that is exploited by private market which defines the value of this resource (Zertuche, Penn, & Griffiths, 2012). The latter has become one of the underlying causes of aforementioned urban issues. This study aims to examine the relation between accessibility and spatial configuration by incorporating space syntax theory. Space Syntax was evolved by Bill Hillier which involves a set of theory and tools for morphological analysis; it helps measure and deducts variations over network configuration of urban form using a set of accessibility measures to perform this analysis.

1.1. Background and Justification

Issues pertaining to study of growth and distribution of land use in Latin American cities have been mostly modelled through patterns of population and economic process, rather than considering urban space as a critical variable (Ortiz-Chao, 2008). Excluding other decisive factors pertaining to network and spatial configuration can lead to an uneven distribution of land, at the same time denounces urban population from acquiring residential space with substantial accessibility.

Urban growth is considered to drift away from dynamic mono – centric development to balanced spatial arrangement and polycentric agglomeration, caused by residential fragmentation (Salvati & De Rosa, 2014). Guatemala City is considered to have a mono – centric urban morphology, which used to have a metropolitan area of 225 Km2 in 2002 and has been expected to extend by an additional 307 Km2 in 2020 (Metropolitano de la ciudad, 2005). With such colossal growth, it's crucial to identify and evaluate the behaviour of centrality in this case area. An evaluation of centralities can provide insight into the composition of activities in such areas that act as dominating factor alongside the spatial configuration that attracts the formation of these activities.

According to Claudia Ortiz (2008), Theory of cities as movement economies describes land use patterns as partial result of movement flows wherein the latter is a result of urban grids, in which case highly accessible locations would be exploited by retail use while residential areas would be devoid of such location. Such phenomenon are said to be increasingly normal in major Latin American cities.

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This might be true when considering centrality as a process (B Hillier, 1999), but there are studies that describe polycentric urban expansion as an imperative condition for balanced growth and to reduce territorial disparities such as fragmentation, rather than to cause the latter.

For example, Luca Salvati describes polycentric development as a "candidate strategy to promote spatially balanced growth", such growth has been attributed to place – oriented interventions instead of top – down policies that create place specific development patterns leading to path dependant, fragmented and peculiar urban forms (Salvati & De Rosa, 2014). This can be considered for Guatemala City, where in market driven development has been accounted for accelerated horizontal growth (Morales, 2013). It's crucial to understand the role of urban grid and the dynamics of spatial configuration, which can subsequently explain the previously mentioned accelerated developments. In this research, the characteristic of spatial configuration are to be identified in terms of sub – centrality and later evaluated in terms of active centrality.

Sub – centre has been formally defined as "a site that represents a structural element of an urban sub-system within the metropolitan configuration" (Salvati & De Rosa, 2014). Although not all sub – centres act as agents of fragmentation, some of them called 'active centres' in fact do. Formations of sub – centres have been related to the expansion of urban fabric, such expansion are attributed towards development of the main core / centre or traditional centre saturation (Gurgel, 2012), while the transformation of these sub – centres into 'active centre' are caused by effect of converging movements, that respond to local and global demands (Gurgel & Trigueiro, 2012).

The retail sector has traditionally considered being one of the key measures in determining centres position in urban hierarchy, also a vital determinant of urban vitality (Vaughan, Jones, Griffiths, & Haklay, 2009). 'Active centre' have been observed to demonstrate large scale patterns of movement due to non – residential activities (For example, retail), they have been assumed influential in identifying activities favoured by services that cause movement, trade and leisure – which in turn generate more movement. With respect to Hillier's study (B Hillier, 1999), it has been observed that 'active centre' is a point where urban activities that correspond to metropolitan scale converge in numbers and variety at local level (Gurgel, 2012).

To summarize the above distinct characteristics of these two centralities, sub – centres tend to cater to local demands and functions as a proxy centre at local level, but active centres provide services to both local and global demands (Refer: 2.1.2). Thus, the identification of these active centres can result in interventions that can provide an organized sub – centre development with place – specific policies.
Sub – centres are said to have a dual function of either linking a movement by functioning as a destination or a place in their own way, due to multiple spatial functions and activities. Space syntax acts as a tool to analyse this dual functionality of sub – centres (Vaughan et al., 2009).

1.2. Research problem

In the year 2000, the Inter - American Development (IADB) Bank has stated that although Guatemala City has ample amount of residential land, accessibility to the same has been limited. The report has identified sites with affordable land value, but at the same time it has also observed such urban sites are disappearing (Inter-American Development Bank, 2000). According to Salvati and De Rosa (2014) such limitation can lead to functionally indistinct sub –centres around a compact and dense city core. This in turn has been accounted for the emergence of fragmented and scattered settlements. In the case of Guatemala city a rapid extension of the metropolitan area has been reported (Trivelli, 1986), with no significant control of such growth the urbanization process was considered to be uncoordinated.

To sum up, most recent report (IADB) indicates restricted access to land for domestic use while earlier report (Trivelli, 1986) has acknowledged a form of haphazard growth in periphery and elsewhere in the case area. Thus, it's necessary to distinguish the regions within the case area based on their spatial configuration and influence. Such demarcation can be performed through the identification of sub – centres. On the other hand, an evaluation of this sub – centres to assess their active nature is required to conceptualize the reason behind restriction of land for domestic use. Identification and evaluation of centres can boost polycentric growth through the development of existing and emerging sub – centre, which can strengthen the core and re-localize economic activities with upgraded urban functions (Salvati & De Rosa, 2014). Thus, a study of the city's morphology leading up to several hierarchies of centrality and accessibility is required.

1.3. Research identification

1.3.1. General objective

The research proposal is based upon the emerging concept of urban polycentricism, with an intention to apprehend the different scales of centrality. In this context the general objective has been formulated: *to analyse sub – centrality through the evaluation of spatial configuration and land use components, by applying space syntax analysis to explore connectivity pattern and accessibility of individual centres.*

1.3.2. Specific objective

1. To examine polycentrism through modelling of topological and topo – geometric accessibility using space syntax analysis.

2. To evaluate active behaviour of sub -centres by exploring the effects of syntactic measures with respect to land use.

1.3.3. Research questions

1.3.3.1. Specific objective 1:

- What are the different mobility pattern and movement flow experienced by the zones?
- What are the syntactic values of the road networks?
- To what extent syntactic value affect the mobility pattern and / or movement flow of the networks?
- What are the syntactic values of the networks at topological and topo – geometric scale?
- Which zones correspond most to the syntactic value at topological and topo – geometric scale?
- Which areas host multiple zones that reflect the characteristics of centrality?
- What is the consistency of different centralities displayed?

1.3.3.2. Specific objective 2:

- Do the identified centralities exhibit dominant land use pattern?
- How do these land use correspond to the syntactic value of zones in the centralities?
- To what extent these zonal syntactic measures influence land use of the centralities?
- Which zones display characteristics that are active in nature?
- What are the effects of active centres in the distribution of land use?

1.4. Conceptual framework

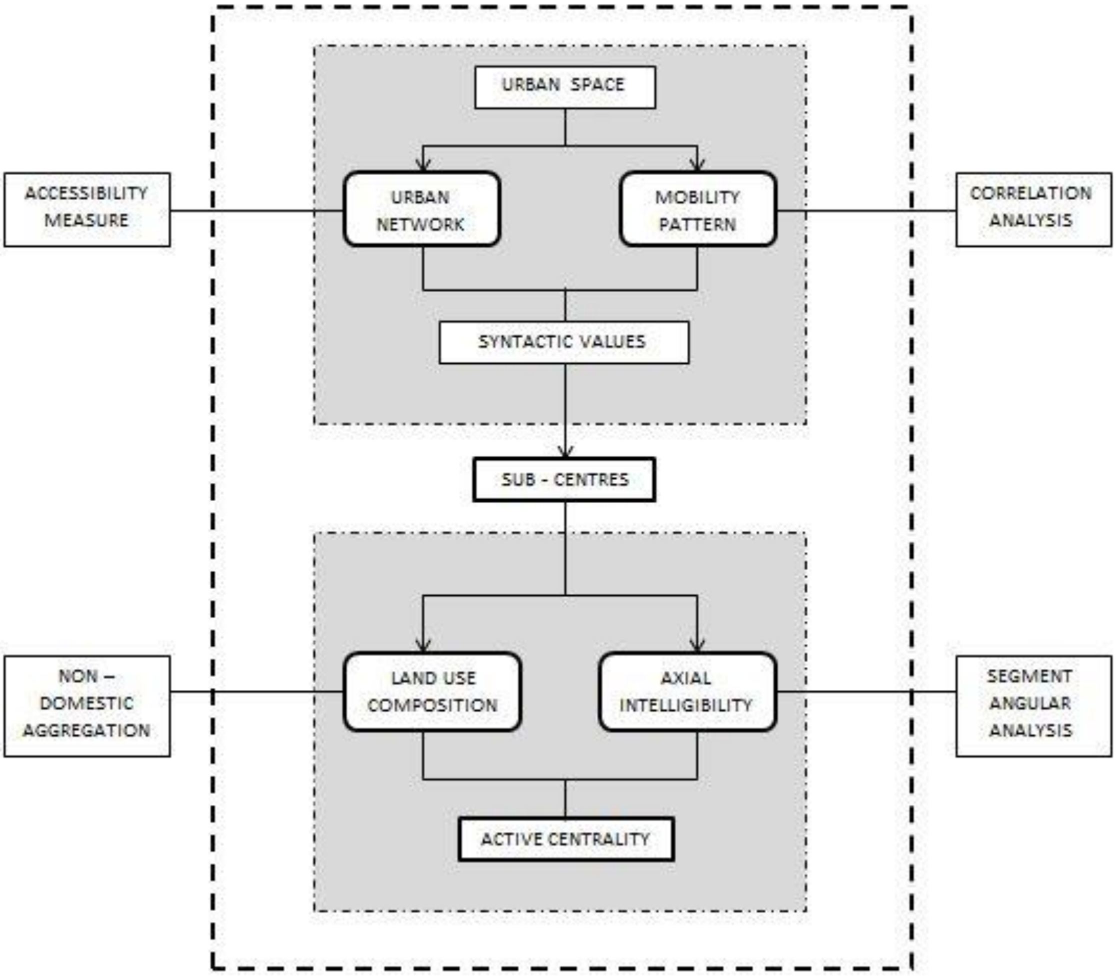

Figure 1: Conceptual framework of the study

The above mentioned flow diagram conceptualizes the framework of the study. Framework initially contemplates the area of focus for sub – centre delineation, followed by subsequent analysis in order to explore the nature of sub – centrality in the form of active and live centres. Thus, the whole process is divided it into two parts. Part (A) constitutes of the theories and analysis associated with sub – centre, while part (B) depicts the same for the rest.

1.5. Research design

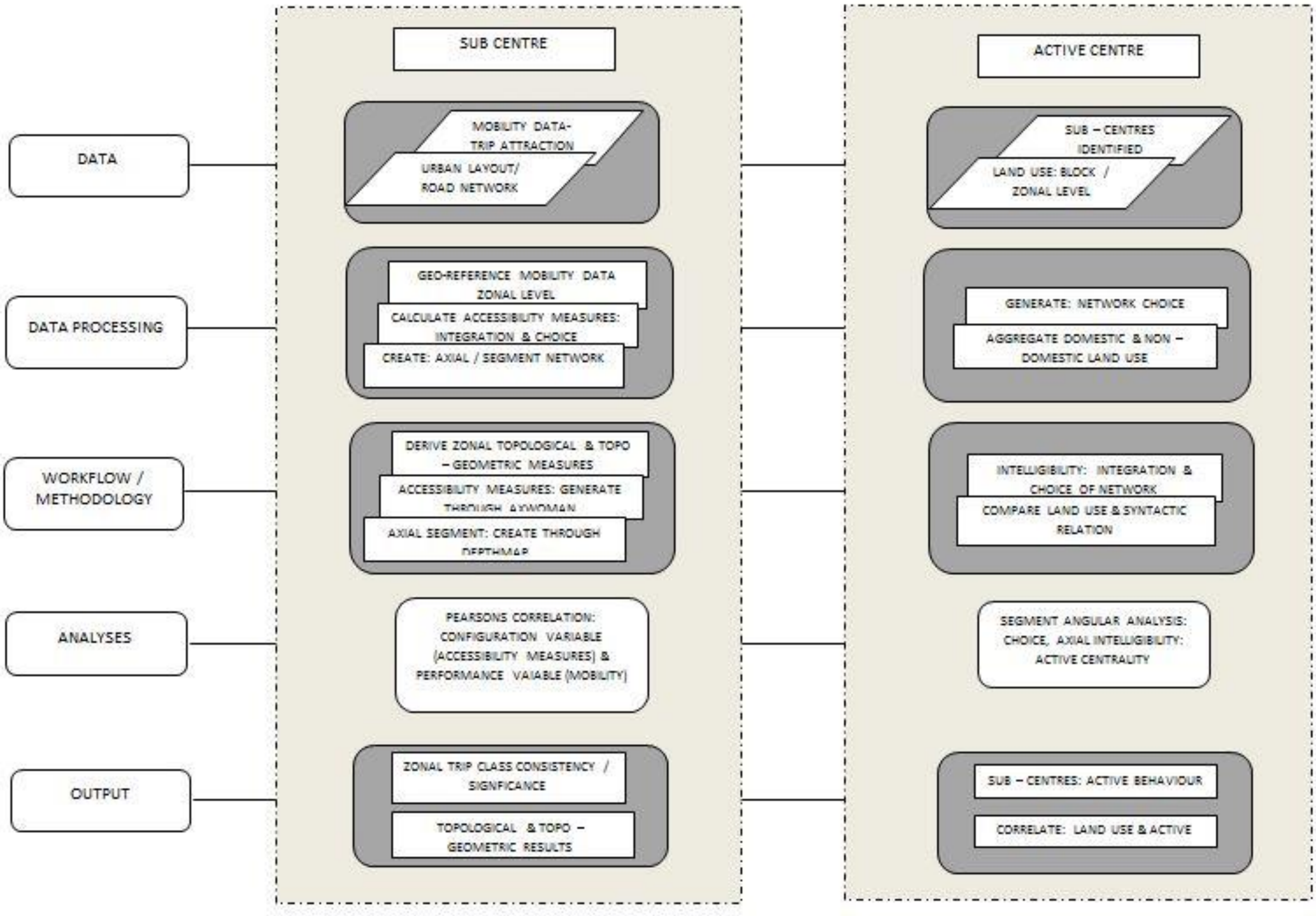

Figure 2: Research data, methodology & output

1.5.1. Data requirements

Initial study requires mobility data in the form of trip generation and / or trip attraction, alongside urban layout and road network of the case area. The sub – centre delineation is based upon movement flow and axial network produced in accordance to space syntax theory. Later stages of the studies require land use data, for integration along with identified sub –centres.

1.5.2. Data processing & Methodology

The aforementioned data need to undergo different processing techniques before further analysis. In short, the processing has been divided with respect to the type of centrality analysis they fall in, this has been elaborated in the following section.

1.5.2.1. Data processing: Sub – centrality

For sub – centrality the processing begins in the form of geo –referencing mobility data to specific scale, such as zonal level. In this context the study intends to use the near function in arcmap. The near function is one of the simplest ways of attributing the nearest feature in terms of distance.

Successive processing involves extraction of accessibility measures from the road network of the urban layout with respect to space syntax theory. This is intended to be performed via axwoman, an analytical tool based on space syntax theory for urban morphological analysis(Bin Jiang, 1999). Axwoman is an extension for arcmap, which is said to enhance the GIS abilities of spatial analysis into urban morphological analysis.

Subsequent data processing involves production of axial and segment network by usage of application known as Depthmap, visibility graph analysis software introduced by Turner (2001) to analyse spatial environment with respect to space syntax theory.

1.5.2.2. Data processing: Active – centrality

Land use being one of the driving forces in the nature of centrality, it's important to analyse the same. This acts as a provision to explore the dominant land use in different centralities identified. Subsequently, non –residential use were aggregated to each zone, which was aggregated through vertical adjacency. In this case, such vertical adjacency is to be performed through arcmap by connecting points to polylines through line segments (ArcGIS, 2012).

1.5.3. Data analyses

In terms of sub – centrality, the analysis intends to explore the relation between accessibility measures extracted through space syntax tools alongside the mobility data. In this context, correlation tests are intended to be performed by using syntactic values (accessibility measures) as configurational variables while mobility data are meant to be used as performance value.

Pearson's correlation test has been chosen on the terms that such a test allows to measure the degree and the direction of the linear relation between two variables(Gravetter & Wallnau, 2006), which is crucial in understanding the effect of various accessibility measures over movement flow in different nodes and street networks of the case area.

As discussed earlier, axial intelligibility has been considered in this study to identify active and live segments in the sub – centres. Segment angular analyses involving correlating various neighbourhoods at different radii of integration can be used to identify active segments, alongside correlation of choice and integration (axial intelligibility) can assist in analysing accessibility and overlap (Vaughan et al., 2009). Such overlap of segments can be decisive in identifying the configuration at particular scales of activity, i.e. either primarily servicing localised area or serving both local and main centre.

2. SPACE SYNTAX & CENTRALITY

This section provides insight into space syntax theory, the general concepts related to the same and their relevance in the context of this study. Previous studies related to the concept of functional polycentrism have been reviewed alongside studies conducted on centrality through the application of space syntax theory. Accessibility measures based on space syntax are elaborated to understand the link between urban space and movement pattern.

2.1. Space syntax

Space syntax modelling techniques can be applied to represent and quantify inequalities in topological accessibility in urban space. It's a tool to explore space through the theory's own accessibility measures. Normally studies based on space syntax undergo empirical observation by correlation of spatial configuration to that of commuter's movement. The theory breaks down urban space into smaller components known as unit spaces. By further analysis of the topological aspects and accessibility measures of these unit spaces the functionality of the urban space can be inferred along with its effects on the activities occurring in that space. Through the exploration of accessibility measures, movement flow and land use, different scales of centrality can be conceived.

2.1.1. Basic conceptions

The following terms are simple elaboration of the basic concepts involved in the space syntax theory (Klarqvist, 1993), further description of concepts in the context of this study has been provided in the forthcoming sections.

- Convex space: is a space where no line between any two of its points crosses the perimeter. A concave space has to be divided into the least possible number of convex spaces.
- Axial space: or an axial line is a straight line, possible to follow on foot.
- Isovist space: is the total area that can be viewed from a point.

Figure 3: (From L - R) Convex, Axial & Isovist Space
(Source: http://suzanneodonovan.wordpress.com/research-theory/2012-drakes-place-garden-_-m-arch-year-1/)

The spatial structure of a layout can be represented using three types of syntactic maps:

- Convex map: depicts the least number of convex spaces that fully cover a layout and the connections between them. The interface map is a special kind of convex map showing the permeable relations between the outdoor convex spaces to the adjacent building entrances.
- Axial map: depicts the least number of axial lines covering all convex spaces of a layout and their connections.
- Isovist map: depicts the areas that are visible from convex spaces or axial lines.

2.1.2. Axial lines

The axial lines (Refer: 4.2.1) will cross and intersect each other creating an axial map which thereafter can be thoroughly studied. Axial lines were first proposed by Bill Hillier and Julianne Hanson in 1984. Previous studies based on axial maps have concluded that movement flow of urban space is significantly related to the morphological characteristics (B Hillier, Penn, Hanson, Grajewski, & Xu, 1993).

After the creation of axial network map, there are varieties of methods to analyse the urban space such as:

- "To-movement": This shows how easily accessible a space is or how easy it is to get to a place or an area. This is analysed by methods such as integration.

- "Through-movement": This allows one to analyse the likelihood of a pedestrian or vehicle going through a specific road. Through-movements can be analysed by a method called choice.

To-movement and through- movement can be exposed through different radii giving nearer or further apart streets either more or less weight. This gives rise to a local and global measurement for analysis. For example, Local measurements will have a smaller radius which will put a higher weight on the network nearby. A larger radius would be an example of a global measure, which focuses on the grid for a larger part of that area.

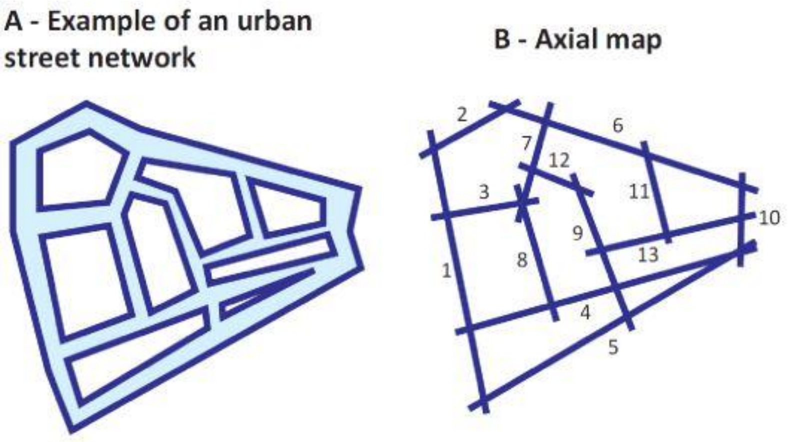

Figure 4: Urban Network vs. Axial Map
(Source: http://people.hofstra.edu/geotrans/eng/methods/dual_graph.html)

2.1.3. Metric & Topo – geometric analyses

Metric measurements here refer to short – distance trips accounting to destinations that are closest, while topo-geometric measurement refer to the effects on network configuration caused by connectivity (movement flow) and geometric features. Thus in local scale measurements leading to metric analysis are considered, while at a global scale topo-geometric measurements are preferred. It has been argued that commuters decide route based on geometric and topographic aspects rather than metric distance after a particular degree of distance (Bill Hillier & Turner, 2007).

Space syntax studies generally employ both metric and topo-geometric analysis for computing different accessibility measures. Past studies have considered distance alongside angular measurements, which are metric and topological in nature respectively. Such studies have resulted in successful computation of various syntactic accessibility measures such as integration and choice in street segment analysis(Bill Hillier & Iida, 2005). Subsequent studies found that angular method was better to study morphological features of the urban space when considering metric and topo-geometric measurements (Turner, 2007).

2.1.4. Spatial configuration

Configuration of spaces is an interim part of space syntax theory. It describes states the connection between different spaces and to each other. Through spatial configuration a topological description is made rather than a geometrical one by understanding the functionality of these connections (Bill Hillier, 1996). Space syntax models the spatial configuration of urban spaces by using graph theory representations. Street structures are generalised into space syntax models by abstracting the streets into nodes and edges, with the points of intersection between streets as edges.

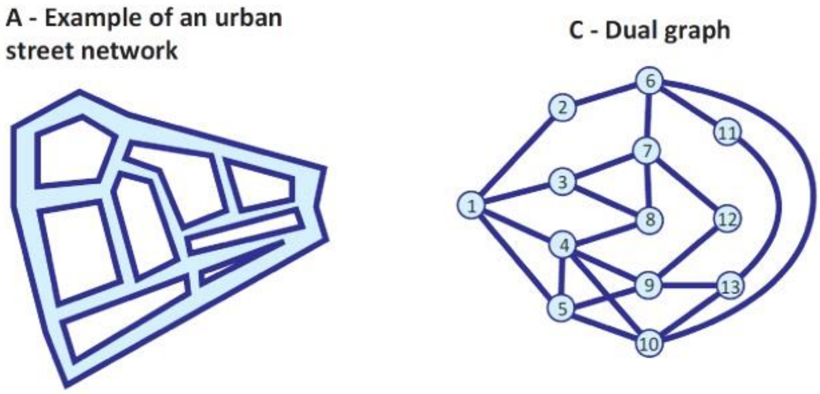

Figure 5: Spatial configuration using graph representation,
(Source: http://people.hofstra.edu/geotrans/eng/methods/dual_graph.html)

2.1.5. Accessibility measures in Space Syntax

To explore urban spatial configuration and movement flow, space syntax analysis includes accessibility measures to understand the relation between the aforementioned (Hillier & Iida, 2005). There are two major measures involved in this accessibility analysis; Firstly, centrality measures for analysing network and their functions which has different ways of measuring through closeness, between-ness and other centrality related variables. Secondly, there are other forms of centrality measures that involve integration and choice.

Studies have observed that there is a significant correlation between integration and movement flow indicating that integration is an influential parameter in the mobility pattern of urban network, according to Hillier's initial studies (1987). Further studies have also concluded that choice is a definitive syntactic value to analyse and predict movement flow.
There are four syntactic measures that can be calculated. They are used in quantitative representations of building and urban layouts (Klarqvist, 1993):

- Connectivity measures the number of immediate neighbours that are directly connected to a space. This is a static local measure.

- Integration is a static global measure. It describes the average depth of a space to all other spaces in the system. The spaces of a system can be ranked from the most integrated to the most segregated.

- Control value is a dynamic local measure. It measures the degree to which a space controls access to its immediate neighbours taking into account the number of alternative connections that each of these neighbours has.

- Choice is a dynamic measure of "flow" through a space. A space has a strong choice value when many of the shortest paths, connecting all spaces to all spaces of a system, passes through it.

The above mentioned are considered first order measures, while it is possible to produce second order measures as well, such as intelligibility. It is the correlation between connectivity and integration and describes how far the depth of a space from the layout as a whole can be inferred from the number of its direct connections.

2.2. Polycentricsm

Centrality was mainly focussed on population concentration; especially in mono-centric growth model such assumption was prevalent during the 70's. There are three major urban development concepts that are recognized, beginning with Burgess's (1925) concentric zone model based on the concept that cities grow in circular pattern around a single main centre. Later, these zones were classified according to their use (for example: zone of transition, commuting zone and zone of working residents etc.) (LeGates & Stout, 2011).Subsequent development concepts included Hoyt's (1935) sectoral model which described development of different sectors leading to various economic centres, but was still based on a single centre. Later, multiple nuclei model developed by Harris (1945) debated about cities growth based on not one but many economic bases. It can be concluded that these three models exhibit the transformation of mono-centric to polycentric development, but at the same time it has been argued that the application of polycentrism hasn't been completely evolved as development tool in the course of urban growth (Kloosterman & Musterd, 2001).Rapid decentralization of economic activities, increase in mobility, fragmentation of land use distribution and complex cross commuting etc. have been accounted for the emergence of new centralities(Davoudi, 2003).

2.2.1. Sub – centrality

Functional linkages between centres of urban systems are considered to be crucial part of polycentricism. By exploring the connectivity of individual centres to the whole urban system, functional polycentricity can be analysed. Previous studies have suggested that such polycentricity mostly reflect 'multi-nodal development of human activity' (Kloosterman & Musterd, 2001; Vasanen, 2012).

Polycentricity is considered to be highly scale dependant, wherein on one scale the development may look polycentric while on a different scale it might look mono-centric. Morphologically adjacent centres are generally considered to be might refer to polycentricity, but recent studies have observed that functional linkages between nodes are required in order to consider these centres polycentric in nature(Crookston, 2011; Vasanen, 2012).

Previous sub – centre delineation involved diverse approaches ranging from employment density to population using parametric methods like negative residual exponential analysis of employment and non – parametric methods like adjusting locally weighted regression models. But such methods have been reduced by limitations such as defining sub – centre entirely by employment density or population, rather sub – centres should be considered 'poles of influence and reference' as per Cladera and Duarte (2009). And such influential poles are said to be associated with territorial surroundings reflected through movement flows and interaction.

2.2.2. Active centrality

In general, active centres are associated with sub – centres that have dominant retail and commercial (and other movement – oriented use) land use structures. Hillier's work (2007) have disclosed crucial characteristics of active centralities such as the grid intensification caused by the inter – commuting (accessibility) within a centre, subsequently resulting in fall of movement flow due to distance – decay of these centres in metric distance.

Previous studies have determined that active centrality occurs when accessibility measures of choice and integration overlap in an axial segment. Such overlap are attributed to choice measure of through – movement and integration measure of to – movement, where the highest value of these measures overlap leading active nature of these segments(Dhanani & Vaughan, 2013).

2.3. Related works

2.3.1. Sub – centrality via Space Syntax

Nogueira (2005) established crucial relationships between various syntactic values and their adverse effect on the urban network configuration. These relationships went on to describe the role of spatial configuration in restricting its inhabitants from interacting with the whole urban space. For instance, in the early stages of the study it was conclusive that synergy (Global and local integration) alongside intelligibility (choice and integration) decrease as the main depth increases i.e. city's growth.

The study attempts to identify regions exhibiting sub – central behaviour by relating spatio – syntactic value of the individual region to the syntactic values in urban context at global scale. Although the study considers most of the syntactic measures at the configurational level, it omits any form of performance variable. As discussed in earlier sections regarding polycentricism and sub – centrality, most researchers have agreed upon the requirement of influential parameters such as employment, population density and movement flow / traffic data.

2.3.2. Sub – centrality: Urban transport analysis

Pereira & Holanda (2011) have acknowledged that syntactic values at configurational level do indeed clarify 'the spatial distribution pattern of flow on different streets in the urban grid' but at the same time the authors have sought to test the syntactic values in analysing the trip performance variables. Following the aforementioned, the study describes the limitation of syntactic measures when it comes to traditional topological analyses that views urban network configuration strictly in one dimension.

Hence, the researchers subsequently introduced topo-geometric analyses of the configurational variable to address the metric aspects of the network alongside topological parameters. These metric aspects were introduced in the form of segment length by angular segment analysis. The study concludes that mean depth variables and global integration values indicated acceptable significance level with trip performance, also higher metric radius of mean depth variables seemed to indicate a higher significance level than topological configuration variables.

2.3.3. Spatial signature: Active centre

The defining characteristics of active centrality, has been discussed in earlier sections of literature review. These characteristics of axial intelligibility as conceptualized by Vaughan et al. (2009) have been reviewed in the forthcoming sections of methodology.

3. CASE AREA: GUATEMALA CITY

Rapid extension of the city has been widely acknowledged, especially in the periphery of municipal boundary. The municipality has stated that due to concentration of jobs in the city, people are already travelling as far as 50 kilometres from nearby places like Escuintla and Chimaltenango to the city for work (Compromiso ciudadano, 2011). This trend is said to have caused unsustainable fuel consumption, alongside an inequitable living condition for people. Citizens belonging to marginal economic background are prone to bear the expense of accessing 'urban centrality'. Moreover, these additional travel time and related expenditure are proven to have a negative effect on the citizen's productivity and quality of life.

	2008	**2009**	**2010**
Population	2,994,047	3,049,601	3,103,685
Growth (%)		1.86%	1.77%
Vehicle	893,097	949,693	1,021,166
Growth (%)		6.33%	7.52%

Table 1: Population vs. Vehicle (Source: Compromiso ciudadano, 2011)

The report also infers an increase in periphery-centre-periphery trips mostly through primary road network, adding to socio-economic and environmental woes such as congestion, fuel consumption and operating costs, increased pollution of the air, lost productivity, and detrimental to the quality of life of residents, environmental degradation, etc. Aforementioned peripheral development has led to localization of housing especially of lower and middle income groups and these peripheral areas are said to lack proximity of centralities.

These localized peripheral areas are plagued by inadequate road infrastructure and insecurity of public spaces; this has also been ear-marked by socio-spatial segregation in terms of closed condominiums (Compromiso ciudadano, 2011). The report points towards an absence of development planning in these peripheral regions leading to lack of encouragement for these 'peripheral centres' to grow and provide equity in access to other centralities.

These facts and figures presents a necessity for assessing the development of the different parts of the cities with respect to trip attraction, at the same time evaluate the so called 'urban centres' on the rise. Such identification and evaluation of centralities can lead up to a better understanding of their network configuration, and comprehend the cause behind high rate of trip attraction in terms of land use. Thus, development of such otherwise unplanned centres can be restricted for sustainable growth and / or encouraged for equity through unbiased resource allocation.

4. METHODOLOGY

4.1. Data

Data regarding trip attraction will be used from the ODC matrix; the land use and the OD matrix were facilitated by the PhD advisor through the Urban Mobility Office from the Guatemala Municipality. The ODC matrix dates back to 2005, while the land use was last updated on 2004-05. The road network extraction and space syntax visualizations were carried out separately, processes involved in the same are discussed in the following section.

4.1.1. OD – Matrix: Average daily trip & Peak hour trip

The OD – matrix contained 173 minizot (traffic analysis zones) of which 109 zones fell under the municipal boundary of the case area. There were diverse types of datasets which could be broadly categorized for private (PRIVADO) and public (PUBLICO) traffic volume counts (Refer: Appendix for sample). These traffic counts were then again performed for two different durations – average daily trip (DM) and peak hour trip (HP). In this research the private traffic inflow was considered for both average daily trips and peak hour, for the research focusses on traffic behaviour of individual locals rather than the accessibility of public transports to derive centrality behaviour.

The following statistics summarize the values of private – average daily trip and peak hour trip vehicle counts:

Descriptive Statistics

	Range	Minimum	Maximum	Mean	Std. Deviation
MOB_DAT_DM	46821.1099	87.4899	46908.5999	7820.3423	8223.3908

Table 2: Descriptive statistics - Average daily trips

Descriptive Statistics

	Range	Minimum	Maximum	Mean	Std. Deviation
MOB_DAT_HP	7537.2700	21.4000	7558.6700	1327.6688	1393.7749

Table 3: Descriptive statistics - Peak hour trips

4.1.2. Data extraction: Road centre / axial line

The shape file of the road network was retrieved from an Open Street Map community site (http://download.geofabrik.de/). The shape file has the street network in the form of polylines which requires to be converted in to axial lines. Now, within this conversion there are sub – conversions that need to be performed before converting these polylines in to axial lines by using axwoman – an extension for ArcGIS that can automatically generate axial lines (Sun, 2012). The detailed conversion processes are as follows:

- The shape file had the road network with regards to whole of Guatemala; the municipal boundary retrieved from the land use layer was used to clip the network layer.

- The network layer was projected to the same co-ordinate system as the municipal boundary using project before proceeding further.

- Isolated lines in the network were identified using Get isolate lines in the axwoman toolbar.

- Arcs in the network junctions had to be converted into segments, these are called natural streets. This topological conversion is performed through Data interoperability tool more specifically Quick export, by exporting it in the format of ESRI ArcInfo Coverage.

- The final step in natural streets creation involves axwoman tool – Generate axial lines, wherein a predefined angle of 45 degrees was provided as a threshold to connect each street segment.

4.1.3. Data generation: Axial / segment map

The natural streets layer was converted into DXF format which is the only supported format in DepthmapX, the following procedures elaborate the creation of axial and segment maps:

- After using import in Depthmap, the DXF file was converted into axial lines using convert drawing layers tool. Following this the axial line layer was turned into segments using convert active layer tool[1].

- Segment angular analyses and Metric radii analyses were performed for retrieval of further syntactic parameters.

Following the generation of various syntactic maps, MapInfo Professional was used to visualize these files into SHP format.

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[1] Segment maps can't be generated directly from DXF files, the transition of polylines to axial lines are mandatory.

4.2. Sub – centre: Identification

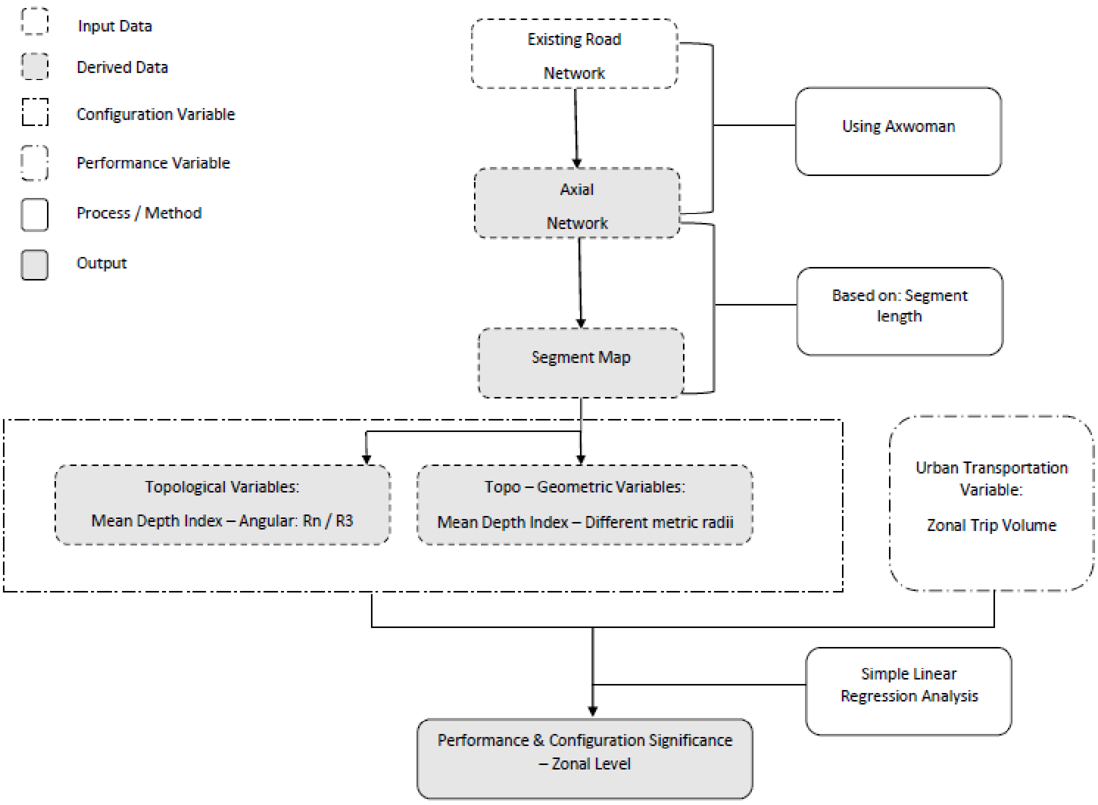

Figure 6: Identification of sub - centres

4.2.1. Space Syntax network representation: Axial map

In earlier sections of literature review, various spatial representations of networks with respect to space syntax were discussed. Preliminary analyses of space syntax theory naturally require generation of axial network through street network map. Axial lines are attributed to the "longest line that can be drawn through an arbitrary point in the spatial configuration", while an axial map is termed to be "least set of (axial) lines which pass through each convex space and makes all axial links" (Turner, Penn, & Hillier, 2005).

But studies (Batty & Rana, 2004) have come across some issues prevalent in the above mentioned definition of making sure to link all axial lines, wherein the axial lines that fulfil these criteria can't be accurately held and the same has been acknowledged by Hillier and others in later studies describing the algorithm behind generating these axial networks (Turner et al., 2005).

4.2.2. Segment analysis of network

After such skepticism in axial network generation, it led to alternatives to generate syntactic values that can preserve the characteristic of axial lines alongside proper emphasis on road centre line representation. Of which, angular segment analysis has proven to display high correlation with vehicular flow (Trip generation) according to previous studies (Turner, 2007).

The analysis breaks the axial lines into segments, and then records the sum of angles turned from one segment to another in the system.

4.2.3. Mean depth index – Angular

Depth in space syntax morphological analysis is generally considered as the number of steps taken from one node to reach another. A node is considered deep if it requires many steps to reach it, while the same node is considered shallow if it is connected through only few steps (Bin Jiang, Claramunt, & Klarqvist, 2000). In case angular depth, the same is calculated through angular turn from one segment to another through shortest angular route, and the mean depth is the average of all shortest path (Turner, 2007).

$$C_\theta(x) = \frac{1}{n}\sum_{i=1}^{n} d_\theta(x,i)$$

The above equation summarizes the calculation behind angular mean depth index, where n signifies the number of angular turns and dϴ (x, i) signifies the angular turn between two segments x and i. Integration of a node simply denotes the "degree to which the node is integrated or segregated", this can be calculated considering the system as a whole – Global (Rn) or for a part of the system – Local (R3).

4.2.4. Mean depth index – Metric

The aforementioned depth measurement is strictly topological, where it accounts only for conversions – number of turns. While with the help of the recent version of Depthmap, syntactic parameters for different radii of the network can be extracted.

4.3. Active centre: Evaluation

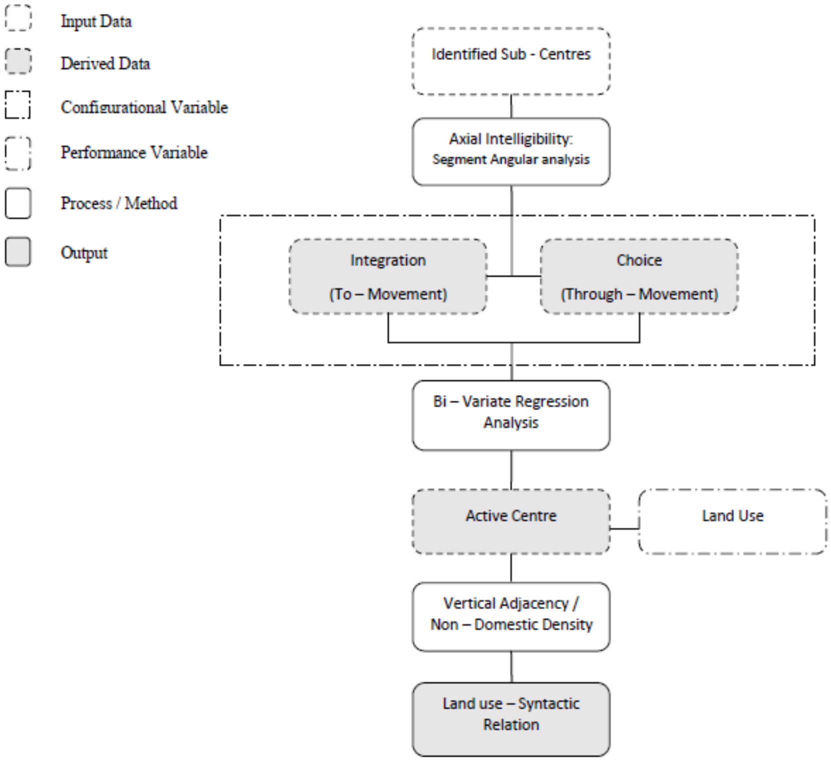

Figure 7: Active - centre evaluation

4.3.1. Choice: Angular Betweenness

Shortest path between all segments in the system accounting to lowest angular cost between each of this system is considered as Betweenness or Choice in space syntax theory. The sum of flow through each segment according to how many journeys are made through each segment, and divide through by the total number of possible journeys are attributed for Angular Betweenness (Turner, 2007).

4.3.2. Overlap: Axial intelligibility

Sub - centres attributing to the co – presence of different trips at differing lengths are considered to exhibit an overlap of through movement (choice) and to – movement (integration). Such overlap are accounted for active centrality of centres, wherein segments spatially overlap in the syntactic value of choice and integration (Dhanani & Vaughan, 2013).

4.4. Preliminary results: Syntactic measures

This chapter discusses the preliminary results extracted through various spatio – syntactic analyses discussed in the methodology. The initial results are mostly attributed towards generating topological and topo – geometric syntactic values in the urban network of Guatemala City metropolitan area.

4.4.1. Angular mean depth

It has been proved that degree of depth of a street is inversely proportionate to the degree of integration with respect to other streets in the network at global level (Rn), whereas in case the local level (R3) the depth is directly proportional to topologically nearest streets (Pereira & Holanda, 2011). The following results were produced with regards to both global and local scale

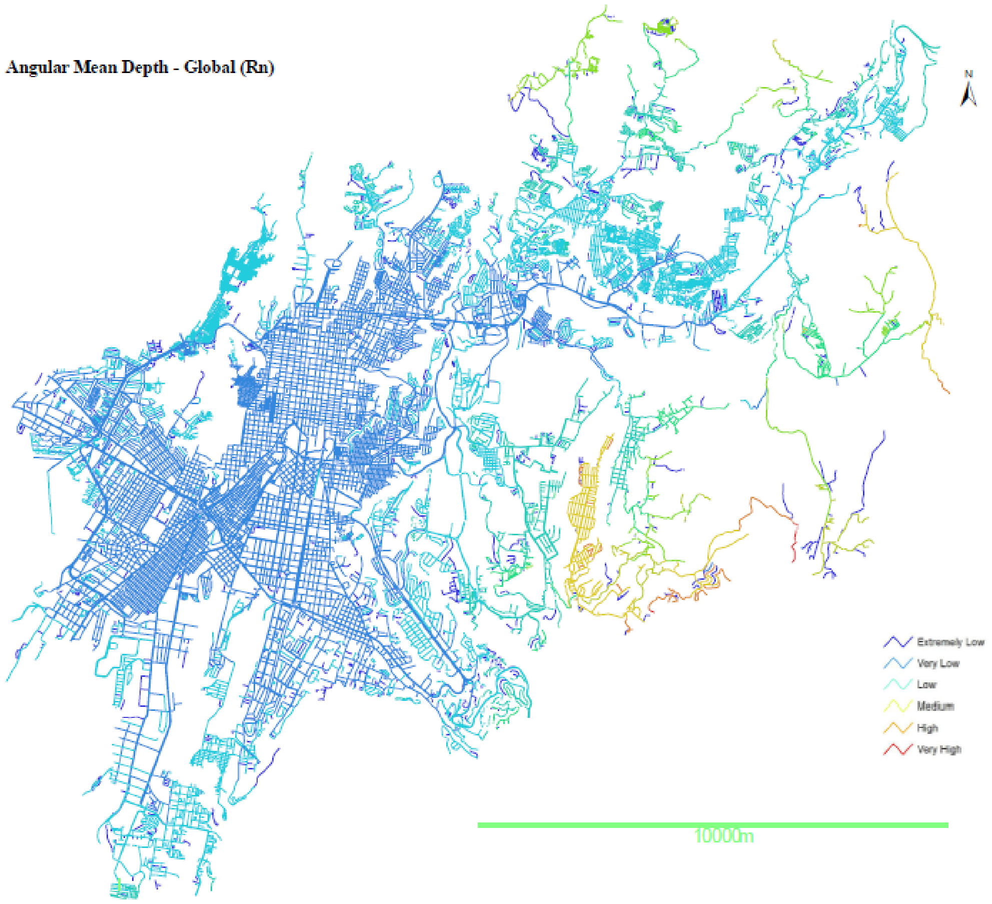

Figure 8: Angular Mean Depth - Rn

The below visualized depth map (Figure 9) is directly proportional to the degree of integration as mentioned earlier, thus it can be noted that south east part of the city with its symmetrical network grid seemingly produces high degree of integration. Although the street networks on the north eastern part of the city are loosely connected to few primary road networks, few concentrated network grids with credible integration can be observed.

The same applies for grids along south central part, where these networks seem to be connected by a single major road but still display conceivable integration.

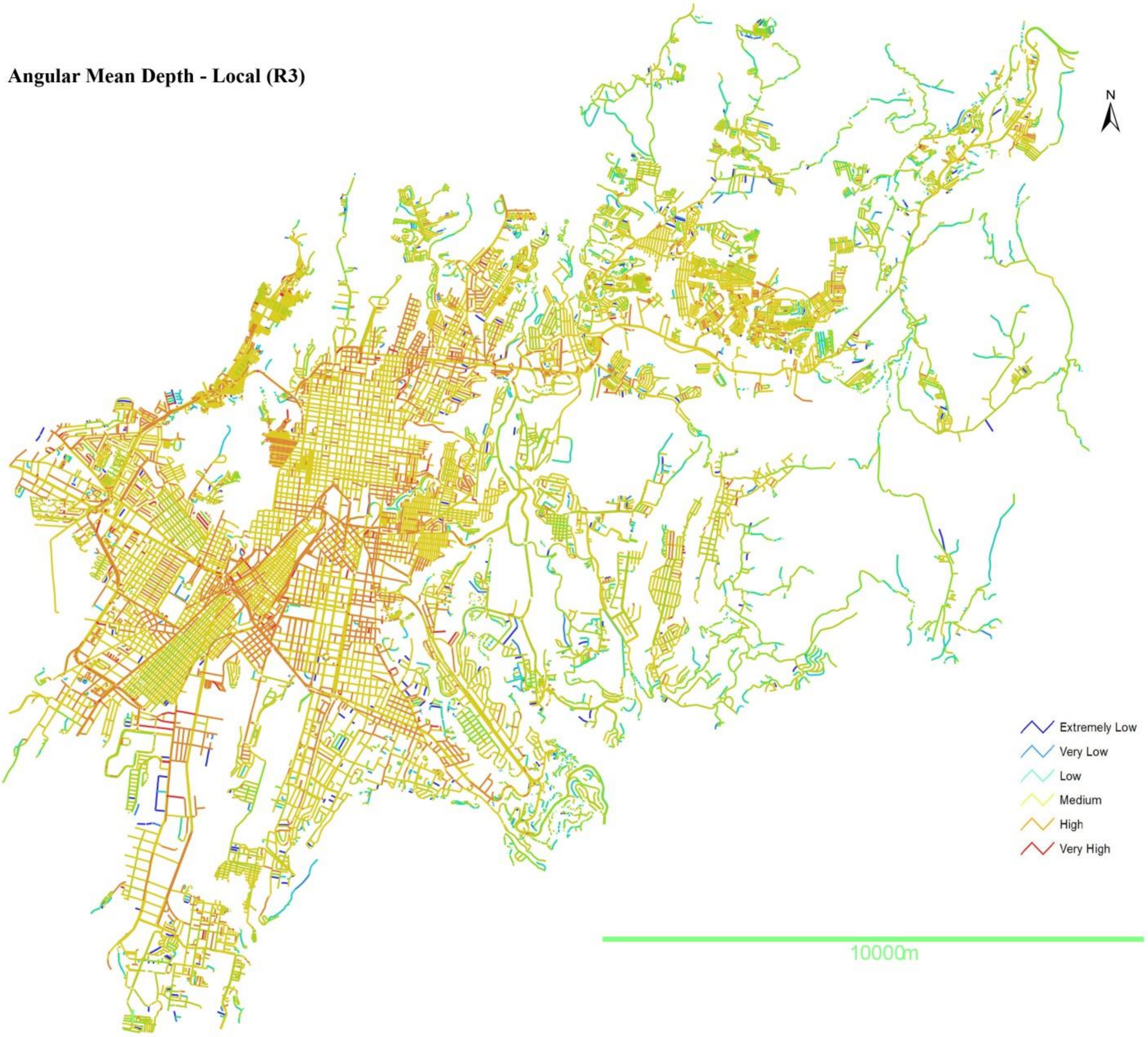

Figure 9: Angular Mean Depth - R3

4.4.2. Metric mean depth

Instead of strictly providing topological restrictions for assessing the accessible streets through mean depth, a metric radius can be provided wherein such streets are valued with respect to a specific metric distance surrounding each street network. The radii were chosen for different percentages of area of the network grid ranging from 10% – 75% (metric units: 2000 – 15000).

This different metric restriction creates mean depth that correlates to local (R3) and global (Rn) measure accordingly. These relations between topo – geometric radius and topological measures in terms of mean depth are summarized in the following section.

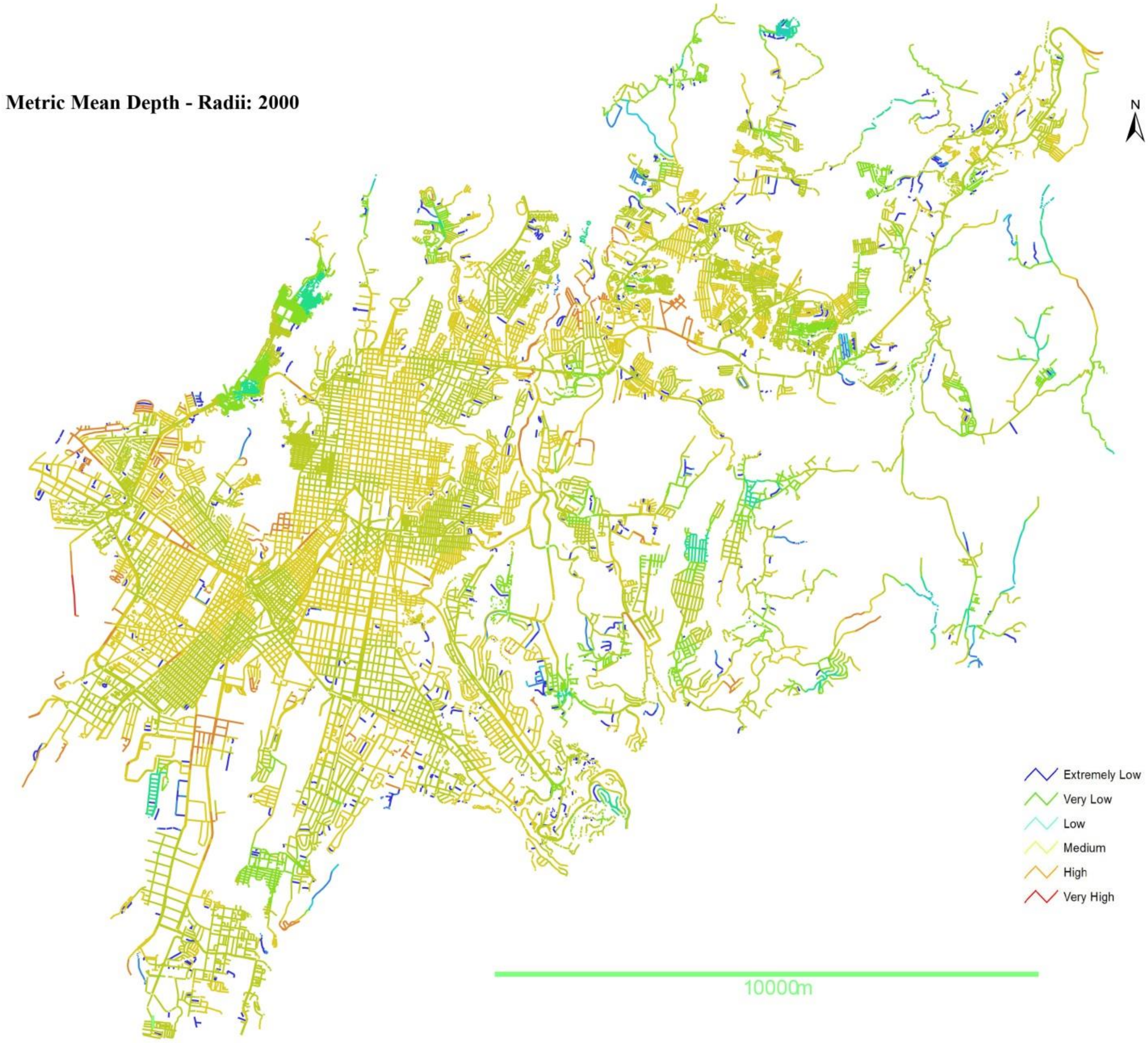

Figure 10: Metric Mean Depth - Radii: 2K

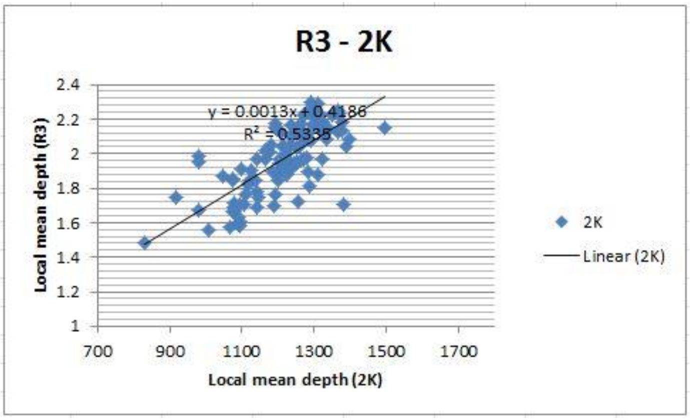

Figure 12: R3 - 2K Local mean depth relation

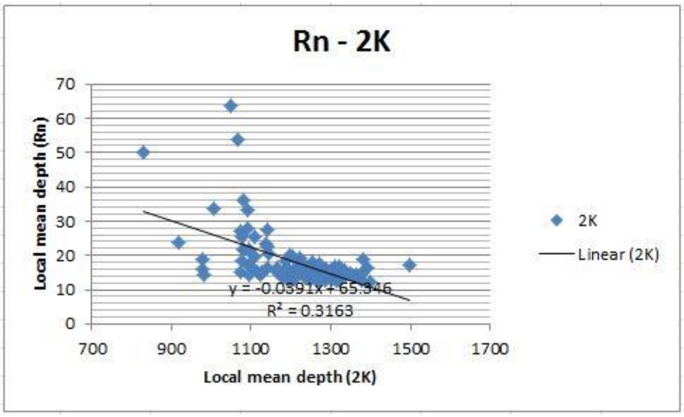

Figure 12: Rn - 2K Local mean depth relation

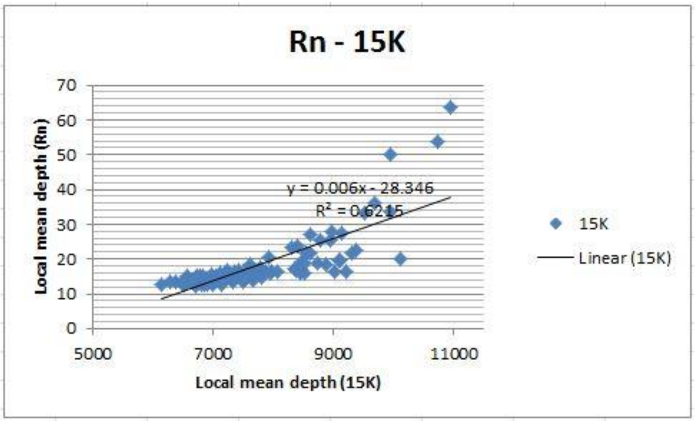

Figure 14: R3 - 15K Local mean depth relation

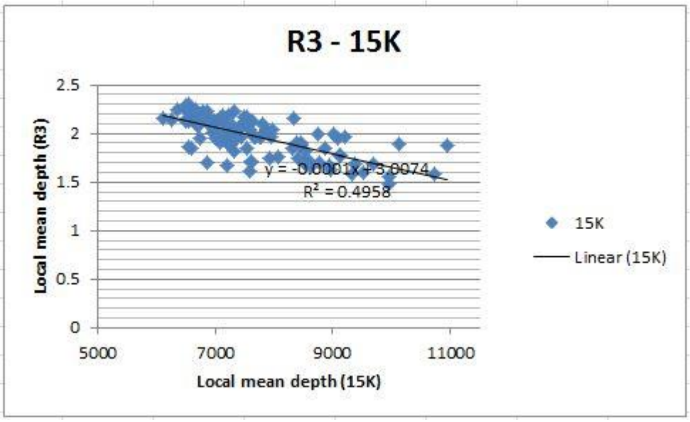

Figure 14: Rn - 15K Local mean depth relation

- On a local topological scale (R3) the smallest topo – geometric radius of 2K exhibits a positive collinearity, with 53.35% of the variations in local mean depth at a scale of 2K influenced by (R3) topological integration. On the contrary, the local topological (R3) scale doesn't seem to influence the local mean depth at a topo – geometric radius of 15K.

- In the case of global topological (Rn) scale, the largest topo – geometric radii of 15K displays a positive collinearity, with 62.15% of the variations in local mean depth at a scale of 15K influenced by (Rn) topological integration. And, global topological (Rn) scale doesn't influence the local mean depth at a topo – geometric radii of 2K.

Thus, the above relations go on to prove that at a smaller topo – geometric radius the local integration has a relatively higher effect on the network than the global integration. On the other hand, a larger topo – geometric radius is more influenced by global integration than local integration.

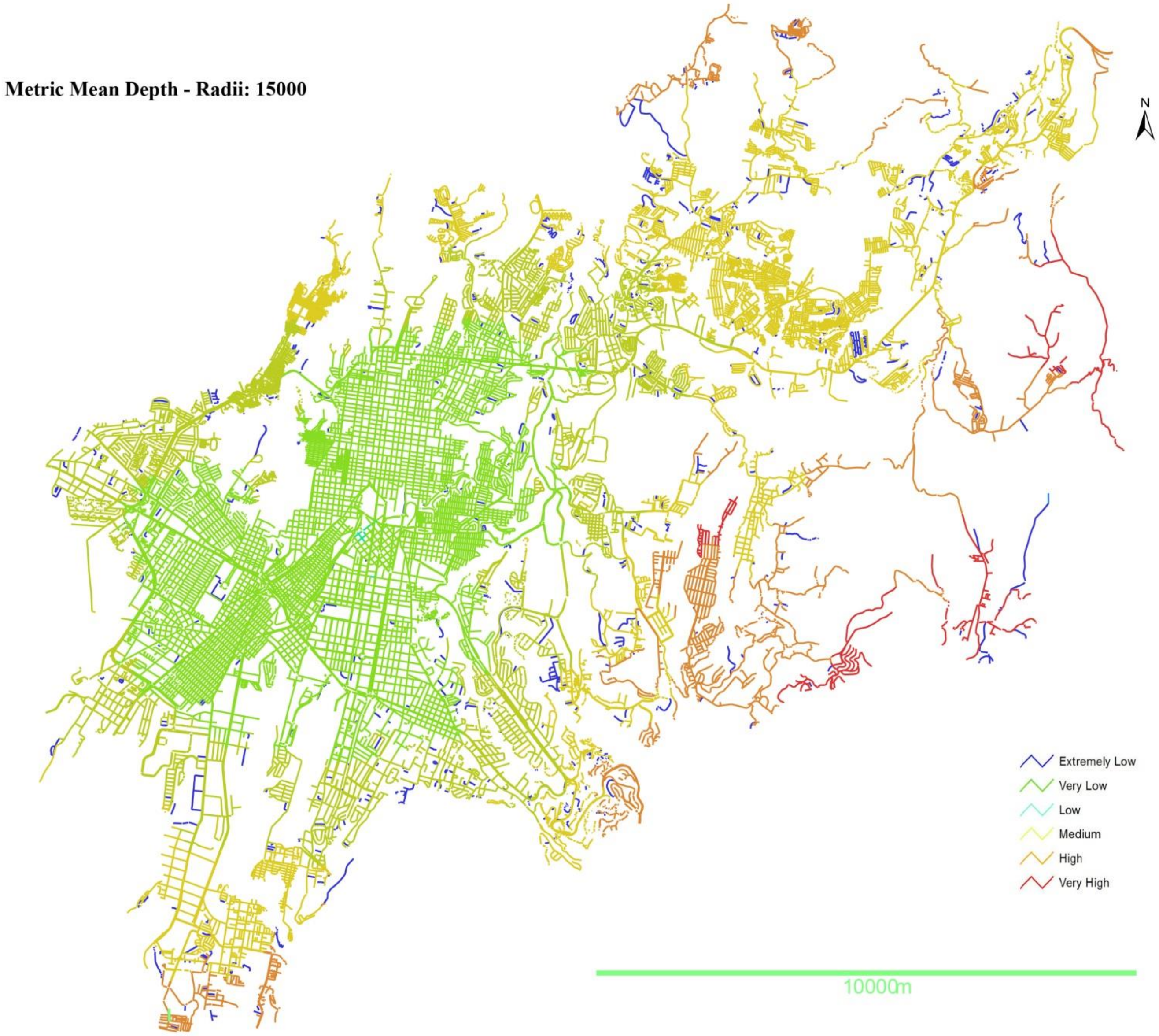

Figure 15: Metric Mean Depth - Radii: 15K

5. CENTRALITY ANALYSIS

This analysis intends to understand and measure the relation between two variables, in other words a correlation of these variables describes the characteristics of their relationship in terms of (Gravetter & Wallnau, 2006):

- Direction of relationship: Evaluates the relationship based on the sign of the correlation. A positive or negative sign describes the direction of such relationship. Positive sign is an indication of increase in the value of one variable when the value of another variable increases. While a negative sign indicates the inverse relation of the same variables.

- Strength or Consistency of relationship: Although a positive correlation indicates an increase in the variable when there is a change in the value of the other variable, this necessarily doesn't have to be in a linear form (same applies for negative correlation). Thus, the consistency (strength) of a correlation is measured in numerical value. Wherein, a perfect consistent correlation will indicate a correlation value of 1.0 (or -1.0) while a correlation with no consistency will produce a value of 0.

The degree of consistency is thus measured through intermediate values ranging between 0 and 1. Also, the signs (+ or -) and the strength of the correlation are independent. A correlation with a value of 1.0 irrespective of being positive or negative indicates a consistent relation. The assessment of such consistencies can be performed through a categorized format developed by Cohen, 1992. The categorization involves the following:

Category	**Consistency**
Low	0.10 – 0.29
Medium	0.30 – 0.49
High	0.50 – 1.00

Table 4: Cohen's assessment of consistency of correlation

5.1. Independent variable: Syntactic measures

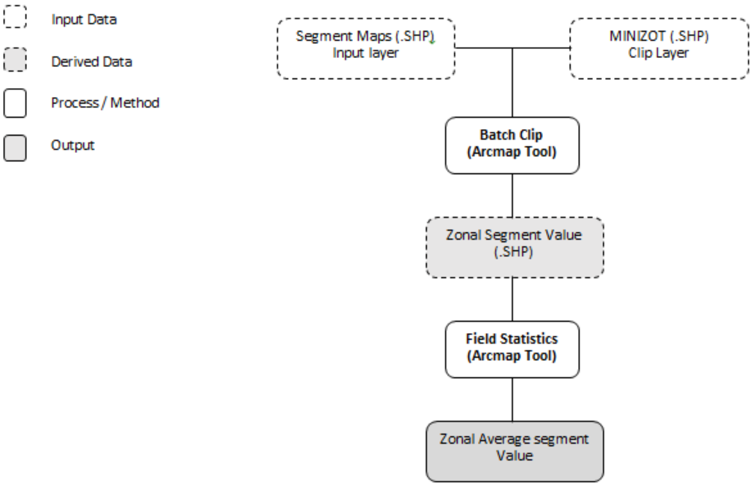

Figure 16: Independent dataset extraction

As aforementioned in the correlation section, the analysis calculates the relationship between two variables and in this case the research intends to measure the correlation between variables namely: independent and dependent variables. The independent variables are the syntactic measures produced through space syntax analysis performed earlier, while the dependent variables the mobility data of the case area.

The independent dataset were extracted through a combination of syntactic tools (Depthmap) and GIS (Arcmap). The procedure and methodologies applied in the same are visualized in the above mentioned flow diagram. The intention was to calculate the average segment value for each zone, so the same can be correlated with the mobility data for those respective zones. It must be noted that the syntactic values remain intact even after such zonal segregation, as the field values were imported from a separate syntactic analyses and were not produced in the GIS platform itself.

5.2. Dependent variable: Mobility data

In this stage of analysis, the daily average of trip attraction for privately held vehicles was chosen (PRIVADO – DM173Z). The other dataset included trip data for peak hour: private and public, and daily average of public transport. The chosen dataset included trip volume ranging roughly from 88 to 47,000 vehicle count for different traffic analysis zones (TAZ).

The mobility data had to be classified before conducting the correlation analysis; this was done through the help of classifying numeric field tool in Arcmap. For the sake of this classification, natural breaks (jenks) were applied. These class breaks are identified that best group similar values and that maximize the differences between classes. The features are divided into classes whose boundaries are set where there are relatively big differences in the data values.

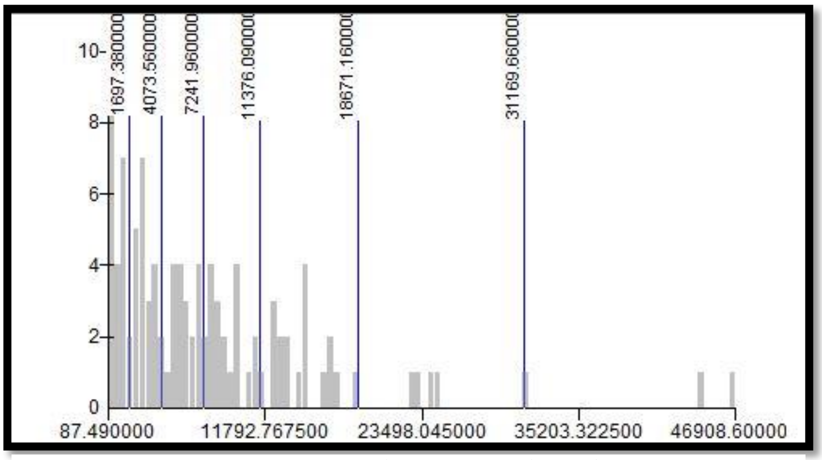

Figure 17: Natural breaks for mobility data

Class	Range
1	87.49 – 1697.38
2	1697.38 – 4073.56
3	4073.56 – 7241.96
4	7241.96 – 11376.09
5	11376.09 – 18671.16
6	18671.16 – 46908.6

Table 5: Classification of mobility data

5.2.1. Classification of mobility data

The classification of trip data led to a better understanding of zonal characteristic for each of the minizot zones within the municipal boundary of the case area. Through this classification it became vividly clear that the zones fell under the same class irrespective of the type of trip taken into consideration (average daily trip / peak hour trips) with the exception of two zones in the northern region of the case area who exhibited a mild increase in their trip class during peak hour. The following could be summarized through the classification of mobility data:

- The trip classification visually conveys the features of the different minizot zones in the case area. For instance, the central district zones are all associated to higher trip classes and the intensity of the trip attraction gradually decrease at peripheral zones. At least, this is the case in the south and mid – eastern region of the case. On the northern part though the zones exhibit a medium to high level trip attraction. Thus, trip classification seemingly articulates the geographical characteristic of the zones in terms of traffic inflow.

- Another advantage of classifying the trip data led to consolidate multiple zones with a common dependant factor (mobility) which were later correlated with the said zones network configuration that could validate the relation in between them. Performing this task for the consolidated zones based on the class enabled the study to clearly demonstrate the aforementioned mobility – network relation, which couldn't have been possible using the pre-delineated boundary based on the minizots (zones) which portrayed diverse scale in terms of area. Through the classification of the zones into classes, it was possible to include a fairer area of network structure to be taken into consideration alongside the consolidated zones. Subsequently, this enabled the study to carry out the analyses with due importance given to both dependant variable (mobility) and the independent variable (syntactic measures).

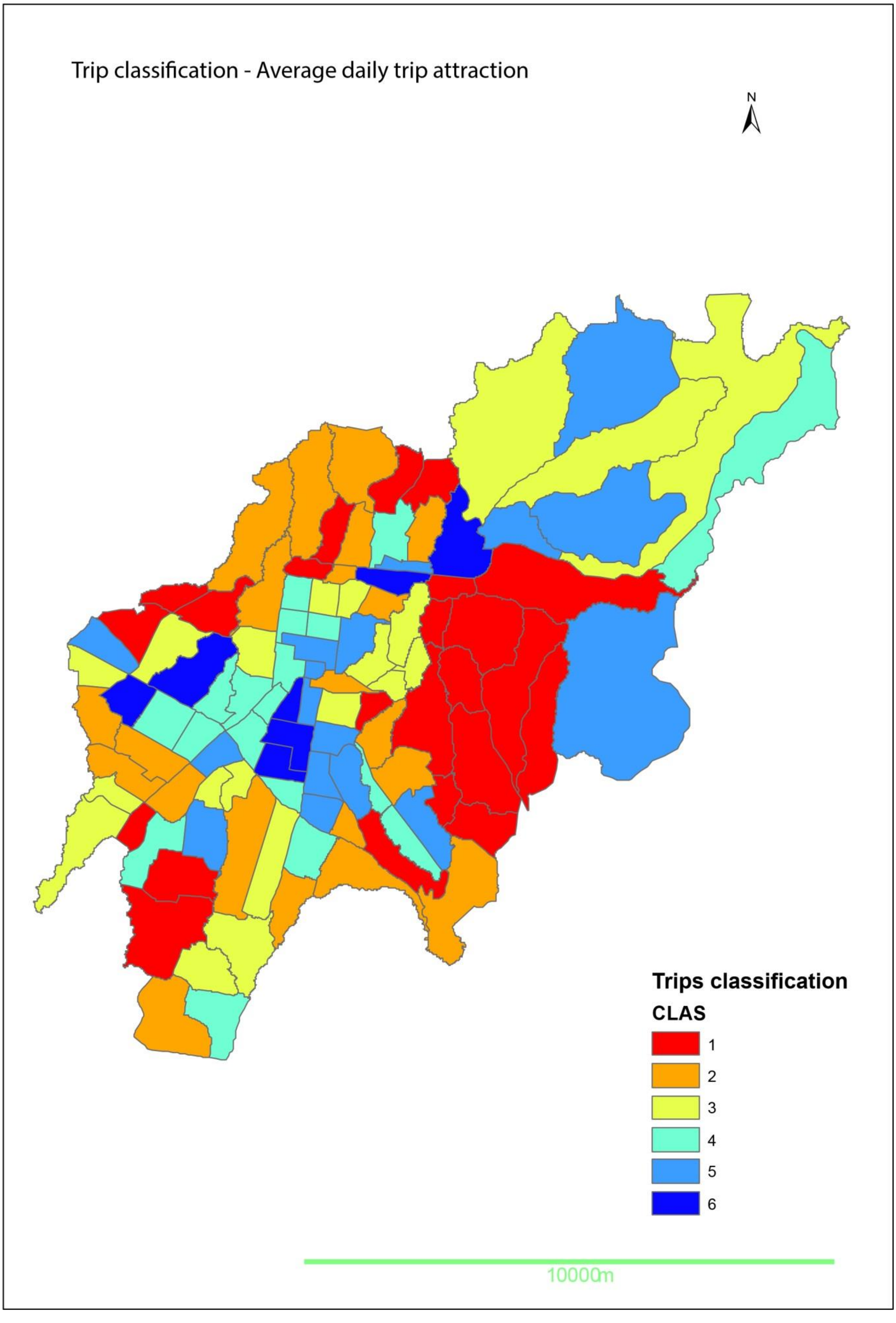

Figure 18: Average daily trip attraction

5.3. Correlation analysis: Average daily trip attraction

The following tables indicate the Pearson's correlation, sum of squares and covariance. The significance and consistency of the relationship between the zonal averages mean depth of the whole system (local (R3) - Topological) and the mobility data. At the same time, the significance of mobility data alongside the mean depth at different radii (namely: 2000, 5000, 10000 and 15000 – Topo-geometric) were also calculated.

Mean Depth / Trip Volume	2K	5K	10K	15K	LC (R_3)
Class 1 (87.49 – 1697.38)	+ 0.395 (M)[2]	+ 0.047	-	-	+0.582**[3] (H)
Class 2 (1697.38 – 4073.56)	+ 0.023	+ 0.027	-	-	-
Class 3 (4073.56 – 7241.96)	-	-	+ 0.133 (L)	+ 0.630** (H)	-
Class 4 (7241.96 – 11376.09)	+ 0.057	-	-	-	+ 0.056
Class 5 (11376.09 – 18671.16)	+ 0.095	-	+ 0.205 (L)	+ 0.041	+ 0.225 (L)
Class 6 (18671.16 – 46908.6)	-	-	-	-	+ 0.331 (M)

Table 6: Correlation results: Average daily trip

The above table summarizes the correlation between dependant and independent variables of the urban space in the case area. The decimals account for a positive Pearson's correlation observed in topological variable (local (R3)) and topo-geometric variables (2K – 15K) with respect to trip data. The innate observations made through these results are described in the following section.

5.3.1. Topo – geometric results

The topo-geometric variables chosen since the beginning of the study account for two smaller radii namely: 2000 & 5000, and for two larger radii: 10,000 & 15,000. Both of these radii produced distinctive results with respect to the dependant variable (trip data).Both these variables exhibit a positive correlation with class 1 & 2 trips. Out of which correlation accounting for 5K is almost negligible for consistency prescribed by Cohen, 1992. On the other hand, radii of 2K show a medium consistency with class 1 trips, while negligible consistencies with class – 2, 4 & 5 trips. Unlike the previous radii, these larger radii don't exhibit positive correlation with minimal trip classes like 1 & 2. On the contrary they display a consistent correlation with higher trip classes: 3 & 5. Within this consistency, radii 10K accounts for a low level performance with the aforementioned classes. But the largest radii of 15K produce a high consistency with class 3, while displaying a medium consistency with class 5 too. The following thematic maps summarize these results visually.

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[2] H – High, M- Medium & L – Low Consistency.

[1] Correlation is significant at the 0.01 level (2-tailed).

5.3.1.1. Topo – geometric statistics

The above calculated p – values with consistency where then compared alongside their coefficient of determination (R2) value. This was performed to evaluate the relation between the dependant and independent variable with in the zonal class trips that exhibited consistent performance in topo – geometric scale. The following table summarizes this evaluation:

Radius: 15K Class	Correlation coefficient (R)	Coefficient of determination R2
3	0.630	0.3965
5	0.041	0.002

Table 7: 15K radius statistics

As indicated earlier (Table 6) trip class 3 produced maximum consistency alongside significant correlation. Thus, a natural curiosity arises behind such significant performance which can now be understood with the R2 value of 0.3965. This coefficient of determination in other words describes the capability of the independent variable (local mean depth) for determining the inflow of the traffic. In this case, the independent variable accounts for 39.65% of the dependant variable (trip attraction).

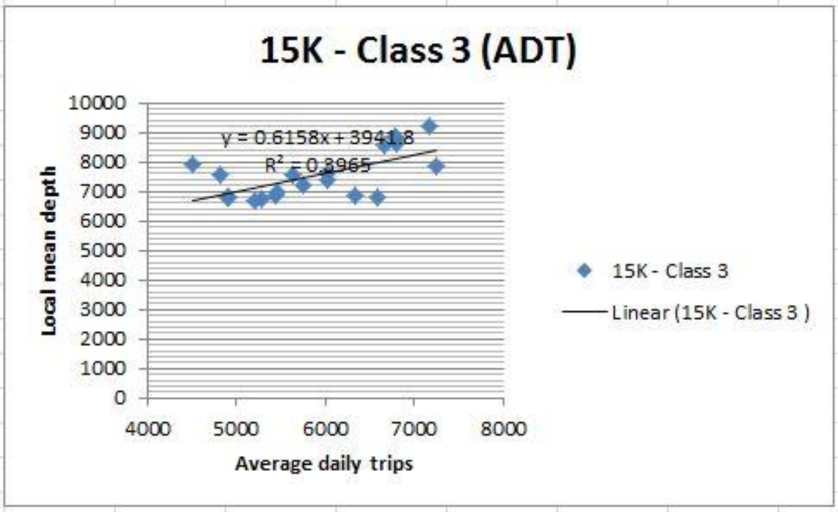

Figure 19: Local mean depth / 15K - Class 3 (ADT)

The above scatterplot describes the relation between class 3 trips and local mean depth at a topo – geometric radii of 15K. There is gradual increase in the trips as the level of integration rises in the form of mean depth. Overall, there is a positive collinearity of the mid – level class trip 3 at this scale. In terms of centrality, these class 3 zones can be accounted for sub – centres that cater to near – distance areas at a metric radius of 15K.

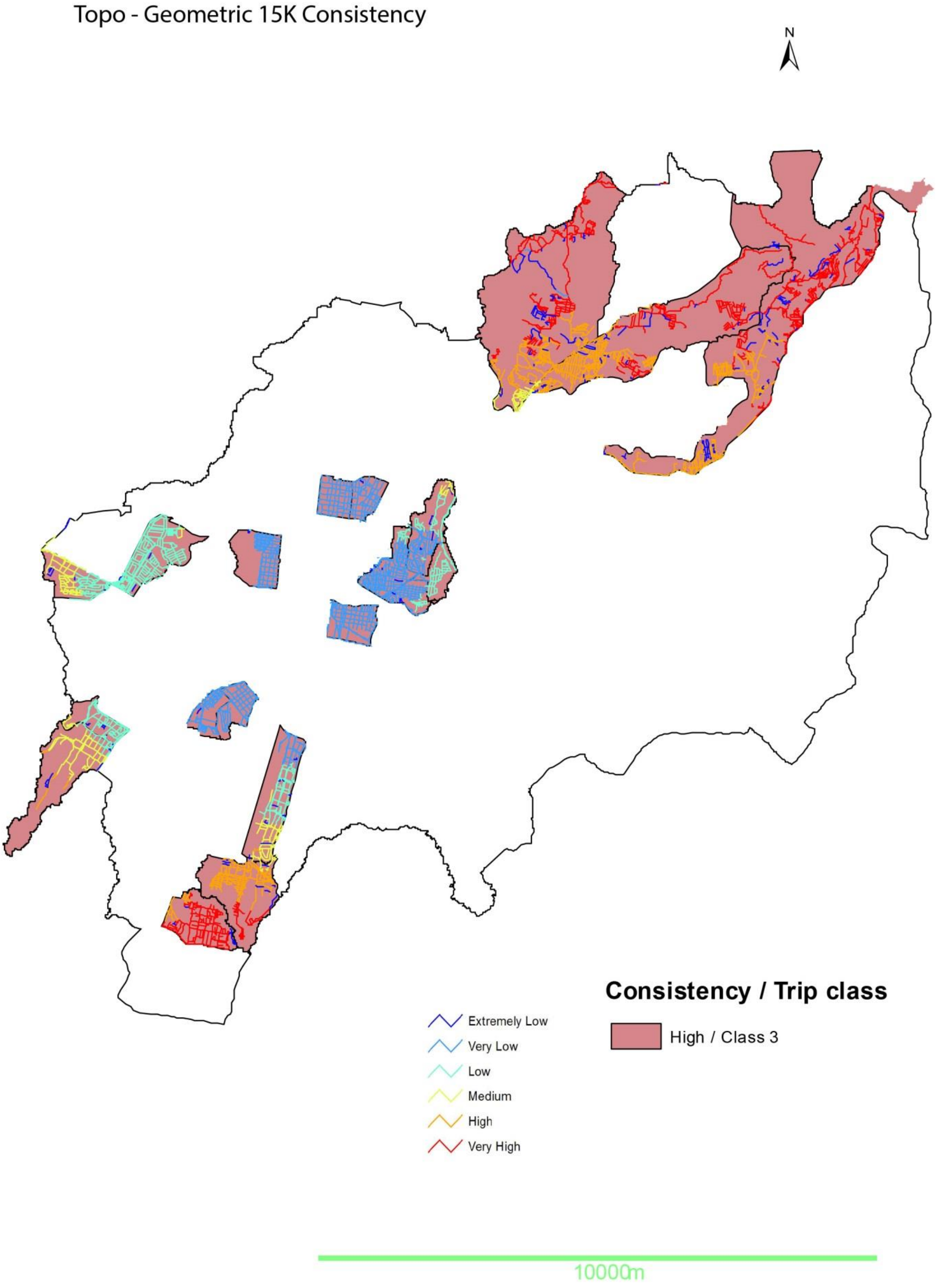

Figure 20: Topo-geometric consistency: 15K

5.3.2. Topological results

The local (R3) topological variable exhibits fairly better consistency with different classes of trips unlike the topo-geometric variables. Except for trip classes 2 & 3, the local level correlation tested positive for rest of the classes at a significantly consistent level.

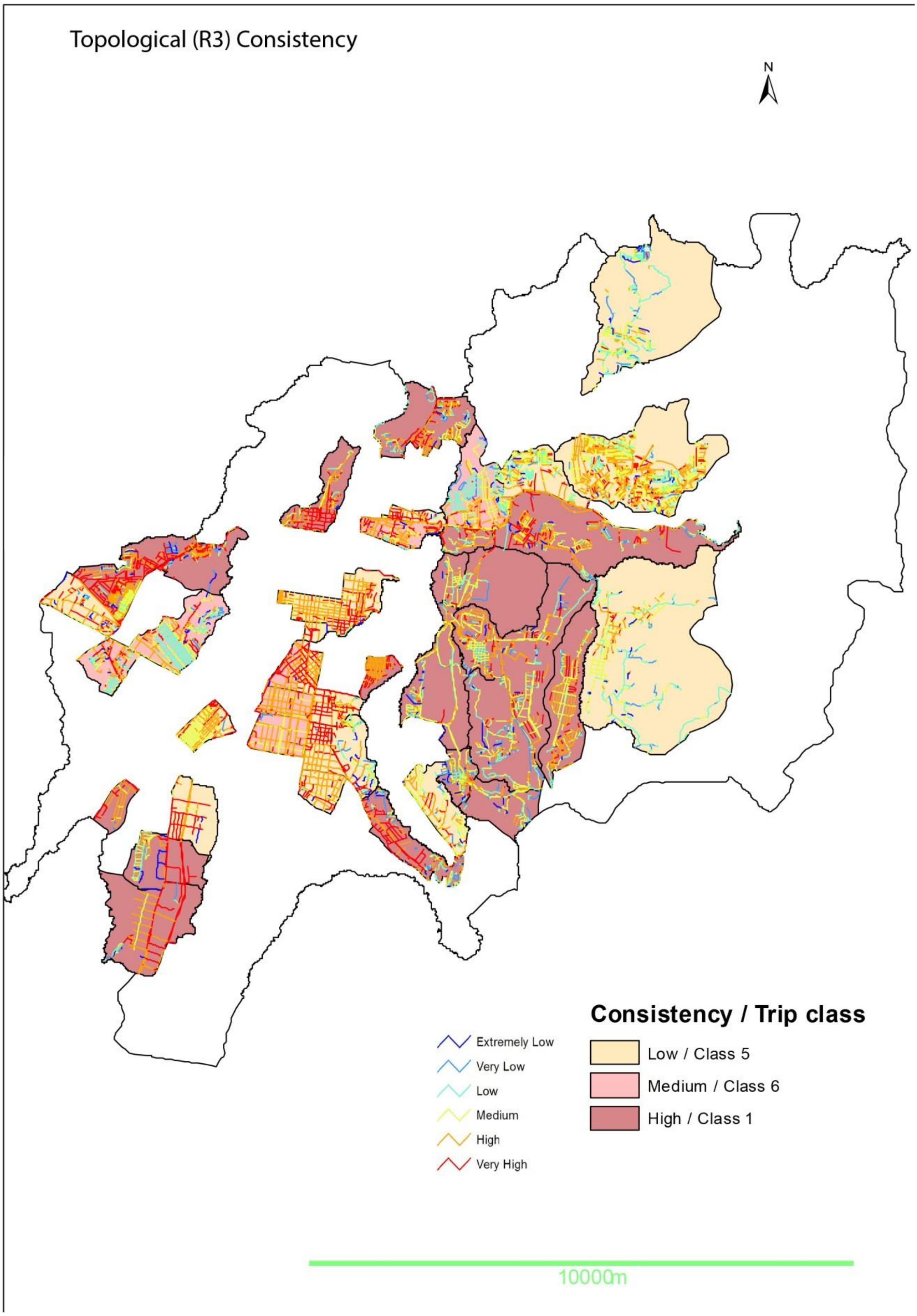

Figure 21: Topological Consistency: Local (R3)

5.3.2.1. Topological statistics

The previously described statistical comparison performed for topo – geometric correlation was done for topological results as well. Correlation result of different class trips at a topological scale (Table 6) unravelled the highly consistent and significant performance of class 1 trips. The following table summarizes the p – value and coefficient of determination for class trips in topological (R3) scale:

Topological: R3 Class	Correlation coefficient (R)	Coefficient of determination R2
1	0.582	0.3391
5	0.225	0.0504
6	0.331	0.1120

Table 8: Topological (R3) statistics

As mentioned earlier, class 1 trips stood out at the topological scale followed by class 6 and 5 trips. Now, as seen from the table above the coefficient of determination (R2) describes the relation between the class 1 trips and their consequent independent variable (local mean depth (R3)). Local mean depth at this topological scale accounts for 33.91% of the trips attracted in class 1 trip zones. The following scatterplot indicates their relation:

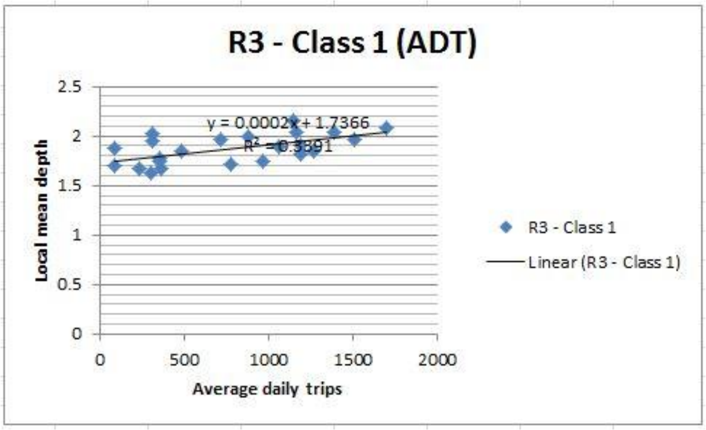

Figure 22: Local mean depth / R3 - Class 1 (ADT)

Although class 6 zones correlation coefficient are comparatively weaker than that of class 1, they nevertheless exhibit a consistent correlation with local mean depth value providing accountability for certain proportion of their respective traffic inflow. The scatter diagram depicts the linear relation between the class 1 trips and local mean depth (R3), there is a moderate positive collinearity between them. Again, a gradual rise in trip attraction is visible with an increase in integration (local mean depth). Thus, class 1 trip zones are functioning as sub – centres not only for the nearest areas but for the whole urban system at a topological scale.

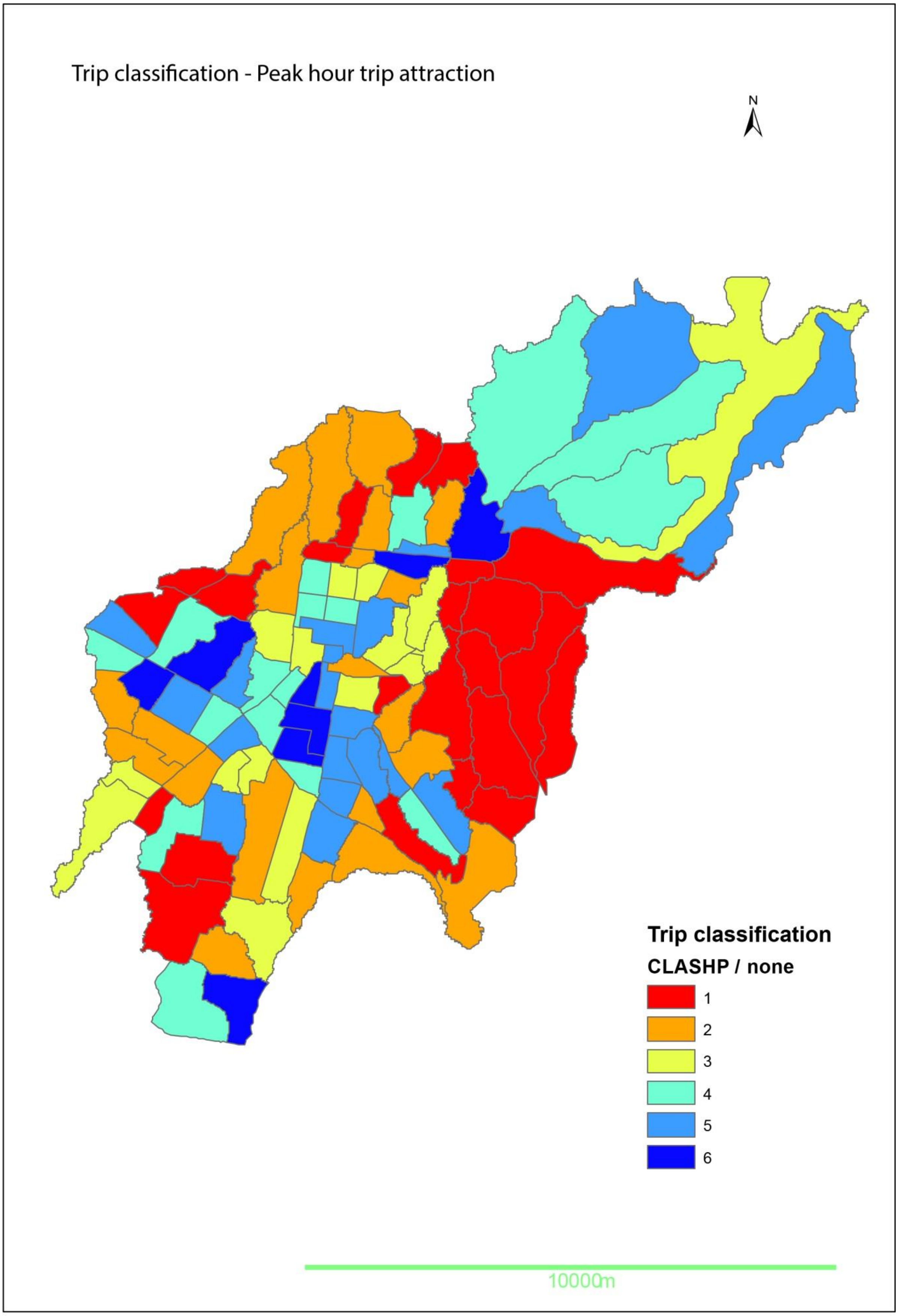

Figure 23: Trip classification - Peak hour trip attraction

5.4. Correlation analysis: Peak hour trip attraction

The previous methods were repeated for another correlation analysis, this time the dependant variables were the peak hour mobility data. The mobility data has been classified for correlation; this using classifying numeric field tool in Arcmap using natural breaks (Jenks).

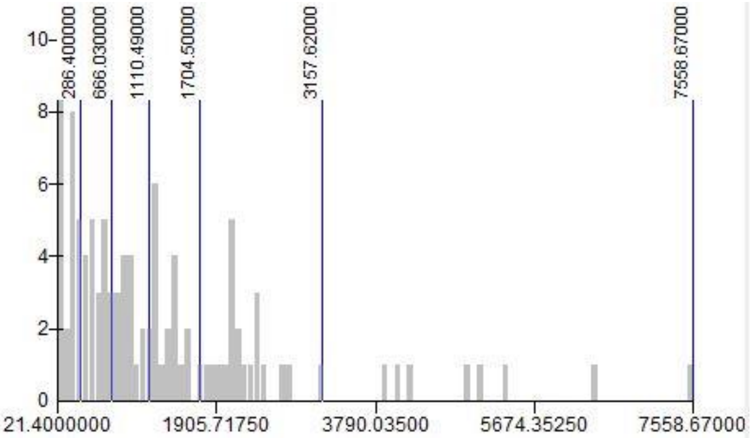

Figure 24: Natural break peak hour mobility data

Class	Range
1	21.4 – 286.4
2	286.4 – 666.03
3	666.03 – 1110.49
4	1110.49 – 1704.50
5	1704.50 – 3157.62
6	3157.62 – 7558.67

Table 9: Classification peak hour mobility data

The following table summarizes the results of the correlation analysis with respect to topo – geometric (Radii: 2000 – 15,000), Topological variable (Local R3) and peak hour trip mobility data.

Mean Depth / Trip Volume	2K	5K	10K	15K	LC (R_3)
Class 1 (21.4 – 286.4)	+ 0.306 (M)	+ 0.065	-	-	+0.486*[4] (M)
Class 2 (286.4 – 666.03)	+0.099	+0.092	-	+0.029	-
Class 3 (666.03 – 1110.49)	-	-	+0.10 (L)	+ 0.317 (M)	-
Class 4 (1110.49 – 1704.50)	+0.141 (L)	-	-	-	+0.408 (M)
Class 5 (1704.50 – 3157.62)	-	-	-	+0.042	+ 0.001
Class 6 (3157.62 – 7558.67)	-	+0.011	-	-	+ 0.256 (L)

Table 10: Correlation results: Peak hour trips

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[2] Correlation is significant at the 0.05 level (2-tailed).

5.4.1. Topo – geometric results

In terms of a radius of 2K, the Class 1 trips produced a significantly consistent correlation while Classes like 2 & 4 exhibited a low level consistency. On the other hand, radius 5K hardly displayed consistent correlation with class trips except for a low level consistency with class 2 trips. Class 3 trips were exhibited consistent correlation with both the larger radii; rest of the classes didn't display any significant results.

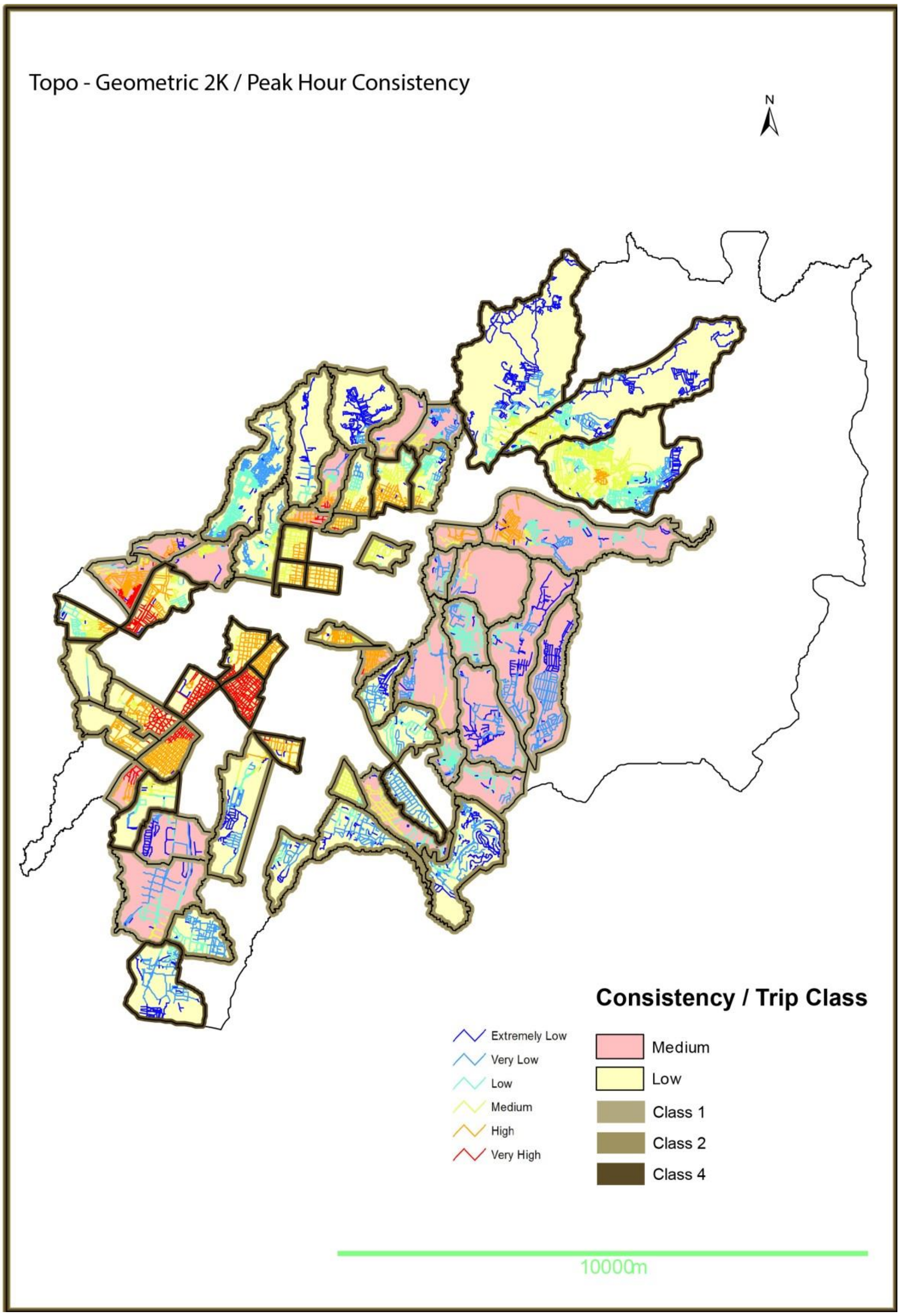

Figure 25: Topo - Geometric / Peak hour Consistency: 2K

5.4.1.1. Topo – geometric statistics

The peak hour trip classes produced fairly consistent performance lower radii of 2K. Hence, the statistical comparison was carried out for p – values at this lower level topo – geometric radius. The following table summarizes the result:

Radius:2K Class	Correlation coefficient (R)	Coefficient of determination R2
1	0.306	0.094
4	0.141	0.020

Table 11: 2K radius statistics

As seen from the table above, class 1 trips provide a consistent correlation which also happens to have a coefficient of determination (R2) of 0.1517. Unlike average daily trips (Page: 27), peak hour trips don't seem to have much accountability from independent variable (topo – geometric radius) which is promptly visible from the difference in their R2 values. In this case, local mean depth accounts for approximately 10% of the peak hour trips as compared to local mean depth's accountability of 39.5% in class 3 average daily trips at topo – geometric radii of 15K. The following scatterplot describes class 1 peak hour trips relation to that of topo – geometric radii of 2K:

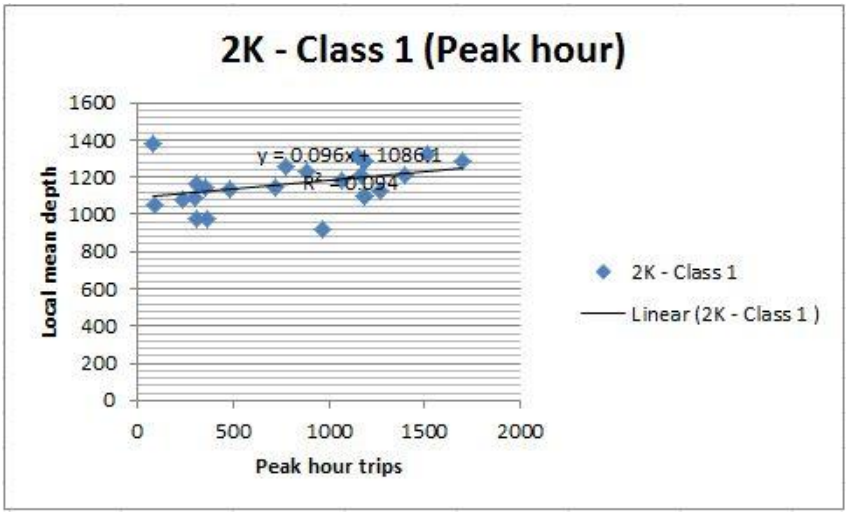

Figure 26: Local mean depth / 2K - Class 1 (HP)

Class 1 trip zones seem to function at a local level and host trips from closest neighbourhoods at a metric radius of 2K during peak hour. This suggests that class 1 zones have dual functions that constitutes of city – level characteristic at topological scale (average daily trip), and that of a micro level characteristic at topo – geometric scale.

5.4.2. Topological results

The local (R3) topological variable displayed a significantly consistent correlation with both lower level and medium level trip classes like 1 & 4. At the same time, class 6 displayed a low level consistency at this topological scale.

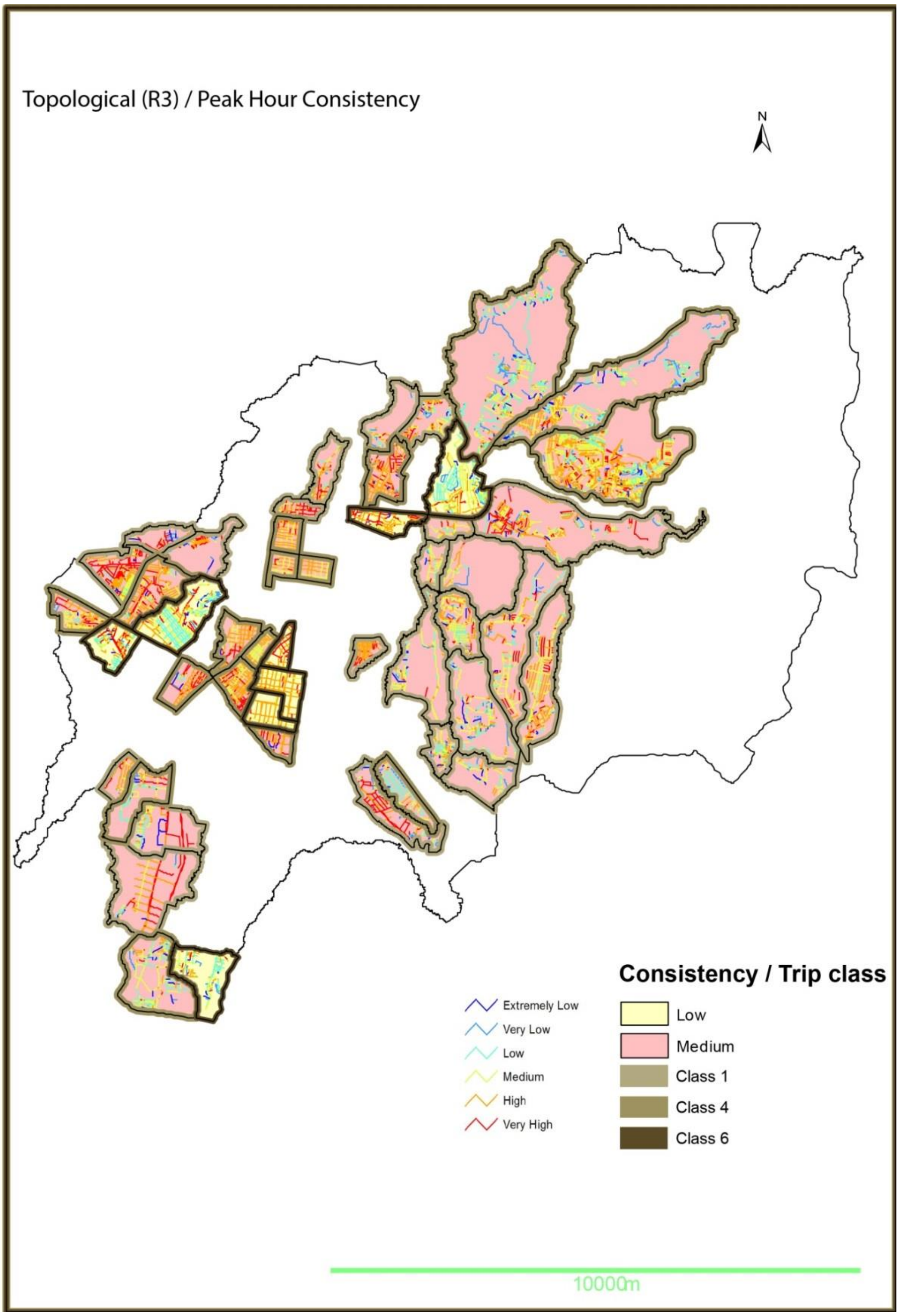

Figure 27: Topological Local (R3) / Peak hour Consistency

5.4.2.1. Topological statistics

Similar to average daily trips, the peak hour trips produced different levels of consistent performance of various class trips at topological scale (Table 10). The following table summarizes class trips p – value and their respective R2 values:

Topological: R3 Class	Correlation coefficient (R)	Coefficient of determination R2
1	0.486	0.236
4	0.408	0.183
6	0.256	0.065

Table 12: Topological (R3) statistics

It comes as no surprise that class 1 trips produced a fairly high coefficient of determination, as this class displayed a highly consistent performance in the correlation alongside being significant. As discussed in previous section, these R2 values provide the accountability of the independent variable (local mean depth (R3)) for the dependant variable (trip attraction – peak hour). In this case, topological – local mean depth accounts for 23.6% of trips in class 1 zones and 18.3% of trips in class 4 zones during peak hour. The following scatterplots summarize the aforementioned relation:

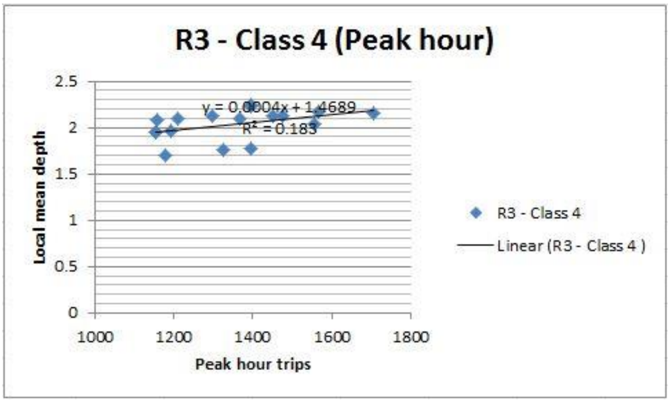

Figure 29: Local mean depth / R3 - Class 4 (HP)

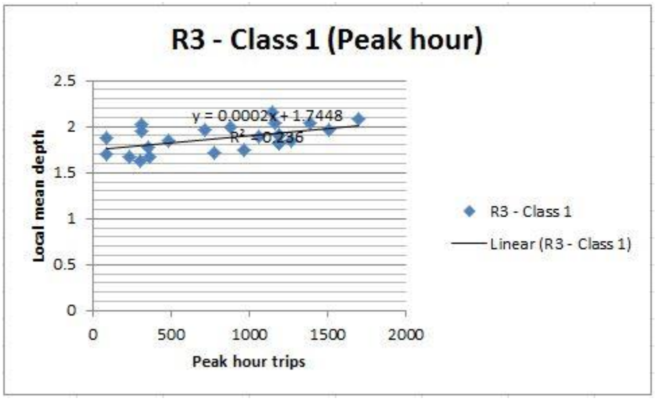

Figure 28: Local mean depth / R3 - Class 1 (HP)

It's interesting to note that during peak hour multiple trip class zones display centrality behaviour at topological scale. Class 4 trip zones are the ones which are both located near the central business district and also fall in both directions (south & north) of the peripheral region in the urban layout. Majority of the area belonging to class 4 zones include highly integrated network that account for increased trip attraction, which is visible during the peak hour.

5.5. Comparison of statistics: Sub – centrality

From the aforementioned statistical comparisons performed on the basis of average daily trip and peak hour trips, different class trip zones attribute towards centrality behaviour in different scales (Topo – geometric & Topological). The following tables summarize the results:

Class	Centrality	Correlation coefficient (R)	Coefficient of determination R2
3	Topo - geometric	0.630	0.3965
1	Topological	0.582	0.3391
6	Topological	0.331	0.1120

Table 13: Average daily trip based centrality

- The medium level trips attracted to class 3 zones are displaying centrality behaviour in topo – geometric scale at a radius of 15K. The variations in the local mean depth at a radius of 15K was earlier accounted to global topological (Rn) integration (Refer: Figure 13). And now, the trips coming under this zone at this topo – geometric radius indicate accountability of their respective local mean depth (Refer: Figure 19).

- On a topological scale, class 1 trips indicate centrality behaviour alongside class 6 zones with their nominal consistency as compared to class 1 zones significant correlation. Unlike class 3 at topological scale which are restricted to a metric level and cater to near – distance areas at a radius of 15K around their respective zones, class 1 trip zones function for the whole of urban system.

Class	Centrality	Correlation coefficient (R)	Coefficient of determination R2
1	Topological	0.486	0.236
4	Topological	0.408	0.183

Table 14: Peak hour trip based centrality

- With respect to peak hour trips, multiple centralities were exhibited by zones belonging at a topological scale. More importantly, the zones attracting higher trips in class 4 displayed centrality behaviour with highly integrated networks attracting increased trips (Refer: Figure 29) during the peak hour.

- Although class 1 trip zones have relatively lower integration (Local mean depth) than that of class 6 zones, the former zones have consistently stood out in terms of centrality behaviour collectively based on both average daily trips and peak hour trips. Subsequently, this indicates the accountability of this zones network configuration for attracting present trips and their potential to attract increased trips.

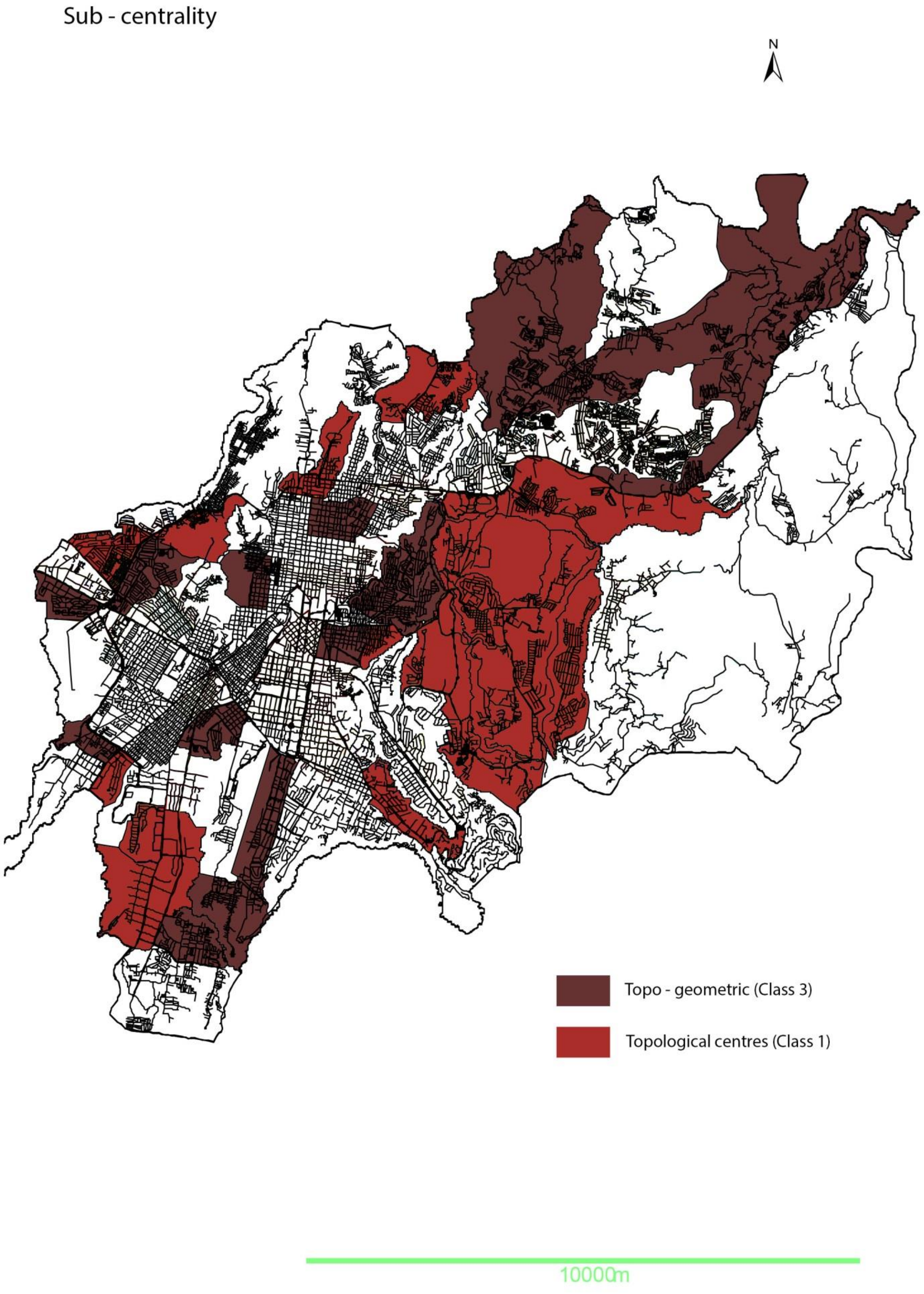

Figure 30: Sub - centres - Topo - geometric / Topological

5.6. Sub – centres: Topo – geometric & Topological

From the previous section it could be seen that two class zones stood out in topo – geometric and topological scale in terms of centrality. The class 3 zones have displayed a highly significant correlation with a R2 accountability close to 40% for traffic inflow. On the other hand class 1 zones have exhibited significant correlation in terms of network configuration (Local mean depth) and traffic inflow through the usage of both average daily trip and peak hour. With these observations the following could be summarized:

- Class 1 zones are geographically concentrated in the mid-eastern part of the case area, adjoining higher trip class zones like class 5 & 6 (Refer: Figure 18). As mentioned earlier class 1 zones have been accounted for sub – centrality behaviour based on their relation between network configuration and subsequent trip attraction, in other words this relation fits into the criteria of being a structural system that imitates a metropolitan configuration at a local level. Thus, the aforementioned relation suffices the description of sub – centrality (Refer: Page 2).

- As described earlier class 1 zones are dominant in the mid-eastern geographical region of the city, they are also scattered in other parts of the city like the peripheral areas. For instance, there is a large zone belonging to the class 1 trips down south of the case area which can be attributed to the localized peripheral centres (Refer: Case area). Such localized peripheral centres have been observed to be detrimental in nature with inadequate infrastructure to access the main centres (CBD's).

- At the topo – geometric scale class 3 zones have come out with centrality behaviour; the same relation for class 1 zones applies for these zones as well in terms of network configuration and traffic inflow but with an added element of metric radius of 15K. Class 3 zones for major part of the geographical location are in near proximity to the active zones in the central district. An overload in terms of density and / or development could easily spill in to these areas due to such proximity. In terms of centrality, due to their geographical location these zones ought to be the most sought after the CBD's. A near – distance radii of 15K suffices almost the entirety of the urban network system, which means parts of the class 3 zones located at the centre of the city must be already acting as proxy centres.

- Both class 1 and class 3 zones possess the potential to attract more traffic inflow with their network configuration and geographical location. Although, these zones fall under medium to low level traffic inflow they nevertheless feature the characteristics to transform the same (into increased traffic attraction) with their network structure and proximity to access developed areas. In other words, these zones feature areas that provide fewest numbers of turns to reach other parts of the urban network system.

6. AXIAL INTELLIGIBILITY

6.1. Sub – centres: Average daily trip

Based on the sub centres identified through the consistency of average trip class to that of topological (Local R3) mean depth an axial intelligibility was carried out wherein the integration (To – movement) is correlated with choice (Through – movement). The following results indicate the correlation result:

Trip class	Axial intelligibility: correlation
Class 1 (87.49 – 1697.38)	+ 0.505*[5]
Class 5 (11376.09 – 18671.16)	+ 0.751**[6]
Class 6 (18671.16 – 46908.6)	+ 0.881**

Table 15: Axial intelligibility - Average daily trip centres

6.2. Sub – centres: Peak hour trip

The above analysis was performed for the sub – centres identified through peak hour trip as well. The below results indicate the performance of the correlation:

Trip class	Axial intelligibility: correlation
Class 1 (21.4 – 286.4)	+ 0.505*
Class 4 (1110.49 – 1704.50)	+ 0.538*
Class 6 (3157.62 – 7558.67)	+ 0.910**

Table 16: Axial intelligibility - Peak hour trip centres

The following section visualizes the above results, it's noteworthy to view class 6 in both aforementioned cases wherein active centrality accounts to the centres with higher trip classes.

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[5] Correlation is significant at the 0.05 level (2-tailed).

[6] Correlation is significant at the 0.01 level (2-tailed).

6.3. Correlation result: Axial intelligibility

As the aforementioned results (Table 13, Table 14) indicate, the class 6 trip zones attribute towards highest significance in terms of axial intelligibility which subsequently account for active centrality. Class 6 being the highest trip attracting zones should be accounted for both to – movement integration (integration) and through – movement (choice). For a better understanding the following graphs represent the coefficient of determination (R2) in between integration and choice at R3 (local).

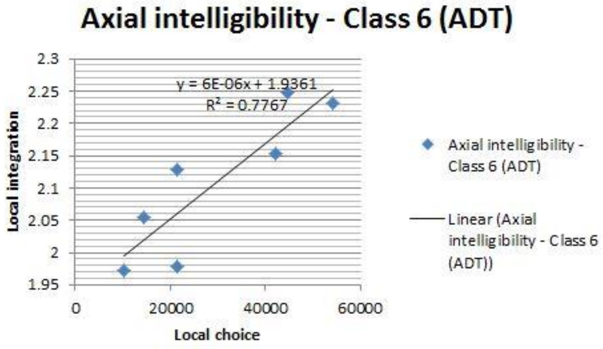

Figure 31: Axial intelligibility - Average daily trip

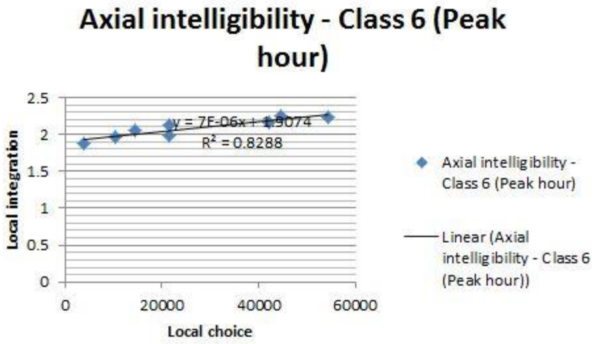

Figure 32: Axial intelligibility - Peak hour trips

6.4. Comparison of results: Active – centrality

Through the axial intelligibility analyses the following deductions can be made:

- As seen from the previous scatterplot, the relation between local (R3) choice and integration is positively linear in the zones with high trip attraction (both ADT, Peak hour). Meaning, in these zones as the local integration value increases so does the choice.

- These zones accounting for highly integrated network seamlessly attribute to both to – movement and through – movement. Subsequently being the reason for zones with high trip class. These zones must be host to movement generating activities in terms of land use.

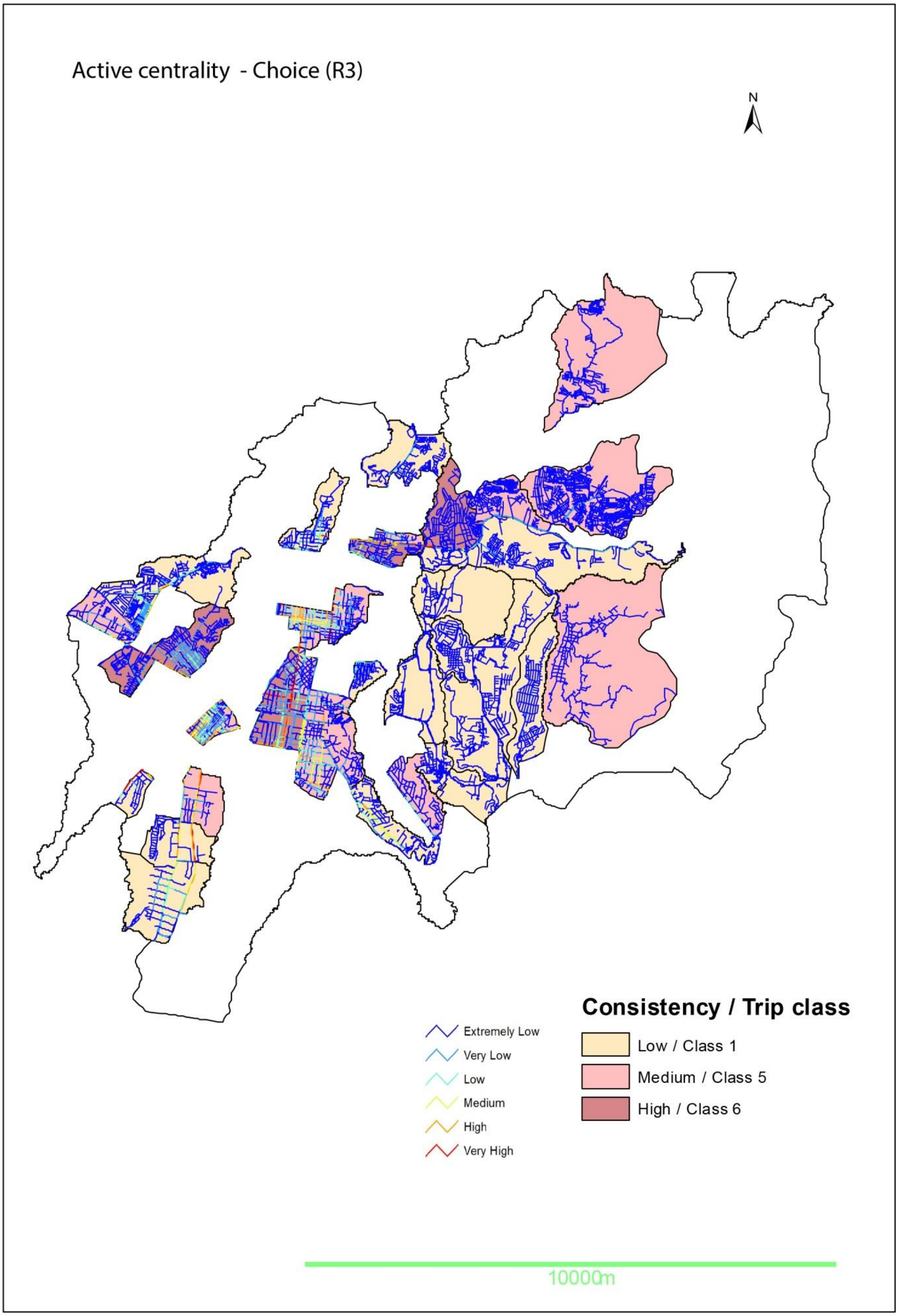

Figure 33: Active centre via Average daily trip

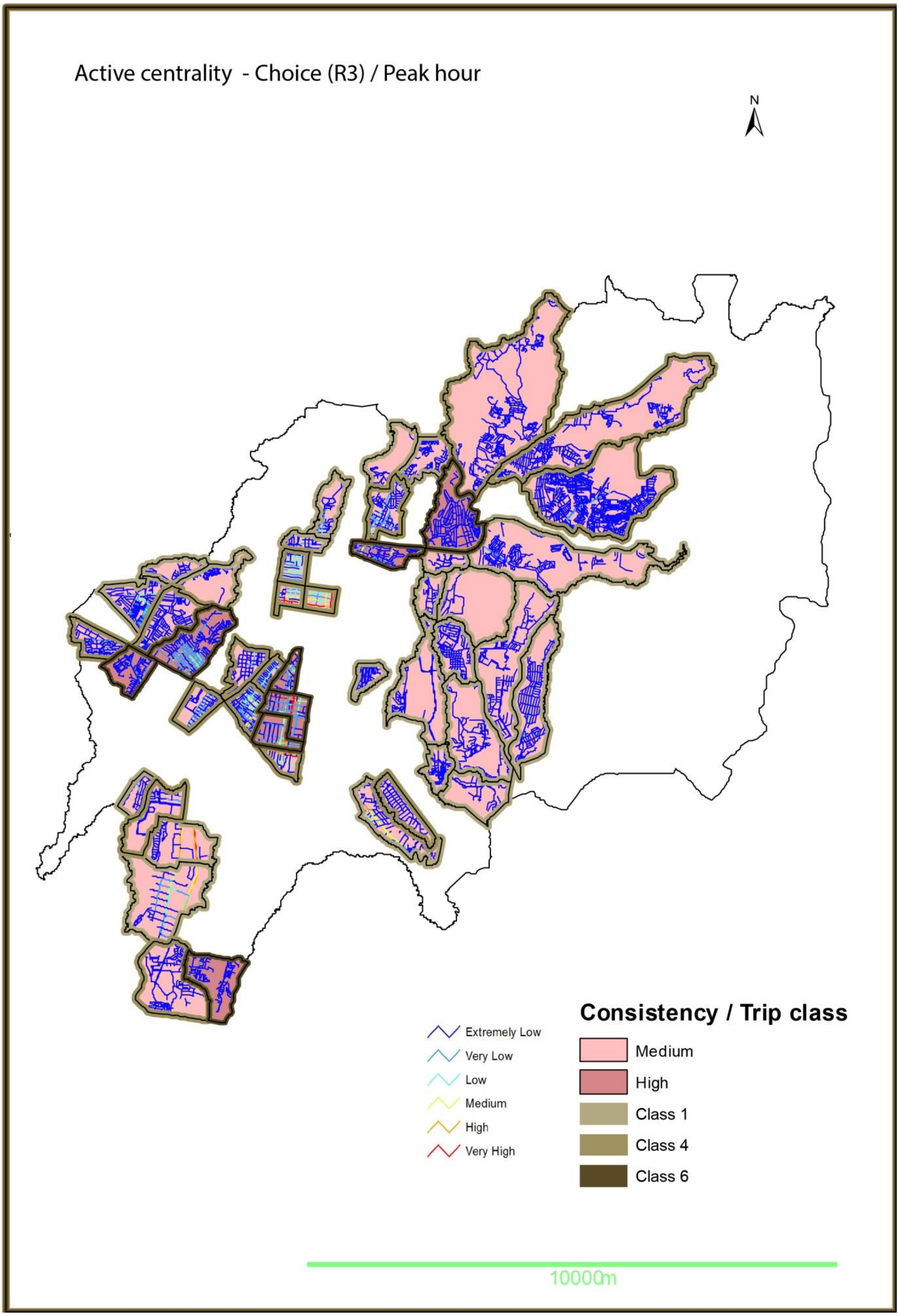

Figure 34: Active centre via Peak hour trip

6.5. Comparison: Sub – centres, Active centres

The ordeals of localized peripheral areas were discussed in one the previous chapter (See: Case area), such peripheral centres came to light in the sub – centre analyses. These peripheral areas belonged to trip class 1, and displayed a consistent strength in correlation with respect to topological local mean depth. Such centres are found in the edge of the city at south – east and north east as well. It can deduced from aforementioned scatter diagrams (Figure 22, figure 29) that trips at topological scale accumulated to class 1, correspond to fairly well integrated (Figure 21) networks (local mean depth).

Thus, these peripheral zones presently hosting class 1 trips are in fact bearers of network configuration that has the potential to attract more movement. These zones hone the potential to accommodate high density development with their sub – centrality behaviour at the local level. The other centres identified were located in the city centre which already accommodates the zones adjoining central business district; these zones fell in trip class 4 – the higher movement attracting zones. Zones in this location accounted highly integrated street networks, which subsequently attributed for such increased trip attraction (Figure 29).

Active behaviours were found in zones amounting to trip class 6, located in south central and north central parts of the city. The active zones in the south were more or less associated with the existing CBD. The zone in the north though, has a well-integrated network connecting other non – active centres with segregated network system. The zones belonging to class 1 trips in the south and north east part of the case area are adjoining zones (Figure 33) containing higher class trips (4 – 6), with such proximity and network configuration alongside a potential to attract more movement these zones are likely to attract spill from the higher trip class zones (if any) in the future. On a whole, there are zones (peripheral) which are acting as local sub – centres, that has the potential to attract movement and can be developed to accommodate such increase in the future. On the other side there are these active zones, which are already attracting increased movement with their existing well-integrated street network. These zones require further inspection before their networks get overloaded with increased movement, that can't be sustained by the present capacity.

6.6. Active centres: Land use behaviour

The previously discussed active centres were evaluated on the basis of their land use, to assess the said land use in the context of syntactic parameters. Identified active centres were put under the scanner to understand their existing land use for each TAZ zones. The following graph summarizes the percentage of use for each zone under the active centres:

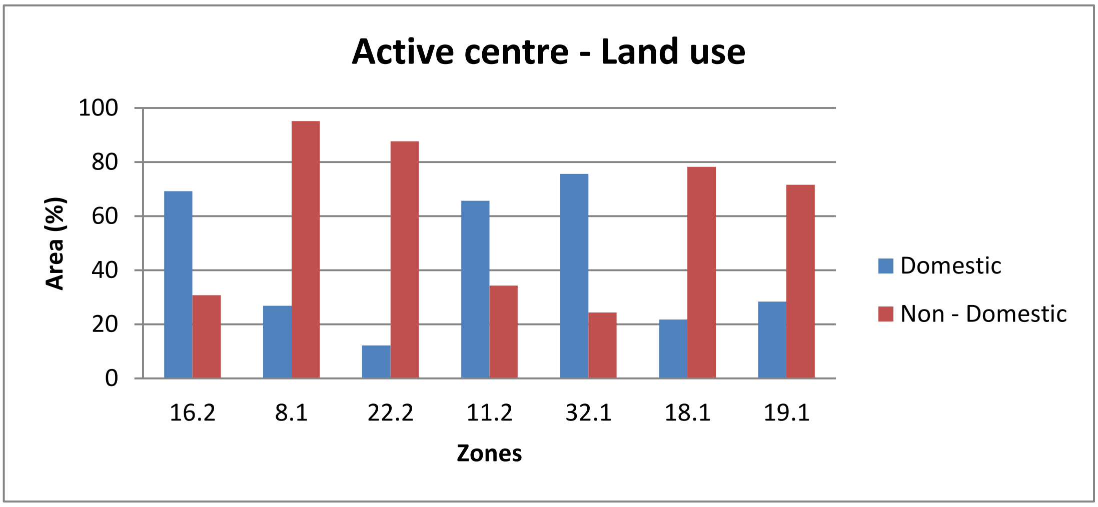

Figure 35: Active centre: Land use composition

6.6.1. Zonal land use composition

The aforementioned land use composition classifies diverse uses into two primary uses namely: domestic and non – domestic. The domestic use consists of housing purposes such as: Residencial (Residential), Apartamento (apartment). On the other hand non – domestic uses composed of a broader category of uses like: Comercio (commercial), Hoteles tipo 'B' (hotel), Industria (industry). Colegios (colleges), Oficina (office), Edificio publico (public buildings), Mixto (mixed – use), Estacionamientos (parking / storage facilities), Parqueo al aire libre (outdoor parking), Edificio en construccion (buildings construction) and Uso especial (special use).

Based on the previous zonal use composition (Figure 35), zones that correspond to dominant non – domestic use were further studied. This was performed to identify the dominant factor in the form of land use in each of these zones and the results were as follows:

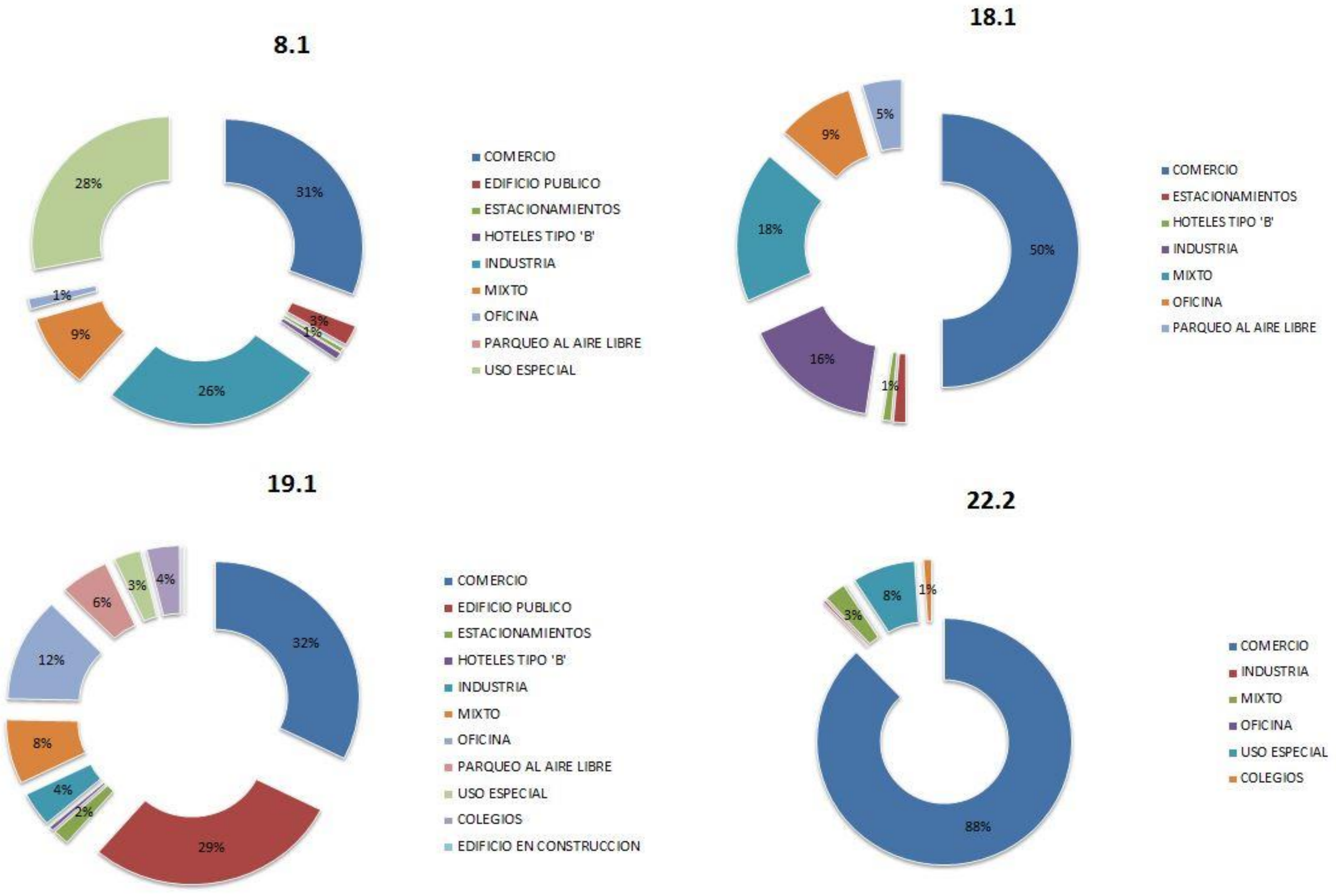

Figure 36: Non - domestic land use composition

Commercial sector clearly seems to be the driving force when it comes to active centres, followed by industries, public buildings and rest. It's noteworthy to remember that these are the zones attracting high trips (class 6), and as discussed in the beginning of this research (Refer: 1.1) theory of cities as movement economies has attributed movement – oriented use (land use) for the intensification of urban network (Ortiz-Chao, 2008).

6.6.2. Land use and network configuration

Hillier (2007) had previously described the result of movement – oriented use in the intensification of grid mostly caused by commercial and retail sectors. The study also pointed out fall of movement flow due to distance decay in terms of metric distance. In the context of this study, the case area exhibited similar characteristics in terms of domestic and non – domestic use. The following scatterplot describes the relation between local integration (R3) and their zonal land use composition.

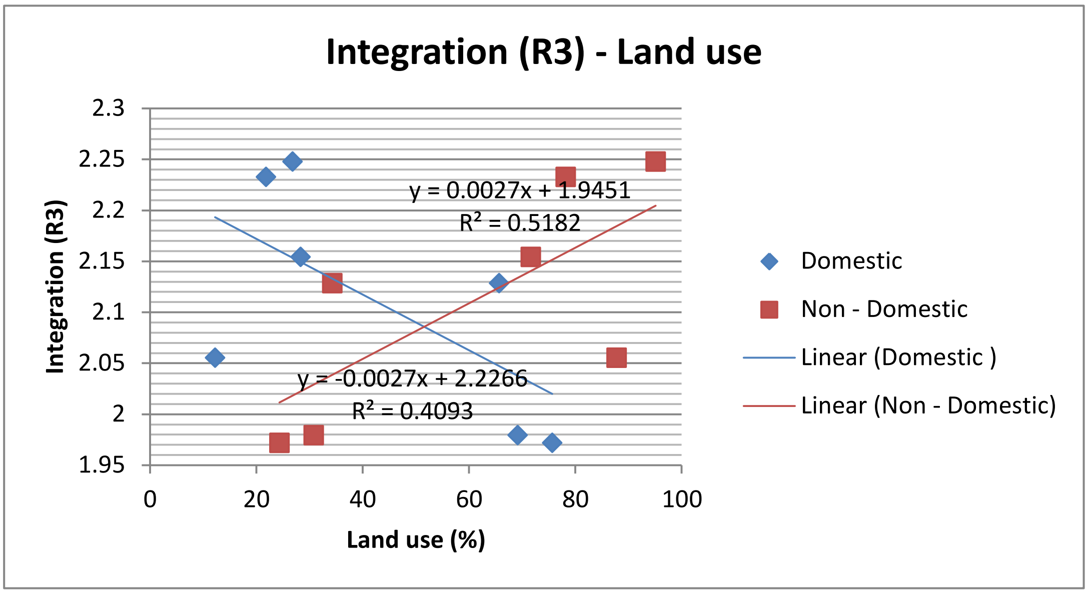

Figure 37: Correlation: Integration (R3) - Land use

The above collinearity sheds light on the relation between integration of street network alongside the type of land use. It is clear that both primary uses produce distinctive relations to that of the syntactic variable (integration (R3)). Domestic use on one hand produces a negative collinearity, while on the other hand non – domestic use produce a highly positive collinear relation. To summarize, the following can be deduced through this relation:

- With respect to non – domestic use, the percentage of such uses increase steadily as the integration of the network increases. In other words, non – domestic use tend to occupy more integrated and accessible networks. This fits perfectly in Claudia Ortiz (2008) description on exploitation of accessible networks by commercial and retail sectors, while residential use become devoid of such location.

- The latter half of the previous inference clearly explains the ordeals of domestic use with respect to network configuration. As seen in the scatterplot, the composition of domestic use drastically decreases with respect to increase in integration. Majority of domestic use in these active centres are located in comparatively less integrated network.

7. CONCLUSION

The primary objective of this thesis revolved around the identification of sub – centres based on poles of influence – trip attraction and accessibility (syntactic) measures of network configuration at zonal level. This was followed by an evaluation of such sub – centres, which can earmark the active behaviour of such centres. The former objective was successfully carried out at both topological (local (R3)) and topo – geometric (metric radii: 2K – 15K) level, this helped in establishing the behaviour of different class trips in these diverse syntactic scale. Subsequently sub – centres were delineated through the verification of their consistency to procure the strength of individual correlation results of different class trips. The results through this consistency check produced low to medium level correlation strength of trip data at both topo – geometric and topological scale. In order to demarcate centrality, the collinearity of these trip class zones were evaluated alongside their independent variable (local mean depth) which unveiled the accountability of these syntactic measure over trip attraction to their respective zones. Later, it was inferred that mid – level zone (class 3) exhibited centrality behaviour at topo – geometric (radii: 15K) scale. While on the topological scale, class 1 and class 6 exhibited such behaviour.

These sub – centres were then taken into consideration for the next stage of analyses namely: axial intelligibility. Wherein a segment angular analysis was ran to extract the choice (through – movement), which was later correlated with integration (local mean depth) to evaluate the active behaviour of these sub – centres. Presumably, the active centres happened to be the zones attracting high trip volume. This was a confirmation that increased overlap of integration and choice does attract considerably more movement than networks that cease to have such an overlap. Further in-depth analyses of these active centres were carried out to create an accountability of their land use. The analyses were performed in the form of an assessment of land use composition at zonal level for these individual centres. This was later correlated with the integration (local mean depth) of network configuration, which produced a convincing result indicating exponential drop of domestic use in networks that were highly integrated, in other words easily accessible.

Although active centres account for movement – oriented use that can boost economic activities, it can't be ruled out that they also create a form of segregation at the local level wherein the domestic activities can access scarce space. This explains the growth of localized peripheral developments in the case area, mostly caused by a push back of domestic use by non – domestic use. Presently, other sub – centres (zones: Class 1, 5) aren't exhibiting consistent strength in terms of axial intelligibility (active centrality) but nevertheless they are significant enough to become active in nature. An increase in movement – oriented use (commercial, retail) can easily set-off these sub – centres from hosting domestic use to becoming an active economic hub in the future. On the other hand these localized peripheral centres have been subject to inadequate road infrastructure, insecurity of public space (See: Case area) which restrict these zones from becoming re-localized economic centre.

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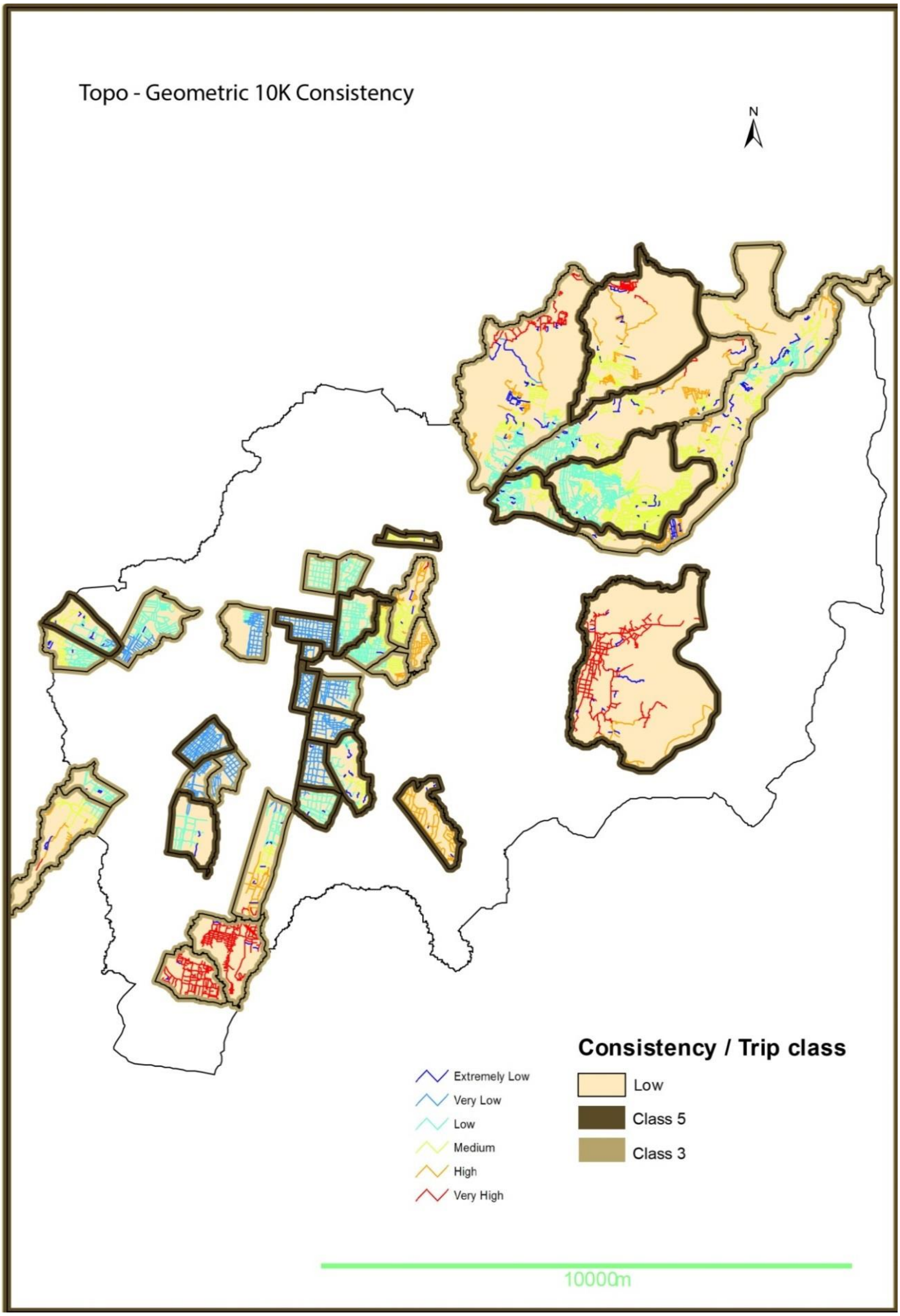


Figure 38: Topo-geometric consistency: 10K

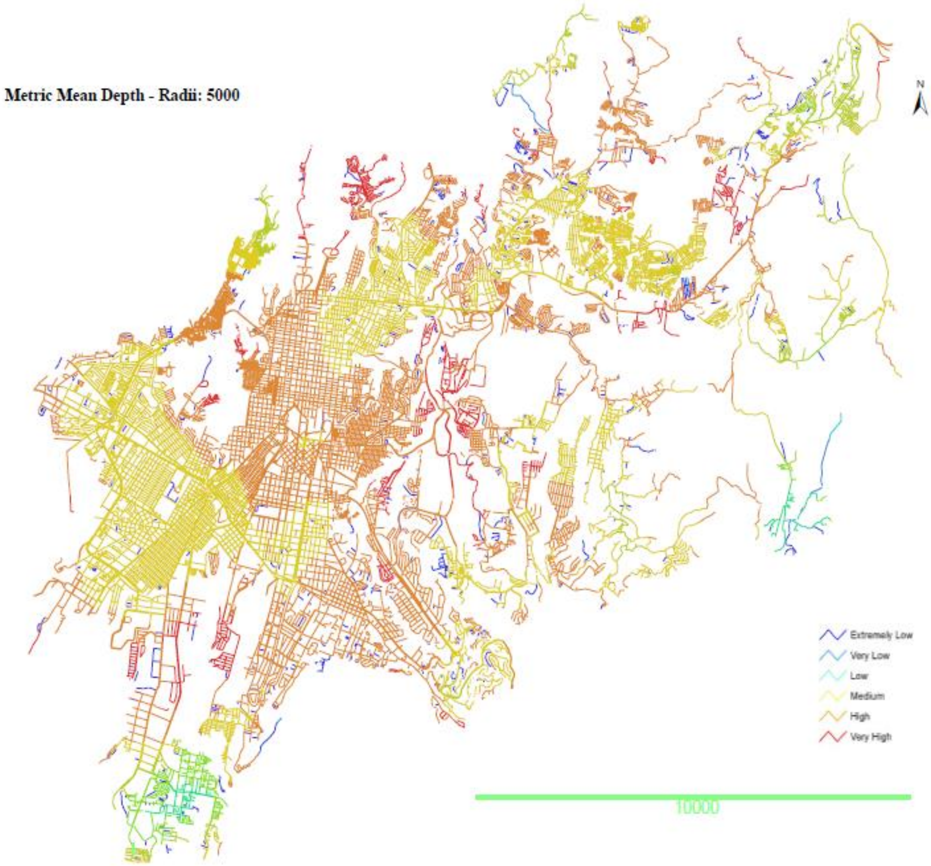


Figure 40: Metric Mean Depth - Radii: 5K

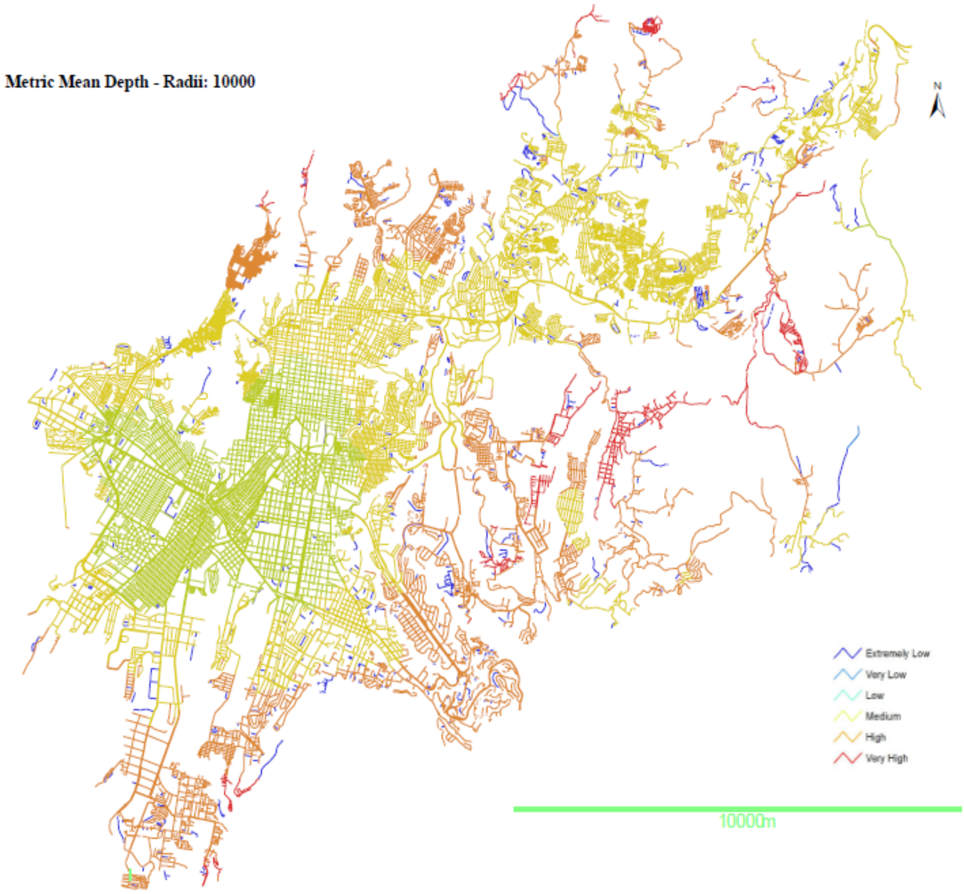


Figure 40: Metric Mean Depth - Radii: 10K

Model Summary[a]

Model	R	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
1	.630[b]	.396	.363	.396	11.825	1	18	.003

a. CLAS = 3.0

b. Predictors: (Constant), LC_15K

Table 17: Correlation summary: Topo - geometric radii 15K / Class 3

Model Summary[a]

Model	R	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
1	.582[b]	.339	.308	.339	10.773	1	21	.004

a. CLAS = 1.0

b. Predictors: (Constant), LC_MD

Table 18: Correlation summary: Topological (R3) / Class 1

Model Summary[a]

Model	R	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
1	.331[b]	.110	.068	.110	.616	1	5	.468

a. CLAS = 6.0

b. Predictors: (Constant), LC_MD

Table 19: Correlation summary: Topological (R3) / Class 6

Model Summary[a]

Model	R	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
1	.306[b]	.094	.051	.094	2.171	1	21	.156

a. CLASHP = 1.0

b. Predictors: (Constant), LC_2K

Table 20: Correlation summary: Topo - geometric radii 2K / Class 1 (Peak hour)

Model Summary[a]

Model	R	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
1	.486[b]	.236	.200	.236	6.499	1	21	.019

a. CLASHP = 1.0

b. Predictors: (Constant), LC_MD

Table 21: Correlation summary: Topological (R3) / Class 1 (Peak hour)

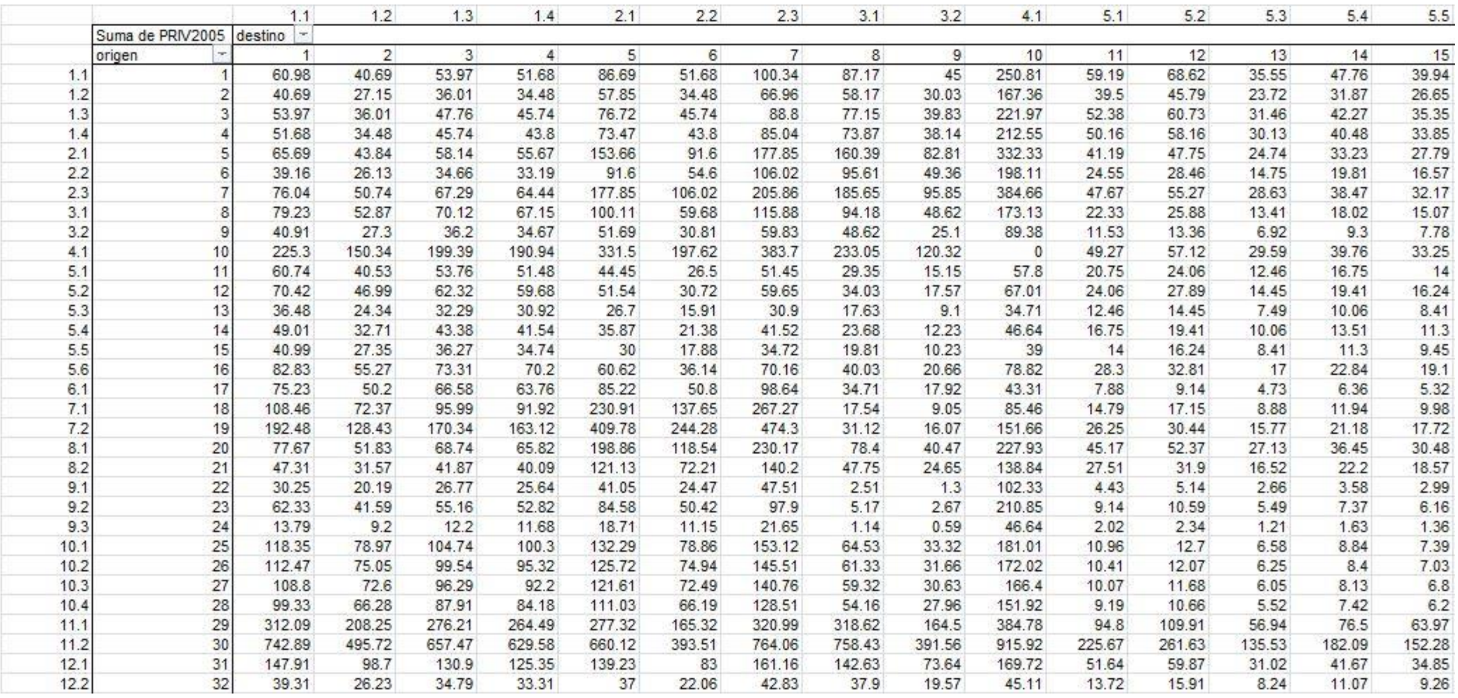
Model Summary[a]

Model	R	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
1	.408[b]	.167	.107	.167	2.801	1	14	.116

a. CLASHP = 4.0

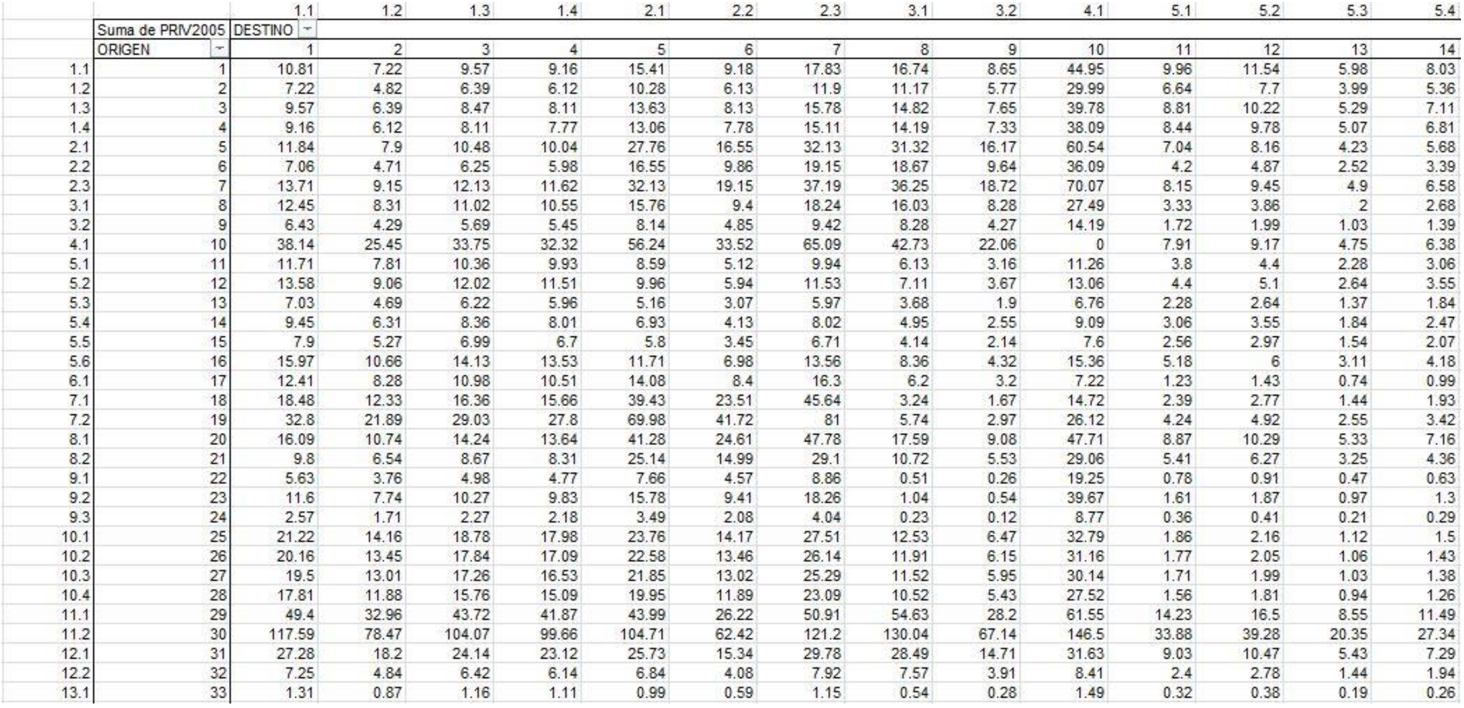
b. Predictors: (Constant), LC_MD

Table 22: Correlation summary: Topological (R3) / Class 4 (Peak hour)



		1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	4.1	5.1	5.2	5.3	5.4	5.5
	Suma de PRIV2005	destino														
	origen	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.1	1	60.98	40.69	53.97	51.68	86.69	51.68	100.34	87.17	45	250.81	59.19	68.62	35.55	47.76	39.94
1.2	2	40.69	27.15	36.01	34.48	57.85	34.48	66.96	58.17	30.03	167.36	39.5	45.79	23.72	31.87	26.65
1.3	3	53.97	36.01	47.76	45.74	76.72	45.74	88.8	77.15	39.83	221.97	52.38	60.73	31.46	42.27	35.35
1.4	4	51.68	34.48	45.74	43.8	73.47	43.8	85.04	73.87	38.14	212.55	50.16	58.16	30.13	40.48	33.85
2.1	5	65.69	43.84	58.14	55.67	153.66	91.6	177.85	160.39	82.81	332.33	41.19	47.75	24.74	33.23	27.79
2.2	6	39.16	26.13	34.66	33.19	91.6	54.6	106.02	95.61	49.36	198.11	24.55	28.46	14.75	19.81	16.57
2.3	7	76.04	50.74	67.29	64.44	177.85	106.02	205.86	185.65	95.85	384.66	47.67	55.27	28.63	38.47	32.17
3.1	8	79.23	52.87	70.12	67.15	100.11	59.68	115.88	94.18	48.62	173.13	22.33	25.88	13.41	18.02	15.07
3.2	9	40.91	27.3	36.2	34.67	51.69	30.81	59.83	48.62	25.1	89.38	11.53	13.36	6.92	9.3	7.78
4.1	10	225.3	150.34	199.39	190.94	331.5	197.62	383.7	233.05	120.32	0	49.27	57.12	29.59	39.76	33.25
5.1	11	60.74	40.53	53.76	51.48	44.45	26.5	51.45	29.35	15.15	57.8	20.75	24.06	12.46	16.75	14
5.2	12	70.42	46.99	62.32	59.68	51.54	30.72	59.65	34.03	17.57	67.01	24.06	27.89	14.45	19.41	16.24
5.3	13	36.48	24.34	32.29	30.92	26.7	15.91	30.9	17.63	9.1	34.71	12.46	14.45	7.49	10.06	8.41
5.4	14	49.01	32.71	43.38	41.54	35.87	21.38	41.52	23.68	12.23	46.64	16.75	19.41	10.06	13.51	11.3
5.5	15	40.99	27.35	36.27	34.74	30	17.88	34.72	19.81	10.23	39	14	16.24	8.41	11.3	9.45
5.6	16	82.83	55.27	73.31	70.2	60.62	36.14	70.16	40.03	20.66	78.82	28.3	32.81	17	22.84	19.1
6.1	17	75.23	50.2	66.58	63.76	85.22	50.8	98.64	34.71	17.92	43.31	7.88	9.14	4.73	6.36	5.32
7.1	18	108.46	72.37	95.99	91.92	230.91	137.65	267.27	17.54	9.05	85.46	14.79	17.15	8.88	11.94	9.98
7.2	19	192.48	128.43	170.34	163.12	409.78	244.28	474.3	31.12	16.07	151.66	26.25	30.44	15.77	21.18	17.72
8.1	20	77.67	51.83	68.74	65.82	198.86	118.54	230.17	78.4	40.47	227.93	45.17	52.37	27.13	36.45	30.48
8.2	21	47.31	31.57	41.87	40.09	121.13	72.21	140.2	47.75	24.65	138.84	27.51	31.9	16.52	22.2	18.57
9.1	22	30.25	20.19	26.77	25.64	41.05	24.47	47.51	2.51	1.3	102.33	4.43	5.14	2.66	3.58	2.99
9.2	23	62.33	41.59	55.16	52.82	84.58	50.42	97.9	5.17	2.67	210.85	9.14	10.59	5.49	7.37	6.16
9.3	24	13.79	9.2	12.2	11.68	18.71	11.15	21.65	1.14	0.59	46.64	2.02	2.34	1.21	1.63	1.36
10.1	25	118.35	78.97	104.74	100.3	132.29	78.86	153.12	64.53	33.32	181.01	10.96	12.7	6.58	8.84	7.39
10.2	26	112.47	75.05	99.54	95.32	125.72	74.94	145.51	61.33	31.66	172.02	10.41	12.07	6.25	8.4	7.03
10.3	27	108.8	72.6	96.29	92.2	121.61	72.49	140.76	59.32	30.63	166.4	10.07	11.68	6.05	8.13	6.8
10.4	28	99.33	66.28	87.91	84.18	111.03	66.19	128.51	54.16	27.96	151.92	9.19	10.66	5.52	7.42	6.2
11.1	29	312.09	208.25	276.21	264.49	277.32	165.32	320.99	318.62	164.5	384.78	94.8	109.91	56.94	76.5	63.97
11.2	30	742.89	495.72	657.47	629.58	660.12	393.51	764.06	758.43	391.56	915.92	225.67	261.63	135.53	182.09	152.28
12.1	31	147.91	98.7	130.9	125.35	139.23	83	161.16	142.63	73.64	169.72	51.64	59.87	31.02	41.67	34.85
12.2	32	39.31	26.23	34.79	33.31	37	22.06	42.83	37.9	19.57	45.11	13.72	15.91	8.24	11.07	9.26

Figure 41: OD Matrix - Average daily trip (PRIVADO DM)



		1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	4.1	5.1	5.2	5.3	5.4
	Suma de PRIV2005	DESTINO													
	ORIGEN	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.1	1	10.81	7.22	9.57	9.16	15.41	9.18	17.83	16.74	8.65	44.95	9.96	11.54	5.98	8.03
1.2	2	7.22	4.82	6.39	6.12	10.28	6.13	11.9	11.17	5.77	29.99	6.64	7.7	3.99	5.36
1.3	3	9.57	6.39	8.47	8.11	13.63	8.13	15.78	14.82	7.65	39.78	8.81	10.22	5.29	7.11
1.4	4	9.16	6.12	8.11	7.77	13.06	7.78	15.11	14.19	7.33	38.09	8.44	9.78	5.07	6.81
2.1	5	11.84	7.9	10.48	10.04	27.76	16.55	32.13	31.32	16.17	60.54	7.04	8.16	4.23	5.68
2.2	6	7.06	4.71	6.25	5.98	16.55	9.86	19.15	18.67	9.64	36.09	4.2	4.87	2.52	3.39
2.3	7	13.71	9.15	12.13	11.62	32.13	19.15	37.19	36.25	18.72	70.07	8.15	9.45	4.9	6.58
3.1	8	12.45	8.31	11.02	10.55	15.76	9.4	18.24	16.03	8.28	27.49	3.33	3.86	2	2.68
3.2	9	6.43	4.29	5.69	5.45	8.14	4.85	9.42	8.28	4.27	14.19	1.72	1.99	1.03	1.39
4.1	10	38.14	25.45	33.75	32.32	56.24	33.52	65.09	42.73	22.06	0	7.91	9.17	4.75	6.38
5.1	11	11.71	7.81	10.36	9.93	8.59	5.12	9.94	6.13	3.16	11.26	3.8	4.4	2.28	3.06
5.2	12	13.58	9.06	12.02	11.51	9.96	5.94	11.53	7.11	3.67	13.06	4.4	5.1	2.64	3.55
5.3	13	7.03	4.69	6.22	5.96	5.16	3.07	5.97	3.68	1.9	6.76	2.28	2.64	1.37	1.84
5.4	14	9.45	6.31	8.36	8.01	6.93	4.13	8.02	4.95	2.55	9.09	3.06	3.55	1.84	2.47
5.5	15	7.9	5.27	6.99	6.7	5.8	3.45	6.71	4.14	2.14	7.6	2.56	2.97	1.54	2.07
5.6	16	15.97	10.66	14.13	13.53	11.71	6.98	13.56	8.36	4.32	15.36	5.18	6	3.11	4.18
6.1	17	12.41	8.28	10.98	10.51	14.08	8.4	16.3	6.2	3.2	7.22	1.23	1.43	0.74	0.99
7.1	18	18.48	12.33	16.36	15.66	39.43	23.51	45.64	3.24	1.67	14.72	2.39	2.77	1.44	1.93
7.2	19	32.8	21.89	29.03	27.8	69.98	41.72	81	5.74	2.97	26.12	4.24	4.92	2.55	3.42
8.1	20	16.09	10.74	14.24	13.64	41.28	24.61	47.78	17.59	9.08	47.71	8.87	10.29	5.33	7.16
8.2	21	9.8	6.54	8.67	8.31	25.14	14.99	29.1	10.72	5.53	29.06	5.41	6.27	3.25	4.36
9.1	22	5.63	3.76	4.98	4.77	7.66	4.57	8.86	0.51	0.26	19.25	0.78	0.91	0.47	0.63
9.2	23	11.6	7.74	10.27	9.83	15.78	9.41	18.26	1.04	0.54	39.67	1.61	1.87	0.97	1.3
9.3	24	2.57	1.71	2.27	2.18	3.49	2.08	4.04	0.23	0.12	8.77	0.36	0.41	0.21	0.29
10.1	25	21.22	14.16	18.78	17.98	23.76	14.17	27.51	12.53	6.47	32.79	1.86	2.16	1.12	1.5
10.2	26	20.16	13.45	17.84	17.09	22.58	13.46	26.14	11.91	6.15	31.16	1.77	2.05	1.06	1.43
10.3	27	19.5	13.01	17.26	16.53	21.85	13.02	25.29	11.52	5.95	30.14	1.71	1.99	1.03	1.38
10.4	28	17.81	11.88	15.76	15.09	19.95	11.89	23.09	10.52	5.43	27.52	1.56	1.81	0.94	1.26
11.1	29	49.4	32.96	43.72	41.87	43.99	26.22	50.91	54.63	28.2	61.55	14.23	16.5	8.55	11.49
11.2	30	117.59	78.47	104.07	99.66	104.71	62.42	121.2	130.04	67.14	146.5	33.88	39.28	20.35	27.34
12.1	31	27.28	18.2	24.14	23.12	25.73	15.34	29.78	28.49	14.71	31.63	9.03	10.47	5.43	7.29
12.2	32	7.25	4.84	6.42	6.14	6.84	4.08	7.92	7.57	3.91	8.41	2.4	2.78	1.44	1.94
13.1	33	1.31	0.87	1.16	1.11	0.99	0.59	1.15	0.54	0.28	1.49	0.32	0.38	0.19	0.26

Figure 42: OD Matrix - Peak hour trip (PRIVADO HP)