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Research Master Planning and Sustainability: Urban and Regional Planning

Mobility Analysis using Gravity Model

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Chapter 1: Introduction

The term mobility refers to the movement of goods or people from one place to another. Workers move daily from their home to work place. In this research, both spatial and statistical data are used to analyse mobility of workers. Gravity model is one such model which allows using both these spatial and statistical data to calculate mobility. Gravity models have been found to fit well and have been extensively used to explain international flows of trade, migration and foreign direct investment.

People always prefer to live near to the work place. This is the reason why the areas nearby the work place gets converted into residential areas. As a result of this, the demand for facilities such as schools, hospitals, parks, play grounds, commercial shops, proper roads, water supply, transport, etc. increases. All this facilities are supposed to be fulfilled by the local government and hence this un-intentional growth leads to urban sprawl of the region.

In this research our main aim to analyse the workers mobility with gravity model and to find the suitable scale to analyse the workers mobility using gravity model. For this we selected four scales that is four type of administrative boundary that are using in local governments for the purpose of planning and development to the future.

"What is the suitable scale to obtain workers flow?" that is in case of we predicting the future flow for a site we should know the right scale to apply model and to get correct flow. In case the new developments are such as housing, industries, colleges, commercial shops, etc. then the future flow of that certain area will be different to find that we should know the right scale and good correlation.

Chapter 2: Literature Review:

2.1 Accessibility:

The concept of accessibility has been developed, and cast into measurable indicators, in parallel with the concept of mobility. Bhat et al. (2000) credit Hansen (1959) with the first significant scholarly work on the subject. While mobility is concerned with the performance of transport systems in their own right, accessibility adds the interplay of transport systems and land use patterns as a further layer of analysis. Accessibility measures are thus capable of assessing feedback effects between transport infrastructure and modal participation on the one hand, and urban form and the spatial distribution of activities on the other hand. Some accessibility measures also include behavioural determinants for activity patterns in space and time, and the responses of transport users to physical conditions.

Litman (2003) points out that traffic and mobility planning have traditionally been concerned primarily with the movement of motor vehicles (traffic) or people and goods in general (mobility), while accessibility explicitly takes on board the land use–transport connection and handles trip numbers and travel time as indicators. There are a number of inherent conflicts or trade-offs between mobility or traffic and accessibility: for example, roads designed for maximum mobility or traffic throughput usually have poor accessibility for adjacent land uses, while precincts where (multimodal) accessibility has been maximised may experience road traffic congestion and parking constraints.

Geurs and van Eck (2001) define accessibility as 'the extent to which the land use–transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport mode(s).' (p. 36)

In contrast, Bhat et al. (2000) use the following definition:

'Accessibility is a measure of the ease of an individual to pursue an activity of a desired type, at a desired location, by a desired mode, and at a desired time.' (p. 1)

It is notable that Geurs and van Eck (2001) make specific reference to land use and transport, thus implying that accessibility is intricately linked to, and primarily determined or 'enabled' by transport infra- structure and urbanisation patterns, whereas this spatial dimension is not at all emphasised, though still implicit, in Bhat's et al. (2000) definition. Geurs and van Wee (2004) make a further differentiation in clarifying the terminology:

'Access is used when talking about a person's perspective, accessibility when using a location's perspective.' (p128) Bertolini, LeClercq and Kapoen (2005) define accessibility as 'the amount and diversity of places that can be reached within a given travel time and/or cost' (p. 209), and sustainable accessibility as accessibility 'with as little as possible use of non-renewable, or difficult to renew, resources, including land and infrastructure.' (p. 212)

In Geurs' and van Eck's (2001) understanding, accessibility consists of four components. The transport component is concerned with measures such as travel time, cost and effort of movement in space. The land use component measures the spatial distribution of activities or opportunities, and contains an assessment of the competitive nature of demand for activities at destina- tions, and of supply of potential users. The temporal component examines the time constraints users experience for their activity patterns, and the availability of activities or opportunities according to the time of the day, week or year. The individual component investigates the needs, abilities and opportunities of transport users and thus takes in socio-economic and demo- graphic factors.

Both Bhat et al. (2000) and Geurs and van Eck (2001) identify several common types of accessibility measures, and discuss the suitable range and limitations of their application. Geurs and van Eck (2001) distinguish between infrastructure-based, activity- based and utility-based accessibility indicators and maintain that while the infrastructure-based type is easiest to measure and interpret, it is also the most limited when it comes to capturing the interplay of land use and transport infrastructure. Conversely, the activity-based indicator type includes the land use component from the outset, but tends to be more complex and sometimes suffers from poorer legibility. The utility-based indicator type crosses over into economic and social disciplines as well as land use and transport, and is characterised by Geurs and van Eck (2001) as an emerging model still requiring substantial research and development.

Hence, accessibility is a multifaceted concept, not readily packaged into a one-size-fits-all indicator or index. In Litman's (2003) words, 'there is no single way to measure transportation performance that is both convenient and comprehensive.' (p.32). However, Geurs and van Wee (2004) produced a checklist of recommendations of how any accessibility measure should behave, regardless of its perspective (or combinations thereof):

1. Accessibility should relate to changes in travel opportunities, their quality and impediment: 'If the service level (travel time, cost, effort) of any transport mode in an area increases (decreases), accessibility should increase (decrease) to any activity in that area, or from any point within that area.' (p. 130).

2. Accessibility should relate to changes in land use: 'If the number of opportunities for an activity increases (decreases) anywhere, accessibility to that activity should increase (decrease) from any place.' (p. 130).

3. Accessibility should relate to changes in constraints on demand for activities: 'If the demand for opportunities for an activity with certain capacity restrictions increases (decreases), accessibility to that activity should decrease (increase).' (p. 130).

4. Accessibility should relate to personal capabilities and constraints: 'An increase of the number of opportunities for an activity at any location should not alter the accessibility to that activity for an individual (or groups of individuals) not able to participate in that activity given the time budget.' (p. 130).

5. Accessibility should relate to personal access to travel and land use opportunities: 'Improvements in one transport mode or an increase of the number of opportunities for an activity should not alter the accessibility to any individual (or groups of

individuals) with insufficient abilities or capacities (e.g. driver's license, education level) to use that mode or participate in that activity.' (p. 130).

Bertolini et al. (2005) discuss the balancing act that is the development of suitable indicators for accessibility: 'In order to be useful for practical planning purposes, an accessibility measure must meet two basic requirements: it must be consistent with the uses and perceptions of the residents, workers and visitors of an area, and it must be understandable to those taking part in the plan-making process.' (p. 210).

'A major methodological challenge [.. .] is finding the right balance between a measure that is theoretically and empirically sound and one that is sufficiently plain to be usefully employed in interactive, creative plan-making processes where participants typically have different degrees and types of expertise.' (p. 218). It is the participants, however, who make or break successful accessibility assessment and its capacity to inform decision-making, as integral communicators within the process. A transparent and legible approach is thus critical in the view of Bertolini et al. (2005), 'not just because of a generic democratic concern, but also because of the importance of mobilising the (tacit) knowledge of different participants in the identification of problems and the search for solutions.' (p. 218).

Gravity measures

The gravity model in the categorisation of Bhat et al. (2000), somewhat related to potential accessibility measures discussed by Geurs' and van Eck (2001), sets out to overcome the shortfall of rigid and/ or arbitrary contour brackets by treating opportunities differently along a continuum of time and distance. In most cases, this is done by identifying the actual travel time for each opportunity enabling different opportunities to be listed by actual travel time and compared) and using a relatively generic distance decay function as a proxy for the disutility experienced by transport users with increasing travel time, cost or effort (Geurs & van Wee, 2004). The model, however, still treats every transport user within the study area equally and disregards variations in individual preferences in relation to the desirability of activities (Baradaran & Ramjerdi, 2001).

2.2 Functional Polycentrism and Urban Network: The Dynamics of Urban Systems

In urban systems theory, introduced by BERRY (1964) and PRED (1977), urban systems are generally referred to as functionally interdependent sets of cities. However, the structure of these urban systems can range from those that are fully monocentric to those that are fully polycentric. The general idea of the monocentric city is that most economic activities are based in the urban core, whereas suburbs only fulfil a residential function. Hence, the relationship between the urban core and its suburbs in the monocentric model is hierarchical– nodal or centralized in the sense that most commuting flows are directed from the suburban areas towards the central cities. For a variety of reasons (that is, cheaper land, a low level of amenities in the city centre, and decreasing transportation costs), firms and households may increasingly choose to locate themselves in secondary employment centres, despite the potential advantages of being located in the central city. As a result, suburban areas are themselves emerging into local centres that develop their own economic activities and gradually become incorporated into an expanded but coherent metropolitan area (ANAS et al., 1998). The result is the development of cities with multiple centres, or polycentric cities, at the intra-urban scale (Fig. 1, A2) (KLOOSTERMAN and MUSTERD, 2001). In such a poly- centric city, commuting is no longer centralized, but reciprocal in the sense that commuting is now directed not only from the suburbs to the urban core, but also from the urban core to the suburbs.

The suburbs become increasingly self- contained in the sense that many suburban residents are employed in the suburban area in which they live. These sub-centres may grow in importance over time as people start relocating to these sub-centres in order to follow their employer, for the benefit of cheaper land, or a better quality of life (VAN DER LAAN, 1998). As such, territorial competition emerges between the original core and the new sub-centres, changing the characteristic of the city to that of a network-city (Fig. 1, A3). In this situation, the central city has lost its primacy: flows of goods, services, and people become decentralized as the number of workers commuting between suburbs, and bypassing the old urban core, increases. Hence, in this state the functioing of the metropolitan area is dependent not only on the central business district, but also on the functioning of its surrounding suburbs. there is a third type of polycentric city region, which consists of multiple, self-contained centres (Fig. 1, A4); in this case, many suburban residents are employed in the suburbs and many urban residents are employed in the urban core (SCHWANEN et al., 2004). In this fashion, transportation costs are minimized. Due to advances in transportation and communication technologies, it is argued that significant functional linkages are formed at increasingly higher levels of scale than those of the 'traditional' city (VAN OORT et al., 2010). As a result, the catchment areas of different cities start to overlap. Metropolitan areas lose significance as an independently functioning 'daily urban system' and could, instead, be perceived as forming part of an urban network.

The polycentric urban region can be represented as an urban network of historically and spatially separate metropolitan areas comprising a region (Fig. 1, B and C) (BOURNE and SIMMONS, 1978; PARR, 2004). These metropolitan areas can be network-cities themselves, but this is not necessarily the case (that is, the urban system can be dominated by a polycentric structure at the inter-urban level and a monocentric structure at the intra-urban level, or vice versa). Likewise, urban network formation at the inter-urban scale is not necessarily the next evolutionary step after the network-city (PARR, 2004). The degree of urban network formation differs between various polycentric urban regions. . First, the distinction between nodal urban networks and fully integrated urban networks is important. Nodal urban networks (Fig. 1, B) (for example, BATTEN, 1995) are characterized by urban network formation between the old urban cores of different metropolitan areas. In contrast fully integrated urban networks also have functional linkages between: (1) the suburbs and urban cores of different metropolitan areas; and (2) suburbs of different metropolitan areas (Fig. 1, C). Second, at the inter-urban level the urban spatial structure can be characterized either as centralized, exchange, or decentralized, depending on the existence or non-existence of a regional hierarchy of the different metropolitan relations.

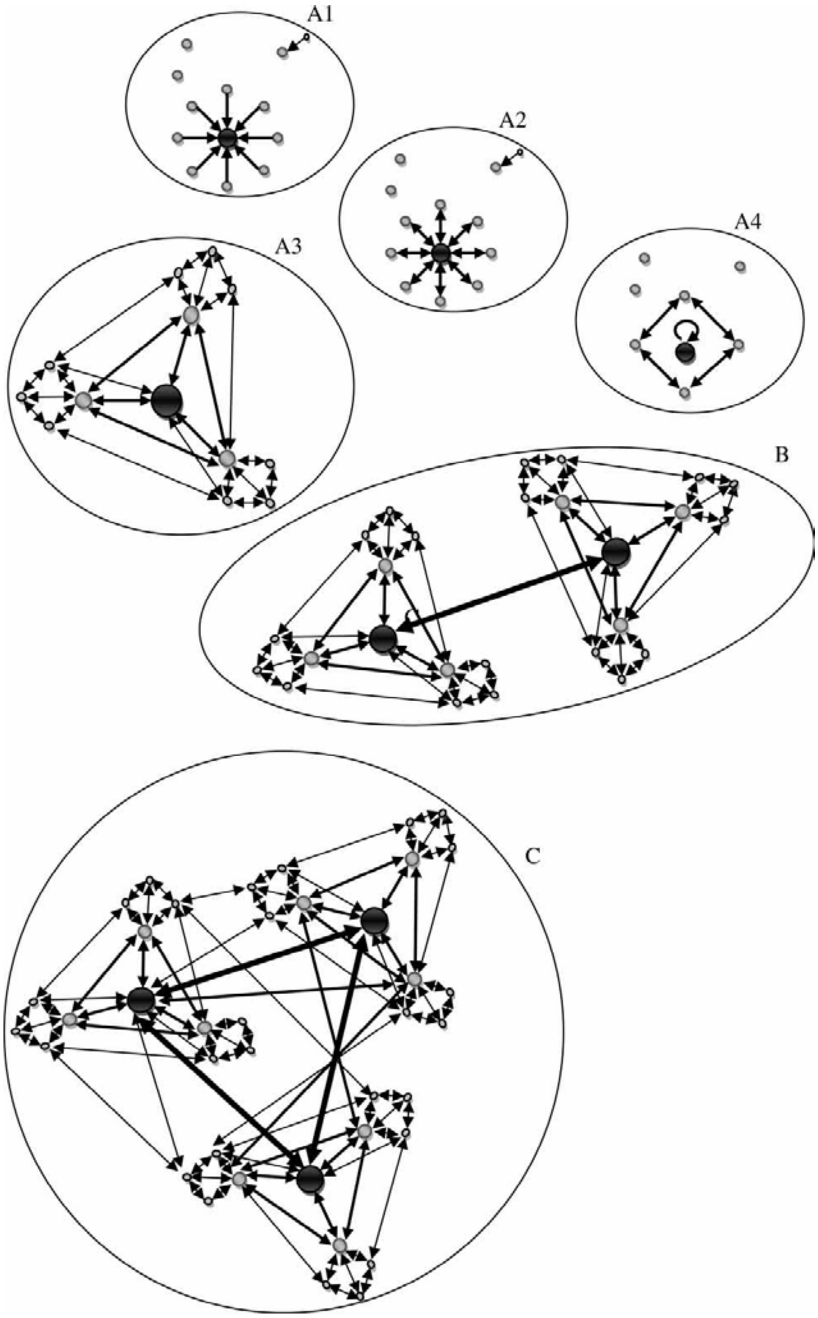


Figure 1: Urban network development on the intra-urban and inter-urban scales

Source: Adapted from VAN DER KNAAP (2002) and SCHWANEN et al. (2004)

2.3 The driving forces behind changing urban systems

Increased flexibility and mobility of firms: The effect of increasing flexibility and mobility of firms on the urban system is known as the restructuring hypothesis. The central theme of the restructuring hypothesis is that trends in urban system dynamics are driven by changes in the spatial distribution of employment opportunities (RENKOW and HOOVER, 2000). These changes in the spatial distribution of employment opportunities are both caused and made possible by key advancements in information and communication technology and are enhanced by the economic change of most Western economies from being dominated by manufacturing to being dominated by services (AOYAMA and CASTELLS, 2002). Moreover, many service firms are also physically constrained by the necessity of face-to-face contact, usually locationally bounded to the 'old' central business district (COUCLELIS, 2000). As such, the old urban cores maintain strong contacts with the suburban areas, creating an ever more complex integrated urban network (GEYER, 2002).

Increased flexibility and mobility of households: The effect of increasing flexibility and mobility of people on the urban system is also known as the deconcentration hypothesis. The deconcentration hypothesis holds that urban system dynamics are the result of widespread changes in residential preferences (RENKOW and HOOVER, 2000). Where the increasing flexibility of firms has changed the nature of the demand for labour, the same advances in transport and communication technologies changed the nature of the supply of labour (CLARK and KUIJPERS-LINDE, 1994; VAN DER LAAN 1998). To some extent, these residential preferences are influenced by enhanced mobility and the increasingly flexible workplace (HALL, 2001). The common factor in these demographic developments is that they have changed the residential preferences of large groups of people, changing residential patterns, and causing dislocation to the traditional monocentric urban system (VAN HAM, 2002).

Local and regional policy: Local and regional policies can have the explicit intention of economic deconcentration and urban network formation, but are most commonly an unintended by-product. A well-known example of an intentional policy towards economic deconcentration was the 'growth pole concept' introduced by PERROUX (1955). The aim of this policy was to create economic development in peripheral areas by moving (semi-)governmental departments to, or by encouraging the establishment of industrial growth centres in, the periphery. Ultimately, this should have led to the development of the hinterlands of these growth centres, in turn spreading the benefits of economic development over a larger area.

Paradoxically, it is suggested that those policies with urban network formation as an unintended by-product are the most particular, restrictions on urban development have had a profound impact on the development of the urban structure (CULLINGWORTH and NADIN, 1997). Governments of many countries have introduced strict land-planning policies, mainly aimed against urban sprawl. The Town and Country Planning Act 1947 in the UK is perhaps one of the best examples of such land-planning policies (BEST, 1981).

The Greater South East as policy initiative:

Researchers and policy-makers increasingly identify the Greater South East in the UK as an integrated urban network. The agglomeration (Fig. 1), which comprises the three Governmental Office regions of London, the South East, and the East of England, 5 has approximately 21 million inhabitants and generates an annual gross domestic product of US$900 billion. The concept of the Greater South East has been used by the relevant English Regional Development Agencies (RDAs) to encourage cooperation in several areas (for example, the 2012 Summer Olympic Games) (SOUTH EAST ENGLAND DEVELOPMENT AGENCY (SEEDA), 2005). The development of the Greater South East reflects London's need for more space; the Green Belt policy ensured that the population and employment growth leapfrogged over the belt, and a well-developed transport network and technological advances facilitated commuting and the mobility of firms (GORDON, 2004; HALL and GREEN, 2005).

2.4 A gravity model of commuting:

In this section, a formal model is used to test the structure in spatial interaction patterns of commuting relations in the Greater South East. The objective is to investigate whether the Greater South East consists of network- cities at the intra-urban scale and whether the adjoining districts form a fully integrated, larger-scale urban network.

A gravity model (HAYNES and FOTHERINGHAM, 1984) is employed to test for these conditions. In this model, Sir Isaac Newton's law of universal gravitation7 is used to explain the interaction between spatial units, in the present case commuting flows between districts. The contemporary use of gravity models in geography and regional science originates from the work of STEWART (1948) and ULLMAN (1954).8 Such models hold that the gravitational force between two spatial units is directly proportional to the product of the mass of the spatial units and inversely proportional to the physical distance between them. More formally, the gravity model can be expressed by:

$$I_{ij} = K\ \frac{Mi^{\beta_1} * Mi^{\beta_2}}{Dij^{\beta_3}}$$

where I_{ij} is the interaction intensity, or the number of commuters between areas i and j; K is a proportionality constant; M_i is the mass of the district of origin; Mj is the mass of the district of destination; d_{ij} is the physical dis- tance between the two areas; $\beta 1$ is the potential to gen- erate commuting flows; $\beta 2$ is the potential to attract commuting flows; and $\beta 3$ is an impedance factor reflecting the rate of increase of the friction of physical distance. In the present estimations, the physical dis- tance between districts is measured as the actual road distance between districts i and j. The road distance is based on the road network in the Greater South East in 2005 and is obtained by linking an origin– destination cost matrix to the road network, where the cost was set to distance.9 However, the overall average road distance between neighbouring districts is likely to be overestimated, as it measures the distance between the two centres of gravity. A dummy reflecting contiguity is included in order to correct for this measurement error in calculating the relevant road distances.

Empirical results:

At the inter-urban scale, there is less indication of development towards urban network formation. The results generally support a monocentric interpretation of the Greater South East at the inter-urban scale, which is relatively stable over time. However, the absence of a hierarchy in the interdependencies on the regional inter-urban scale suggests that a development towards polycentricism is also possible at the inter-urban scale; however, this would require pointed investments in infrastructure and locational employment and planning.

First, commuting data are only one way to investigate the structure of urban systems. Several authors have pointed out that movements of people are not a perfect indicator for economic interactions and should be combined with other data on economic interactions to gain a realistic insight into the structure of urban systems (GLANZMANN et al., 2004). Although different groups of people exhibit various degrees of willingness to travel to work, most people prefer to live relatively close to their main place of work (TURNER and NIEMEIER, 1997; ROUWENDAL 1999).

Second, most currently available commuting data are based on survey questions on daily commuting behaviour. Thus, the choice of studying commuting trips allows a focus on the 'daily urban space' of people. When considering urban network development, however, it might be more useful to assume that interactions over larger distances do not take place every day and to consider the 'weekly urban space' or 'monthly urban space' of people. GREEN et al. (1999) describe how weekly commutes over large distances are increasingly supplanting migration. These 'super commutes' are missing from, or disturbing, the currently available data, as people who commute weekly often have two places of residence.

Third, and related to the previous point, it is also important that future research on functional polycentrism and urban network development concentrates on the less frequent types of trips, such as leisure and business trips (see also LAMBOOY, 1998; and HALL and PAIN, 2006) in addition to other types of functional relationships between cities, such as inter-urban trade (for example, VAN OORT et al., 2010)

The results indicate a development towards urban networks at the intra-urban scale and relatively little development at the inter-urban scale. Thus, transport planning should, therefore, pay particular attention to the intra-urban scale. This might mean that there should be more investment on improving secondary roads and other forms of transport (including public transport and cycle routes) within the existing urban fabric rather than improving high-speed roads linking urban regions.

The Parameters of The Gravity Model are Changing- How and Why?

A gravity model seems to constitute a useful way of describing and analysing these phenomena, and many branches of science are interested in such topics, not least the area-based branches, such as regional science or studies, human and economic geography.

2.5 The parameters of gravity models are not constant, they vary over time?

The dominant trends changing the parameters of gravity model can be

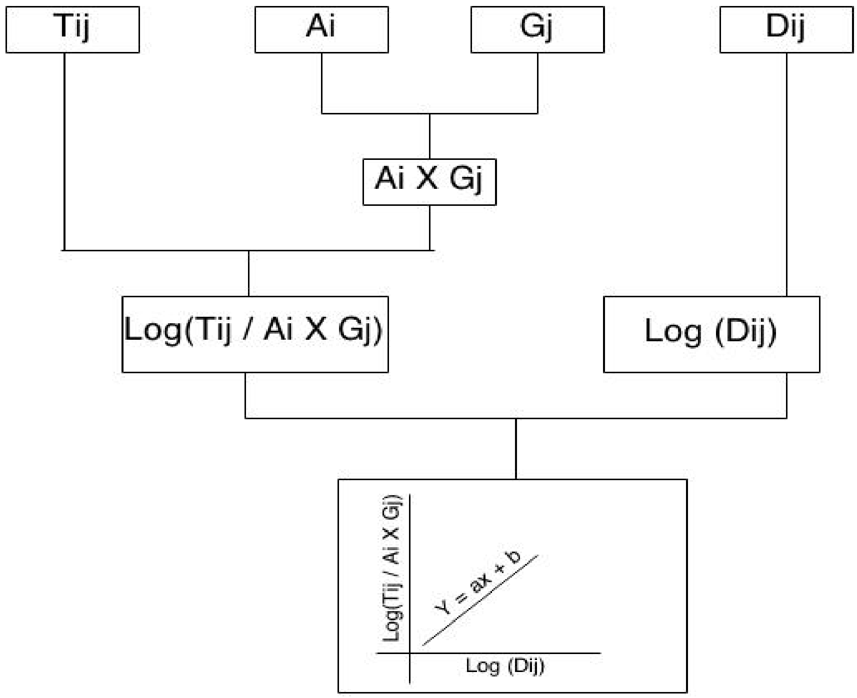
- Growing mobility, due to improvements in the transport network and vehicles, in particular increased private car ownership
- The growth of income and purchasing power
- The increased proportion of married women who go out to work
- The fact those freezers have become more common, reducing the need for shopping trips
- Saturday becoming a common non-working day at the beginning of the 1970s;
- Changes in the geographical distribution of customers
- The establishment of new superstores and hypermarkets in or outside the city centres

- The demise of corner shops and village stores
- Other internal developments within service activities and thus changes in the gravitational force of the centres

The behaviour of the scale and distance parameters of the gravity model during a period of observations stretching over a few decades is in the main non-monotonic. The principal explanation for such a change proves to be the establishment of big retail store units with their various repercussions and, at a more general level, the multidimensional dynamics of the system of centres.

Chapter 3: Calibration Analysis

Gravity model, before you can apply it the characteristic elements of the territory, it is necessary to harvest or build some data base. The variables related to the Gravity model are listed in the flowchart below:



Here, Tij is the Mobility flow between towns A and B.

Ai is Attraction i.e Attractiveness or Jobs in town A.

Gj is Generation i.e Active people in town B.

Dij is the Distance between two towns AB.

3.1 Calculation of Statistical data:

As we have seen, to use the gravity model, we must dispose of mobility or commuting flows in the Indre-et-Loire, the number of active people (Representing the generation in the model gravity) and finally the number of jobs (Representing attractiveness in the model gravity).

In the very first step mobility flow has to be filtered. The data was filtered through only using Excel filters. The data from INSEE "base-flux-mobilite-domicile-lieu-travail-2011" will have vast data consists of overall region centre. For particular scale will have town codes, using this town codes can be filtered through Excel for the required towns. In the annexure 5 shown that the mobility flow data for the scale agglomeration of Tours after filtered in Excel. In the same way CLAP and Active people data can be filtered. Definitions of INSEE data explained in annexure 2. Finally the required Y value calculated using excels formula.

3.2 Spatial data modelling:

The different steps of modelling are:

1) Processing the frame of the layer: correcting the height of each building, number of associated stages, calculation of the unit area, calculating the area developable and deducting the "density the frame ".

2) Processing the network layer: Creation of a buffer zone (Also called "buffer") around each road segment, assignment buildings with buffer zones, assignment buffer zones to roads and commissioning instead of a calculation algorithm of the speed road section.

3) Topology of the road network and creating a new network dataset: creation and analysis of attributes "Meters", "Minutes" and " Oneway" in the attribute table of the road network then create the "New Network Data" Through the Network tool Analyst in ArcGIS ©.

4) OD Cost matrix: OD cost matrix created using the tool OD Matrix in Network Analyst Tool. The steps involved all the process is explained in annexure 1.

3.3 Applying Gravity Model to Different Scales:

The challenge of this study lies in the selection of an appropriate scale that the impact of the implementation of a new zone or residential or even a job new road infrastructure sprawl urban and commuter mobility may be studied in the Department Indre-et-Loire. So we applied the model gravity on four sizes of study of scales different namely the Tours (As single town), Agglomeration of Tours (22 municipalities), Unité urbaine (36 municipalities) and Zone d'emploi for Tours (153 municipalities).

Before illustrating the four scales of study submitted to the gravity model, back on some definitions proposed by the INSEE © for situate our remarks:

Employment Zone or Zone d'emploi (153 municipalities with Tours):

An employment zone is a geographical area within which most of the labour force lives and works, and in which establishments can find the main part of the labour force necessary to occupy the offered jobs.

The division into employment zones provides a breakdown of the territory adapted to local studies on employment. The zoning also defines relevant territories for local diagnoses and can guide the demarcation of territories for the implementation of territorial policies introduced by public authorities or local actors. This zoning is defined at once for metropolitan France and french overseas department.

The updated cutting is based on the flows of movement from residence to work of active persons observed during the 2006 census. The list of the municipalities is the one datum by the Geographical Official Code (COG). (Source: www.INSEE.fr)

Urban area or Aire urbaine (132 municipalities with Tours):

An urban area or a "big urban area" is a group of touching municipalities, without pockets of clear land, encompassing an urban centre (urban unit) providing at least 10 000 jobs, and by rural districts or an urban units (urban periphery) among which at least 40 % of employed resident population works in the centre or in the municipalities attracted by this centre.

The 2010 zoning of urban areas also distinguishes:

- The "average areas", a group of municipalities, without pockets of clear land, constituted by a centre from 5 000 to 10 000 jobs, and by rural districts or urban units among which at least 40 % of the employed resident population works in the centre or in the municipalities which are attracted by this centre.

- The "small areas", a group of municipalities, without pockets of clear land, constituted by a centre from 1 500 to 5 000 jobs, and by rural districts or urban units among which at least 40 % of the employed resident population works in the centre or in the municipalities attracted by this centre. (Source: www.INSEE.fr)

Urban unit or Unité urbaine (36 municipalities with Tours):

The notion of urban unit is based on the continuity of built up land mass and the number of inhabitants. We call urban unity a municipality or a group of municipalities which includes a continuously built up zone (no cut of more than 200 meters between two constructions) and at least 2,000 inhabitants.

If the urban unit is situated on a single municipality, it is called an isolated town. If the urban unit extends over several municipalities, and if each of these municipalities concentrates more than half of its population in the continuously built up zone, it is called a multi-municipal agglomeration.

The municipalities are considered as rural when they go into constitutionare not included in an urban unit: the municipalities of 2000 inhabitants with no continuously built up zone, and the municipalities in which less than half of the municipal population is settled in a zone of built continuously built up zone. (Source: www.INSEE.fr)

Conurbation community or Agglomeration (22 municipalities with Tours):

A conurbation community is an EPCI grouping together several municipalities forming, on its creation date, a set of over 50,000 inhabitants, all adjoining and without enclaves, around one or more centre municipalities with over 15,000 inhabitants. These municipalities are joined together with a view to developing and managing a joint urban development project for their territory.

Conurbation communities were created by the Law of 12 July 1999 on the reinforcement and simplification of intermunicipal cooperation. (Source: www.INSEE.fr)

Town or Municipality or Ville:

Towns and urban agglomerations, also called urban units whereby delimitation is based solely on continuity of habitat, may comprise:

- Two or more municipalities, that is, a town-centre and its suburbs (exceptionally, several town-centres), on the territory of which an agglomerated zone contains more than 2,000 inhabitants; this sort of urban unit is called a multi-municipal agglomeration;
- Just one municipality, the agglomerated population of which is at least 2,000; this sort of urban unit is called an isolated town or, more commonly, a town.

A first delimitation of towns and urban agglomerations was performed in the 1954 census. New urban units were constituted in the censuses of 1962, 1968, 1975, 1982, 1990, 1999 and 2010. (Source: www.INSEE.fr)

Agglomeration of Tours (22 Towns)

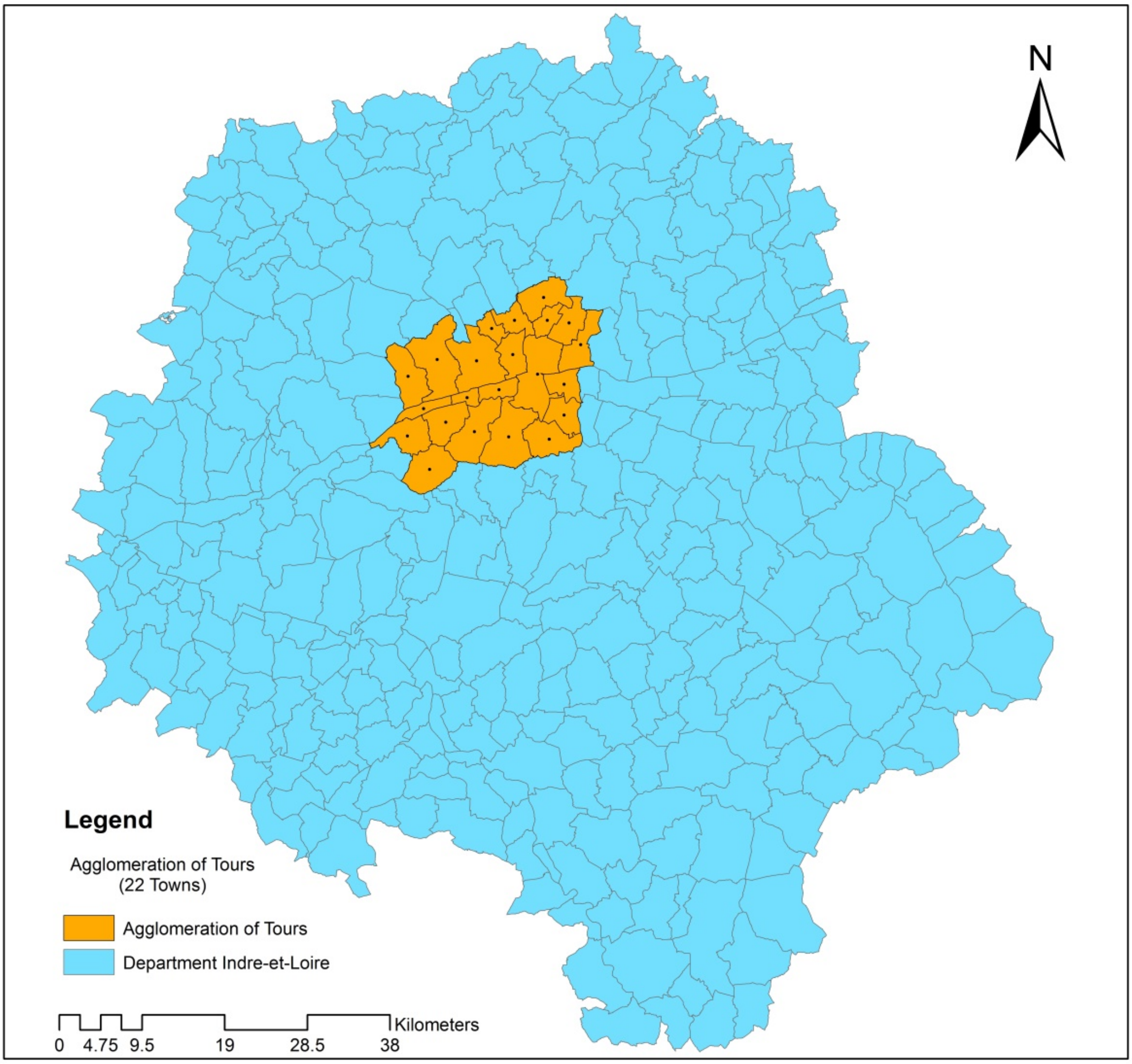


Figure 2: Location of Scale 2- Agglomeration of Tours with 22 towns
Source: BD TOPO (IGN, 2014)

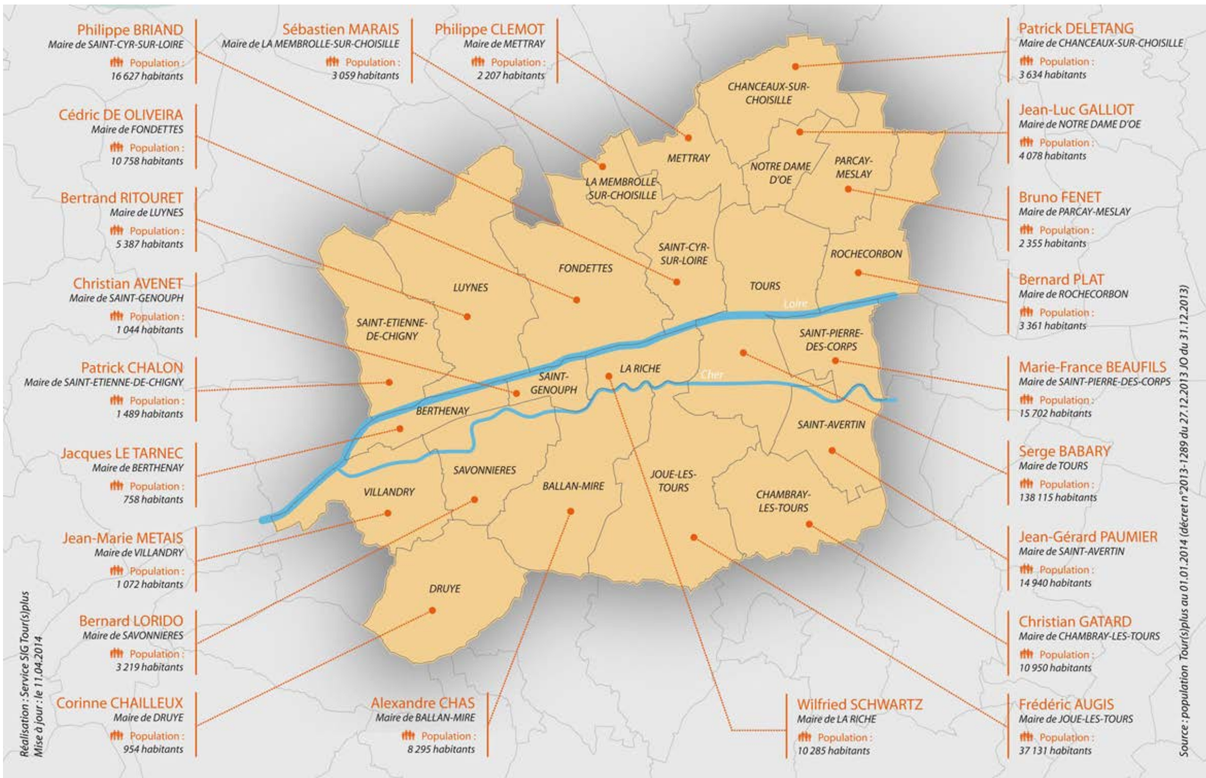


Figure 3: Scale 2- Agglomeration of Tours with 22 towns
Source: Tour(s)plus

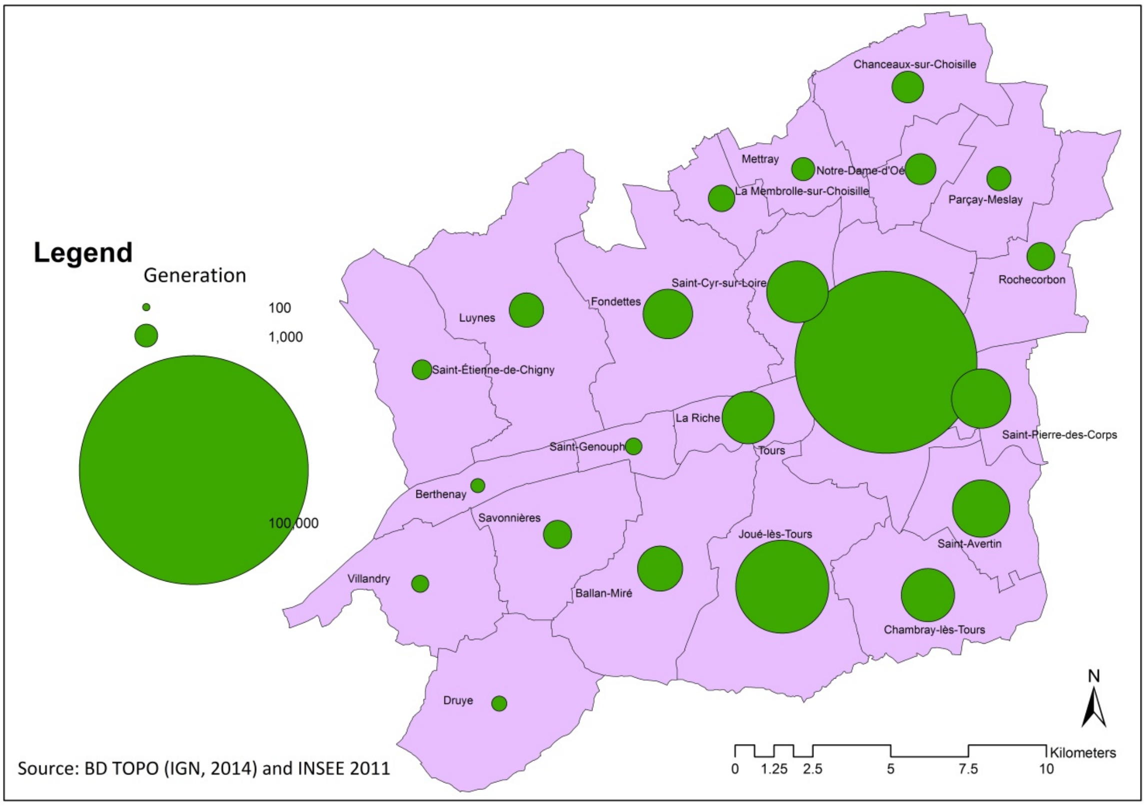


Figure 4: Generation of Agglomeration of Tours with 22 towns

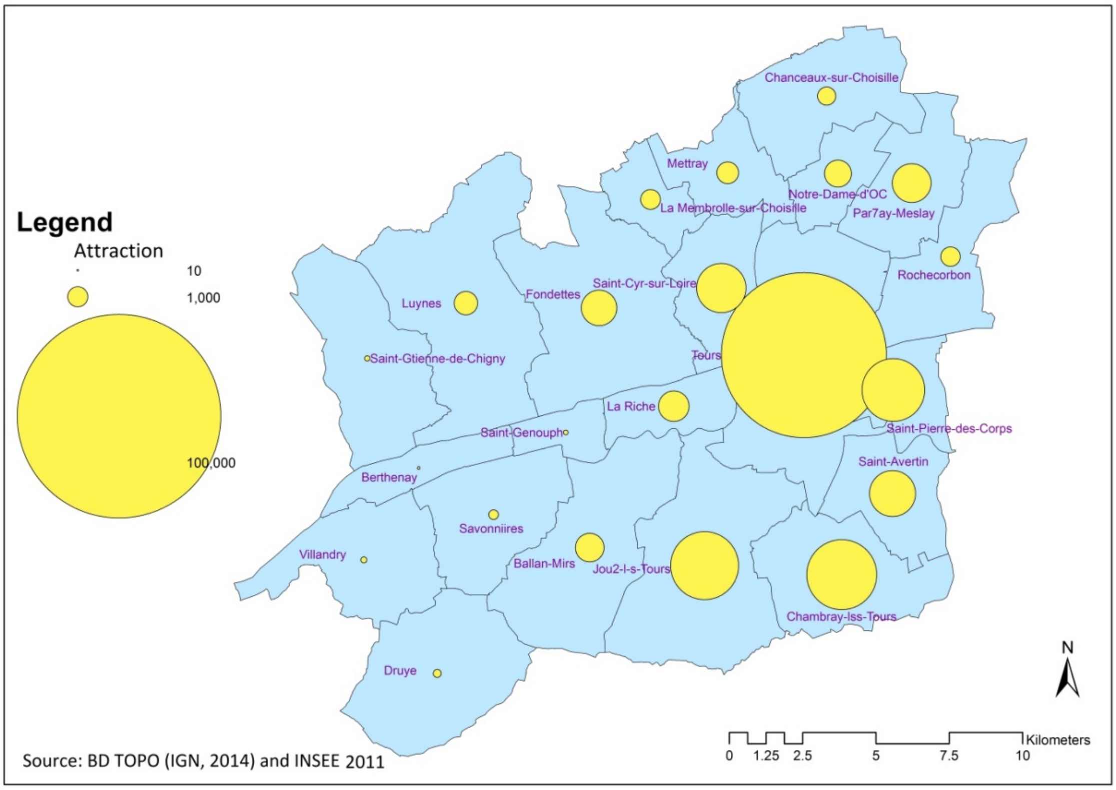


Figure 5: Attraction of Agglomeration of Tours with 22 towns

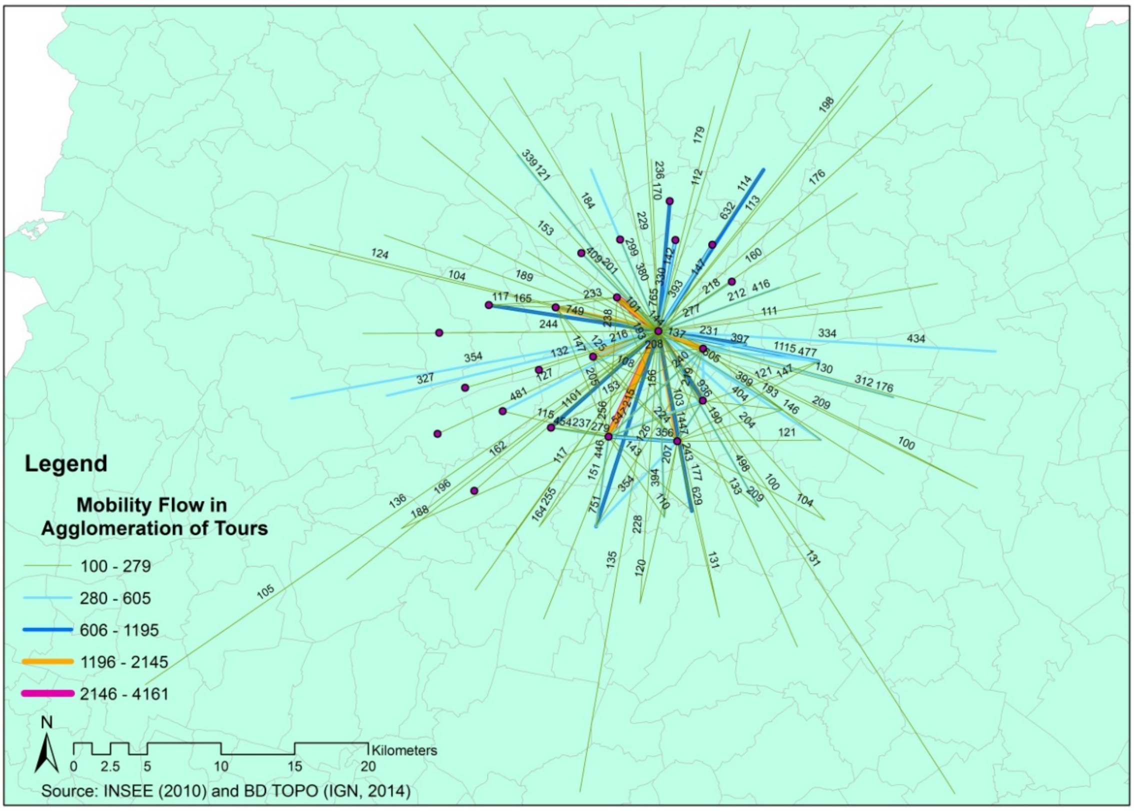


Figure 6: Mobility flow of Agglomeration of Tours with 22 towns

Scale 3: Unit Urban (33 towns)

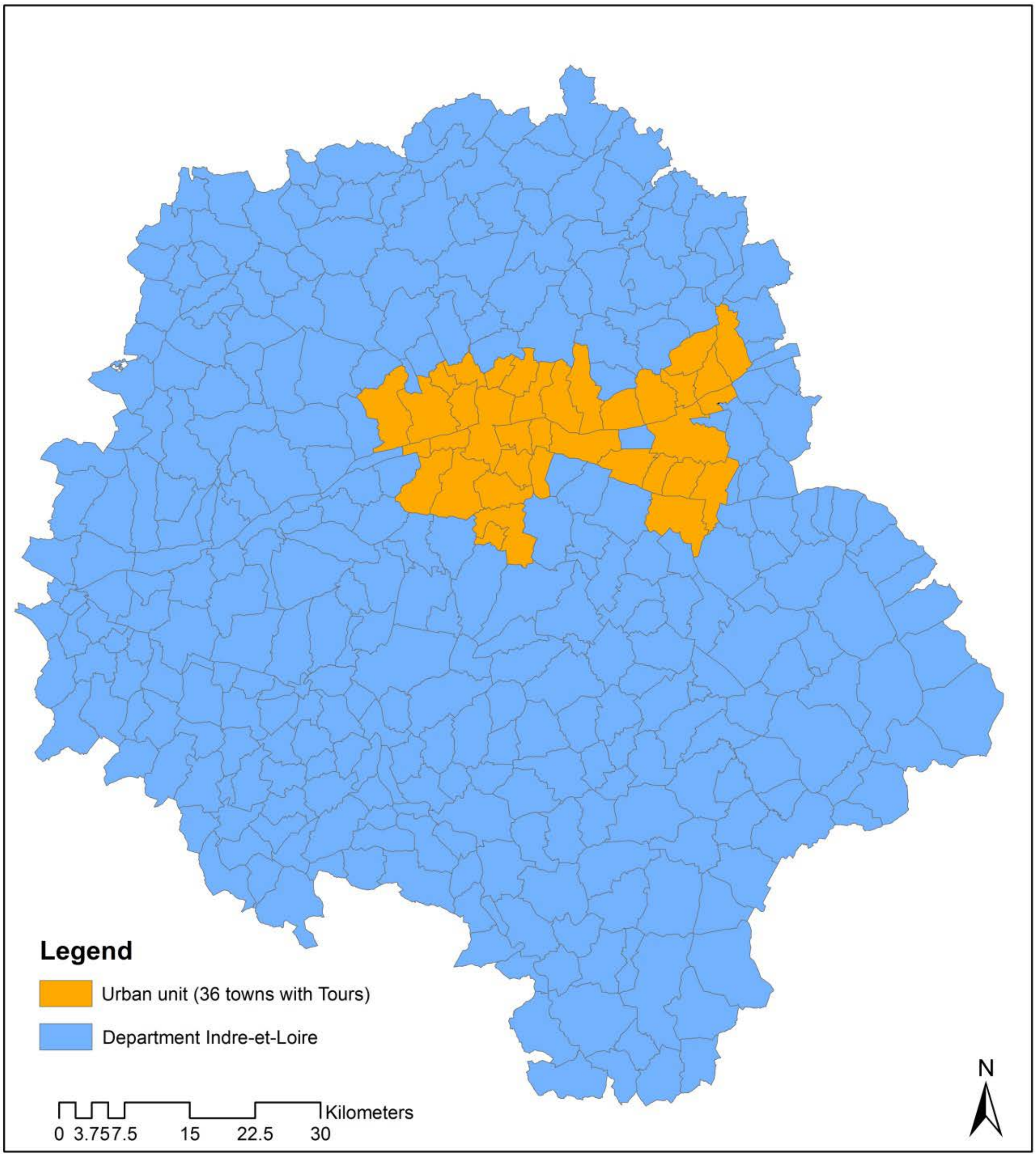


Figure 7: Location of Scale 3- Unit Urban of Tours with 36 towns
Source: BD TOPO (IGN, 2014)

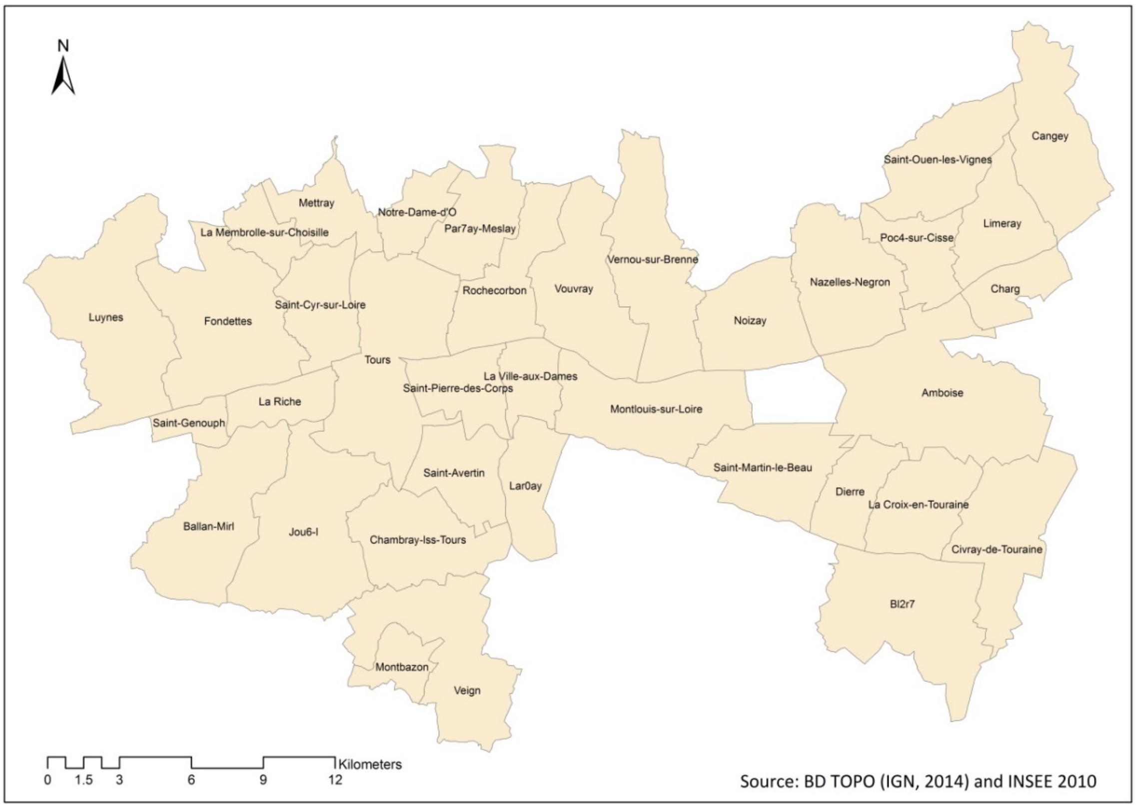


Figure 8: Scale 3- Unit Urban of Tours with 36 towns

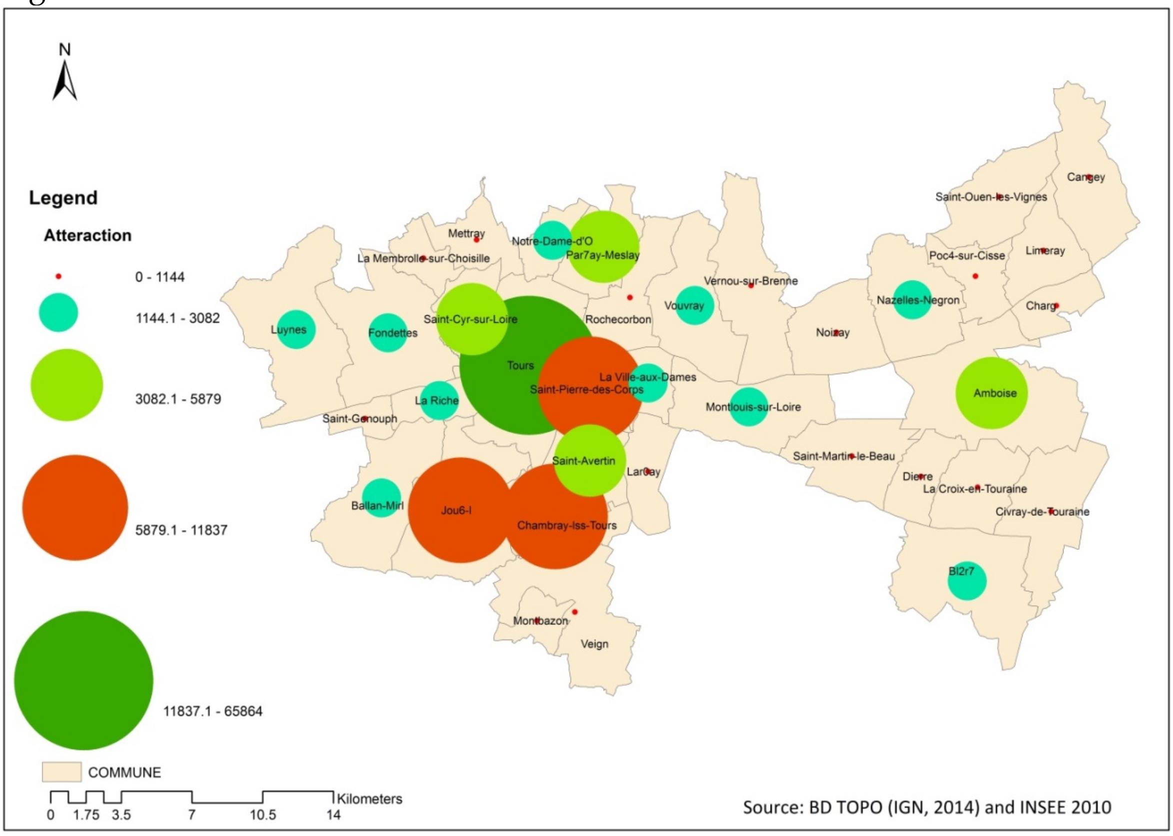


Figure 9: Attraction of Scale 3- Unit Urban of Tours with 36 towns

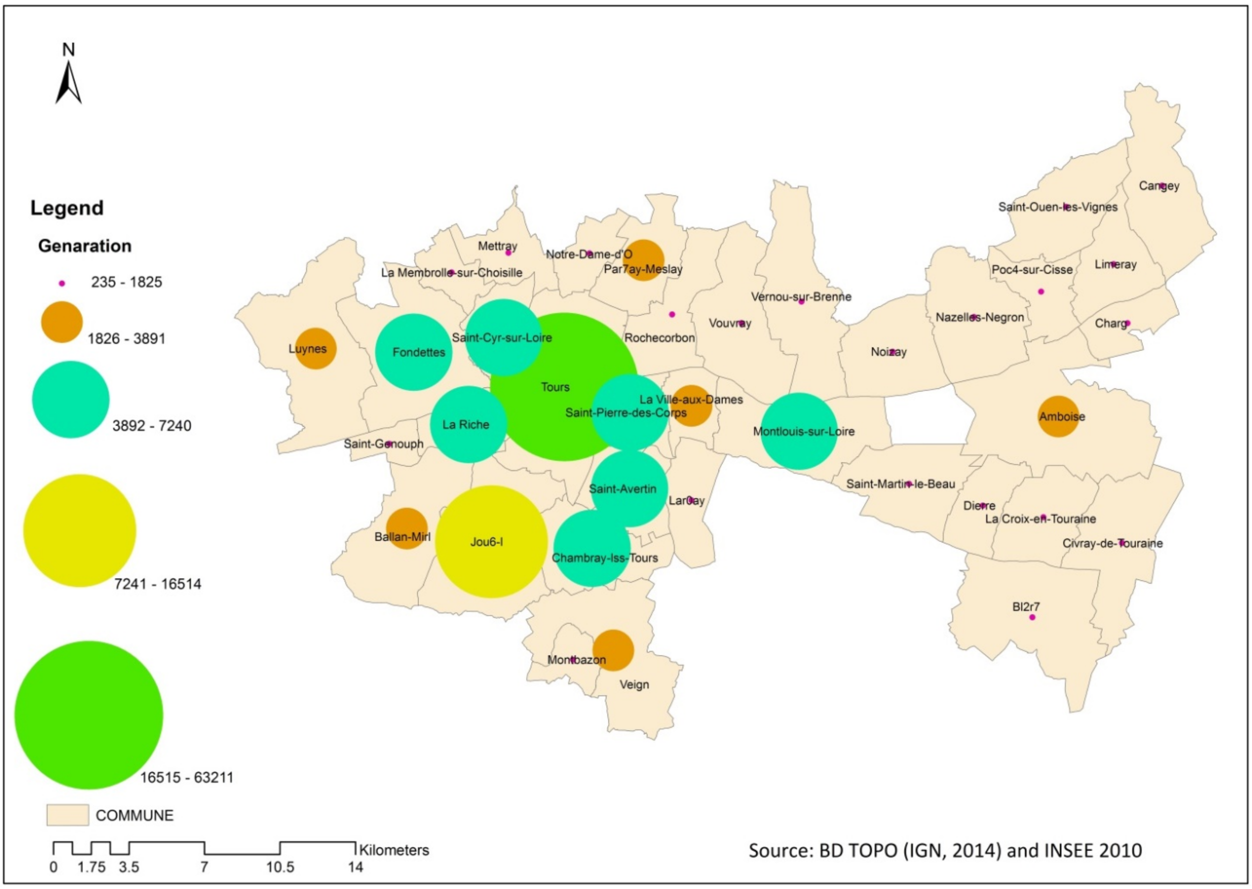


Figure 10: Generation of Scale 3- Unit Urban of Tours with 36 towns

Scale 4- Zone of employment of Tours with 153 towns

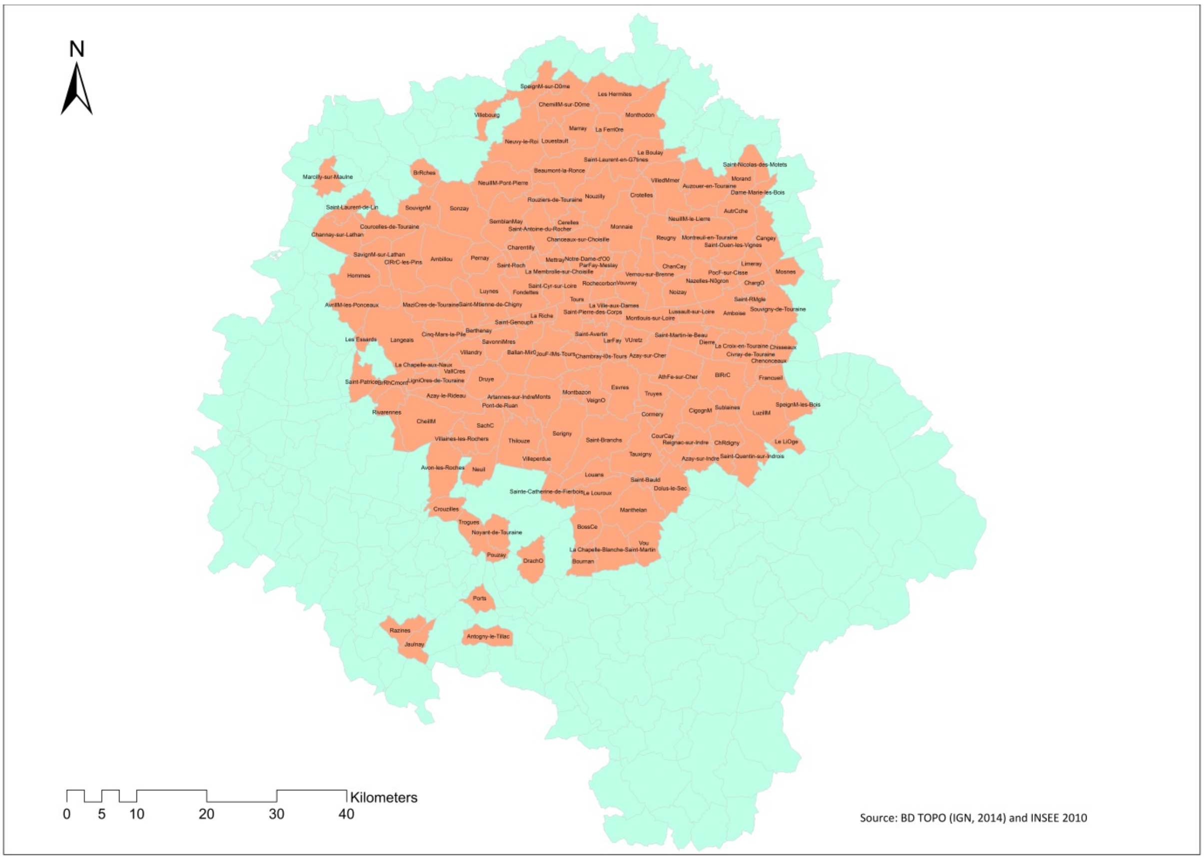


Figure 11: Location of Scale 4- Zone of employment of Tours with 153 towns

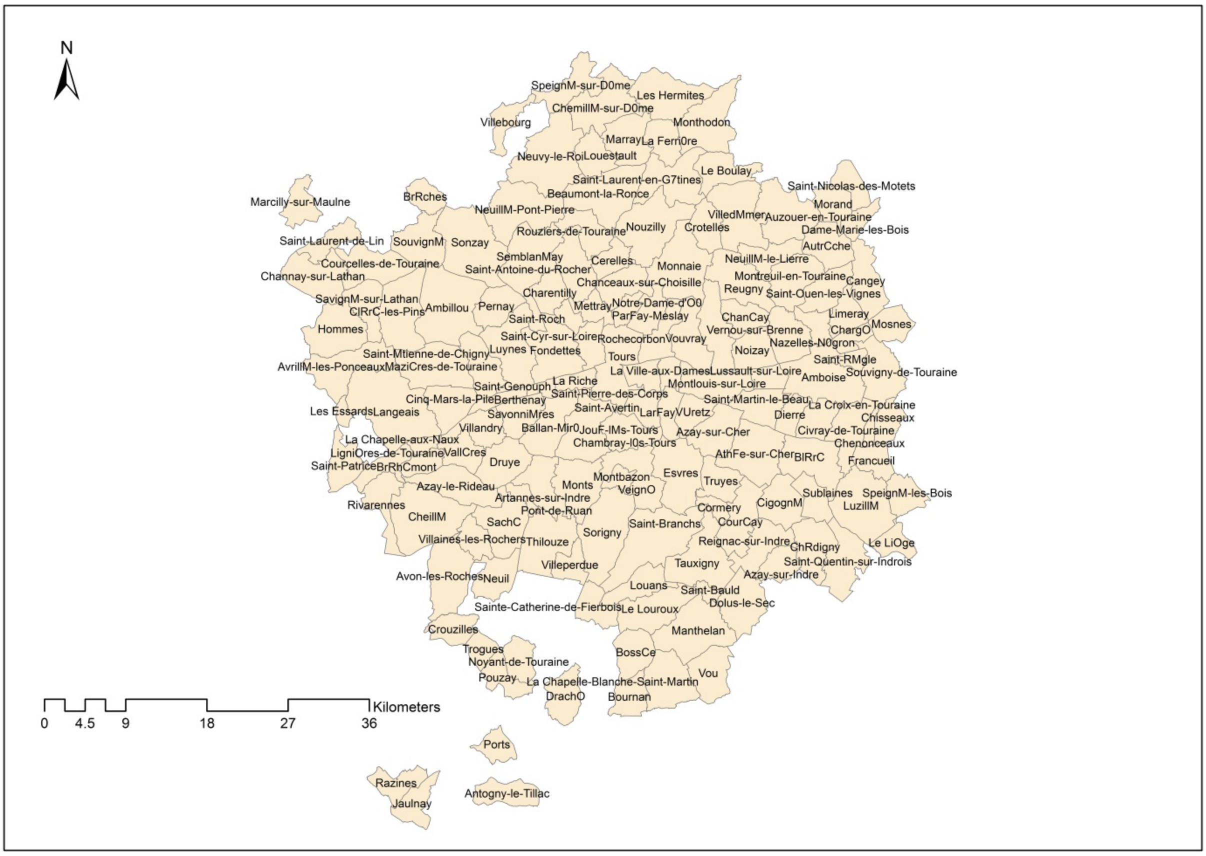


Figure 12: Scale 4- Zone of employment of Tours with 153 towns
Source: BD TOPO (IGN, 2014)

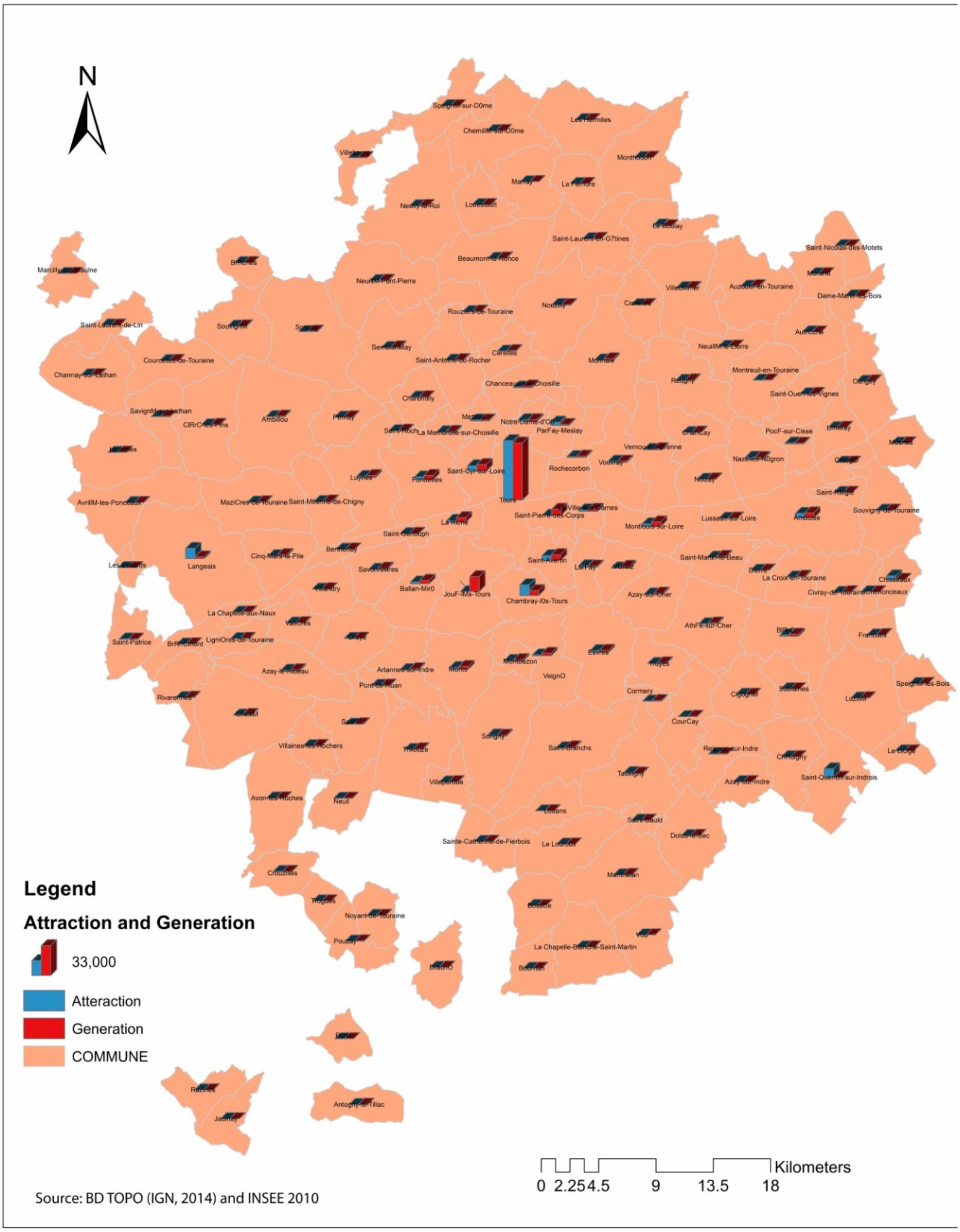


Figure 13: Attraction and Generation of Scale 4- Zone of employment of Tours with 153 towns

Parameters and Variables of Gravity Model:

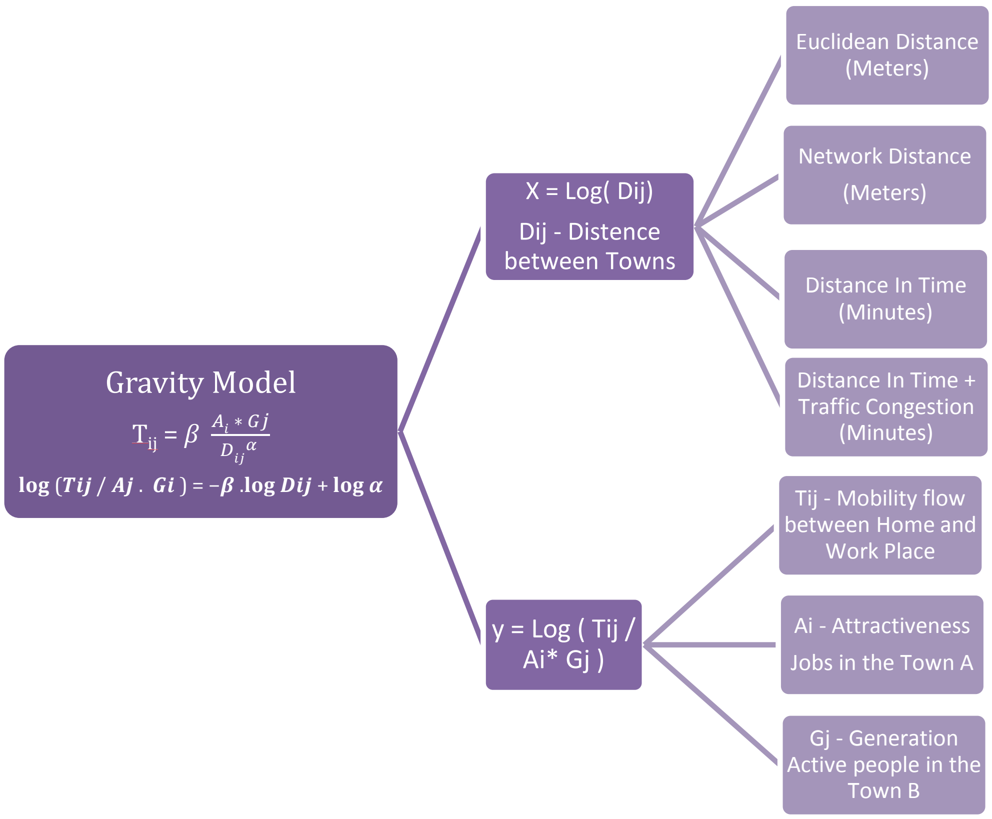


Figure 14: The Process of Calibration analysis of Gravity Model

After all process of calibration analysis will lead to the linear regression line from Excel. For the four different scales we get different results by considering distance as major phenomenon.

When we see the radial flow diagram for the scale of Agglomeration of Tours the maximum interactions was on the south side of Tours. Tours city developed towards south direction.

3.4 Results of Gravity Model from linear regression line: Generation

Distance	Scale	A	B	R^2	R
Euclidean Distance in Meters	Tours	1.87197	1.3152	0.7879	0.88763
	Agglomeration of Tours (22 Towns)	9.36052	1.1253	0.3294	0.57393
	Urban Unit of Tours (36 Towns)	1.77500	1.3958	0.381	0.61725
	Employment Zone of Tours (153 towns with Tours)	3.27491	1.1336	0.2106	0.45891
Network Distance in Meters	Tours	2.4299	1.3189	0.794	0.89106
	Agglomeration of Tours (22 Towns)	3.08176	1.1289	0.347	0.58906
	Urban Unit of Tours (36 Towns)	4.83058	1.4707	0.3848	0.62032
	Employment Zone of Tours (153 towns with Tours)	1.26998	1.2612	0.2313	0.48093
Distance in Time (Minutes)	Tours	16730.15636	0.8724	0.5285	0.72698
	Agglomeration of Tours (22 Towns)	58049.70272	0.7484	0.2098	0.45803
	Urban Unit of Tours (36 Towns)	36349.63045	0.7902	0.1537	0.39204
	Employment Zone of Tours (153 towns with Tours)	33674.41036	0.5509	0.0595	0.24392
Distance In Time + Traffic Congestion (Minutes)	Tours	14269.21232	0.8724	0.5285	0.72698
	Agglomeration of Tours (22 Towns)	50640.73495	0.7484	0.2098	0.45803
	Urban Unit of Tours (36 Towns)	31470.23602	0.7902	0.1537	0.39204
	Employment Zone of Tours (153 towns with Tours)	30450.89067	0.5509	0.0595	0.24392

Table 1: Results of Gravity Model from linear regression line: Generation

The first observation we can make about these results is that the values of R^2 (coefficient of Determination) ranged from 0.05 to 0.79, which means that the gravity model can explain 24% to the phenomenon (in the worst case) and 89% (in the best case).

3.5 Results of Gravity Model from linear regression line: Attraction

Distance	Scale	A	β	R^2	R
Euclidean Distance in Meters	Tours	4.62913	1.0366	0.5521	0.74303
	Agglomeration of Tours (22 Towns)	181.3009	0.7856	0.4129	0.64257
	Urban Unit of Tours (36 Towns)	37.3164	0.9436	0.3721	0.6100
	Employment Zone of Tours (153 towns with Tours)	12.508	1.058	0.3833	0.6191
Network Distance in Meters	Tours	2.79318	1.0726	0.571	0.75564
	Agglomeration of Tours (22 Towns)	83.5987	0.8509	0.410	0.64301
	Urban Unit of Tours (36 Towns)	15.70362804	1.0517	0.3679	0.6065
	Employment Zone of Tours (153 towns with Tours)	4.138	1.1537	0.3931	0.6269
Distance in Time (Minutes)	Tours	15714.47947	0.7151	0.3699	0.60819
	Agglomeration of Tours (22 Towns)	89043.04436	0.4819	0.2131	0.46162
	Urban Unit of Tours (36 Towns)	89598.347	0.414	0.0942	0.3069
	Employment Zone of Tours (153 towns with Tours)	78252.82051	0.4494	0.0908	0.3013
Distance In Time + Traffic Congestion (Minutes)	Tours	13791.13469	0.7151	0.3699	0.60819
	Agglomeration of Tours (22 Towns)	81545.500	0.4819	0.2131	0.46162
	Urban Unit of Tours (36 Towns)	83080.671	0.414	0.0942	0.3069
	Employment Zone of Tours (153 towns with Tours)	72094.145	0.4494	0.0908	0.3013

Table 2: Results of Gravity Model from linear regression line: Attraction

In the both case attraction or generation the model gave good correlation results for the scale: 1 Tours. When increasing the scale the correlation results are decreasing, hence to apply gravity model to workers mobility the suitable scale would be scale 1. That is considering Tours municipality alone will give better results.

Chapter 4: Conclusion

The first explanation that can be advanced regards the restriction of the variables we studied and incorporated into the gravity model. We have given that the movement of people and not of goods. The effects of resistance movement are reduced, which is not fully representative of reality and restricts simulation of the phenomena in place on the territory. Once the scale of study chosen for going further, we could also do varying the parameters Aj (Attraction) and Gi (Generation) by commune in the Gravity model to simulate implantation or relocation of a job area or habitat the territory and see their influence on variables α(Homogenization factor) β(Brake Displacement) R^2 (coefficient of determination) and R (correlation coefficient).

Besides the "network" impedance (in meters) and "time" (minutes), it would also interesting to see the impact of the lever "cost financial" commuting between home and place of work but also on the model results Gravity (β, R^2 and R). Indeed, as we have could see through our different readings, the increasing car dependency plays on vulnerability of households and primarily on their budget.

Finally, the tool which would accurately represent the situation on any territory and forecast its future evolution is a model of transport and even "transport- Urbanism" describing the behaviours mobility. The establishment of such a model incorporating both the real estate development, localisation, the employment development and its location would be a real tool for decision for the elected and would justify sustained development choices and act step by step.

Chapter 5: Limitations

Although the amount of data statistics is the considerable present, certain lack specific element remains all the even palpable. In particular, we can do know precisely the place residence or workplace of each person generating active traffic flows, which is certainly normal for staff and specific to each individual but inevitably engenders approximations in the calculations. Following the application of the Gravity model, we could detect certain heterogeneity of the data, all databases data being independent of each other. On the one hand, for example, we know the number of people employed by joint (base INSEE data © JOB-POPULATION ACTIVE) and on the other, we have the number by common jobs (INSEE database © CHARACTERISTICS AND FIRMS SETTLEMENTS or CLAP) without knowing what individual visits which commune, which can limit this modeling. In addition, during the various stages leading to the creation of the Matrix OD, we had to make some approximations to continue the calculations (including on the values taken for the criteria Speed), which could lead later some discrepancies with the reality of the results without making them unusable.

Given the importance of the territory study, the Department Indre-et-Loire, a large number of data and information have been processed, which is felt particularly when the generation of Origin-Destination Matrices or even during treatments carried out under Access and Excel. Automation of the procedure could be considered subsequently.

Annexure: - 1

Road Network Analysis

The different stages of ArcGIS geoprocessing © to get the OD matrixes for distance network (meters) and long distance (minutes) by using the Network Analyst Tool are detailed in the following:

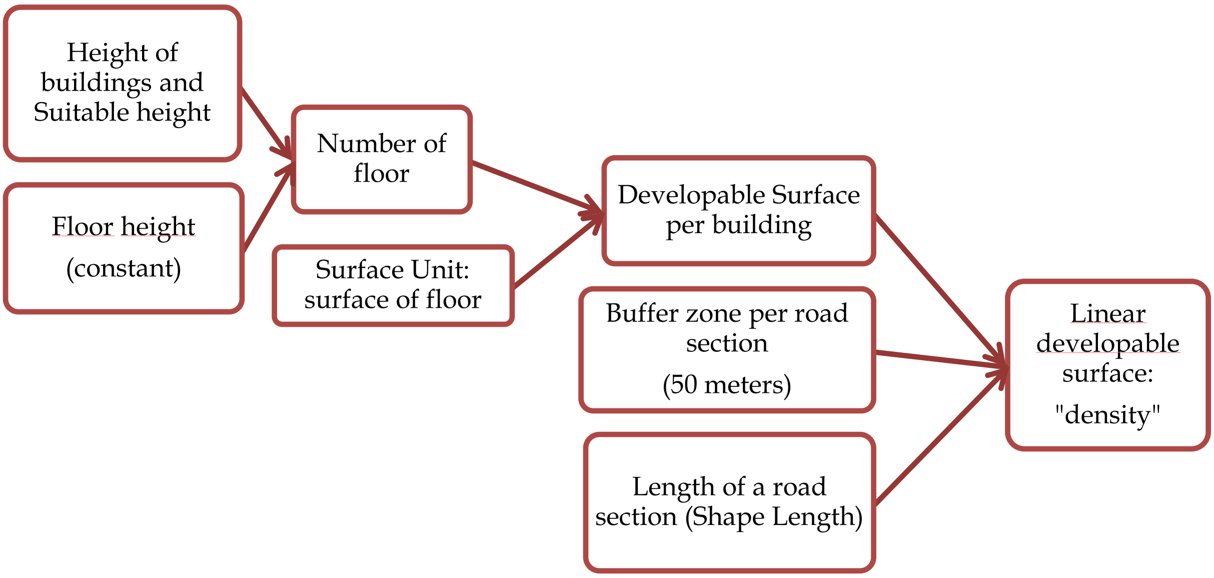


Figure 15: Different stages of ArcGIS geoprocessing © to get the OD matrixes 1
Source: Author: K.SERRHINI

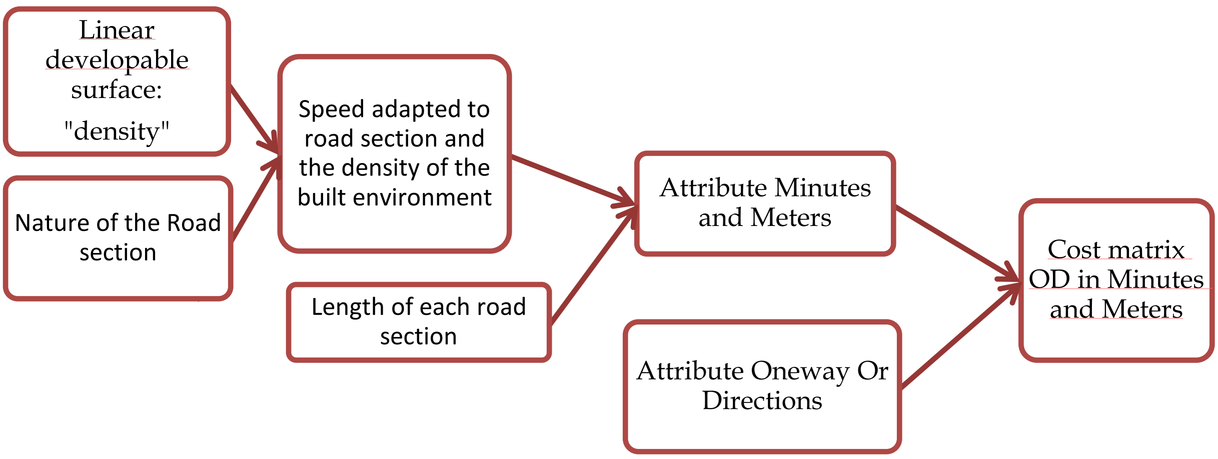


Figure 16: Different stages of ArcGIS geoprocessing © to get the OD matrixes 2
Source: Author: K.SERRHINI

The field "Height"

In the database "bâti" (BD TOPO, IGN 2014) face the field "Height" Referring to height of a building. However, note that the minimum height of some buildings is 0 m, which is impossible if the building exists. Then we create a new column named "H_Corr" In the attribute table to correct the column "Height" And replace the heights equal to 0 m by 1 m, to not to disturb the calculations that follow and deform the "least possible" reality.

Script code Pre-Logic (Visual Basic) associated with the handling of the "Height" field:

```
Dim var
If [HAUTEUR] = 0 Then
 var = 1
Elaeif [HAUTEUR] > 0 Then
 var = [HAUTEUR]
end if

H_cor=
var
```

Figure 17: Algorithm for correcting Height of the building
Source: Author K.SERRHINI

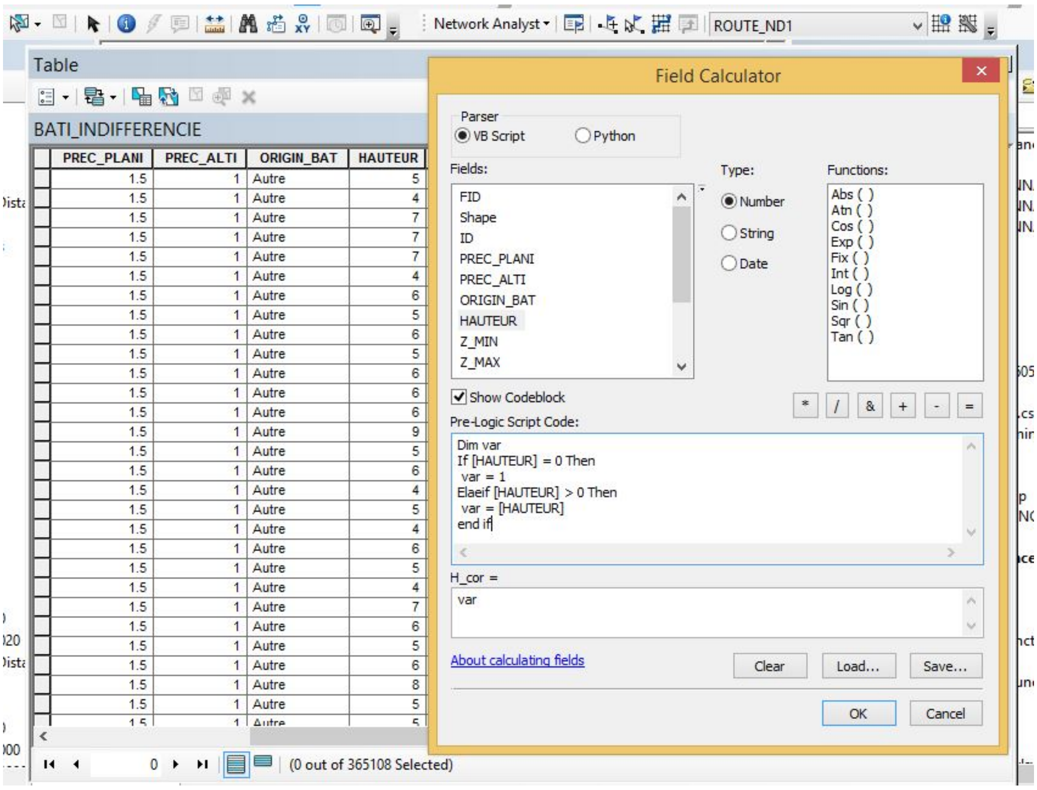


Figure 18: Correcting Height of the building using Field calculator tool

The field "No_Stages"

It is considered that the height of a floor is equivalent to 2.5 m (constant). Then we can calculate the number by building of floors as follows:

$$No\_Stages = [H\_Cor] \ / \ 2.5$$

The resulting values of the field "No_Stages" may in some cases also be zero of the same way as the previous field, we can correct the field "No_Stages" When calculated is 0 to avoid distorting the calculations thereafter. For this, we create a new column "No_Stages_Corr" In the attribute table to replace the fields "No_Stages" Nil by 1.

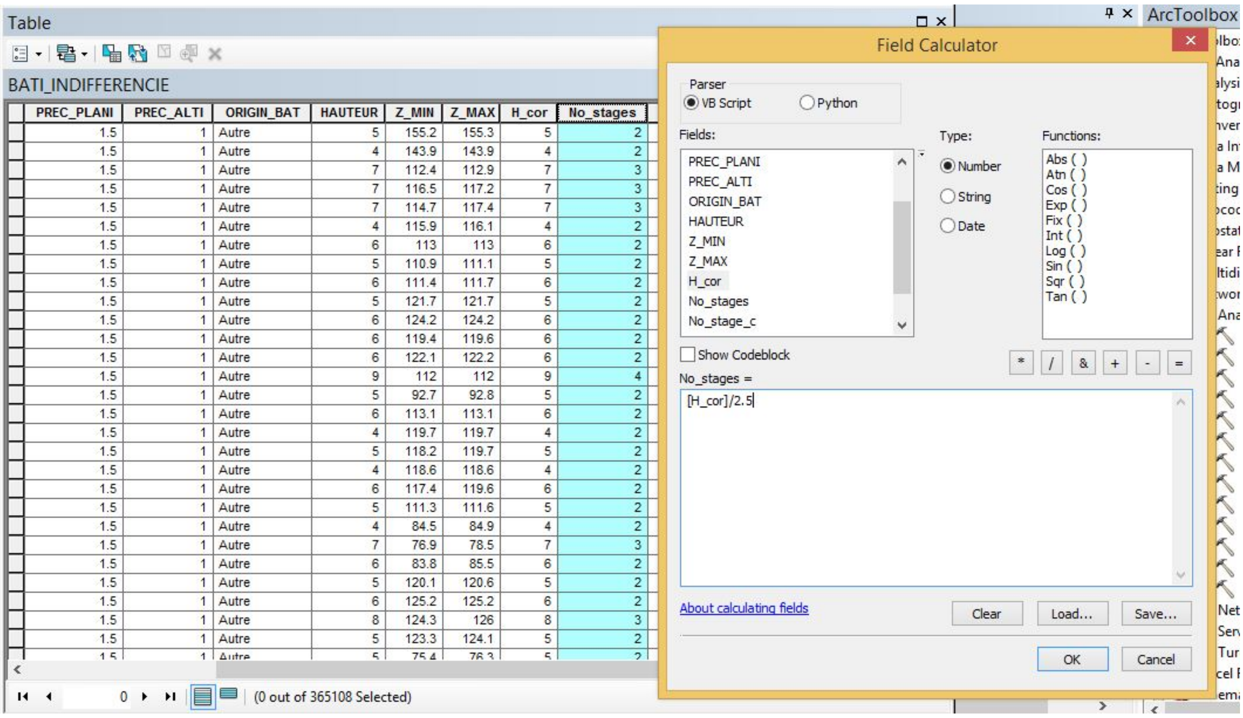


Figure 19: Calculating number of stages of the building using Field calculator tool

Script code Pre-Logic (Visual Basic) associated with the handling of the "No_Stages_c" field:

```
Dim var
If [No_stages] = 0 Then
 var = 1
Elaeif [No_stages] > 0 Then
 var = [No_stages]
end if

No_Stages_c=
var
```

Figure 20: Algorithm for correcting number of stages of the building
Source: Author K.SERRHINI

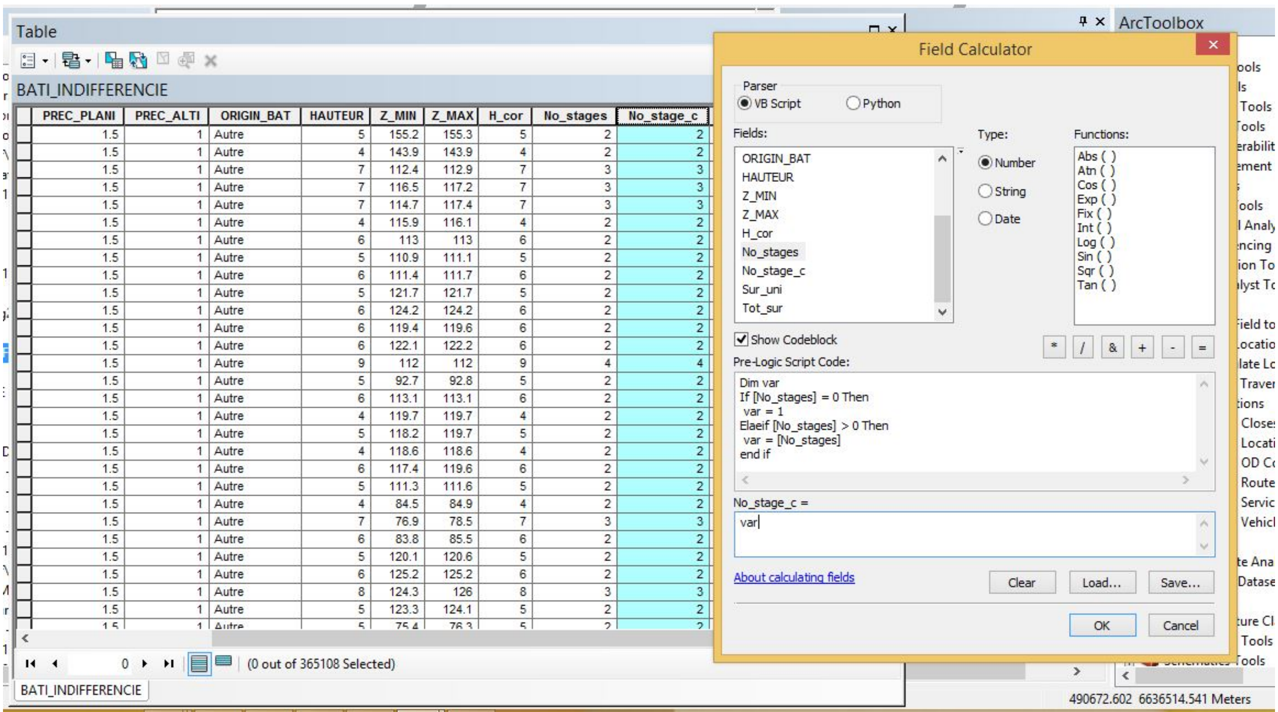


Figure 21: Correcting Number of stages of the building using Field calculator tool

Unit area

Field "Sur_uni" (Surface Unit area in Sq.meters) that is about to calculate is the floor area of each building. We get it by using the function "calculate geometry" proposed by ArcGis ©.

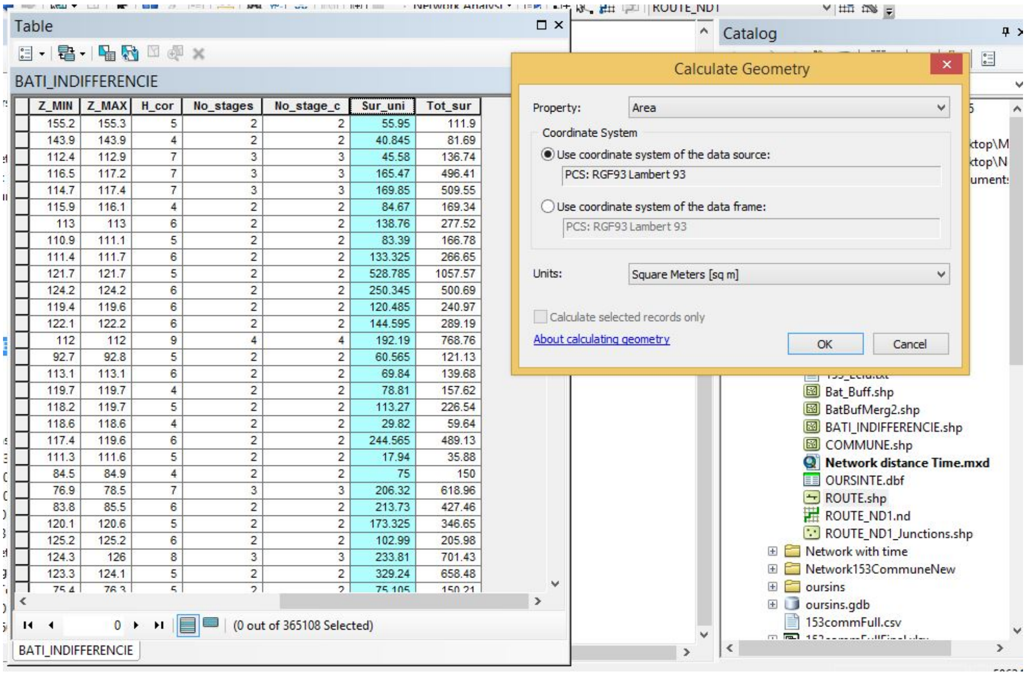


Figure 22: Calculating Surface of the building using Field calculator tool

Developable area per building

In order to get the field "Tot_sur" (Total developable surface in Sq.meters) by building in the attribute table, matching the total area associated with each building, we need to performs the following calculation:

$$Tot\_sur \text{ (Total developable surface)} = [Sur\_uni] \times [No\_Stages\_C]$$

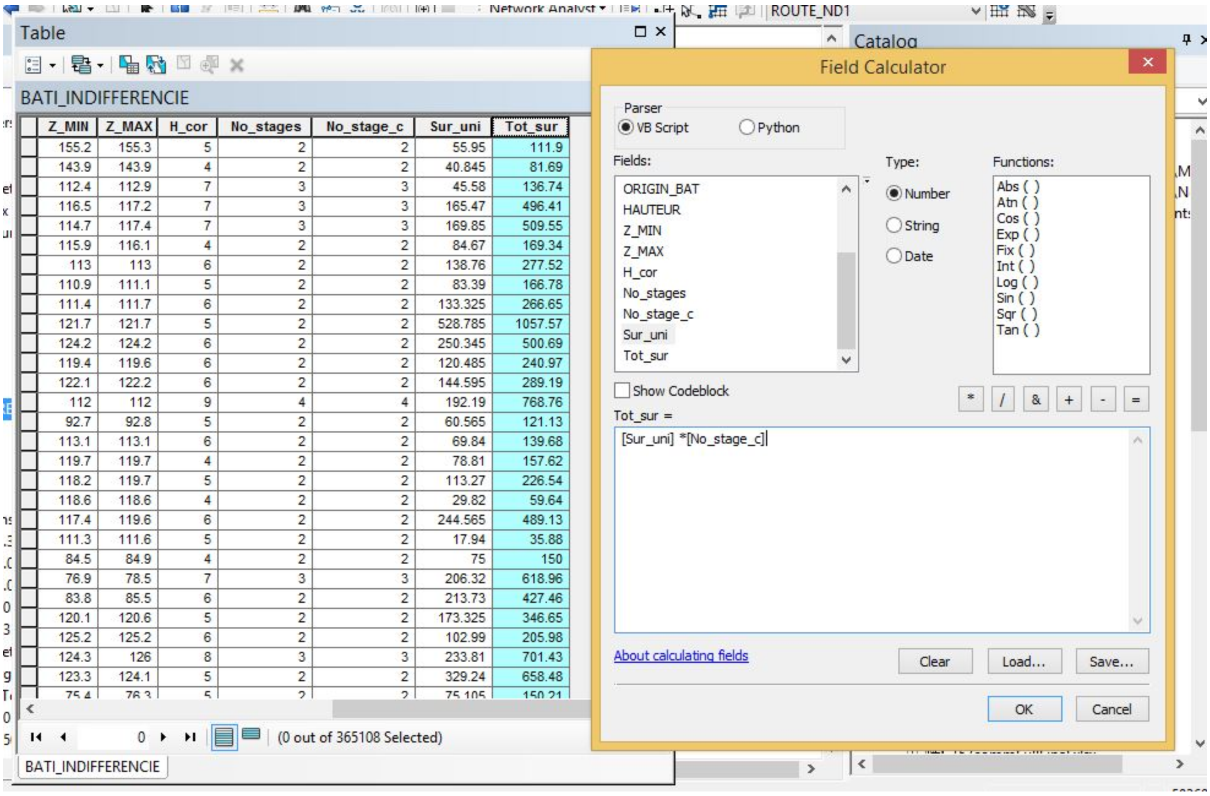


Figure 23: Calculating Total surface area of the building using Field calculator tool

The buffer zone (or "buffer")

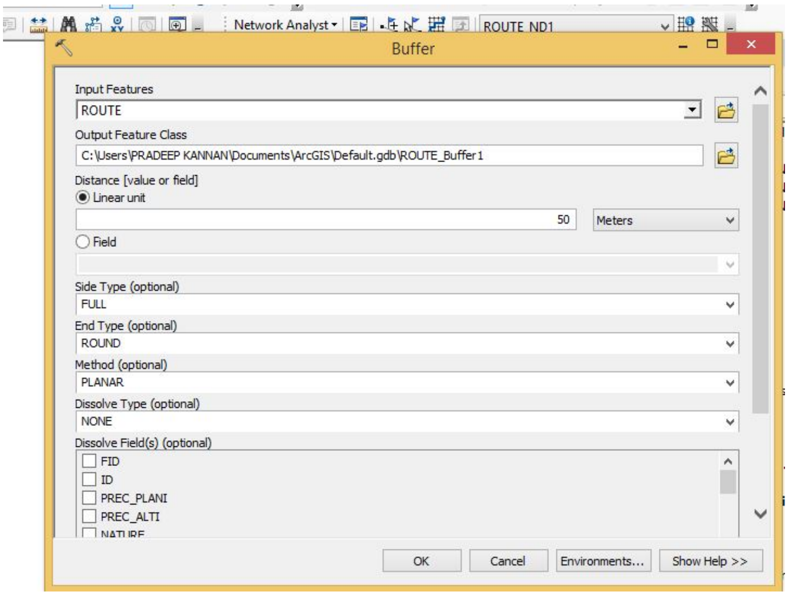


Figure 24: Buffer Tool to crate Buffer Zone

First, we create a "buffer zone" (that is to say an area encompassing buildings in a "Buffer") according to certain criteria. Indeed, there must be a radius of 50 m in the immediate vicinity of roads (so we create a "Buffer" of 50 m around each road section) to eliminate buildings outside of this "buffer zone".

Conversely, we need to identify buildings in this "buffer zone" for determine the building density that will play a role in the allocation of the speed of road sections. (To select these target buildings, we use the "Select by Location" tool. Then we create a new layer from the selected data.)

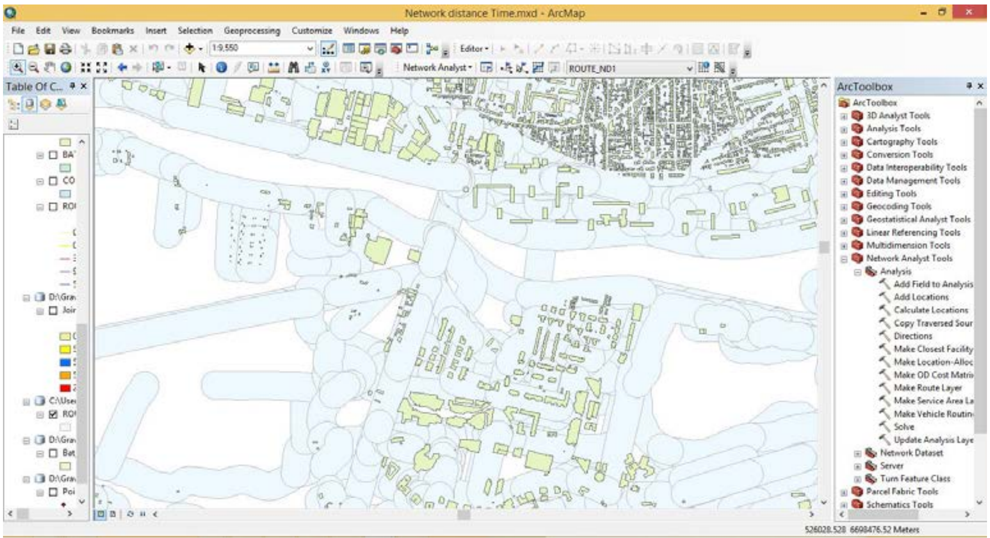


Figure 25: Building selected lies on the Buffer Zone

We then use the "Spatial Join" tool to determine the buildings belonging to each “Buffer”. This joint is made from a common attribute or an element that belongs to a selection tool “Attach data”. We then get the subtotal of the developable surface at “Buffer”. Now we are looking for the developable surface road section, which is to say that we must go the “buffer” the road section (each “buffer” is a road).

Total Developable surface area per buffer

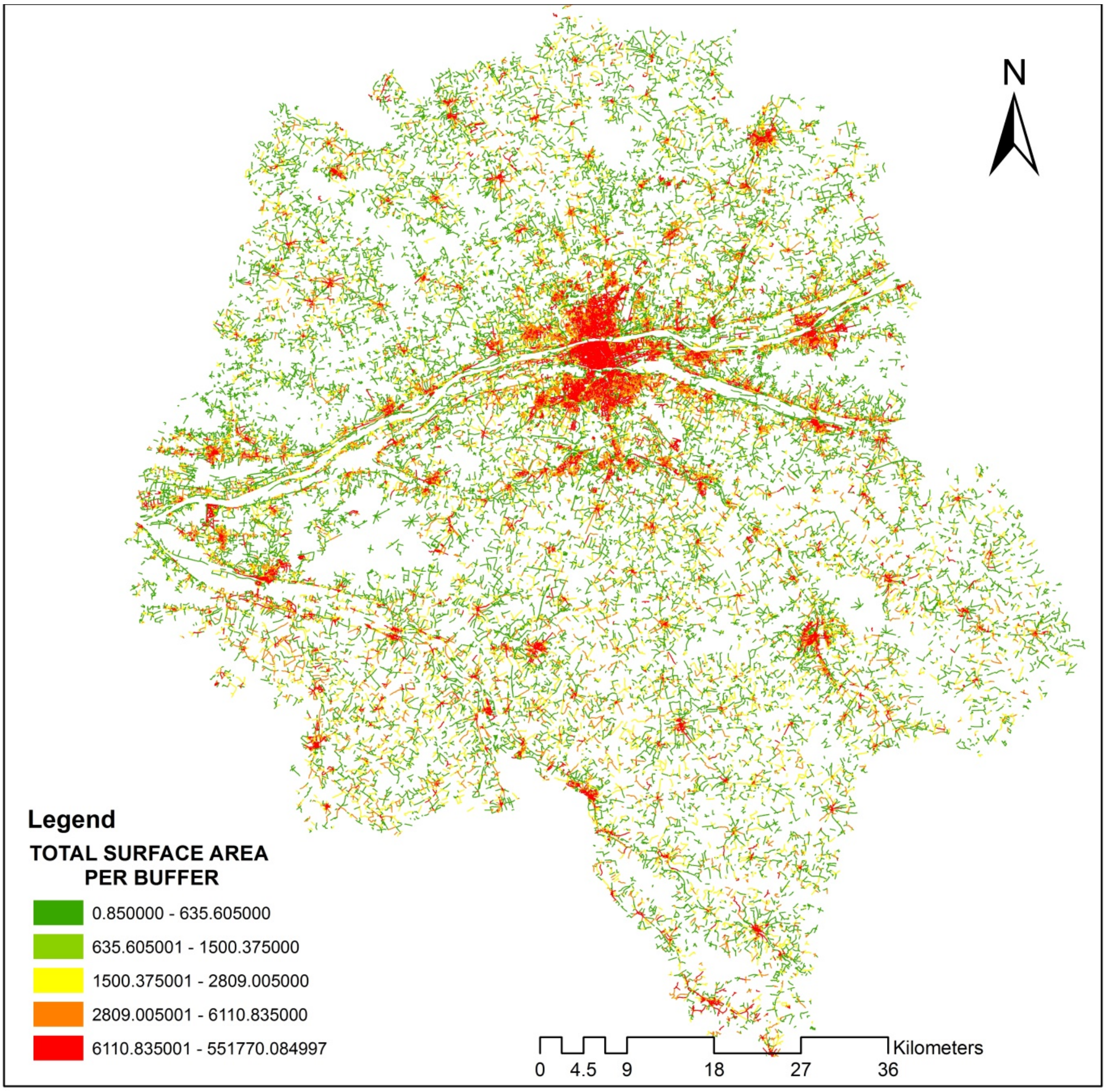


Figure 26: Developable surface area per Buffer
Source: BD TOPO (IGN, 2014) and Drawn in ArcGis

Linear developable surface area (Density):

The frame of the density values (not in the classical sense, that is to say, not the number population relative to the area, but in the sense of total developable surface relative to the length of road section) are too high. To reduce and make them linear, we initially create the field that is having length of each road section using the tool “calculation of the geometry”. Then, to get the “linear developable surface” (or “building density”), we perform the calculation following:

Linear Developable surface (Linear Density) = Sum of Developable surface / Road Length

Thus we get the “Linear Density” corresponding to the number of inhabitants per linear meter road section.

The objective now is to use linear density thus calculated to determine the speed for each of these road sections.

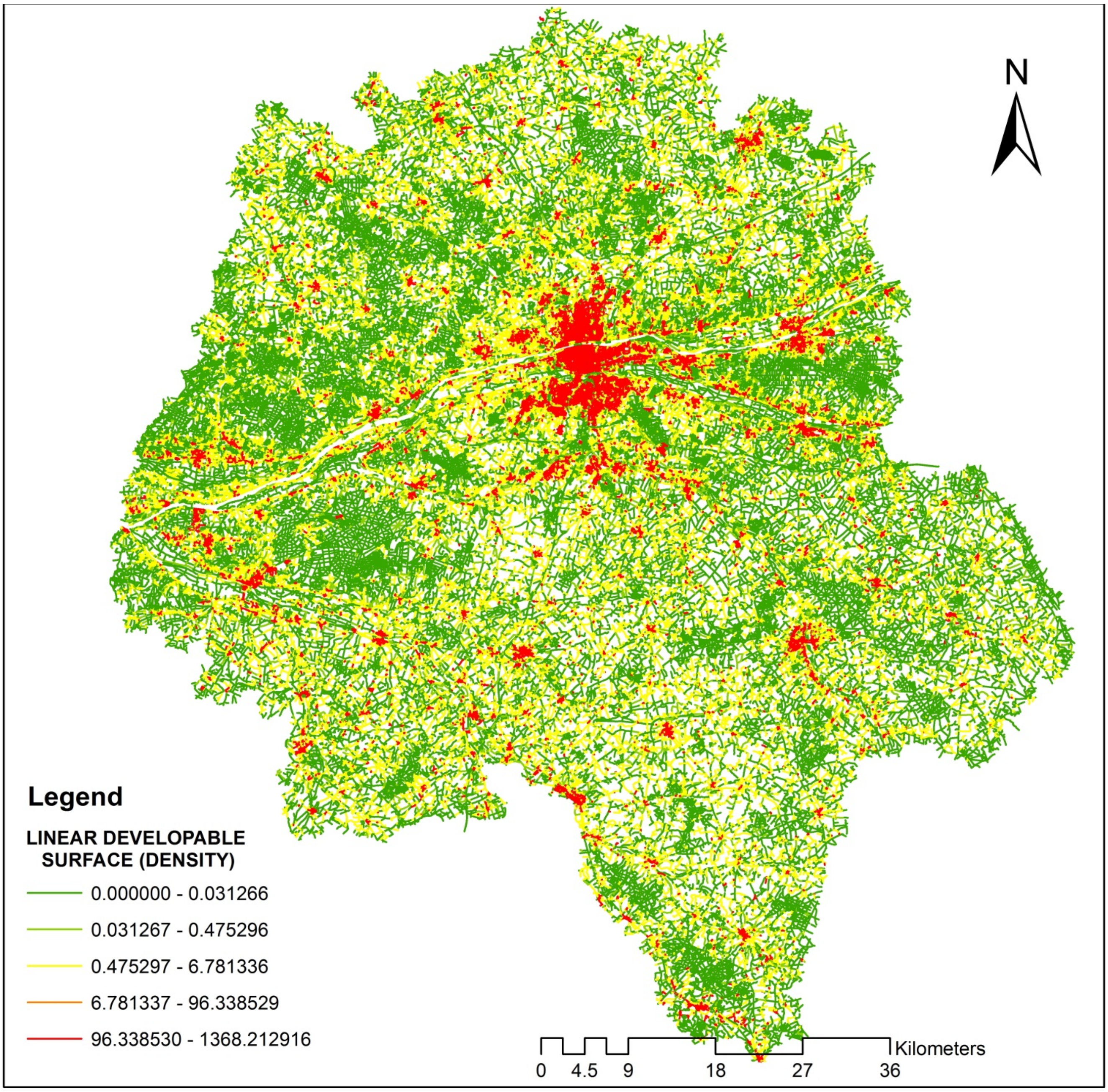


Figure 27: Linear developable surface density per road section
Source: BD TOPO (IGN, 2014) and Drawn in ArcGis

Speed of the road sections

The following step is to adapt the speed limit on the road sections as a function of the density of surrounding buildings. For this, simultaneously exploits the attributes "NATURE" (which are Autoroute, Bretelle, Chemin, Escalier, Piste cyclable, Quasi autoroute, Route empierrée, Route à 1 chaussée, Route à 2 chaussées et Sentier) and "Linear Density" of each road section in the following algorithm.

Script code Pre-Logic (Visual Basic) associated with the manipulation of the field "Speed"

```
Dim var
IF [Routes22Com.NATURE] ="Autoroute" AND [Routes22Com.Dens_Lin] <=0.7 Then
 var=130
ELSEIF [Routes22Com.NATURE] ="Autoroute" AND [Routes22Com.Dens_Lin] > 0.7 Then
 var=90
ELSEIF [Routes22Com.NATURE] ="Quasi-autoroute" AND [Routes22Com.Dens_Lin] <=0.7 Then
 var=110
ELSEIF [Routes22Com.NATURE] ="Quasi-autoroute" AND [Routes22Com.Dens_Lin] > 0.7 Then
 var=90
ELSEIF [Routes22Com.NATURE] ="Route à 2 chaussées" AND [Routes22Com.Dens_Lin] >= 105 Then
 var=50
ELSEIF [Routes22Com.NATURE] ="Route à 2 chaussées" AND [Routes22Com.Dens_Lin] < 105 Then
 var=70
ELSEIF [Routes22Com.NATURE] ="Route à 1 chaussée" AND [Routes22Com.Dens_Lin] < 105 Then
 var=50
ELSEIF [Routes22Com.NATURE] ="Route à 1 chaussée" AND [Routes22Com.Dens_Lin] >= 105 Then
 var=30
ELSEIF [Routes22Com.NATURE] ="Bretelle" Then
 var=30
ELSEIF [Routes22Com.NATURE] ="Chemin" Then
 var=20
ELSEIF [Routes22Com.NATURE] ="Route empierrée" Then
 var=20
Else var=0
End if
__esri_field_calculator_splitter__
var
```

Figure 28: Algorithm for calculating the speed of road sections
Source: Author K.SERRHINI

The values that were taken above to speed patterns are derived from observed densities and are an analytical approach and spatial planning. To create a topological road network and analyze the new data set created in Network Analyst, we need the following two attributes: "Minutes" (which corresponds to the time required to travel the length of the road section) and "Oneway" (which assigns a usable direction Network Analyst to the section).

The attribute "Minutes" is calculated as follows:

$$([\text{Length\_Meters}] \times 60) \ / \ (1000 \times [\text{Speed}])$$

And the attribute "Oneway" is produced as follows.

Script code Pre-Logic (Visual Basic) associated with the handling of the attribute "Oneway"

```
Dim var
If [SENS] = "Direct" Then
 var = "F"
Elseif [SENS] ="Inverse" Then
 var = "T"
Else var=""
end if

__esri_field_calculator_splitter__
var
```

Figure 29: Algorithm for calculating Oneway attribute
Source: Author K.SERRHINI

“F” refers From and “T” refers To.

New network data set

To create the new network dataset in ArcCatalog (application of ArcGIS ©), we use attributes “Minutes”, “Meters” and “Oneway” which was previously created. Once this new game set of network data, it will enable us subsequently to determine the two OD Matrices we need for the gravity model.

Origin-Destination Matrix:

Construction Matrixes Origin-Destination network distance (meters) and time distance (minutes) at the level of the Scale that is Zone of Employment that comprises of 153 towns in the Department Indre-et-Loire through the Network Analyst tool. The last step is to generate OD Matrices network distance and time distance that will serve us in applying the gravity model.

Now that we have created a new network dataset, we activate the extension “Network Analyst “and we display the corresponding toolbar in ArcGIS ©. Then just load the layer associated with the network dataset that has been generated (.ND file) and choose Matrix Cost OD (or OD Cost Matrix). For this we must inform the three fields that are “Origin”, “Destination” and “Lines” .The field “Origin” and “Destination” in correspond to common centroid area in the Department Indre-et-Loire to connect. However, we have only the boundary layer these common administrative and not a one-off layer of their centroid. The tool “Feature To Point”

Proposed by ArcGis © will then allow us to transform these entities into polygon features to point. Thus, we now have a point layer containing the centroids of 153 towns we are going to use to fill the fields "Origin" and "Destination" in "Load locations" tool in ArcGis ©.

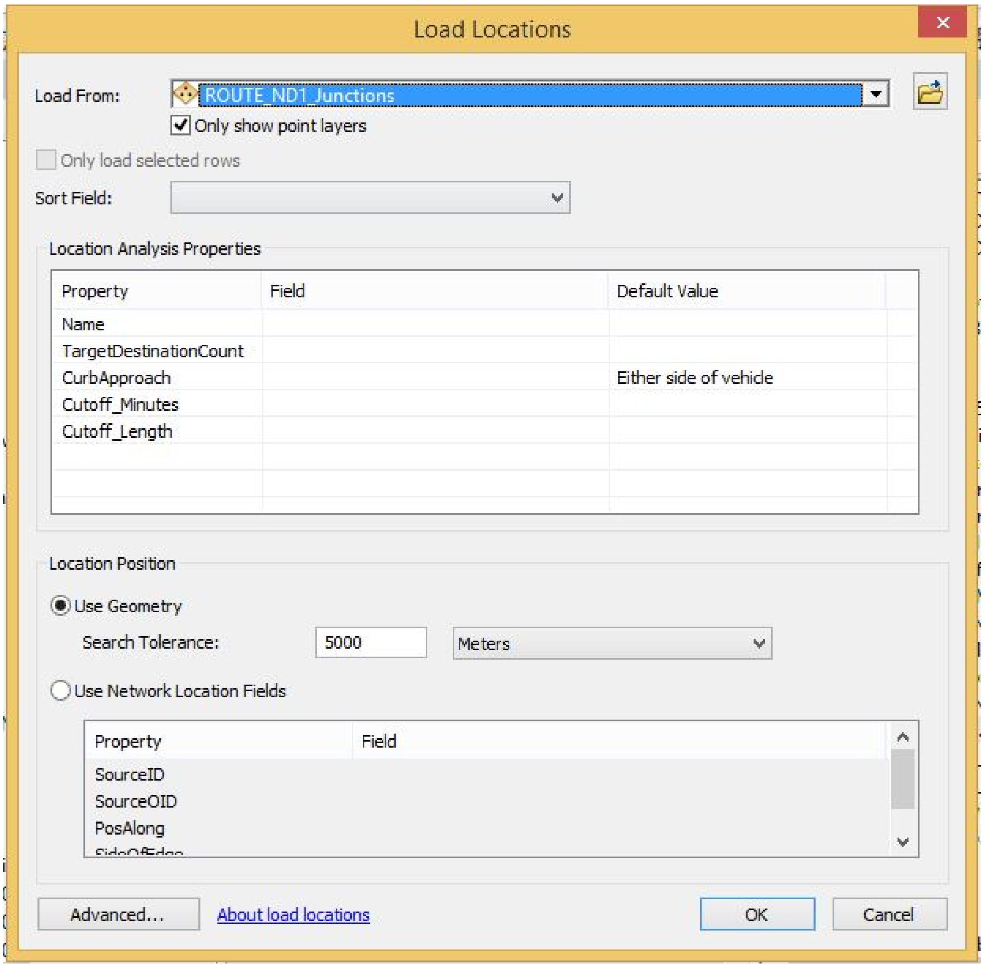


Figure 30: Load Location tool for OD matrix in ArcGis

Location points Origin and Destination Matrix corresponding to 153 centroids in the Department Indre-et-Loire:

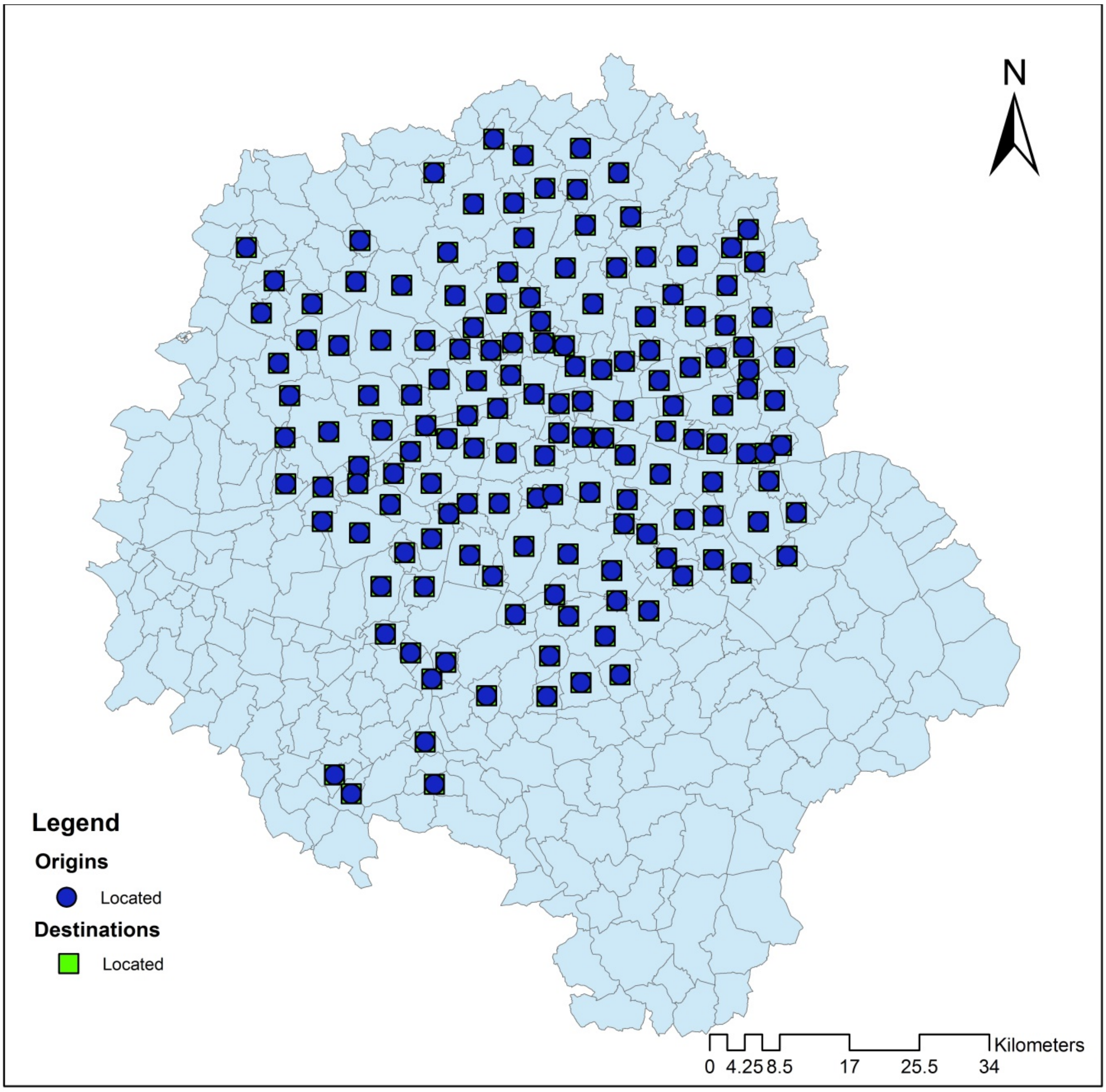


Figure 31: Origin and Destination points for 153 towns OD matrix construction
Source: BD TOPO (IGN, 2014) and Drawn in ArcGis

Then just set the properties of the layer as follows:

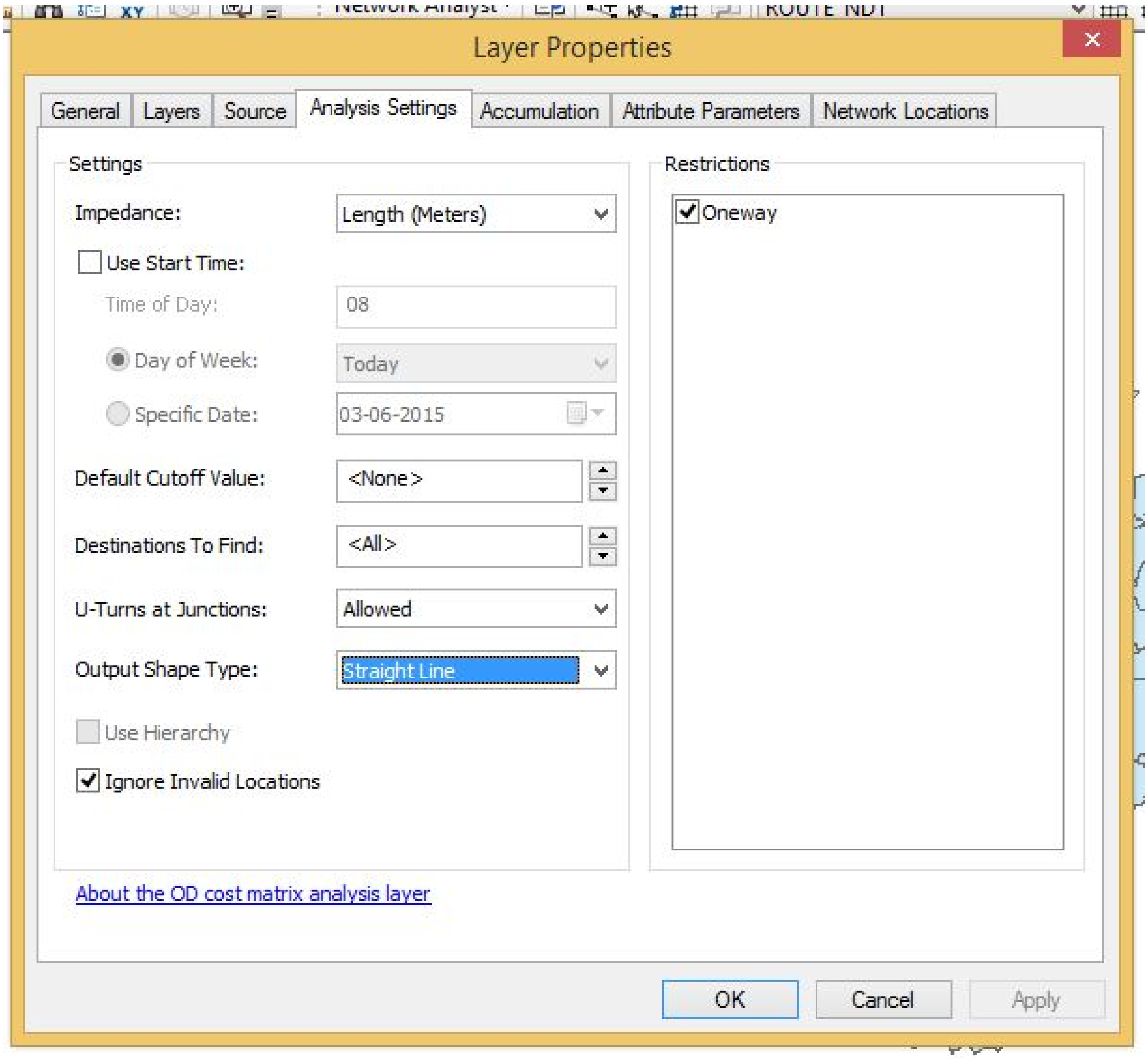


Figure 32: OD Matrix Layer properties in ArcGis

Finally, the “Lines” field is used to store information about the paths from the origins to destinations between 153 centroids. These lines (or paths) appear as straight lines if we but displaying it cost attributes considered always correspond at least cost path following the road network. Once these lines generated, the field Total_Length appears in the attribute table and corresponds the cost (in our case in meters or minutes) for the cumulative path connecting the origin to the destination according the network.

OD Matrix Construction in ArcGis for 153 towns:

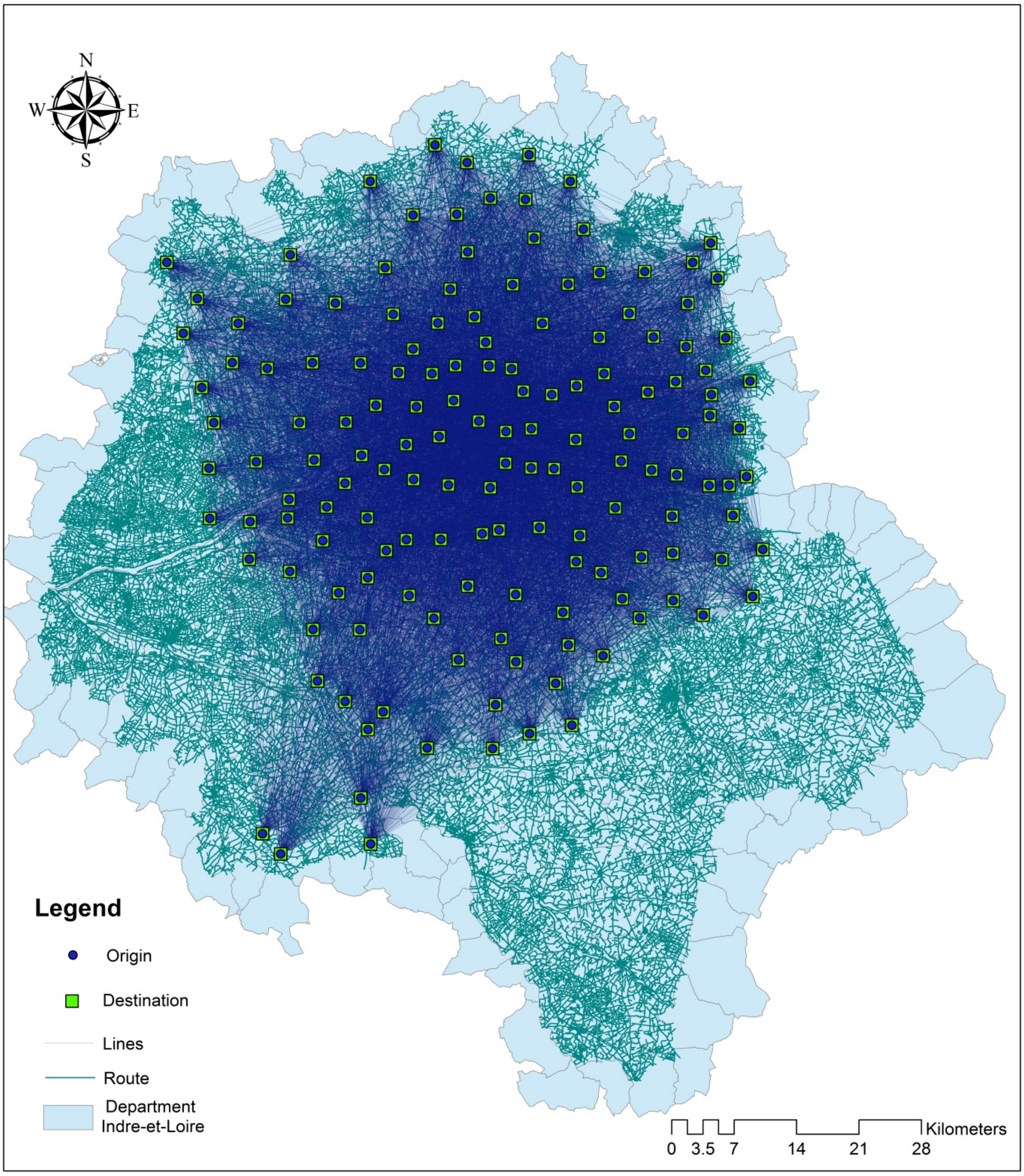
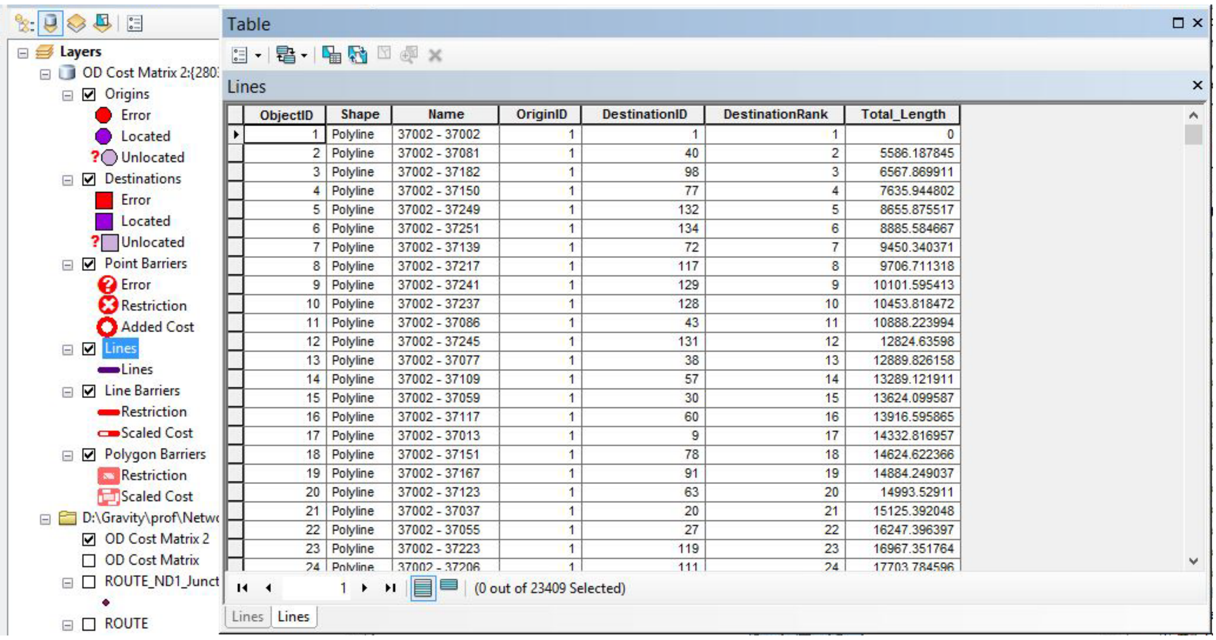


Figure 33: OD Matrix Construction in ArcGis
Source: BD TOPO (IGN, 2014)

Finally, the attribute tables which are obtained are of the following form OD Matrix Network distance (Meters):



ObjectID	Shape	Name	OriginID	DestinationID	DestinationRank	Total_Length
1	Polyline	37002 - 37002	1	1	1	0
2	Polyline	37002 - 37081	1	40	2	5586.187845
3	Polyline	37002 - 37182	1	98	3	6567.869911
4	Polyline	37002 - 37150	1	77	4	7635.944802
5	Polyline	37002 - 37249	1	132	5	8655.875517
6	Polyline	37002 - 37251	1	134	6	8885.584667
7	Polyline	37002 - 37139	1	72	7	9450.340371
8	Polyline	37002 - 37217	1	117	8	9706.711318
9	Polyline	37002 - 37241	1	129	9	10101.595413
10	Polyline	37002 - 37237	1	128	10	10453.818472
11	Polyline	37002 - 37086	1	43	11	10888.223994
12	Polyline	37002 - 37245	1	131	12	12824.63598
13	Polyline	37002 - 37077	1	38	13	12889.826158
14	Polyline	37002 - 37109	1	57	14	13289.121911
15	Polyline	37002 - 37059	1	30	15	13624.099587
16	Polyline	37002 - 37117	1	60	16	13916.595865
17	Polyline	37002 - 37013	1	9	17	14332.816957
18	Polyline	37002 - 37151	1	78	18	14624.622366
19	Polyline	37002 - 37167	1	91	19	14884.249037
20	Polyline	37002 - 37123	1	63	20	14993.52911
21	Polyline	37002 - 37037	1	20	21	15125.392048
22	Polyline	37002 - 37055	1	27	22	16247.396397
23	Polyline	37002 - 37223	1	119	23	16967.351764
24	Polyline	37002 - 37206	1	111	24	17703.784596

Figure 34: OD Matrix Network distance (Meters) Output in ArcGis

Annexure 2

Definitions:

Connaissance locale de l'appareil productif /Local knowledge of the productive system / CLAP

This is an information system fed with data from various sources and with the purpose of providing statistics according to workplace location, down to the municipal level, on paid employment and wages for the different market and non-market sectors.

The list of companies and establishments is compiled on the basis of the National Register of Enterprises and their Establishments (SIRENE).

The data on salaried employment is produced by matching the information obtained from processing:

- DADSs (Annual Declarations of Employment Data);
- URSSAF (Organisation for the Payment of Social Security and Family Benefit Contributions) contribution summary slips;
- Data from the Agricultural Social Mutual Fund (MSA) in addition to URSSAF data for those sectors of activity relating to agriculture (for data relating to the 2007 fiscal year onwards);
- Data from the information system for civil servants.

The local productive system:

- Characteristics of enterprises and establishments (number, size: sectory of activity) and wages paid;
- Jobs offered by enterprises and establishments: number of jobs, socio-professional category, gender, type of employment (including: apprentices, subsidised contracts, interns);
- Salaried employment measured in terms of "jobs" on 31 December of the year in question. Salaried employment is also evaluated in terms of full-time equivalent over the year.

Self-employed workers (craftsmen, the professions, etc.) are not counted. The Clap data are available at a very detailed geographic level (region, department, canton or town, municipality) and for a wide range of zones (employment zone, etc.).

Clap is an information system that is fed from various sources.

1. The enterprises and establishments register or REE-Sirene, is made up from the National Enterprise and Establishment Register (Sirene).

2. Data on salaried employment is produced by aligning information from four sources:

- Annual Declarations of social data (DADS) ;
- Summary contributions forms from URSSAF (Organisation for the payment of social security and family benefit contributions) which make up the "Epure" information system;
- The information system on civil servants;
- Data from the agricultural mutual benefit social fund (MSA) which complements URSSAF data for sectors of activity associated with agriculture (starting with data for the 2007 financial year).

Data on pay that appears in Clap are the total sum of gross wages for employees in an establishment. Pay corresponds to employee salaries and bonuses in the course of the financial year.

The classification used for the data in Clap until the 2007 financial year is the NAF rev.1.

After the 2008 year of reference, the aggregation levels associated specifically with NAF rev. 2 will be used. The Clap information source is used for economic analysis according to workplace location.

Clap is by no means a substitute for the employment estimates that are produced by INSEE; CLAP assesses employment according to job numbers, while INSEE's estimates assess employment according to the number of people occupied at the workplace.

Source: www.INSEE.fr

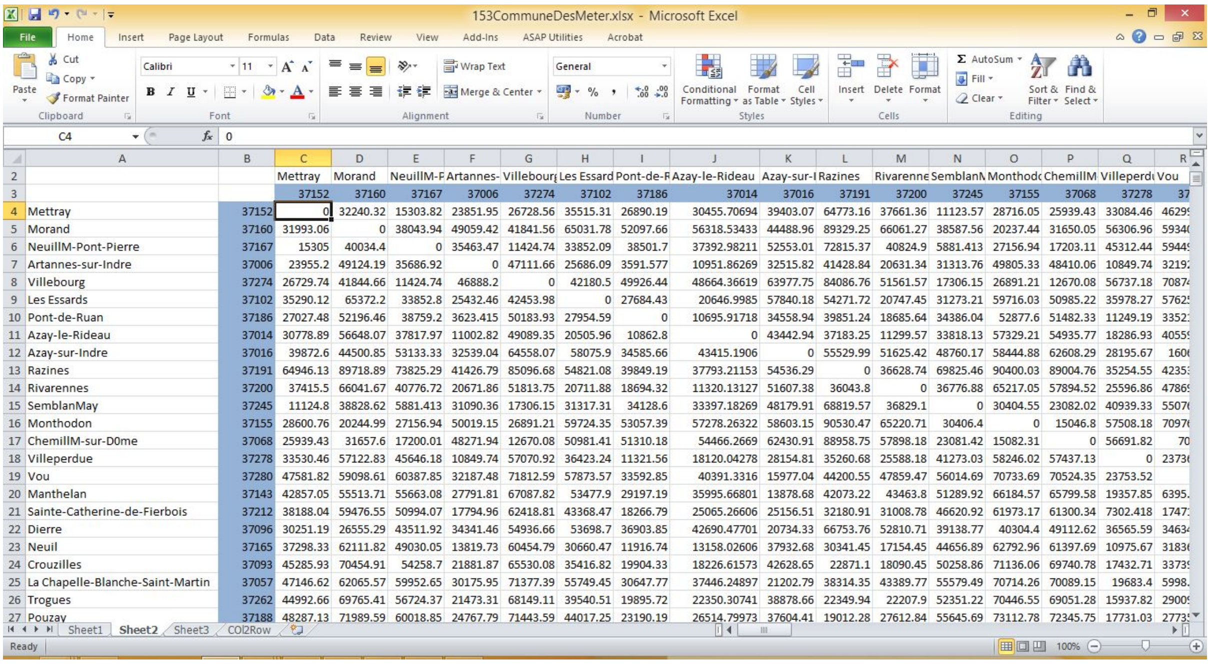
Bases sur les flux de mobilité : mobilités professionnelles (déplacements domicile - lieu de travail) / Mobility Flows Commuting between Home and Work place

The bases on the flow of job mobility provide the number of people making journeys between their home and their workplace. Number of flow is greater than 100 persons was taken into account. The mobility flow less than 100 persons were not mentioned in this data.

Source: www.INSEE.fr

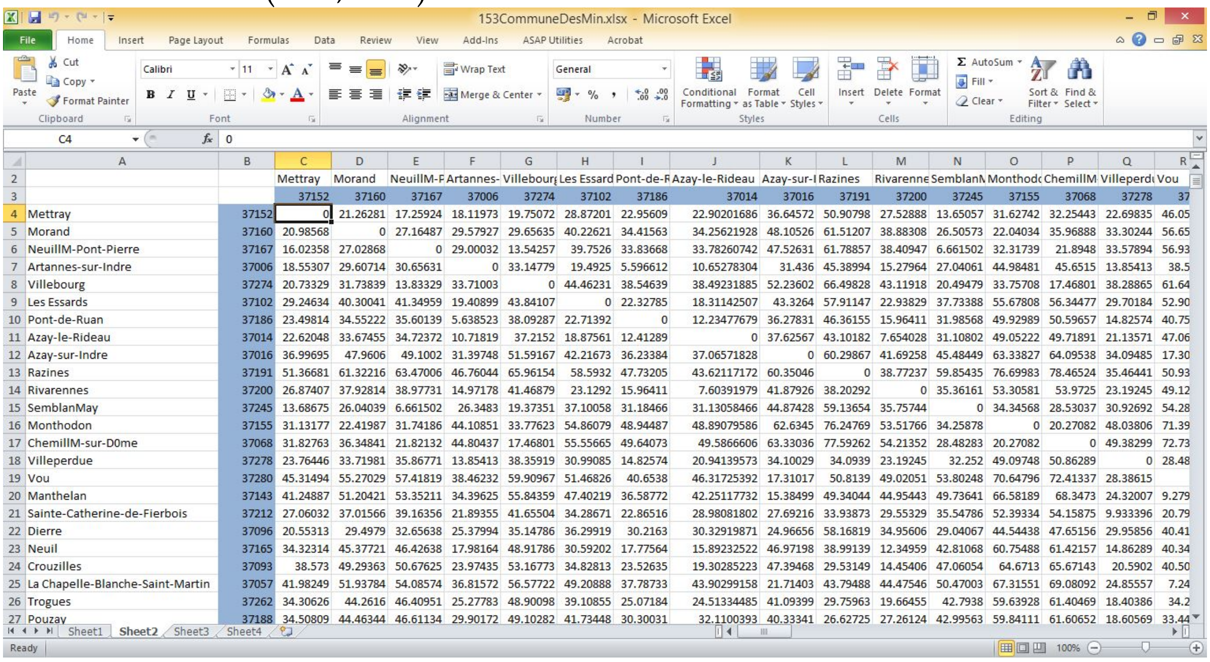
Annexure 3 OD Matrix

The cost OD matrix from ArcGis we exported to dBASE and .txt file format to work in Excel. Finally using excel we constructed OD Matrix for 153 towns in the Department Indre-et-Loire as seen below



		Mettray	Morand	NeuillM-F	Artannes-	Villebour	Les Essard	Pont-de-R	Azay-le-Rideau	Azay-sur-I	Razines	Rivarenne	SemblanM	Monthodo	ChemillM	Villeperdu	Vou
		37152	37160	37167	37006	37274	37102	37186	37014	37016	37191	37200	37245	37155	37068	37278	37
Mettray	37152	0	32240.32	15303.82	23851.95	26728.56	35515.31	26890.19	30455.70694	39403.07	64773.16	37661.36	11123.57	28716.05	25939.43	33084.46	4629
Morand	37160	31993.06	0	38043.94	49059.42	41841.56	65031.78	52097.66	56318.53433	44488.96	89329.25	66061.27	38587.56	20237.44	31650.05	56306.96	5934
NeuillM-Pont-Pierre	37167	15305	40034.4	0	35463.47	11424.74	33852.09	38501.7	37392.98211	52553.01	72815.37	40824.9	5881.413	27156.94	17203.11	45312.44	5944
Artannes-sur-Indre	37006	23955.2	49124.19	35686.92	0	47111.66	25686.09	3591.577	10951.86269	32515.82	41428.84	20631.34	31313.76	49805.33	48410.06	10849.74	3219
Villebourg	37274	26729.74	41844.66	11424.74	46888.2	0	42180.5	49926.44	48664.36619	63977.75	84086.76	51561.57	17306.15	26891.21	12670.08	56737.18	7087
Les Essards	37102	35290.12	65372.2	33852.8	25432.46	42453.98	0	27684.43	20646.9985	57840.18	54271.72	20747.45	31273.21	59716.03	50985.22	35978.27	5762
Pont-de-Ruan	37186	27027.48	52196.46	38759.2	3623.415	50183.93	27954.59	0	10695.91718	34558.94	39851.24	18685.64	34386.04	52877.6	51482.33	11249.19	3352
Azay-le-Rideau	37014	30778.89	56648.07	37817.97	11002.82	49089.35	20505.96	10862.8	0	43442.94	37183.25	11299.57	33818.13	57329.21	54935.77	18286.93	4055
Azay-sur-Indre	37016	39872.6	44500.85	53133.33	32539.04	64558.07	58075.9	34585.66	43415.1906	0	55529.99	51625.42	48760.17	58444.88	62608.29	28195.67	160
Razines	37191	64946.13	89718.89	73825.29	41426.79	85096.68	54821.08	39849.19	37793.21153	54536.29	0	36628.74	69825.46	90400.03	89004.76	35254.55	4235
Rivarennes	37200	37415.5	66041.67	40776.72	20671.86	51813.75	20711.88	18694.32	11320.13127	51607.38	36043.8	0	36776.88	65217.05	57894.52	25596.86	4786
SemblanMay	37245	11124.8	38828.62	5881.413	31090.36	17306.15	31317.31	34128.6	33397.18269	48179.91	68819.57	36829.1	0	30404.55	23082.02	40939.33	5507
Monthodon	37155	28600.76	20244.99	27156.94	50019.15	26891.21	59724.35	53057.39	57278.26322	58603.15	90530.47	65220.71	30406.4	0	15046.8	57508.18	7097
ChemillM-sur-D0me	37068	25939.43	31657.6	17200.01	48271.94	12670.08	50981.41	51310.18	54466.2669	62430.91	88958.75	57898.18	23081.42	15082.31	0	56691.82	70
Villeperdue	37278	33530.46	57122.83	45646.18	10849.74	57070.92	36423.24	11321.56	18120.04278	28154.81	35260.68	25588.18	41273.03	58246.02	57437.13	0	2373
Vou	37280	47581.82	59098.61	60387.85	32187.48	71812.59	57873.57	33592.85	40391.3316	15977.04	44200.55	47859.47	56014.69	70733.69	70524.35	23753.52	
Manthelan	37143	42857.05	55513.71	55663.08	27791.81	67087.82	53477.9	29197.19	35995.66801	13878.68	42073.22	43463.8	51289.92	66184.57	65799.58	19357.85	6395.
Sainte-Catherine-de-Fierbois	37212	38188.04	59476.55	50994.07	17794.96	62418.81	43368.47	18266.79	25065.26606	25156.51	32180.91	31008.78	46620.92	61973.17	61300.34	7302.418	1747
Dierre	37096	30251.19	26555.29	43511.92	34341.46	54936.66	53698.7	36903.85	42690.47701	20734.33	66753.76	52810.71	39138.77	40304.4	49112.62	36565.59	3463
Neuil	37165	37298.33	62111.82	49030.05	13819.73	60454.79	30660.47	11916.74	13158.02606	37932.68	30341.45	17154.45	44656.89	62792.96	61397.69	10975.67	3183
Crouzilles	37093	45285.93	70454.91	54258.7	21881.87	65530.08	35416.82	19904.33	18226.61573	42628.65	22871.1	18090.45	50258.86	71136.06	69740.78	17432.71	3373
La Chapelle-Blanche-Saint-Martin	37057	47146.62	62065.57	59952.65	30175.95	71377.39	55749.45	30647.77	37446.24897	21202.79	38314.35	43389.77	55579.49	70714.26	70089.15	19683.4	5998.
Trogues	37262	44992.66	69765.41	56724.37	21473.31	68149.11	39540.51	19895.72	22350.30741	38878.66	22349.94	22207.9	52351.22	70446.55	69051.28	15937.82	2900
Pouzay	37188	48287.13	71989.59	60018.85	24767.79	71443.59	44017.25	23190.19	26514.79973	37604.41	19012.28	27612.84	55645.69	73112.78	72345.75	17731.03	2773

Figure: OD Matrix: Network distance in meters
Source: BD TOPO (IGN, 2014)



		Mettray	Morand	NeuillM-F	Artannes-	Villebour	Les Essard	Pont-de-R	Azay-le-Rideau	Azay-sur-I	Razines	Rivarenne	SemblanM	Monthodo	ChemillM	Villeperdu	Vou
		37152	37160	37167	37006	37274	37102	37186	37014	37016	37191	37200	37245	37155	37068	37278	37
Mettray	37152	0	21.26281	17.25924	18.11973	19.75072	28.87201	22.95609	22.90201686	36.64572	50.90798	27.52888	13.65057	31.62742	32.25443	22.69835	46.05
Morand	37160	20.98568	0	27.16487	29.57927	29.65635	40.22621	34.41563	34.25621928	48.10526	61.51207	38.88308	26.50573	22.04034	35.96888	33.30244	56.65
NeuillM-Pont-Pierre	37167	16.02358	27.02868	0	29.00032	13.54257	39.7526	33.83668	33.78260742	47.52631	61.78857	38.40947	6.661502	32.31739	21.8948	33.57894	56.93
Artannes-sur-Indre	37006	18.55307	29.60714	30.65631	0	33.14779	19.4925	5.596612	10.65278304	31.436	45.38994	15.27964	27.04061	44.98481	45.6515	13.85413	38.5
Villebourg	37274	20.73329	31.73839	13.83329	33.71003	0	44.46231	38.54639	38.49231885	52.23602	66.49828	43.11918	20.49479	33.75708	17.46801	38.28865	61.64
Les Essards	37102	29.24634	40.30041	41.34959	19.40899	43.84107	0	22.32785	18.31142507	43.3264	57.91147	22.93829	37.73388	55.67808	56.34477	29.70184	52.90
Pont-de-Ruan	37186	23.49814	34.55222	35.60139	5.638523	38.09287	22.71392	0	12.23477679	36.27831	46.36155	15.96411	31.98568	49.92989	50.59657	14.82574	40.75
Azay-le-Rideau	37014	22.62048	33.67455	34.72372	10.71819	37.2152	18.87561	12.41289	0	37.62567	43.10182	7.654028	31.10802	49.05222	49.71891	21.13571	47.06
Azay-sur-Indre	37016	36.99695	47.9606	49.1002	31.39748	51.59167	42.21673	36.23384	37.06571828	0	60.29867	41.69258	45.48449	63.33827	64.09538	34.09485	17.30
Razines	37191	51.36681	61.32216	63.47006	46.76044	65.96154	58.5932	47.73205	43.62117172	60.35046	0	38.77237	59.85435	76.69983	78.46524	35.46441	50.93
Rivarennes	37200	26.87407	37.92814	38.97731	14.97178	41.46879	23.1292	15.96411	7.60391979	41.87926	38.20292	0	35.36161	53.30581	53.9725	23.19245	49.12
SemblanMay	37245	13.68675	26.04039	6.661502	26.3483	19.37351	37.10058	31.18466	31.13058466	44.87428	59.13654	35.75744	0	34.34568	28.53037	30.92692	54.28
Monthodon	37155	31.13177	22.41987	31.74186	44.10851	33.77623	54.86079	48.94487	48.89079586	62.6345	76.24769	53.51766	34.25878	0	20.27082	48.03806	71.39
ChemillM-sur-D0me	37068	31.82763	36.34841	21.82132	44.80437	17.46801	55.55665	49.64073	49.5866606	63.33036	77.59262	54.21352	28.48283	20.27082	0	49.38299	72.73
Villeperdue	37278	23.76446	33.71981	35.86771	13.85413	38.35919	30.99085	14.82574	20.94139573	34.10029	34.0939	23.19245	32.252	49.09748	50.86289	0	28.48
Vou	37280	45.31494	55.27029	57.41819	38.46232	59.90967	51.46826	40.6538	46.31725392	17.31017	50.8139	49.02051	53.80248	70.64796	72.41337	28.38615	
Manthelan	37143	41.24887	51.20421	53.35211	34.39625	55.84359	47.40219	36.58772	42.25117732	15.38499	49.34044	44.95443	49.73641	66.58189	68.3473	24.32007	9.279
Sainte-Catherine-de-Fierbois	37212	27.06032	37.01566	39.16356	21.89355	41.65504	34.28671	22.86516	28.98081802	27.69216	33.93873	29.55329	35.54786	52.39334	54.15875	9.933396	20.79
Dierre	37096	20.55313	29.4979	32.65638	25.37994	35.14786	36.29919	30.2163	30.32919871	24.96656	58.16819	34.95606	29.04067	44.54438	47.65156	29.95856	40.41
Neuil	37165	34.32314	45.37721	46.42638	17.98164	48.91786	30.59202	17.77564	15.89232522	46.97198	38.99139	12.34959	42.81068	60.75488	61.42157	14.86289	40.34
Crouzilles	37093	38.573	49.29363	50.67625	23.97435	53.16773	34.82813	23.52635	19.30285223	47.39468	29.53149	14.45406	47.06054	64.6713	65.67143	20.5902	40.50
La Chapelle-Blanche-Saint-Martin	37057	41.98249	51.93784	54.08574	36.81572	56.57722	49.20888	37.78733	43.90299158	21.71403	43.79488	44.47546	50.47003	67.31551	69.08092	24.85557	7.24
Trogues	37262	34.30626	44.2616	46.40951	25.27783	48.90098	39.10855	25.07184	24.51334485	41.09399	29.75963	19.66455	42.7938	59.63928	61.40469	18.40386	34.2
Pouzay	37188	34.50809	44.46344	46.61134	29.90172	49.10282	41.73448	30.30031	32.1100393	40.33341	26.62725	27.26124	42.99563	59.84111	61.60652	18.60569	33.44

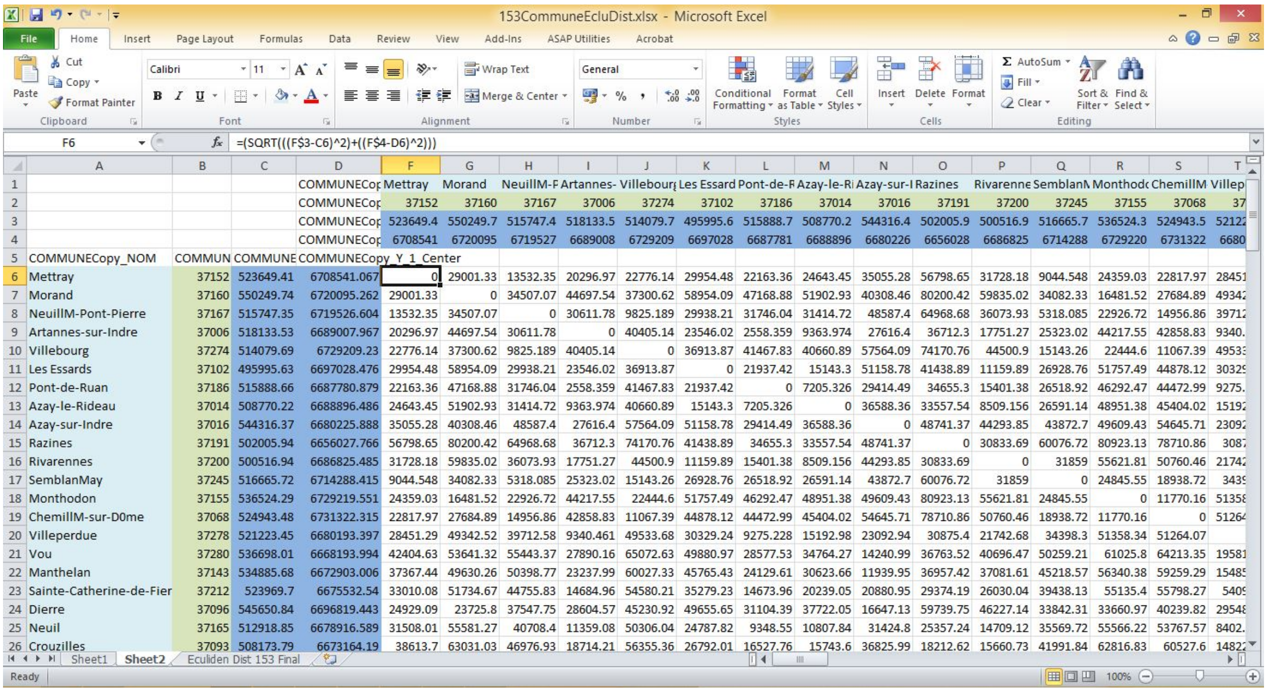
Figure: OD Matrix: Time Distance in Minutes
Source: BD TOPO (IGN, 2014)

Annexure 4 Euclidean Distance

In that same way of generating network distance OD matrix we can generate the Euclidean distance OD matrix using centroids of the each commune. Here we don't use road network data set. This is the shortest distance between the centroid points of each commune. We need the x and y centroids of each commune. To calculate the centroids we can use the tool "Calculate geometry" in ArcGis. By knowing the centroids of each commune we can calculate the Euclidean distance using standard formula

$$\text{Euclidean Distance D} = \sqrt{(X1 - Y1)^2 + (X2 - Y2)^2}$$

Were, X and Y are centroids



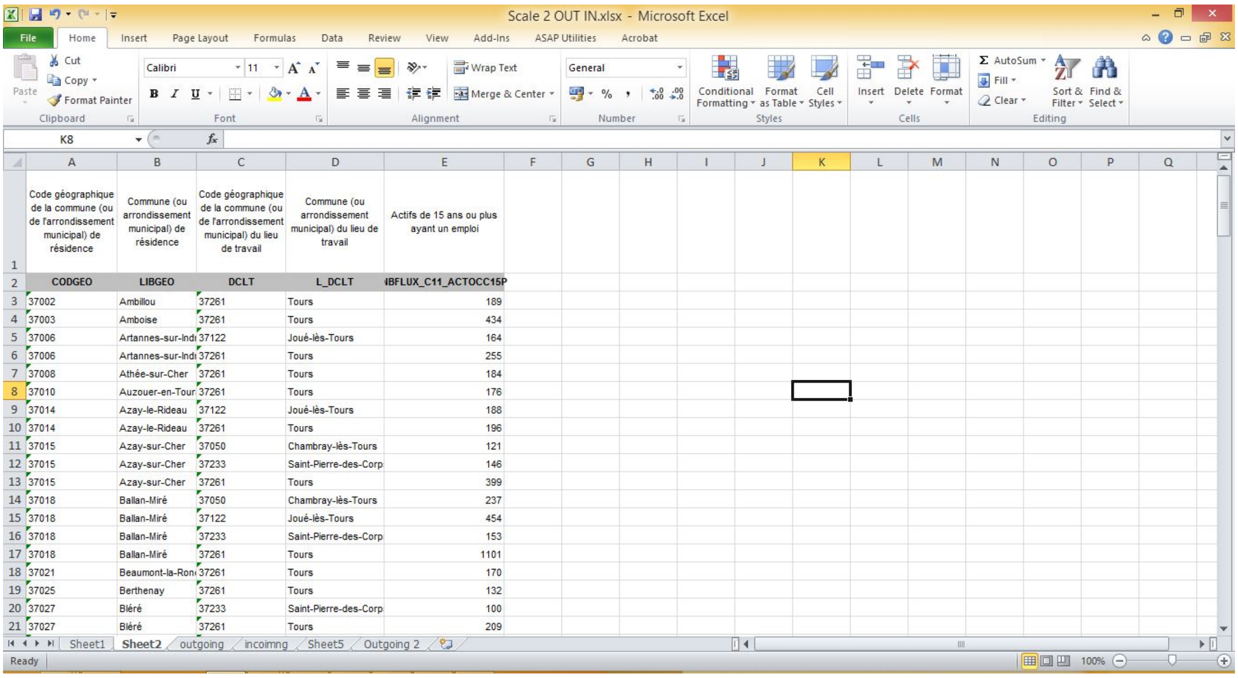
F6 =(SQRT(((F$3-C6)^2)+((F$4-D6)^2)))

	A	B	C	D	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1				COMMUNECop	Mettray	Morand	NeuillM-F	Artannes-	Villebourg	Les Essard	Pont-de-R	Azay-le-Ri	Azay-sur-I	Razines	Rivarenne	SemblanM	Monthodo	ChemillM	Villep
2				COMMUNECop	37152	37160	37167	37006	37274	37102	37186	37014	37016	37191	37200	37245	37155	37068	37
3				COMMUNECop	523649.4	550249.7	515747.4	518133.5	514079.7	495995.6	515888.7	508770.2	544316.4	502005.9	500516.9	516665.7	536524.3	524943.5	52122
4				COMMUNECop	6708541	6720095	6719527	6689008	6729209	6697028	6687781	6688896	6680226	6656028	6686825	6714288	6729220	6731322	6680
5	COMMUNECopy_NOM	COMMUN	COMMUNE	COMMUNECopy_Y_1_Center															
6	Mettray	37152	523649.41	6708541.067	0	29001.33	13532.35	20296.97	22776.14	29954.48	22163.36	24643.45	35055.28	56798.65	31728.18	9044.548	24359.03	22817.97	28451
7	Morand	37160	550249.74	6720095.262	29001.33	0	34507.07	44697.54	37300.62	58954.09	47168.88	51902.93	40308.46	80200.42	59835.02	34082.33	16481.52	27684.89	49342
8	NeuillM-Pont-Pierre	37167	515747.35	6719526.604	13532.35	34507.07	0	30611.78	9825.189	29938.21	31746.04	31414.72	48587.4	64968.68	36073.93	5318.085	22926.72	14956.86	39712
9	Artannes-sur-Indre	37006	518133.53	6689007.967	20296.97	44697.54	30611.78	0	40405.14	23546.02	2558.359	9363.974	27616.4	36712.3	17751.27	25323.02	44217.55	42858.83	9340.
10	Villebourg	37274	514079.69	6729209.23	22776.14	37300.62	9825.189	40405.14	0	36913.87	41467.83	40660.89	57564.09	74170.76	44500.9	15143.26	22444.6	11067.39	49533
11	Les Essards	37102	495995.63	6697028.476	29954.48	58954.09	29938.21	23546.02	36913.87	0	21937.42	15143.3	51158.78	41438.89	11159.89	26928.76	51757.49	44878.12	30329
12	Pont-de-Ruan	37186	515888.66	6687780.879	22163.36	47168.88	31746.04	2558.359	41467.83	21937.42	0	7205.326	29414.49	34655.3	15401.38	26518.92	46292.47	44472.99	9275.
13	Azay-le-Rideau	37014	508770.22	6688896.486	24643.45	51902.93	31414.72	9363.974	40660.89	15143.3	7205.326	0	36588.36	33557.54	8509.156	26591.14	48951.38	45404.02	15192
14	Azay-sur-Indre	37016	544316.37	6680225.888	35055.28	40308.46	48587.4	27616.4	57564.09	51158.78	29414.49	36588.36	0	48741.37	44293.85	43872.7	49609.43	54645.71	23092
15	Razines	37191	502005.94	6656027.766	56798.65	80200.42	64968.68	36712.3	74170.76	41438.89	34655.3	33557.54	48741.37	0	30833.69	60076.72	80923.13	78710.86	3087
16	Rivarennes	37200	500516.94	6686825.485	31728.18	59835.02	36073.93	17751.27	44500.9	11159.89	15401.38	8509.156	44293.85	30833.69	0	31859	55621.81	50760.46	21742
17	SemblanMay	37245	516665.72	6714288.415	9044.548	34082.33	5318.085	25323.02	15143.26	26928.76	26518.92	26591.14	43872.7	60076.72	31859	0	24845.55	18938.72	3439
18	Monthodon	37155	536524.29	6729219.551	24359.03	16481.52	22926.72	44217.55	22444.6	51757.49	46292.47	48951.38	49609.43	80923.13	55621.81	24845.55	0	11770.16	51358
19	ChemillM-sur-D0me	37068	524943.48	6731322.315	22817.97	27684.89	14956.86	42858.83	11067.39	44878.12	44472.99	45404.02	54645.71	78710.86	50760.46	18938.72	11770.16	0	51264
20	Villeperdue	37278	521223.45	6680193.397	28451.29	49342.52	39712.58	9340.461	49533.68	30329.24	9275.228	15192.98	23092.94	30875.4	21742.68	34398.3	51358.34	51264.07	
21	Vou	37280	536698.01	6668193.994	42404.63	53641.32	55443.37	27890.16	65072.63	49880.97	28577.53	34764.27	14240.99	36763.52	40696.47	50259.21	61025.8	64213.35	19581
22	Manthelan	37143	534885.68	6672903.006	37367.44	49630.26	50398.77	23237.99	60027.33	45765.43	24129.61	30623.66	11939.95	36957.42	37081.61	45218.57	56340.38	59259.29	15485
23	Sainte-Catherine-de-Fier	37212	523969.7	6675532.54	33010.08	51734.67	44755.83	14684.96	54580.21	35279.23	14673.96	20239.05	20880.95	29374.19	26030.04	39438.13	55135.4	55798.27	5409
24	Dierre	37096	545650.84	6696819.443	24929.09	23725.8	37547.75	28604.57	45230.92	49655.65	31104.39	37722.05	16647.13	59739.75	46227.14	33842.31	33660.97	40239.82	29548
25	Neuil	37165	512918.85	6678916.589	31508.01	55581.27	40708.4	11359.08	50306.04	24787.82	9348.55	10807.84	31424.8	25357.24	14709.12	35569.72	55566.22	53767.57	8402.
26	Crouzilles	37093	508173.79	6673164.19	38613.7	63031.03	46976.93	18714.21	56355.36	26792.01	16527.76	15743.6	36825.99	18212.62	15660.73	41991.84	62816.83	60527.6	14822

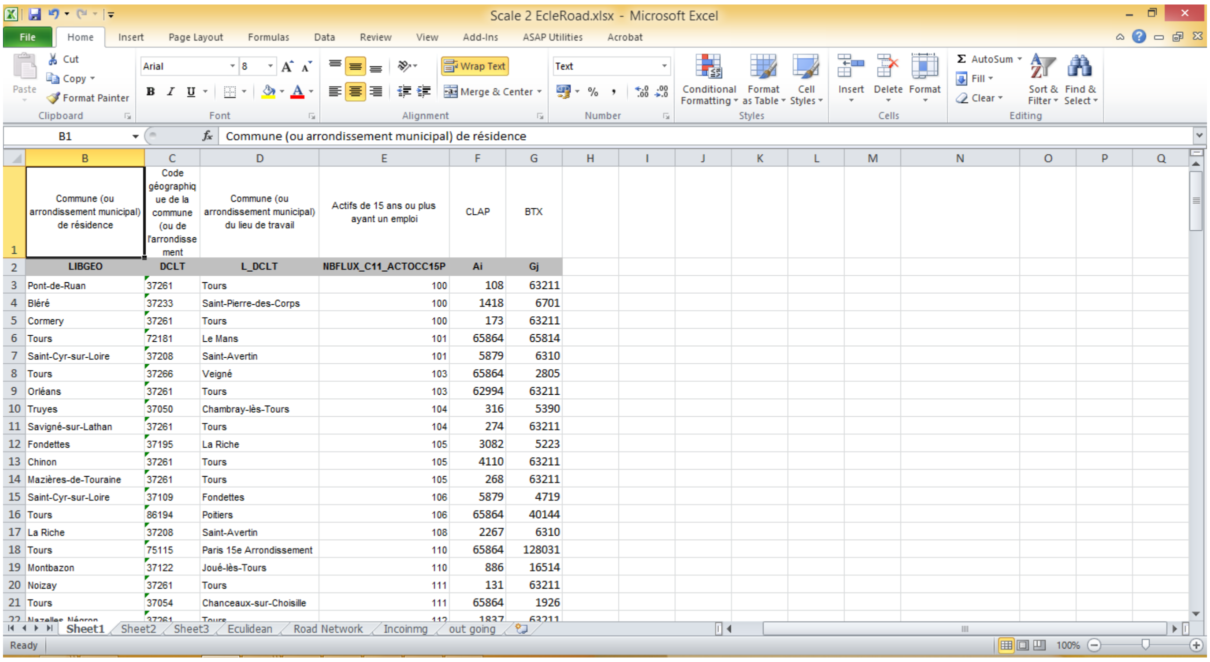
Figure: OD Matrix: Euclidean Distance in Meters
Source: BD TOPO (IGN, 2014)

Annexure 5 Mobility Flow in Agglomeration of Tours

In order to apply the mobility flow in Gravity model we need to filter the data from INSEE for our required scale. Considering the Agglomeration of Tours which comprises of 22 communes and from the Mobility data, Mobility flow in agglomeration of Tours (22 towns) scale was sorted using excel advanced filters. There after we applied corresponding number of attractions and generations from the data CLAP and Residents Activity.



Code géographique de la commune (ou de l'arrondissement municipal) de résidence	Commune (ou arrondissement municipal) de résidence	Code géographique de la commune (ou de l'arrondissement municipal) du lieu de travail	Commune (ou arrondissement municipal) du lieu de travail	Actifs de 15 ans ou plus ayant un emploi
CODGEO	LIBGEO	DCLT	L_DCLT	NBFLUX_C11_ACTOCC15P
37002	Ambillou	37261	Tours	189
37003	Amboise	37261	Tours	434
37006	Artannes-sur-Indı	37122	Joué-lès-Tours	164
37006	Artannes-sur-Indı	37261	Tours	255
37008	Athée-sur-Cher	37261	Tours	184
37010	Auzouer-en-Tour	37261	Tours	176
37014	Azay-le-Rideau	37122	Joué-lès-Tours	188
37014	Azay-le-Rideau	37261	Tours	196
37015	Azay-sur-Cher	37050	Chambray-lès-Tours	121
37015	Azay-sur-Cher	37233	Saint-Pierre-des-Corp	146
37015	Azay-sur-Cher	37261	Tours	399
37018	Ballan-Miré	37050	Chambray-lès-Tours	237
37018	Ballan-Miré	37122	Joué-lès-Tours	454
37018	Ballan-Miré	37233	Saint-Pierre-des-Corp	153
37018	Ballan-Miré	37261	Tours	1101
37021	Beaumont-la-Ron	37261	Tours	170
37025	Berthenay	37261	Tours	132
37027	Bléré	37233	Saint-Pierre-des-Corp	100
37027	Bléré	37261	Tours	209



Commune (ou arrondissement municipal) de résidence	Code géographique de la commune (ou de l'arrondissement)	Commune (ou arrondissement municipal) du lieu de travail	Actifs de 15 ans ou plus ayant un emploi	CLAP	BTX
LIBGEO	DCLT	L_DCLT	NBFLUX_C11_ACTOCC15P	Ai	Gj
Pont-de-Ruan	37261	Tours	100	108	63211
Bléré	37233	Saint-Pierre-des-Corps	100	1418	6701
Cormery	37261	Tours	100	173	63211
Tours	72181	Le Mans	101	65864	65814
Saint-Cyr-sur-Loire	37208	Saint-Avertin	101	5879	6310
Tours	37266	Veigné	103	65864	2805
Orléans	37261	Tours	103	62994	63211
Truyes	37050	Chambray-lès-Tours	104	316	5390
Savigné-sur-Lathan	37261	Tours	104	274	63211
Fondettes	37195	La Riche	105	3082	5223
Chinon	37261	Tours	105	4110	63211
Mazières-de-Touraine	37261	Tours	105	268	63211
Saint-Cyr-sur-Loire	37109	Fondettes	106	5879	4719
Tours	86194	Poitiers	106	65864	40144
La Riche	37208	Saint-Avertin	108	2267	6310
Tours	75115	Paris 15e Arrondissement	110	65864	128031
Montbazon	37122	Joué-lès-Tours	110	886	16514
Noizay	37261	Tours	111	131	63211
Tours	37054	Chanceaux-sur-Choisille	111	65864	1926

Fig: Mobility flow, CLAP, Active people for Agglomeration of Tours scale in Excel

Annexure 6 Linear regression analysis results

Linear regression line after applying the gravity model of the 22 communes Agglomeration of Tours: Euclidean Distance

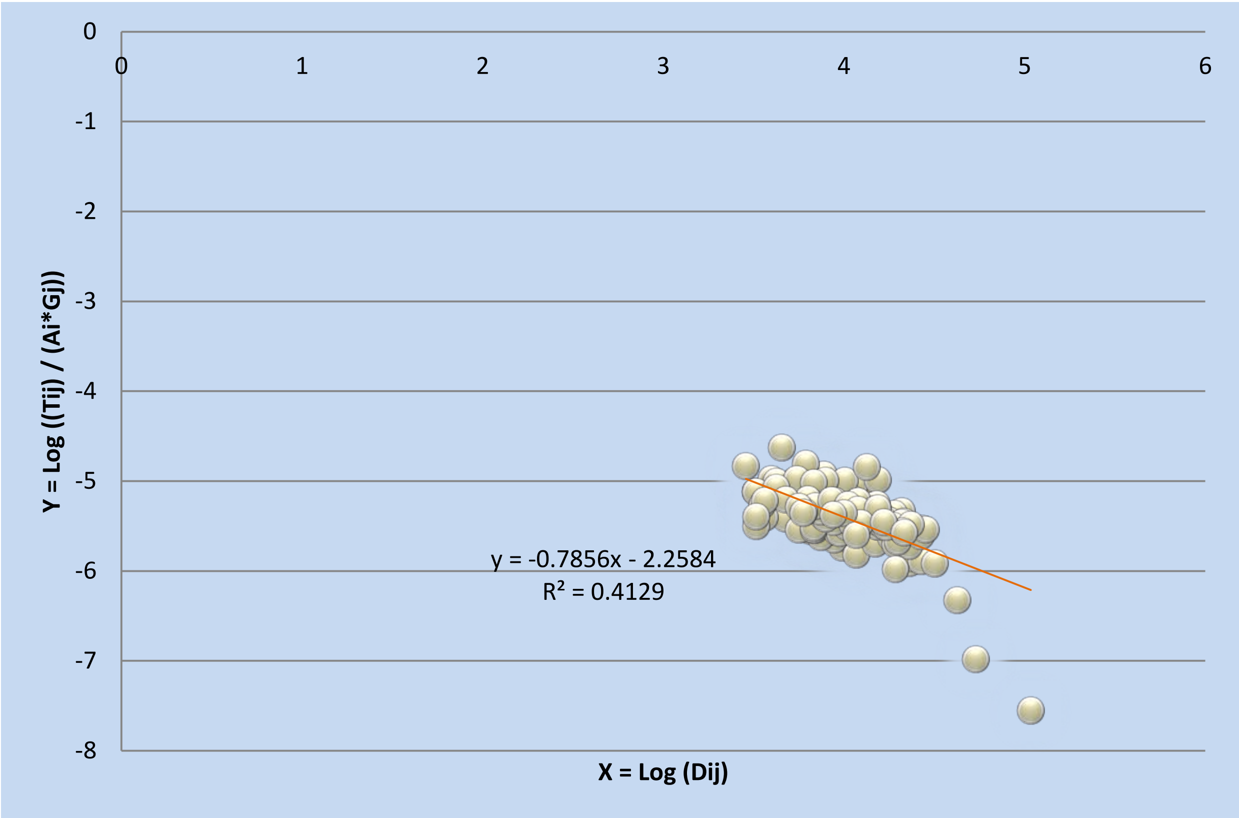


Figure: Linear regression line for Euclidean distance

Source: INSEE, BD TOPO (IGN, 2014)

Linear regression line after applying the gravity model of the 22 communes Agglomeration of Tours: Network Distance

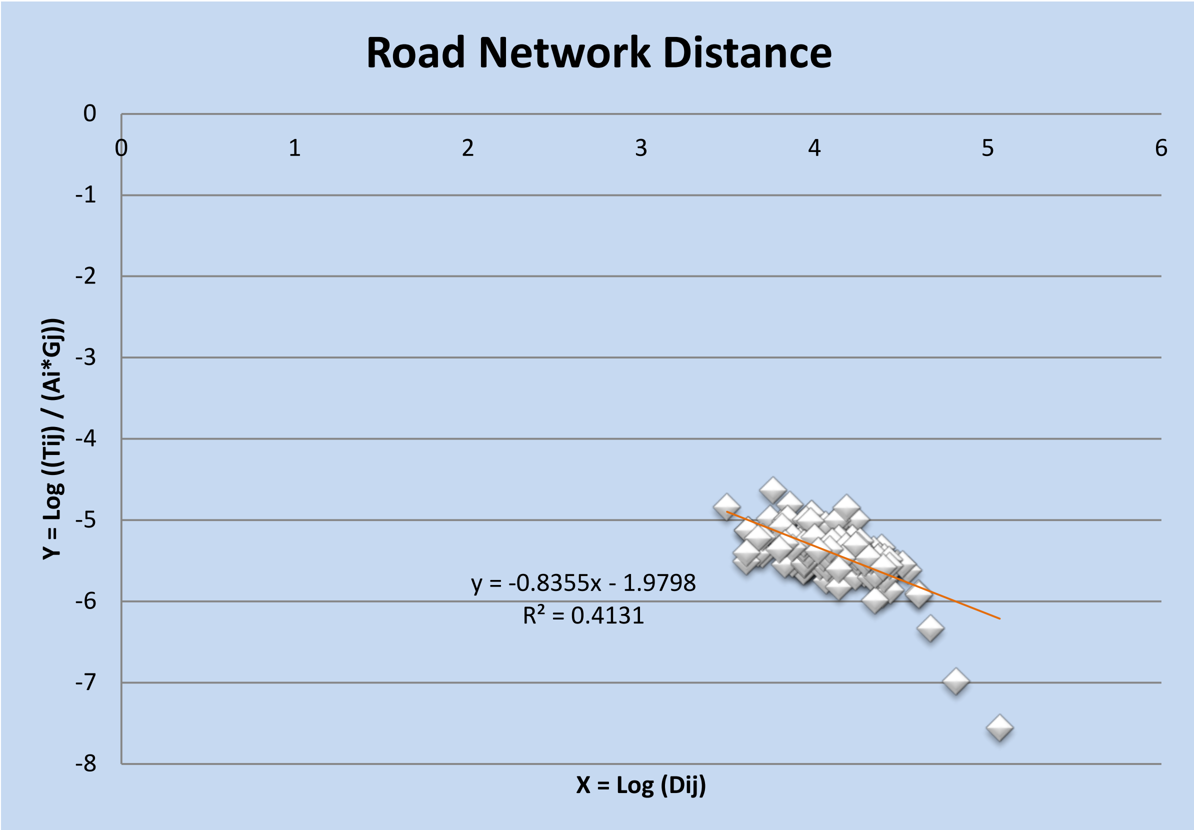


Figure: Linear regression line for Network Distance

Source: INSEE, BD TOPO (IGN, 2014)

Linear regression line after applying the gravity model of the 22 communes Agglomeration of Tours: Distance in Time (Minutes)

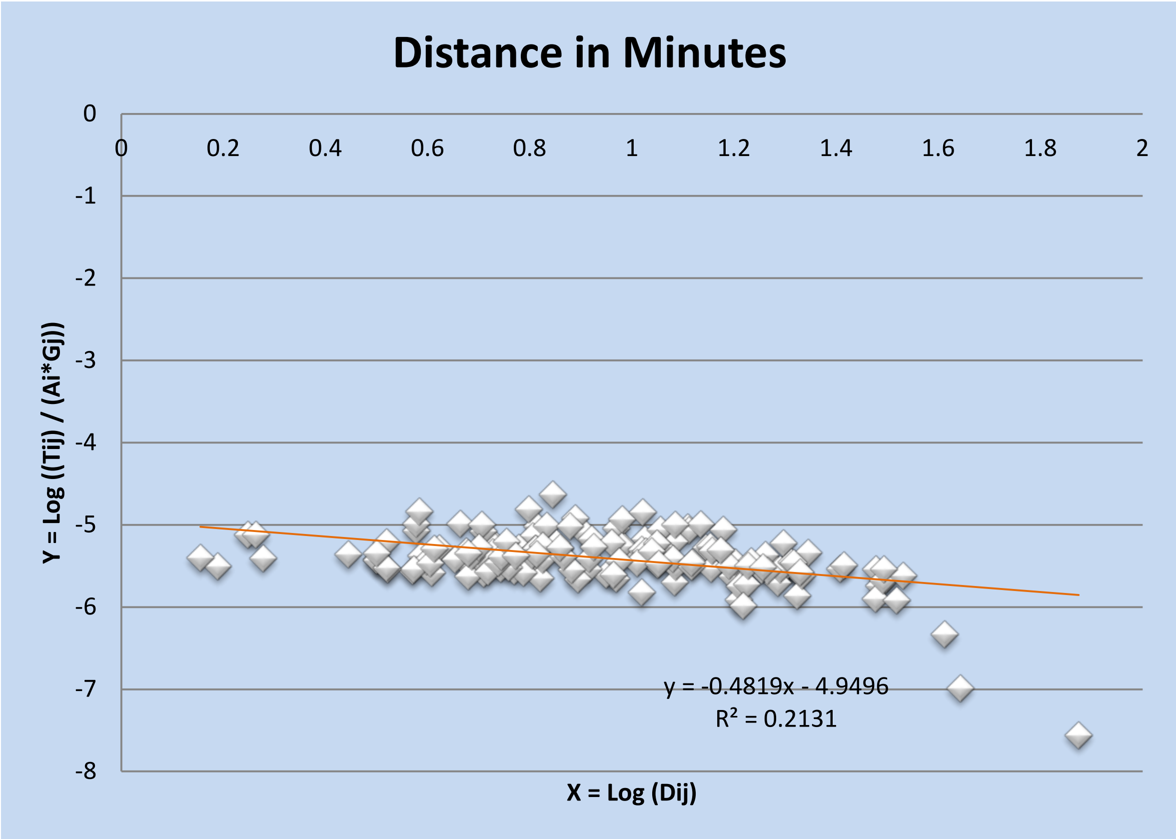


Figure: Linear regression line for Distance in Time (Minutes)

Source: INSEE, BD TOPO (IGN, 2014)

Linear regression line after applying the gravity model of the 22 communes Agglomeration of Tours: Distance in Time (Minutes) and considering 20% Traffic Congestion

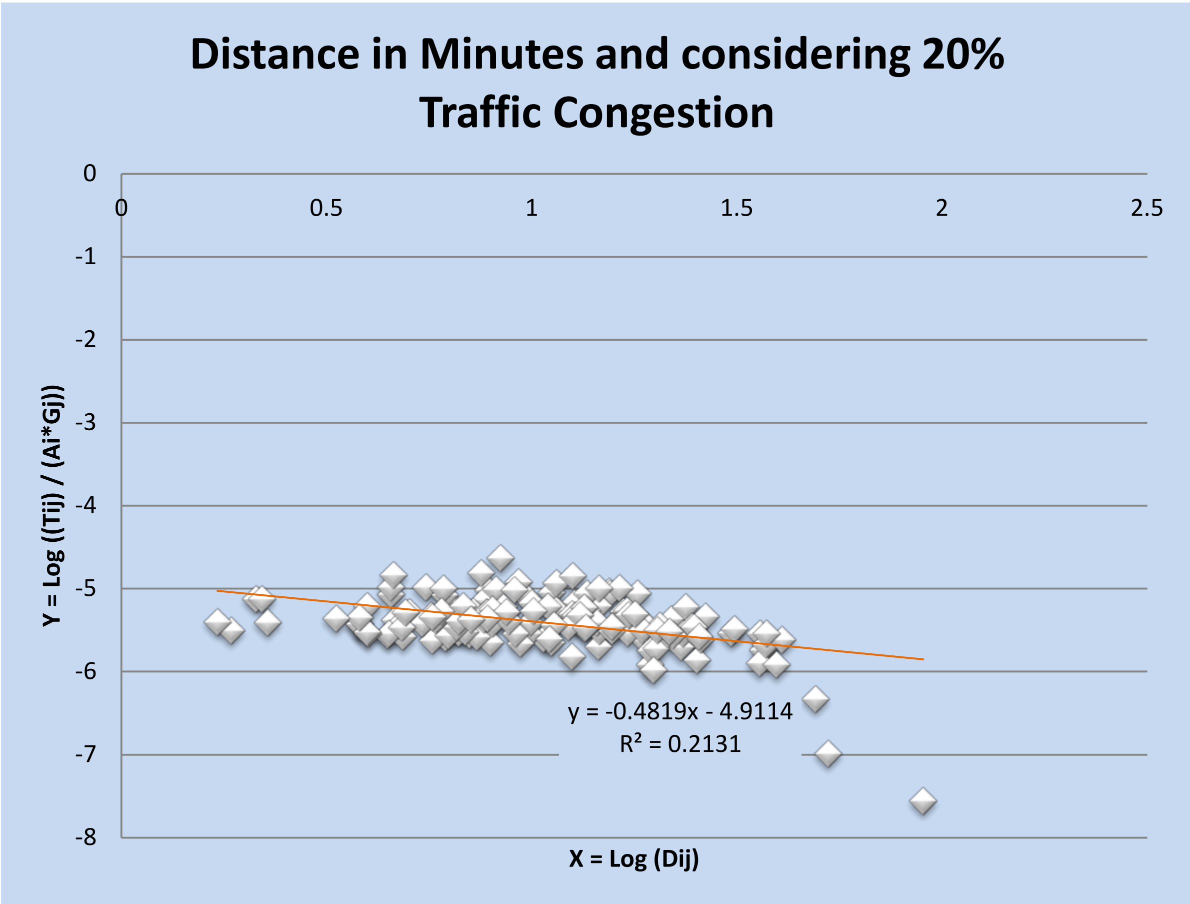


Figure: Linear regression line for Distance in Time (Minutes) and considering 20% Traffic Congestion

Source: INSEE, BD TOPO (IGN, 2014)

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Mobility Analysis using Gravity Model

Abstract :

Mobility refers to the movement of goods or people from one place to another. In this research, Department Indre-et-Loire is chosen as the site as it is the main attraction generation point in Tours Centre. The site is considered into four scales of different administrative boundary. For this site, data such as number of people moving from home to work, number of people active and number of jobs available are taken into account as statistical data and distances between towns as spatial data to analyze the gravity model to find the good correlation of mobility flow.

“What is the suitable scale to obtain workers flow?” that is in case of we predicting the future flow for a site we should know the right scale to apply model and to get correct flow. In case the new developments are such as housing, industries, colleges, commercial shops, etc. then the future flow of that certain area will be different to find that we should know the right scale and good correlation.

Keywords :
Mobility, Gravity Model, Urban Sprawl, Accessibility, Scale

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