Using Accessibility Indicators to Investigate Urban Growth and Motorcycles Use in Ha Noi City, Vietnam

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Abstract: To investigate the impact of urban growth on motorcycles use in Ha Noi City, Vietnam, this paper maps and analysis three types of accessibility indicators. The results show that the levels of accessibility to jobs by public transport are very poor as compared to motorcycle and car, explaining the very low share of public transport in the modal split. People living in satellite cities and towns experience very poor levels of accessibility to jobs for all transport modes, including motorcycle. The analysis shows that most urban growth takes place in areas that have relatively high levels of accessibility to jobs by motorcycle or car. This result can help to explain why Hanoians “like” to use motorcycle rather than public transport and why urban growth is not taking place in satellite cities or towns as generally assumed but concentrates around the main (accessible part of the) city.

Keywords: Accessibility to jobs, Ha Noi, urban growth, motorcycle, average travel time.

1. INTRODUCTION

Since the Doi Moi policy, which was launched in 1986, Ha Noi’s - the capital city of Vietnam - administration has been transformed rapidly from a highly centralized planning system (i.e. a planned economy) into an open market system with much more economic diversity. Since then, Ha Noi has been witnessing a rapid urbanization and motorization, further stimulated by an accelerated economic growth in association with high levels of industrialization. This becomes particularly clear from population statistics that has increased from 5.3 million in 2002 to about 6.7 million in late 2010 (Ha Noi Statistical Bureau). Ha Noi’s population is expected to further increase to about 8.0 million by 2020 and 10.0 million in 2030. Levels of urbanization were about 33% in 2000, 39% in 2005, and 40% in 2009 and are expected to increase further to about 65-70% by 2030 (PPJ 2010). It is evident that urban growth has been particularly fast and dynamic in the main city, whereas there has almost been no urban development in the satellite cities and other small towns around Ha Noi which were expected to grow after the shift away from the planned economy. One of the reasons for this may be the inequalities in transport accessibility.

Ha Noi's transportation system can be characterized by its high share of private motorcycles (MC), which account for about 70% of the total passenger daily trips, while public transport (PT), conventional buses, only accommodates about 10% of the total travel demand (JICA 2007; PPJ 2010). In 2009, the total number of private registered cars in Ha Noi was 255,400 car units while the number of motorcycles was tenfold with 2.54 million units (Quỳnh Như 2009). By the end of 2011, this figure had gone up, to about 3.8 million of motorcycles (Chung Hoàng 2012), still 90% of the motorized vehicle fleet. This growth rate of private motorcycles and cars in Ha Noi of about 12-15%/year (Quỳnh Như 2009) is putting high pressure on Ha Noi's transport system. According to JICA (2007), 84% of the households own a motorcycle, of which 40% have more than two. Car ownership is about 15-20 car units/1.000 inhabitants while motorcycle ownership is about 600 units/1.000 inhabitants (Anh Tuấn 2012). It is observed that most working class people use motorcycles while very few use buses for their daily travel. The main customers of the bus seem to be students and retired people (JICA 2007, Annex 2: Urban Transportation; Online survey in 2012 by the first author).

Such rapid urbanization in combination with high rates of motorization are putting high pressure on urban infrastructure, especially the transport system, and cause many urban problems such as urban sprawl, informal settlements, traffic congestion, air pollution, etc. Even under such circumstances, in 2008, Vietnam government decided to expand the urban area by three times (from 921 km^2 to about 3,000 km^2) and to plan for the city to change from a mono-centric into a poly-centric land-use form with 5 satellite cities around (PPJ 2010). A master plan for 2030 with a vision to 2050 for new Ha Noi has been prepared by an international joint-venture of Korean and American consultants, i.e. Perkins Eastman, Posco E&C and JINA (PPJ). According to this master plan, a massive transport infrastructure, including an urban mass rapid transit (UMRT) system, will be introduced. Besides this, job creation will be targeted in the satellite cities to increase opportunities for outmigration. It is expected that people living in the main city can go to work in the satellite cities and vice versa. One of the ambitious targets in the master plan is a reduction in the use of private motorized vehicles and increase the share of public transport up to 50-60% by 2030 (PPJ 2010).

From an urban planning point of view, a number of important questions can be raised: Why do Hanoians stick to using their motorcycles rather than using public transport for their daily travel? Why does urban growth concentrate around the urban core only rather than in the satellite cities and is this possibly related with the dominant use of MC? With the current urbanization trend, where is this expected growth likely to concentrate? Will the development of satellite cities will take-off or will the main city maintain its dominant position as in the current trend? And will the emerging development patterns affect a potential shift from using motorcycle to using public transport system or to private car? Answering such questions requires some understanding of the peoples' travel behavior.

A person's day often typically starts at home and ends at home, and for most of people, other daily activities are constrained by the time they spend on their daily travel from home to work (Tilahun 2010). Daily travel is constrained by the time budget which is available for daily travel. It is recognized that for centuries the average travel time is relatively constant at aggregate level with just around 1.1+/- 0.2 hour per person a day (Hupkes 1982; Schafer & Victor 2000; Schafer 2000; Marchetti 1994; Tanner 1981; Zahavi & Talvitie 1980; Metz 2010; Metz 2008; Levinson & Kumar 1994; Schwanen & Dijst 2002; Godefrooij et al. 2009; Metz

2011). Therefore, daily travel time is an important factor in the decision of places to live and work as well as choice of transport mode. Due to the constrained time budget for daily travel then the daily travel time can determine whether people shift to higher mobility transport modes, shift their jobs or relocate their homes (to migrate to live near job locations) (Gordon et al, 1991; Tilahun, 2010). In cities of developed countries, the transport system is usually well integrated with the land use systems to bring opportunities (jobs and social facilities/services) closer to people, hence increasing levels of accessibility to jobs and social facilities/services, reducing or avoiding travel (in terms of numbers of trip and travel time/distance) and/or encouraging people to shift to public transport and non-motorized modes (PT+NMT) rather than using private motorized vehicles (MC and car) (Geurs 2006; van Wee & Maat 2003; van Wee 2002). In other words, people are likely to live in areas that provide them with high levels of accessibility to jobs/social services and travel time by available transport modes as long as this is within acceptable ranges. Accessibility indicators are usually applied to evaluate this integration of land-use and transport and the impacts/performance of policy plans on the functioning of the society in general (Geurs & van Eck, 2001; Geurs, 2006; Handy & Niemeier, 1997; van Wee & Maat, 2003; van Wee, 2002).

The main aim of this paper is to apply a number of accessibility indicators that focus on the accessibility to jobs to investigate the two mentioned urban problems (urbanization and motorization) in Ha Noi City, Vietnam. We start with the selection of accessibility indicators that is applied in the evaluations in section 2. The data preparation and all assumptions used in the modeling and evaluation are discussed in section 3. Next, the levels of accessibility to jobs in the past (2005) and present (2010) is mapped and discussed in section 4. The paper ends with some short conclusions.

We present the results of the investigation in the past (2005) and present (2010) only. Predictions of the future of Ha Noi are beyond the scope of this paper. Furthermore, given the dominance of motorcycles in contemporary Ha Noi, we will focus on accessibility evaluations between motorcycle and public transport only. The study area with Ha Noi and surrounding satellites, towns and road systems are shown in Figure 1.

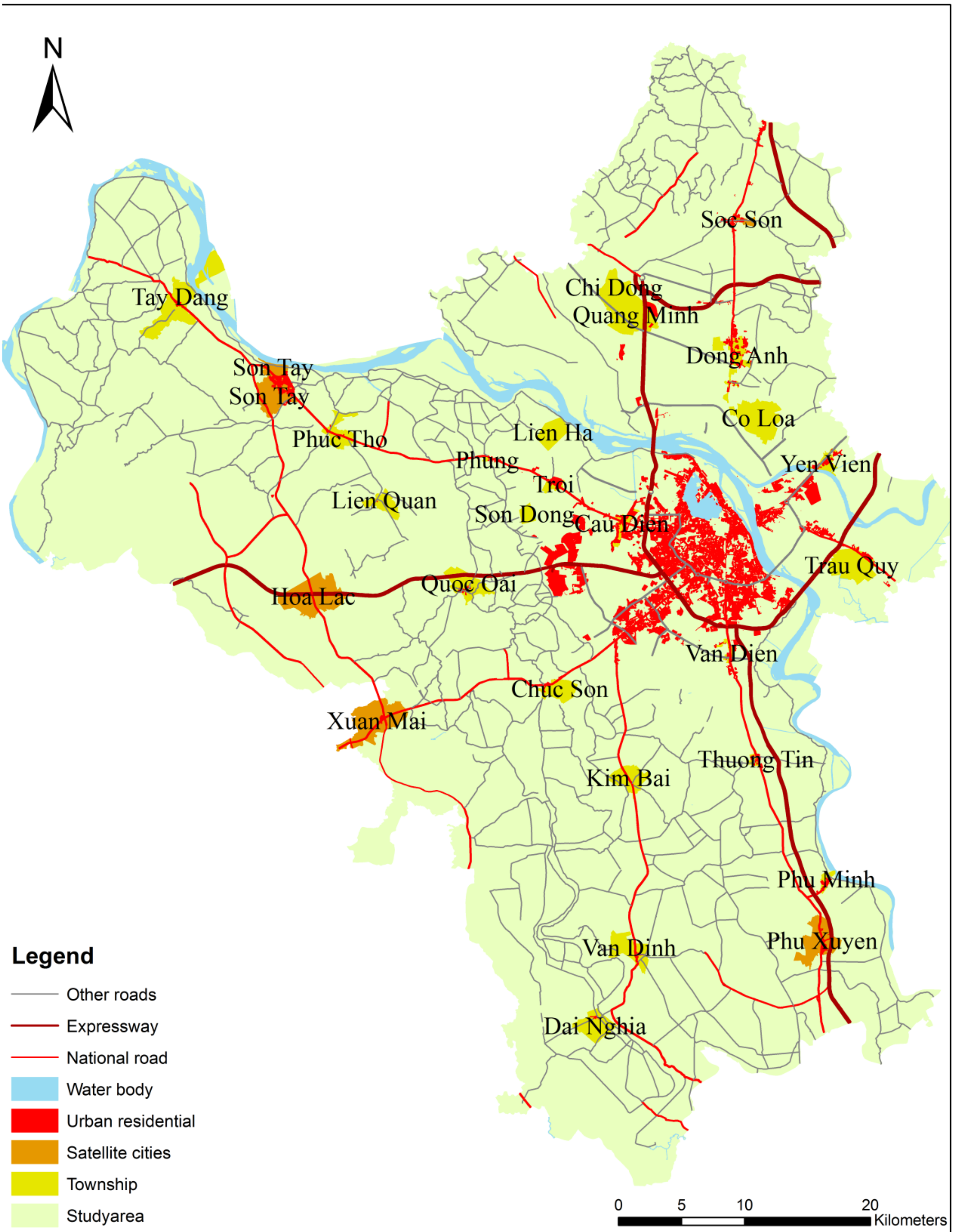

Figure 1: Ha Noi City, satellite cities and towns

2. SELECTION OF ACCESSIBILITY INDICATORS

A wide variety of accessibility measures have been developed in literature and can be categorized into three main groups (Handy & Niemeier 1997; El-Geneidy & Levinson 2006; Geurs & van Eck 2001; Geurs 2006):

(1) Infrastructure-based measures that describe the level of service of transport infrastructure. Typical indicators are congestion levels, travel time and average speeds on road network.

(2) Activity-based measures that describe the level of access to spatially distributed activities. Activity-based measures can be subdivided into:
   a. Location-based measures in which accessibility is analyzed at macro level
   b. Person-based measures in which accessibility is analyzed at micro level (Geurs, 2006).

(3) Utility-based measures that focus on the (economic) benefits people derive from access to spatially distributed activities.

Among the above mentioned measures, infrastructure-based measures do not include a land use component and they are typically used in transport planning field only. Person-based and utility-based measures typically focus mainly on the individual component, i.e. understanding personal behavior and choices at a disaggregate level (Geurs, 2006). Moreover, they require an intensive data which is very difficult to obtain for a large urban area such as Ha Noi (Ha et al., 2011). Therefore, these accessibility groups are considered not suitable for the Ha Noi case study. The location-based measures is more advantage since it takes into account both the land uses and transport system (Geurs, 2006). In practice, location-based measures are preferable and widely used in urban planning and geographical studies because this kind of measure provides a balance between required data and quality of results. Furthermore, they can generally be easily computed using existing land use and transport data, and/or models, traditionally employed as input for estimating infrastructure-based measures (Ha et al., 2011). Therefore, these measures are thus capable for evaluating integrated land use/transport infrastructure planning strategies. The location-based measures can again be subdivided further in contour based and potential accessibility based indicators (El-Geneidy & Levinson, 2006; Geurs & van Eck, 2001; Geurs, 2006; Handy & Niemeier, 1997; Koenig, 1980).

2.1 The Contour Based Accessibility Indicator (CT_{im})

The contour accessibility indicator (also known as isochronic or cumulative opportunity measure) indicates the number of opportunities reachable within a given travel time or distance, from a specific point of origin. This indicator indicates that accessibility increases if more opportunities can be reached within a given travel time or distance. The result depends on the transport component and the distribution of land use/activities in space, for example, the number of job. If $c_{ijm} \leq$ {predefined threshold distance or travel time between i and j by mode m}, the formula of this cumulative opportunity measure becomes:

$$CT_{im} = \sum_{j=1}^{n} O_j \quad \forall i, m \tag{1}$$

where CT_{im} is the accessibility in location i for mode m, O_j is the number of opportunities present in location j, and c_{ijm} is the travel impedance (measured in time or cost) between i and j by mode m.

2.2 The Potential Accessibility Indicator (A_{im})

The potential accessibility indicator (A_{im}) discounts the opportunities over the distance. As a consequence, the level of accessibility of a point of origin i increases relative to the number of opportunities (jobs for example) in destination j and is corrected for travel impedance c_{ijm} between i and j. The general formula reads as follows:

$$A_{im} = \sum_{j=1}^{n} O_j * f(c_{ijm}) \quad \forall i, m \tag{2}$$

where $f(c_{ijm})$ is the distance decay function (a monotonously decreasing function with increasing travel impedance) and other identifiers have the same meaning as in the formula 1.

Among all accessibility measures, potential accessibility measures are amongst the most popular accessibility measures, and have been widely used in urban and geographical studies (Geurs, 2006). So far, there are some newly modified accessibility indicators that have been developed from this traditional potential accessibility measure.

2.2.1 The Average Travel Time (T_{im})

Average travel time of a zone (T_{im}) was proposed and used by Geertman & Van Eck (1995), Guttiérrez (2009) and Gutiérrez et al. (1996) as an alternative to the potential accessibility indicator in formula 2. This indicator is easily interpreted and more meaningful for policy making. The potential average travel time from a location is calculated as follows.

$$T_{im} = \frac{\sum_{j=1}^{n} (A_{ijm} * t_{ijm})}{\sum_{j=1}^{n} A_{ijm}} = \frac{\sum_{j=1}^{n} (t_{ijm} * O_j * f(c_{ijm}))}{\sum_{j=1}^{n} (O_j * f(c_{ijm}))} \quad \forall i, m \tag{3}$$

with T_{im} is average travel time of location i, t_{ijm} is the travel time from zone i to zone j by mode m, and other identifiers have the same as before.

2.2.2 Network Efficiency Indicator (E_{im})

This indicator was introduced by Guttiérrez (2009) following on the average travel time indicator. This indicator reflects the relative ease of access or efficiency of the transport system.

$$E_{im} = \frac{\sum_{j=1}^{n} (\frac{t_{ijm}}{T^*_{ijm}} * A_{ijm})}{\sum_{j=1}^{n} A_{ijm}} = \frac{\sum_{j=1}^{n} (\frac{t_{ijm}}{T^*_{ijm}} * O_j * f(c_{ijm}))}{\sum_{j=1}^{n} (O_j * f(c_{ijm}))} \quad \forall i, m \tag{4}$$

In which, E_{im} is network efficiency of location i, T^*_{ijm} is the "ideal" time spent between the location i and location j, assuming the hypothetical existence of a high-speed (or near to free-flow) infrastructure (motorway or high-speed train, according to the mode used) by mode m.

This indicator can be used to evaluate the efficiency of public transport compared to private motorized vehicles (for example MC or car). In this case, T_{ijm} is replaced by (network based) travel time by MC or car while t_{ijm} is travel time by public transport modes.

2.2.3 Accessibility with Competition (A^c_{im})

In reality, employees from zone i going to work in zone j have to compete with employees coming from other zones. Therefore, a competition factor (λ_j) can be added to the traditional potential accessibility to reflect the competition at destinations and make the accessibility value more realistic. This accessibility indicator was developed and proposed by a number of researchers such as van Wee et al, (2001); Breheny (1978); Joseph & Bantock (1982);

Mattsson & Weibull (1981); Weibull (1976). The accessibility with competition is calculated as follows:

$$A^{c}_{im} = \sum_{j=1}^{n} Job_j * f(t_{ijm}) * \lambda_{jm} \quad \forall i, m \tag{5}$$

where in,

Job_j is the number of jobs present in zone j, t_{ijm} is the travel time from zone i to zone j by mode m, $f(t_{ijm})$ is distance decay function

λ_{jm}: the competition factor at destination j.

$$\lambda_{jm} = \frac{\sum_{k=1}^{n} Job_k * f(t_{jkm}) * \lambda_{km}}{\sum_{k=1}^{n} Pop_k * f(t_{kjm})} \quad \forall j, m \tag{6}$$

where, Job_k is the number of jobs present in zone k, Pop_k is the number of population living in zone k, t_{jkm} is travel time from zone j to zone k by mode m, t_{kjm} is travel time from zone k to zone j by mode m, and λ_{km} is the competition factor at zone k.

2.2.4 Accessibility with balancing factor:

To make the accessibility value more realistic balancing factors (a_i, b_j) were added to balance with either the demand or supply or both (Dalvi & Martin, 1976; Geurs & van Eck, 2001; Geurs, 2006; Kirby, 1970; Vickerman, 1974; Wilson, 1971; Wilson, 2010). There are two levels of balancing, i.e. singly constrained and doubly constrained.

(1) At the singly constrained level, the accessibility value will be adjusted with either at demand side or supply side only. For example, a_i is added in order to balance A_{im}=Pop_i. Therefore:

$$A_{im} = \sum_{j=1}^{n} (a_i * Job_j * f(c_{ijm})) = \sum_{j=1}^{n} \left(\frac{Pop_i * Job_j * f(c_{ijm})}{\sum_{j=1}^{n} Job_j * f(c_{ijm})} \right) = \sum_{j=1}^{n} \left(\frac{Job_j * f(c_{ijm})}{\sum_{j=1}^{n} Job_j * f(c_{ijm})} * Pop_i \right) \forall i, m \tag{7}$$

or b_j is added in order to balance B_{jm}=Job_j. Therefore:

$$B_{jm} = \sum_{i=1}^{n} (bj * Pop_i * f(c_{ijm})) = \sum_{i=1}^{n} \left(\frac{Job_j * Pop_i * f(c_{ijm})}{\sum_{j=1}^{n} Pop_i * f(c_{ijm})} \right) = \sum_{i=1}^{n} \left(\frac{Pop_i * f(c_{ijm})}{\sum_{j=1}^{n} Pop_i * f(c_{ijm})} * Job_j \right) \forall j, m \tag{8}$$

(2) At the doubly constrained level, the accessibility values will be adjusted according to both the demand and supply sides (Pop_i and Job_j). Subject to total trip constraint are A_{im}=Pop_i and B_{jm}=Job_j.

$$A_{im} = \sum_{j=1}^{n} (a_i * Job_j * b_j * f(c_{ijm})) = \sum_{j=1}^{n} (a_i * b_j * Job_j * f(c_{ijm})) \quad \forall i, m \tag{9}$$

where in: $a_i = \dfrac{Pop_i}{\sum_{j=1}^{n} Job_j * b_j * f(c_{ijm})}$; $b_j = \dfrac{Jobj}{\sum_{j=1}^{n} Pop_i * a_i * f(c_{ijm})}$

with A_{im} is accessibility of zone i to the relevant type of opportunities, using transport mode m, and a_i, b_j are the balancing factors.

In practice, singly constrained level can be implemented easily but it should be applied only in the case that urban planners or decision makers want to get a more precise value of accessibility. The doubly constrained accessibility is relative complex since the result is an iterative process, incorporating both the demand and supply sides. Therefore, it is rarely used in literature so far (Geurs, 2006).

Among the location-based measures and its potential-based accessibility indicators, accessibility with competition (formulas 5, 6) and accessibility with balancing factors (formulas 7, 8 and 9) can be applied in cases when there is a need for more precise values of accessibility. This is not really necessary if we want to compare relatively the accessibility level between areas or alternatives. Besides, it requires more data (both on Pop and Job) and makes the calculation process more complex and time consuming. Therefore, they were not selected for our case study in Ha Noi.

The contour measure (formula 1) has limitations that it can only be calculated for a limited number of origins and it does not take into account the individual's behavior but it has an advantage that it can give a general view of accessibility for some specific regions or service locations, for example the city' centers, hospitals, universities, etc. The potential accessibility A_{im} (formula 2), in particular average travel time indicators T_{im} (formula 3) can be applied in the case study for Ha Noi to calculate accessibility to jobs and average travel time from home to jobs. These indicators can be used to evaluate the quality of life of citizens living in an urban area as well as to evaluate the quality of integration of transport and land uses. They can be used to predict the places where urban growth is more likely to occur. The assumption here is that areas having high accessibility to jobs by a transport mode can be good candidates for urban expansion and residential densification. Besides, the T_{im} indicator can show the probability of using a certain transport mode. Therefore, these indicators can help to investigate the urban growth and motorcycle use in Ha Noi and suggest the answers to the questions raised in the section 1.

3. DATA PREPARATION FOR MODELLING

The named accessibility indicators were implemented for Ha Noi case study using network analysis extension of ArcGIS software of ESRI. In many studies, the Transport Analysis Zone (TAZ) or ward (commune) is used as the base for accessibility evaluation, for example Geurs, (2006); Gutiérrez (2009); Ha et al. (2011). However, the size of a ward or TAZ is still quite large and not homogenous therefore in this case study a net of hexagon of 1200m was created in order to improve the quality of evaluation. The size of hexagon 1200m was decided as the balance between the limitation of the hardware and an acceptable quality of evaluation. The potential accessibility A_{im} and average travel time to jobs T_{im} were calculated for different available transport modes such as motorcycle and public transport in combination with walking using Origin-Destination (OD) cost matrices of travel time in which the hexagon's centroids were considered as origins or destinations. The dataset which was used for modeling and their preparation will be described below.

3.1 Preparing a Road Network and Public Transport Network

To prepare for modeling, the road network for 2005 and 2010 was converted into ArcGIS shape files, using data collected from the master plan in AutoCAD format prepared by PPJ (2010) and extracted from a cartographic map (2009), scale 1:10.000, in MicroStation format made by Công ty Trắc địa Bản đồ-BQP 2009. The road network 2005 was adjusted from the road network 2010 using local knowledge. Bus network 2005 was imported from program BusIS 2.0 developed by VIDAGIS in GIS format in 2004. Bus network 2010 was prepared by authors based on the paper map of Ha Noi public transport issued by TRAMOC. The average speeds and frequency of MC were assigned based on the survey data by Haidep study team in 2005 (JICA 2007) and a survey by the first author in 2006 (Quang et al, 2007) in combination with local knowledge. The average speed of buses was calculated based on the theory of urban traffic, depending on the distance between bus-stops (Khải 1999). The assigned speeds were presented in the tables 1, 2, and 3.

Table 1: Assumed speeds of motorcycles and pedestrians

No	Road type	MC Speed (km/h)		Walk Speed (km/h)	Note
		City center	Out of city center		
1	Expresssway		45	0	Pedestrians cannot enter expressways
2	National road		40	3.5	
3	Province road		35	3.5	
4	District road		30	3.5	
5	Primary road	25	30	3.5	
6	Secondary road	22	25	3.5	
7	Local main street	18	22	3.5	
8	Small road	15	20	3.5	

Table 2: Assumed speeds of buses

No	Transport mode	Average Speed (km/h)	Frequency (minute)	Access time (minute)	Egress time (second)	Note
1	Bus	22	5-15	Frequency/2	15-20	in the city center (within the ring road no.2);
		28	5-15	Frequency/2	15-20	Urban fringe (between ring road no. 2 and ring no. 3
		35	10-20	Frequency/2	15-20	Out of the city center

Table 3: Calculating speeds of buses by region

No	Region	Distance between bus stations (m)	Vmax (km/h)	Stopping time at bus stops (second)	Caculated average speed (km/h)	Proposed average speed (km/h)
1	City center	500-600	25-30	15-20	20.0-23.7	22.0
2	Urban fringe	600-800	35-40	15-20	25.0-31.4	28.0
3	Out side the city	1200-1500	40-45	15-20	33.85-37.28	35.0

It is important to note that:

- The characteristic of Ha Noi's road network is that in the city centre there are many small and narrow roads that cars and buses cannot enter but motorcycle can access. Therefore, in the city centre the use of motorcycles is somewhat more effective than cars/buses because of its flexibility. Out of the city centre, cars/buses always have higher speed than motorcycle.
- MCs (and cars) have to stop at intersections and there are usually more intersections in the city centre therefore average speeds are always lower in the city center.
- The Ha Noi' bus service is variable in terms of network coverage and frequency. In the main city centre the bus network is quite dense and bus frequency is every 5-15 minutes depending on the bus line. Some buses connect the main city with all satellite cities and

neighborhood towns as well. The frequency of those buses is every 10-20 minutes. On average, the access time was calculated as half of bus frequency.

- In this paper, the speeds in non-peak hours were applied to evaluate the accessibility values between transport modes in 2005 and 2010.
- During the period 2000-2010 many new roads have been built or widened, including some important corridors such as the ring road no. 3, Thanh Tri and Vinh Tuy bridges, Le Van Luong street, and Ha Noi-Cau Gie and Lang-Hoa Lac expressways, etc. In the urban core, it is very difficult to expand a road due to high residential density and high cost for land acquisition. Public transport has also been improved by expanding network coverage, opening new bus lines and increasing bus frequency. These changes were also updated in the model.

3.2 Job Data Preparation

By 2010, Ha Noi still had a typical mono-centric urban form where jobs and most of the main land uses such as government offices, business enterprises, companies, co-operations, hospitals, research institutes, universities, and schools as well as other commercial land uses such as shops, hotels, restaurants, supermarkets, etc are highly concentrated in the main city, especially in the urban core. The land uses in the main city are different with satellite cities and towns in term of in both the number of land uses and job density. Organizations which are located in the city centre have small land footprints but their number of staff is much higher than organizations located in satellite cities and towns that have generally larger land area but less staff. Based on the historical land use data and statistical data 2005 and 2010, the number of jobs per land use category was calculated and transferred to the net of hexagons 1200m. To approximate reality, it was assumed that the job density of organizations located in the city centre, towns and rural area was 3, 2 and 1 respectively.

4. RESULTS

To have a general view on the quality of transport networks (road network and public transport system) the contour measure from locations such as the city centre (figure 2) and the centers of satellite cities (figure 3), were calculated and mapped. Then, the potential accessibility to jobs was calculated and mapped (figure 4) to evaluate the ability of accessing jobs between locations by MC and public transport. Finally, the average travel time to jobs was used and mapped (figure 5) to compare between modes and to justify if people can accept to travel with available transport modes. For the contour measure CT_{im} formula 1 was used. For potential accessibility A_{im} (formula 2) job competition and balancing factors were excluded. The formula 3 was applied to calculate the average travel time indicator (T_{im}).

4.1 Indicator 1-Contour measure (CT_{im})

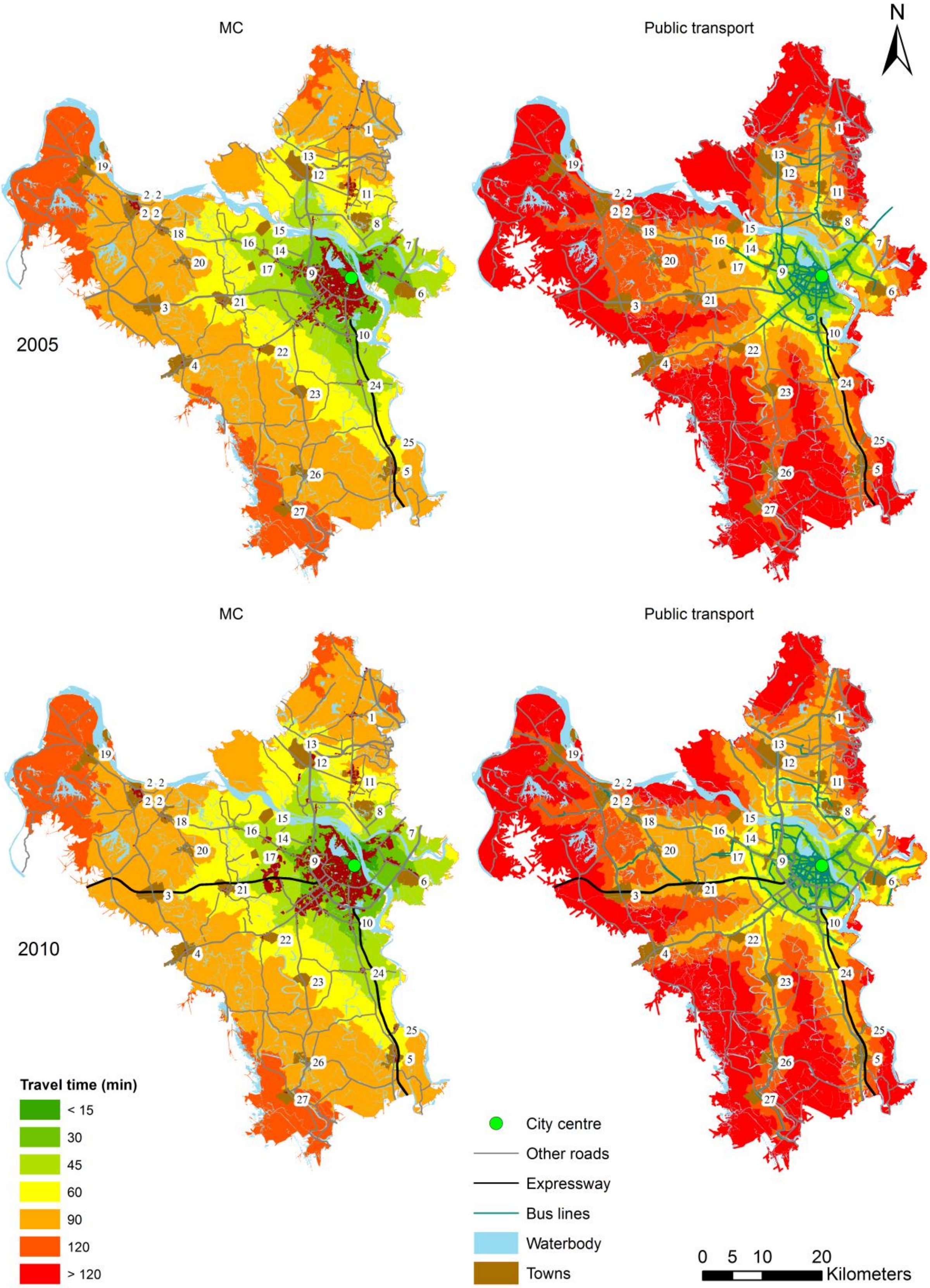

Figure 2: Contour measure to/from the city centre in 2005 and 2010

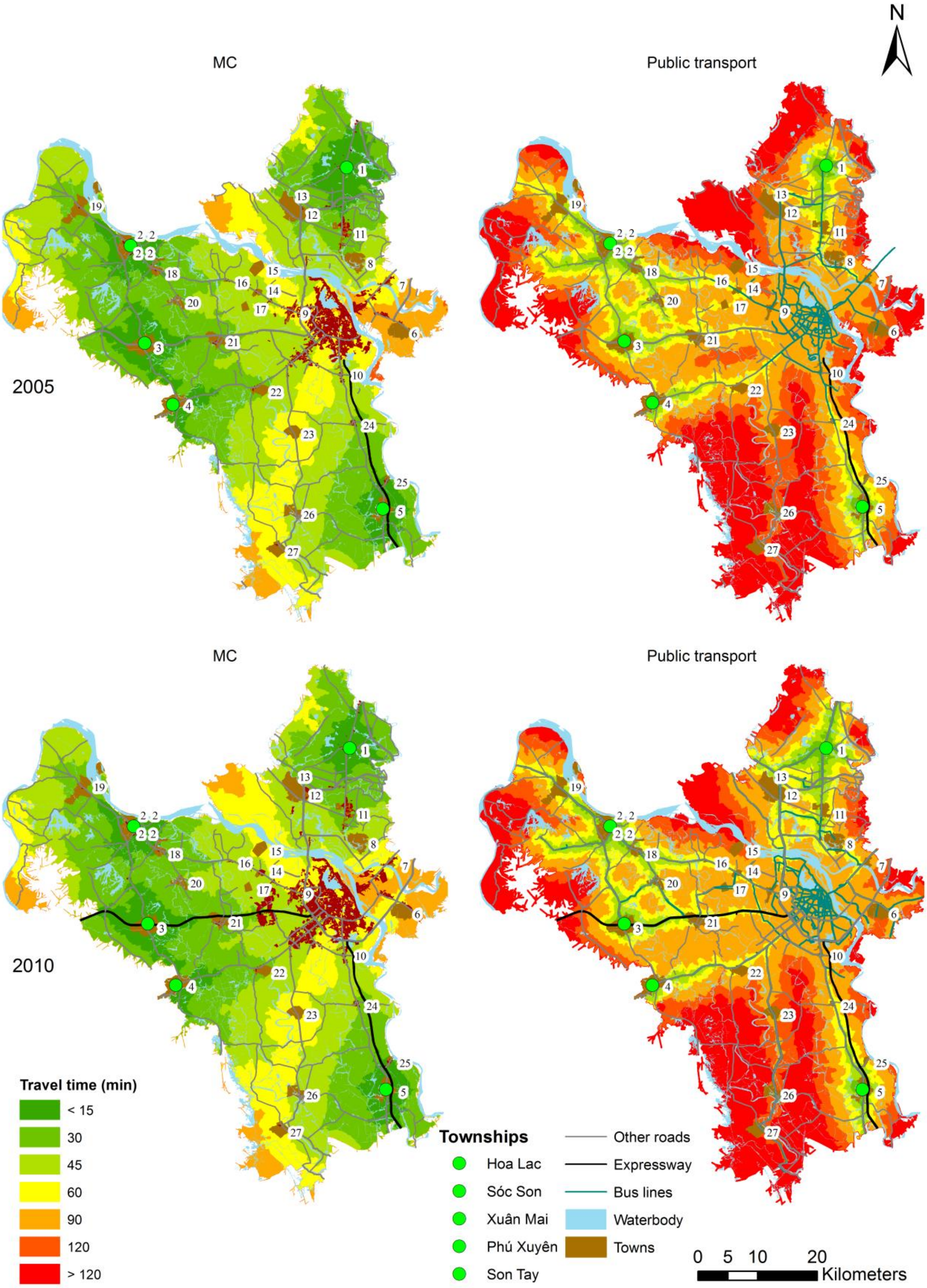

Figure 3: Contour measure to/from the satellite cities in 2005 and 2010

4.2 Indicator 2-Potential accessibility to job (A_{im})

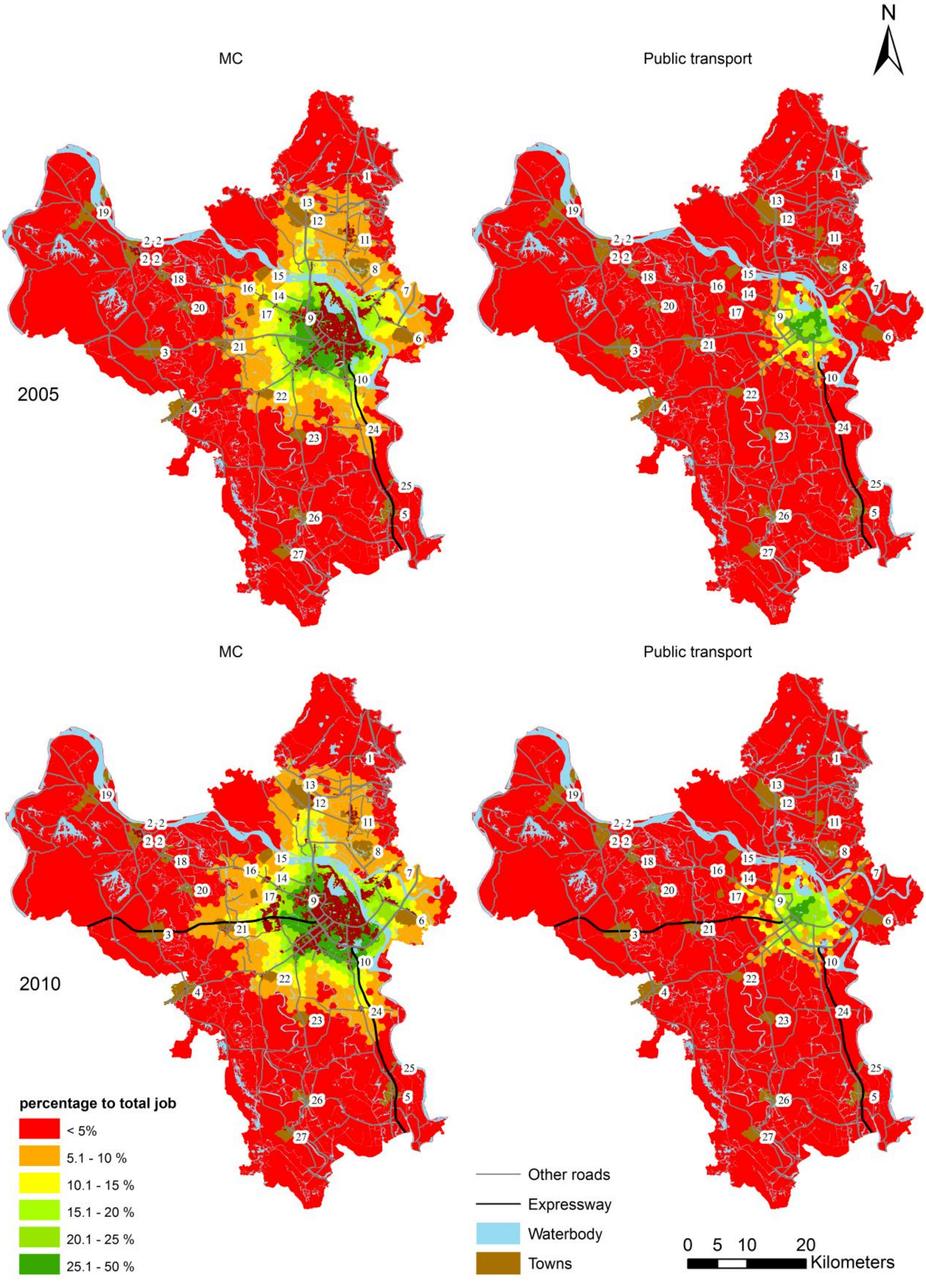

Figure 4: Potential accessibility to jobs for years 2005 and 2010

4.3 Indicator 3-average travel time to jobs (T_{im})

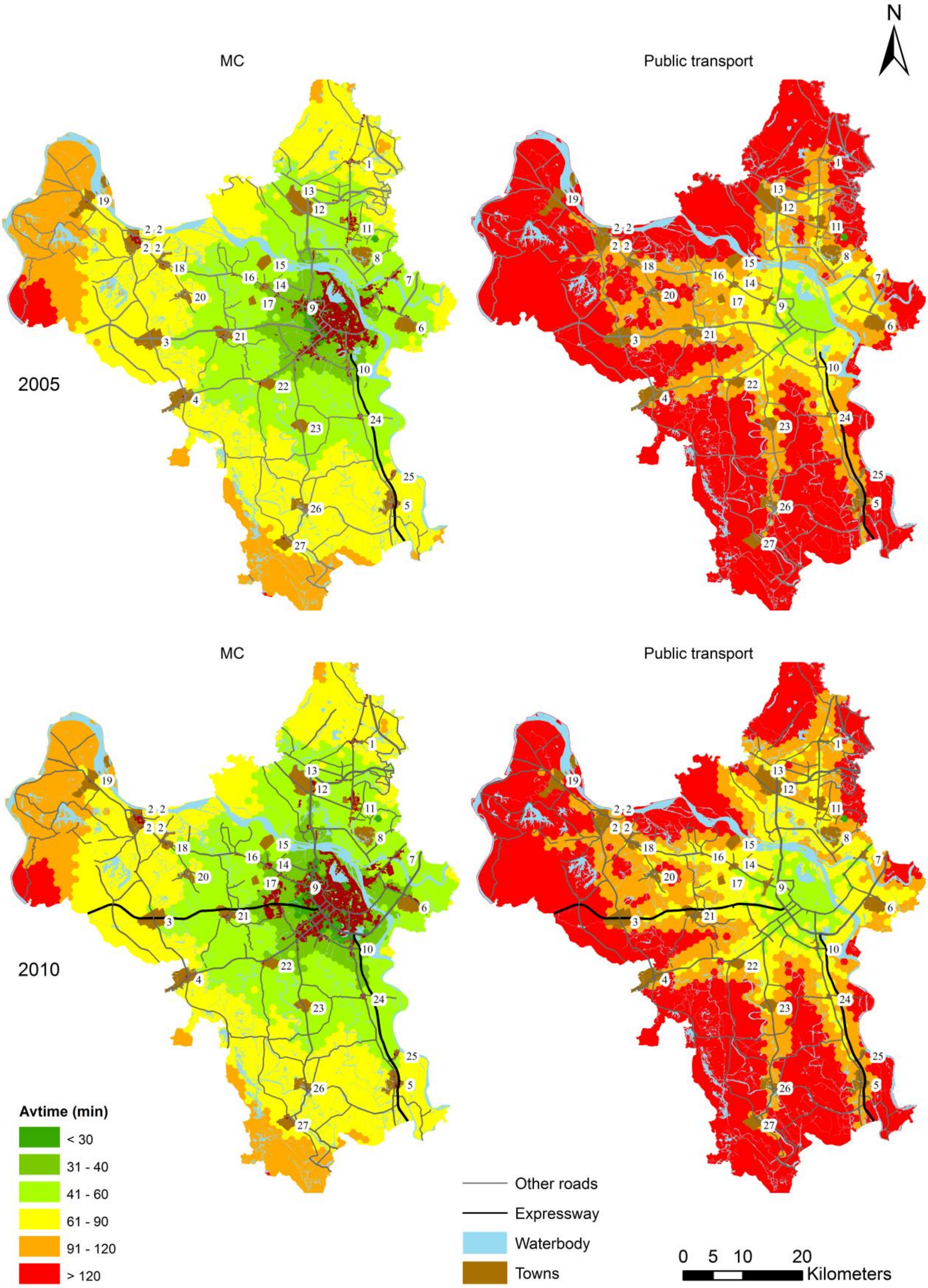

Figure 5: Average travel time to jobs for years 2005 and 2010

Table 4: Numbers and names of townships appearing in figures 2-5

Town_ID	Name of town	Town_ID	Name of town	Town_ID	Name of town	Town_ID	Name of town
1	Soc Son	8	Co Loa	15	Lien Ha	22	Chuc Son
2	Son Tay	9	Cau Dien	16	Phung	23	Kim Bai
3	Hoa Lac	10	Van Dien	17	Son Dong	24	Thuong Tin
4	Xuan Mai	11	Dong Anh	18	Phuc Tho	25	Phu Minh
5	Phu Xuyen	12	Quang Minh	19	Tay Dang	26	Van Dinh
6	Trau Quy	13	Chi Dong	20	Lien Quan	27	Dai Nghia
7	Yen Vien	14	Troi	21	Quoc Oai		

At the first sight, the contour measure (figures 2 and 3) allows us to draw some preliminary conclusions that in general accessibility by public transport is very poor compared to MC. It takes about 60-90 minutes and even more than 90 minutes to reach satellite cities from the city centre by public transport while it just takes about 45-60 minutes by MC. The potential accessibility (indicator 2, A_{im}, figure 4) shows clearly that the satellite cities and towns have very poor accessibility to jobs in comparison to the main city. Potential accessibility to jobs in the main city is about 10 times higher as compared with the satellite cities. The Long Bien and Gia Lam towns in the East side, Quang Minh and Chi Dong towns in the North have higher accessibility to jobs for all modes as compared to other satellite cities and towns. In addition, the potential number of jobs accessible by public transport is very poor as compared to the jobs by motorcycle.

The urban residential land use layer shows quite clearly that the most dynamic urban areas of Ha Noi were located in areas that have highest accessibility to jobs by MC. Indicator 3 (T_{im}) in figure 5 shows that overall the average travel time to jobs in 2010 has been improved significantly from 2005 for all transport modes. On the other hand, indicator 3 (T_{im}) shows that the most dynamic urban areas are located in areas where travel time to job is within about 40 minutes by MC. It supports the conclusions drawn from indicator 2. In the urban core, the average travel time to jobs is just about 30 minutes, while accessibility by public transport is poorer with about 40-60 minutes average time to access to jobs. In the urban fringe, it takes about 30-40 minutes on average to go to work by MC while it takes about 60-90 minutes on average to go to work by public transport.

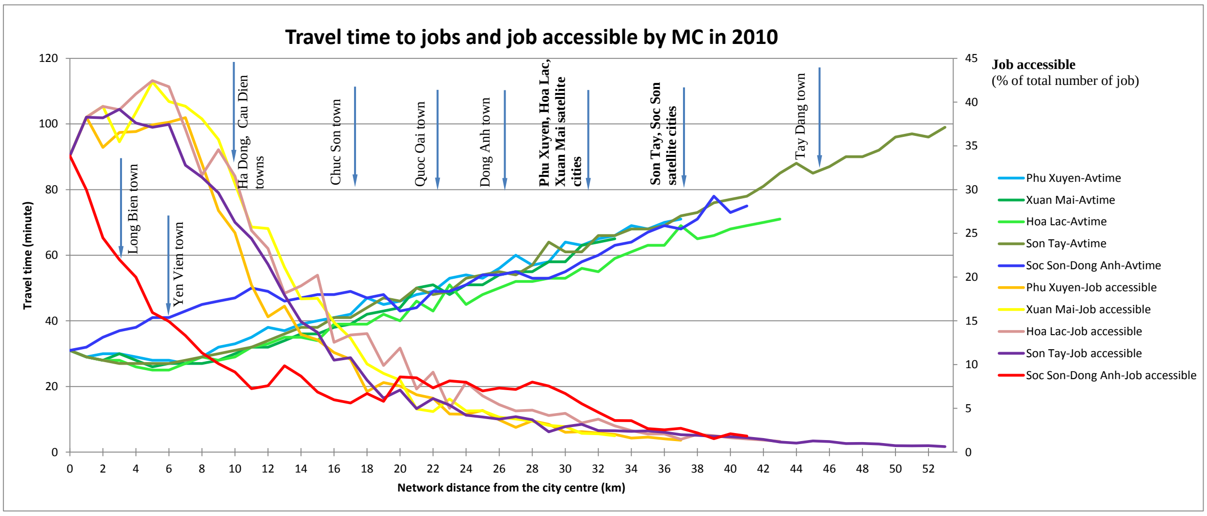

Figure 6: Average travel time to jobs and potential number of job accessible by MC in 2010 of five cross sections through the satellite cities

A comparison was made for the 5 shortest routes from the city centre (the Hoan Kiem lake) through satellites/towns. For every route the average travel time to jobs and potential accessibility by MC in 2010 was obtained from the underlying hexagon layer. The resulting values are displayed in figure 6. The x-axis represents the distance while the y-axis shows a) the average travel time and b) the number of potential jobs by MC as a percentage of the total number of jobs. Figure 6 shows that all satellite cities and most of towns have much poorer accessibility to jobs in terms of both travel time to jobs and the number of jobs accessible with all transport modes, even with a MC. Therefore, such areas tend not to be attractive for new urban development. It also shows that Long Bien and Yen Vien towns have significantly low accessibility to jobs although their distance to the city centre is very near. It is the consequence of the high concentration of jobs in the West side of the city rather than in the North and the East sides.

For many people living in rural areas, towns and satellite cities migration to the main city is one way to improve access to jobs and other opportunities that city life offers. But is public transport a good alternative to access jobs for main city residents? Looking closer, we calculate the average travel time to jobs for people living in the main city assuming people are going to work in areas which are within 45 minutes by MC around the main city centre. The comparison of travel time by MC and buses of people living in the main city as of 2010 was presented in figure 7 and frequency was presented in figure 8. It shows clearly that in the main city the majority can travel to jobs within 35 minutes by MC while it takes more than 40 minutes by bus. The result confirms that public transport (buses) is not an option as daily transport mean to work in Ha Noi.

Generally, the three accessibility indicators give an overview of accessibility to jobs in Ha Noi in 2005 and 2010. These indicators can help to reveal some of the reasons why people don’t like to use public transport while MC is predominant in Ha Noi. Besides, they help to understand why by 2010 there is almost no development in satellite cities and towns while urban dynamically grow in the main city where people have high accessibility to jobs and average travel time to jobs by MC is within acceptable ranges.

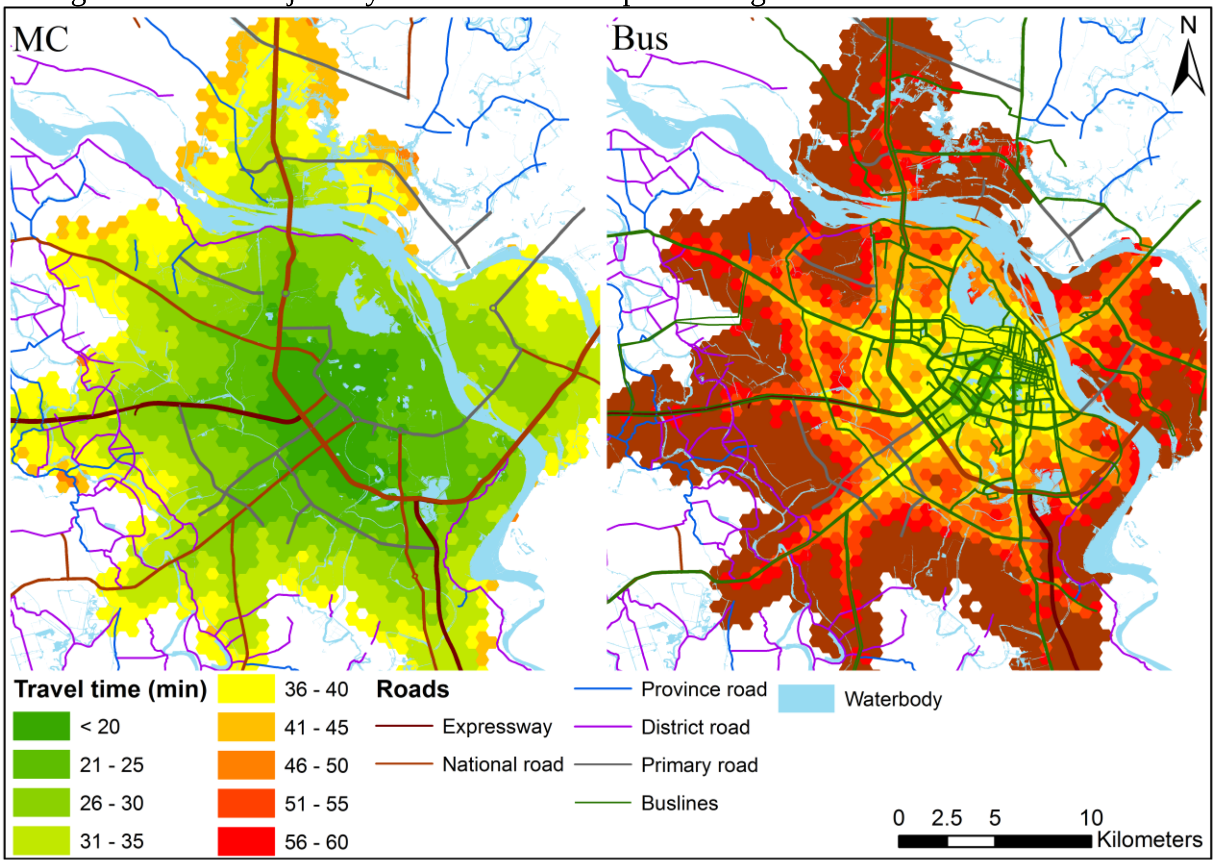

Figure 7: Average travel time to jobs by MC and bus from the main city as of 2010

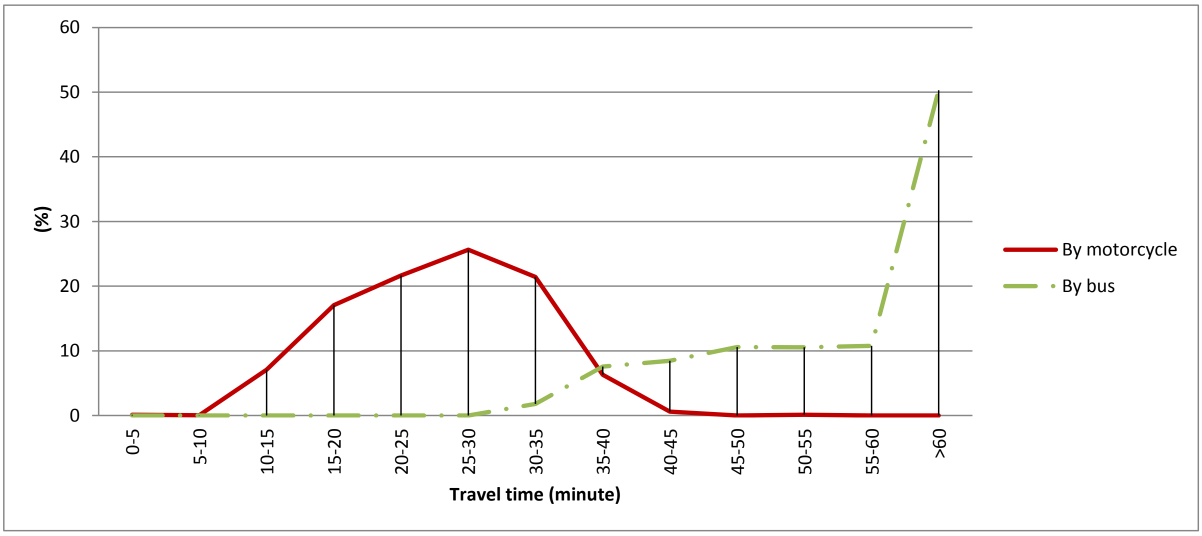

Figure 8: Frequency of average travel time by MC and bus in the main city as of 2010

5. CONCLUSIONS

In this study, three indicators have been applied to understand the changes in accessibility in Ha Noi between 2005 and 2010. Each indicator shows a different aspect of the overall picture of the reality in Ha Noi that can be useful for decision and policy makers. Moreover, potential accessibility to jobs (A_{im}) and average travel time to jobs (T_{im}) can give suggestions on places where people likely live and what their main transport mode to commune will be under the assumption that people more likely live in areas that have high accessibility to jobs and the travel time to jobs by a transport mode is within an acceptable range.

From the analyses, it can be seen that in both years accessibility to jobs by public transport is very poor as compared to MC. People cannot commune to work by public transport every day since the accessibility to jobs in terms of the number of jobs accessible is too low and travel time by public transport is too long compared to MC. These findings help to explain why MC is such a predominant transport mode in Ha Noi. Besides, it is clear that people living in the main city have very high accessibility to jobs while people living in satellite cities and towns have very poor accessibility to jobs, even with MC. The connection between the main city and satellite cities is poor in term of accessibility to jobs, which could be a major stimulus for rural urban migration and a constraint for the development of Ha Noi's satellite cities, despite planning doctrines that promote polycentric development.

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