TRANSPORTATION NETWORK AND ACCESSIBILITY ANALYSIS IN EASTERN ASIA BASED ON A GEOGRAPHICAL INFORMATION SYSTEM

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Abstract: The globalization process observed during the last decade contributed to the rise of international economic blocks worldwide. Eastern Asia, for years a hot spot of economic growth, is an immediate example of this trend. It is conventional wisdom that such regional economies would have not surged, and would not remain viable, without supporting infrastructure and services – in particular transportation. So far there have been no attempts, however, at measuring the levels of accessibility, the main product of a transportation network, at the continental level in Eastern Asia. In this study we adopt an indicator of accessibility and use a Geographic Information System to estimate continental accessibility levels, and then examine the relationship between accessibility and economic growth. Furthermore, as an example of the kind of scenarios that could be explored using our system, we estimate accessibility gains due to two hypothetical situations involving new transportation facilities and regional socioeconomic changes.

Key Words: International Accessibility, Eastern Asia, Geographic Information System

1. INTRODUCTION

The globalization process observed during the last decade contributed, through a combination of better communications, more integrated markets and competition, to create international economic blocks of various sizes and scales. Eastern Asia, for years a hot spot of economic growth, is an immediate example of this worldwide trend. Economic blocks in the region include the Northeast Asian Sub-Region, followed by the Yellow Sea Sub-Region, the South China Economic Zone, the Mekong Economic Zone, as well as the "Indonesia-Malaysia-Thailand" Growth Triangle, the Singapore-Johore-Riau Economic Zone, and the Baht Economy among the most important (figure 1). In addition, another large-scale Free Trade Area in the ASEAN region has been proposed (AFTA: ASEAN Free Trade Area). Since the total population of the ASEAN region is as large as 480 million, it represents one of the largest markets in the world, comparable to, and potentially competitive with EU and NAFTA. Although current regional demarcations of economic zones in Asia are more or less informal, the lack of a hard definition does not detract from the reality of economic integration. It is generally agreed that the factors leading to economic integration and the creation of regional economies are likely to be varied and complex. In this study, however, we concern ourselves with arguably one of the most important among them. Conventional wisdom has it that economic blocks such as those mentioned above would not have surged and hereafter would not remain viable without supporting infrastructure and services – in particular transportation. It is therefore generally accepted that well-organized transportation networks are the *sine qua non* of economic growth and the development of regional economies. So far, however, we are not aware of any study that estimates, in an Eastern Asian context, the levels of accessibility (the main product of a transportation network), or that relates accessibility to economic production in the region. The reasons for this apparent lack of attention include the difficulties associated with building a large and comprehensive data base for as many as 20 countries and regions, on top of the technical difficulties of processing and analyzing large amounts of data to obtain coherent and easily interpretable output.

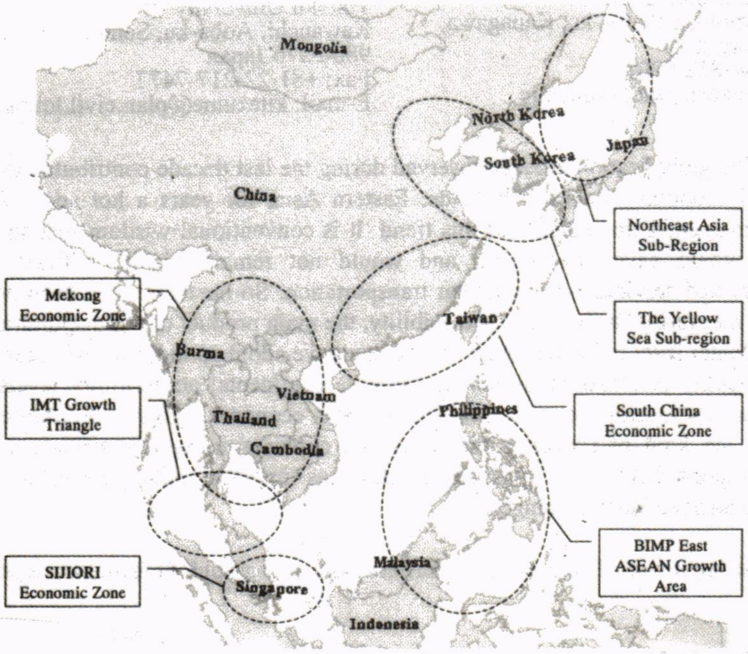

Figure 1. Regional Economies in Eastern Asia

In this study we address the above points by adopting an indicator of accessibility that is at the same time simple and theoretically sound (section 2), and by basing our analysis on a Geographic Information System, whose database, and graphical and analytical capabilities greatly facilitate the analysis of data and the presentation of results (section 3). In particular, we draw from the European EUNET project (Schürmann *et al.*, 1997) that aims to explain economic development using factors ranging from accessibility to demographic conditions. The objective of the present study is twofold: firstly, we attempt to quantitatively evaluate the levels of accessibility in the Eastern Asia Region, and secondly we examine the potential link between transportation development and the generation and growth of regional economies.

To achieve these goals, we build a region-wide GIS database that includes economic production and demographic data for a large number of major cities, in addition to length, cost, speed, travel time and other link attributes for an extensive roadway-airway Asian network (section 3). Based on this data and powerful GIS-based network analysis capabilities, we calculate disaggregated accessibility indicators for nearly 700 major cities, and map the results to depict continental accessibility levels throughout the region (section 4.1). Following, we explore the relationship between the accessibility levels thus obtained and economic production (section 4.2). These results show the current situation of accessibility and economic production in the continent. Finally, as an example of potential applications, we examine one hypothetical situation in which new transportation facilities and/or services are introduced (section 4.3). In the conclusions (section 5) we summarize our findings and suggest some possibilities for further research.

2. ACCESSIBILITY INDICATORS

Accessibility, a term broadly defined as nearness, proximity or alternatively as the configuration of opportunities for interaction between locations in space, is a concept that has played an important role in transportation (and regional) studies since its inception (Martellato and Nijkamp, 1998). Studies have used the concept of accessibility, for example, to focus on the relationship between transport and urban form, and to investigate the effects on growth by infrastructure projects (Schürmann *et al.*, 1997). More specifically, accessibility is defined as a multiplicative function of weight (a measure of how attractive a location is), and impedance, in turn a function of cost and thus determined by position within, and state of a network. In analytical form, the accessibility A_i for location i is given by a function such as:

$$A_i = \sum_j g(W_j) f(c_{ij}) \quad (1)$$

where $g(W_j)$ is a measure of the attractiveness or weight (W_j) of location j, and $f(c_{ij})$ is an impedance function that quantifies, based on cost c_{ij}, how easy it is to move from location i to location j. It is clear that the larger the weight, the higher the accessibility. Impedance is a decreasing function on its argument, and therefore, as cost increases the attractiveness is progressively discounted for the purposes of interaction. Commonly used functions are lineal, inverse and quadratic decay functions. In the present study, we opt for a lineal function for the case of the weights, and a negative exponential function for the impedance, to give an indicator of accessibility of the following form:

$$A_i = \sum_j W_j \exp(-b \cdot c_{ij}) \quad (2)$$

The above formulation is simple, with only two arguments (W_j and c_{ij}) and one parameter (b), and moreover founded on the theoretically sound and well established concepts of agglomeration economies and distance-decay. Its simplicity allows us to experiment, without much difficulty, with various parameter definitions, which in turn permit different interpretations of the meaning of accessibility. This is further discussed in sections 3.3 and 4. Moreover, since we deal with the Asian roadway-airway network, we adopt a definition of intermodal accessibility in which the cost is decomposed in two parts, one corresponding to each mode – road (r) and air (a):

$$c_{ij} = c_{ij}^r + c_{ij}^a \quad (3)$$

The analysis of intermodal networks is generally more complex than single-mode networks because it requires the ability to calculate the shortest (minimum cost) path between nodes. In this case, we take advantage of powerful GIS-based network analysis functions (TransCAD) to calculate the cost of travel between nodes in the network, with the system automatically selecting the modes that minimize transportation costs.

Variables commonly used to represent weight include size of a target facility, number of jobs, population, and economic production. Since our objective is to explore the relationship between accessibility and economic development, we decide to use the local share of GDP as a measure of attractiveness. Accordingly, accessibility is interpreted as the potential for economic interaction. A plausible alternative (which we do not explore here) would be to use the local population, to give the potential for interpersonal exchanges. Measures of cost frequently found in the literature include distance, time, cost, or combinations thereof to obtain a generalized cost. In the case of the EUNET project, time was used as a measure of cost. In an Eastern Asian context, time appears to be of limited interest, because one important aspect of accessibility analysis here is thought to be the economic disparities among countries/regions. Another important difference with the European case is the existence of immigration controls, which result in pecuniary as well as time costs. We thus opt for a generalized cost given by a combination of pecuniary and opportunity costs. Summarizing, the variables needed by our system are economic (GDP, Local Share of GDP, Per Capita GDP), demographic (population), and link-related attributes to calculate transportation costs (length of link, speed, unit cost, etc.) These are used to build a GIS database as described in the following section.

3. GEOGRAPHICAL INFORMATION SYSTEM: DATA BASE BUILDING AND OPERATION

Data was collected for 17 countries/regions/cities in Eastern Asia (Table 1), and for the continental road-air network. Two types of data were used: geographical data (points to represent cities, lines for network links, areas to depict regions), and alphanumeric data for the corresponding attributes (GDP, costs, population, etc.) In some instances, data was not readily available, and it had to be derived from primary sources. This limitation, which argues for an integrated and comprehensive database for regional transportation studies, must be kept in mind when interpreting the results.

3.1 Population and Economic Production

In the present study, the basic unit of analysis is considered to be the city. Geographical data was obtained from the World Geographic Data '99 (see Caliper Corp., 1999), which contains a large number of cities and other populated places, but no information regarding population or income. To maintain the size of the sample within manageable limits, we selected 682 Asian cities with populations above 100 thousand persons, and capitals regardless of the population. Data was matched by name with the cities in the geographical database. It is clear that the criterion of using only cities with 'large' populations is likely to introduce bias in the case of regions where there is a large component of rural population. The alternative, however, of introducing more, less populous settlements, appears to be extremely data intensive, and it is our guess that the bias is probably small in any case, and that the big picture will not be considerably altered by this omission. The number of cities by region can be seen in the first column of Table 1. The figure in the second column is 'total' urban population, however considering only those cities in the sample.

Local GDP is not a statistic readily available, and therefore, it must be derived from available (primary) data. In order to calculate the local share of GDP for each city (the measure of weight in Equation 2), and to make it representative of urban economic production, only the secondary and tertiary sectors where considered. The local GDP was calculated as follows:

$$W_i = D \cdot P_i / \sum_n P_i \tag{4}$$

where:

W_i : City i – Local share of GDP

D : sum of secondary and tertiary sector components of GDP

P_i : City i – population

n : number of cities with population > 100 000 in the country/region

Third column of table 1 shows the total of thus calculated 'urban' GDP, followed by the figure for GDP per capita. It must be kept in mind that by calculating the local share of GDP in the above fashion, we are smoothing away regional within-country differences – or in other words, we are assuming the distribution of income to be homogeneous. This is clearly an unrealistic assumption even for a country with more or less homogeneous income distribution as Japan, since income in Tokyo may be twice (or more) the income in less developed districts. On the other hand, more detailed data, if available, would probably only accentuate the accessibility trends obtained in this manner. At this stage, and in the absence of more detailed data, this seems to be the most parsimonious solution. The largest economy in the region is Japan, followed by China, the most populous country in the area, and it is expected that they will represent perhaps the two biggest components of accessibility. Worth of attention as well are South Korea and Taiwan, the third and fourth biggest economies in the region respectively.

Table 1. Data Summary – Countries, Regions and Cities.

City/Region/Country	Number of Cities with Pop>100 000	Total Local GDP (USD)	GDP Per Capita (USD)	Value of Time (USD)	Purchasing Power Parity
Brunei	1	6,231.00	18000	9	0.735
Cambodia	1	4,514.99	715	0.358	0.029
China	390	679,517.17	3460	1.73	0.141
Hong Kong	1	153,732.91	23674	11.837	0.966
Indonesia	34	183,247.07	4600	2.3	0.188
Japan	143	4,447,313.76	24500	12.25	1
Laos	1	2,764.80	1150	0.575	0.047
Malaysia	11	89,994.46	11100	5.55	0.453
Mongolia	2	3,578.69	3460	1.1	0.09
Myanmar	8	54,168.40	262	0.131	0.011
North Korea	9	21,800.00	900	0.45	0.037
Philippines	34	68,243.93	3200	1.6	0.131
Singapore	1	91,336.18	24600	12.3	1.004
South Korea	21	494,206.47	13700	6.55	0.559
Taiwan	6	272,344.07	14200	7.1	0.58
Thailand	10	165,883.72	8800	4.4	0.359
Vietnam	8	18,274.53	1700	0.85	0.069

The value of time was calculated individually for each region as it is a component of the cost function in the accessibility expression. It was considered that a working day is 8 hours long, and that the active year consists of 250 days. In this fashion, the value of time was obtained from the following formula:

$$VT = E/(250 \cdot 8) \tag{5}$$

where E is the corresponding country/region/city GDP per Capita. Finally, a GDP-based Purchasing Power Parity was introduced to account for the economic disparities in the region.

3.2 Road and Air Networks

In this study we calculate accessibility to economic production from the viewpoint of the Asian roadway-airway network (figure 2). The road network was obtained from the World Geographic Data '99 CD provided by Caliper, Corp., including information regarding the type and functional status of the links (Caliper Corp., 1999). All links of type 'paths and trails' were excluded from the original dataset, and where appropriate, new links were digitized. The links were classified according to importance, with classifications ranging from 'Road' to 'Double Lane' (a category unique to Japan and South Korea). The corresponding attributes are as shown in table 2. The air network was not available so it was digitized to connect the 49 most important international airports in the region. We introduce two types of air links: active and project. For active lanes economy-class costs for were obtained from Air Tariff 2000 (IATA and SITA, 2000). It is worth noting that the costs were in general asymmetric, with different tariffs according to the direction of the flight. In-flight times and distances were obtained from OAG Flight Guide (2000). Other attributes are as shown in table 2.

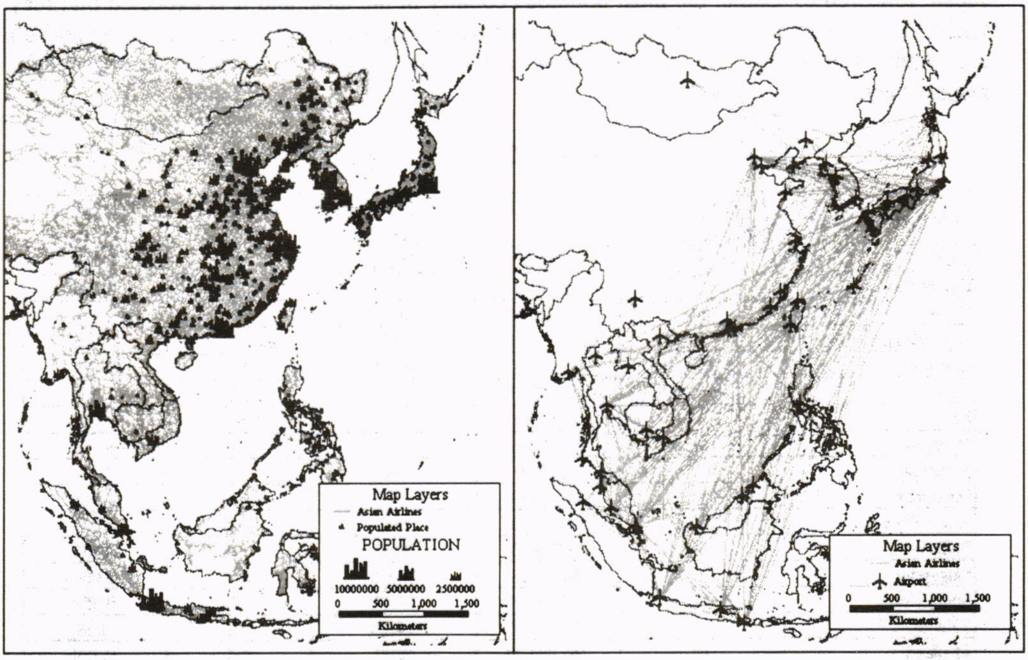

Figure 2. Asian Road-Air Network – Major Cities and Airports.

Table 2. Asian Road-Air Network – Link Summary, Speeds and Costs.

Link Type	Number of Links	Total Length (km)	Speed (km/h)	Cost
Road				
Asia Arterial Road	50303	789396.49	40	$ 0.05 / km
Asia Highway	3675	47257.86	80	$ 0.07 / km
Japan & Korea Arterial Road	10955	79693.26	60	$ 0.10 / km
Double Lane	826	5423.81	100	$ 0.30 / km
Air				
Air Active	379	864773.21	616.95	As per OD pair
Air Project	8	10821.81	616.95	$ 0.32 / km

3.3 Generalized Travel Cost

As discussed in section 2, accessibility is jointly determined by a measure of weight, in this case local share of GDP by city, and an impedance function that depends on the cost. In this study we use a generalized cost measure, in which pecuniary (out-of-pocket) costs and opportunity costs are taken into consideration. Moreover, the cost has two different components, for the road and the air segments of each route (Equation 3). The form of the components of the cost function is as follows:

$$c_{ij}^{r} = \sum_{t} l_{ijt} u_{t} + VT_{i} \cdot t_{ij} + v_{j} \qquad (6)$$

where

c_{ij}^{r} : Generalized road cost from city i to city j (USD)

l_{ijt} : total road length of link type t between city i and city j (km)

u_t : unitary transportation cost for link of type t (USD/km; see table 2)

VT_i : City i residents' value of time (USD/h, as per country/region; see table 1)

t_{ij} : total road travel time between origin city i and destination city j (h)

v_{ij} : Visa cost; 50 USD if a visa is required to travel from i to j, 0 else

The air cost component is as follows:

$$c_{ij}^{a} = C_{ij} + VT_{i} \cdot t_{ij} + v_{j} \qquad (7)$$

where

c_{ij}^{a} : Generalized air cost from city i to city j (USD)

C_{ij} : total air tariff between cities i and j (USD; unitary cost by length in the case of links of type project – see table 2)

VT_i : City i residents' value of time (USD/h, as per country/region; see table 1)

t_{ij} : total air travel time between origin city i and destination city j (h)

v_{ij} : Visa cost; 50 USD if a visa is required to travel from i to j, 0 else

In addition to travel time, we have set transfer penalties for moving between links of different types as follows: 2 hours for moving from a road link to an air link; 1 hour for moving from an air link to a road link; 1 hour for moving between air links; and 0 hours for moving between road links. Network analysis is used to find the shortest (minimum cost) path between origins and destinations. In some cases this involves several transfers between modes; for instance, a trip starting in Beijing would go to the nearest international airport by road, by plane to Hong Kong, transfer to Chiang Kai Shek International and finally by road to Taipei. The result is a matrix of (minimum) generalized costs between locations that are adjusted by the PPP by origin (table 1), and that can be used to calculate the accessibility.

Before accessibility can be calculated, however, it is first necessary to select parameter b in equation 2. This parameter defines the steepness of the decay curve and can thus be interpreted as a parameter of scale. It can be seen in figure 3 that smaller parameter give less steep decay curves (i.e. smoother rates of discount). Four different parameters are used to reflect situations ranging from mainly local trips (trips more costly than about 500 USD receive very low weights) to international trips (the weight of a location about 3000 USD apart is discounted by about 60%). In the next section we apply these elements to calculate the levels of accessibility in Eastern Asia.

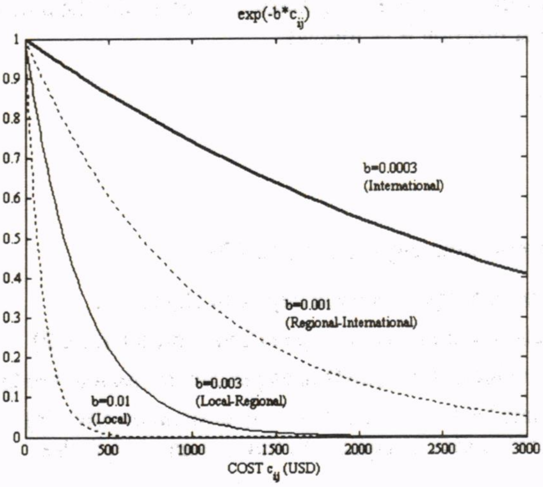

Figure 3. Impedance Function and Choice of Parameters.

4. APPLICATIONS AND DISCUSSION

4.1 Present Situation

The first application is concerned with the present situation of accessibility in Eastern Asia. At this step, we make an attempt at fact finding. Therefore, we conduct network analysis without considering a small number of air 'project' links, and moreover, to reflect the situation of North Korea, for North Korean cities we consider only domestic accessibility while ignoring their contribution to calculate the accessibility of cities in other countries/regions in the continent. Using parameters as discussed in section 3, minimum generalized cost between cities, and the local share of GDP as a measure of attractiveness we are able to calculate the continental accessibility levels using equation 2. Results appear in figures 2-5, where ACC1 uses b= 0.01, ACC2, ACC3 and ACC4 use b= 0.003, b= 0.001 and b= 0.0003 respectively, progressing from local to international accessibility.

Examining figure 4a, in which accessibility due to short distance (or small costs, i.e. local) interactions can be seen, the first thing that we notice is that accessibility levels are high in Japan, in particular along the Tokyo-Osaka corridor, and in South Korea. These results are consistent with our definition of accessibility as access to economic production. Accessibility levels in China do not appear to be very high, in spite of being the second largest economy in the region. Upon reflection, this seems to be due to three factors: economic production is more evenly distributed among a large number of populated places, and at the same time, distribution disparities between coastal cities and others have been smoothed. In addition, the effect of applying a Purchasing Power Parity correction to the costs is to make trips originating in China a relatively more expensive matter.

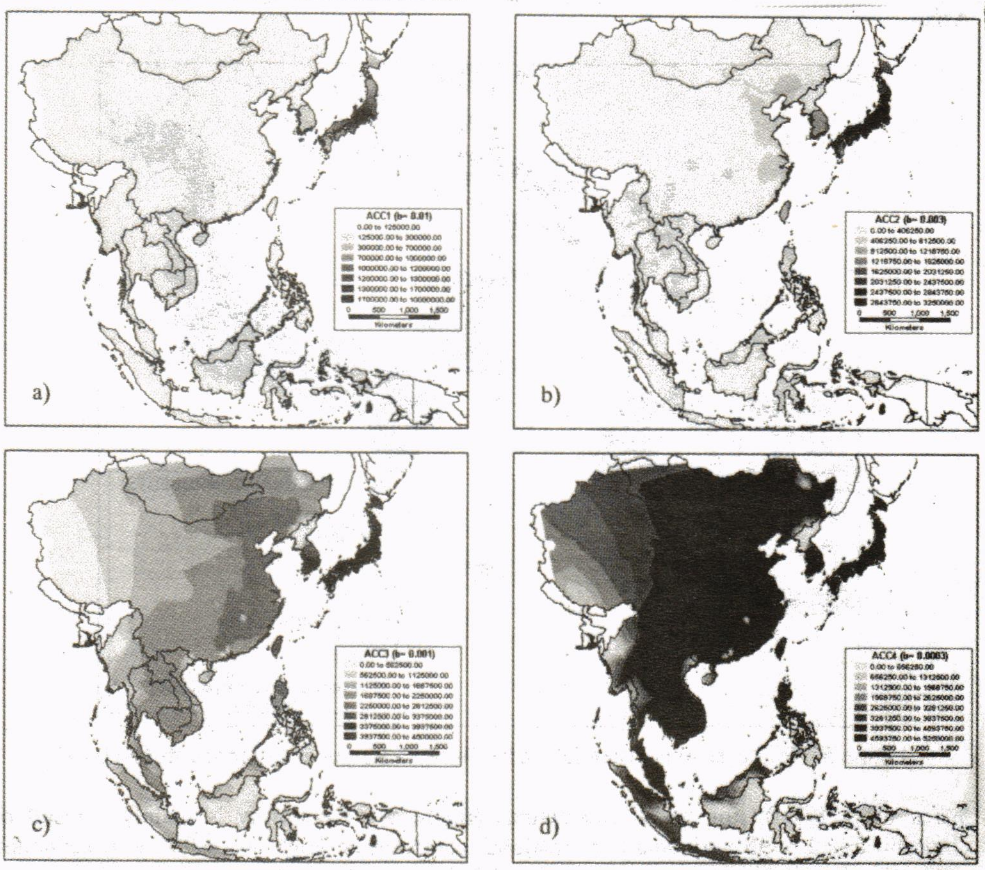

Figure 4. Potential Accessibility – Present Situation: Local (b=0.01), Local-Regional (b=0.003), Regional-International (b=0.001), International (b=0.0003)

Figures 4b, c and d show the effect of making the impedance function less steep, or in other words, of moving from local to regional and international interactions. There is a clearly discernable trend consisting of increased levels of accessibility radiating from Japan towards the east coast of China. Accessibility 'gains' due to a decreased rate of discount, are more marked among the coastal cities of western China, the southernmost part of the Korean Peninsula, and Taiwan. North Korea, on the other hand, shows consistently low levels of accessibility due to the lack of an international component in its accessibility.

At this point (figures 4b and 4c), accessibility to economic production in Southeast Asia does not appear to be very high. This is initially puzzling, especially when one notes that some middle size economies locate there: Singapore, Thailand and Malaysia. On the one hand, this might be partly due to lower levels of transportation service in that area. On the other hand, there is the fact that most accessibility increments in Northeastern Asia are due to the Japanese component of accessibility. Domestic accessibility in Japan tends to a plateau, but the effects spillover to neighboring regions. However, due to the effect of applying a PPP correction, the converse is not true: domestic levels of accessibility in China, South Korea and Taiwan increase, but no to the extent of affecting accessibility in Japan. This trend is clearly seen in figures 5 and 6, which shows the regional components of accessibility in Northeastern Asia.

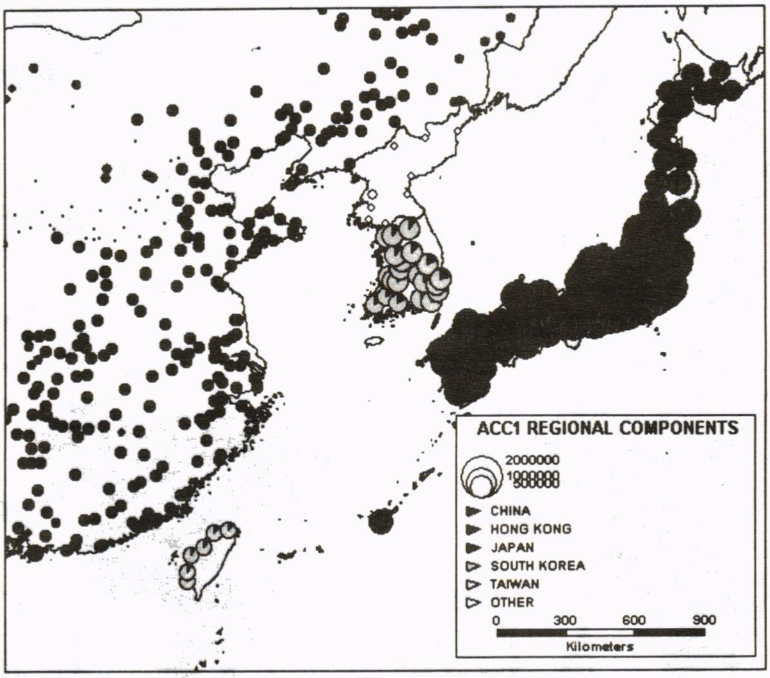

Figure 5. Northeast Asia Potential Accessibility – Regional Components (b= 0.01)

When using b=0.01 for 'local' interactions (figure 5) accessibility is mainly a result of domestic travel, with very small international components. High accessibility to economic production is high in Japan, South Korea and Taiwan mainly to domestic interactions, while in Chine the dispersed distribution contributes for relatively lower levels of accessibility, with a peak in Hong Kong and surrounding areas.

At the other end of the accessibility spectrum, when using b=0.0003, accessibility levels increase rapidly in South Korea, northeast China and Taiwan. Higher accessibilities are a result of wider areas of influence. At this point, however, accessibility in most of the region is considerably affected by the size of the Japanese economy (figure 6). In this sense, it is natural that accessibility becomes higher in this area (where transportation infrastructure is available) because the tendency is towards better accessibility in the geographical center of the region. Accessibility increments in Southeast Asia are better appreciated when the cost of travel does not result in drastic discounts in the impedance function.

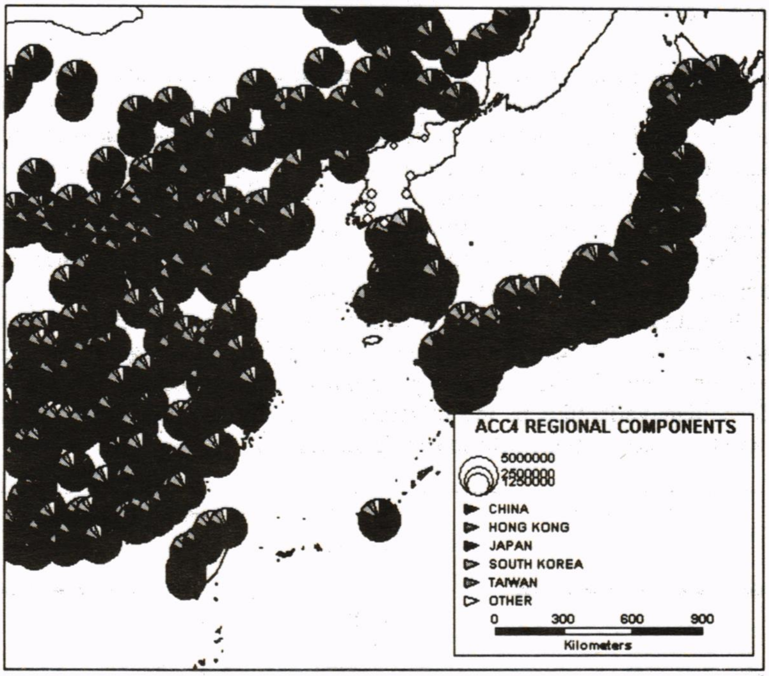

Figure 6. Northeast Asia Potential Accessibility – Regional Components (b= 0.0003)

In this study we are concerned with economic production. However, it seems likely that if we used population instead of economic production as a measure of attractiveness (i.e. to define opportunities of interpersonal exchange), the overall picture would show a shift of high accessibility levels towards the west coast of China. Verifying this remains a possibility to explore in future research.

4.2 Accessibility Indicators and Economic Production

The previous section was devoted to the calculation of accessibility levels corresponding to the present situation of economic development, transportation infrastructure and service levels in Eastern Asia. In this section the link between accessibility and economic development is explored. We mentioned before that economic development is likely to be a complex combination of several perhaps interrelated factors. It is interesting to note, however, that according to our results there is a good degree of correlation between accessibility and per capita GDP, the main indicator of economic development. Scatterplots showing the distribution of values of accessibility and per capita GDP appear in figure 7 below. Two goodness-of fit indicators accompany each figure: the correlation coefficient, and the coefficient of determination for a simple linear regression of accessibility on per capita GDP. The values of these indicators show that in general there is a good correspondence between variables, with correlation coefficients as high as 0.94 for ACC2, and values above 0.8 for ACC1 and ACC3. The coefficients of determination are also high: 0.89 for ACC2, 0.79 and 0.63 for ACC1 and ACC3 respectively. This means that per capita GDP can be explained in almost 90% by the relatively local accessibility measure given by ACC2. On the other hand, the relationship breaks down for the case of ACC4, where high accessibility does not correlate well with high per capita GDP, most likely due to the influence of international accessibility components, as seen in section 4.1.

Appealing as these figures are, it must be kept in mind that statistical correlation does not necessarily imply causal relationships and at best suggests some potential links. In addition, it is important to consider, beyond the goodness-of-fit indicators, at least some of the most evident characteristics of the data. For instance, one striking characteristic made evident by the scatterplots is the considerable variability of values at the high-income end of the scale. This is likely to translate into high variance in linear models and poor predictions at the extreme. On the other hand, it is clear that this effect is at least partially a consequence of the method used to distribute GDP into local shares, in fact ignoring domestic income distribution disparities. If detailed data could be obtained, then per capita GDP would be more continuously distributed, instead of being at discrete intervals as in figure 7. It seems safe to assume that a more realistic distribution of per capita GDP that considered regional disparities would reduce high variability in the extreme, and result in more accurate accessibility indicators and better correlations with economic production.

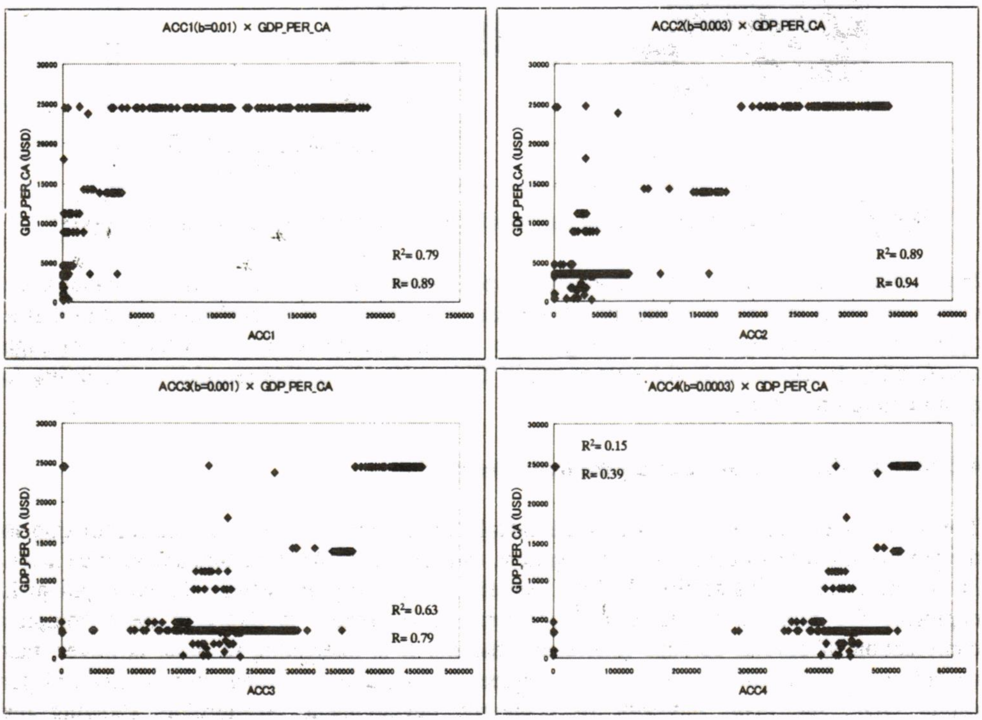

Figure 7. Economic Production and Accessibility – Correlations and Coefficients of Determination.

Another factor to consider is the convenience of using linear regression, since it seems that perhaps some transformation of the data might give a more adequate functional form to represent the relationship. All these factors counsel caution in the interpretation of results, and highlight the notion that accessibility is better seen as an enabling condition, rather than a determinant of economic development (Schürmann *et al.*, 1997; p. 4). However, even after all the above has been considered, it is still of interest to find that causal relationship or not, accessibility and economic development appear to go side by side, at least as far as local to regional accessibilities are concerned.

4.3 Accessibility Change: Direct Flights between Mainland China and Taiwan

The results in the previous two sections show the current situation of accessibility and economic production in the continent. They do not represent, however, the only use of our system. Potential applications include: the identification of necessary accessibility conditions for the development of regional economies, the study of influential transportation development projects to create new economic zones, and the localization of future transportation network bottlenecks that could limit further growth of existing economic zones. With talks undergoing regarding important transportation projects in the region, such as the Siberian Rail that would also connect North and South Korea, the High Speed Train between Beijing and Shanghai, and rail projects in the Malay peninsula, the importance of an evaluation system is highlighted. At this stage, unlike the EUNET project, we do not benefit from specific projects to analyze, so in order to demonstrate the scenario-analysis capabilities of the system, we resort to a hypothetical situation. This section explores the accessibility consequences of a new transportation service, assuming that direct flight routes are established between some important airports in China and two airports in Taiwan

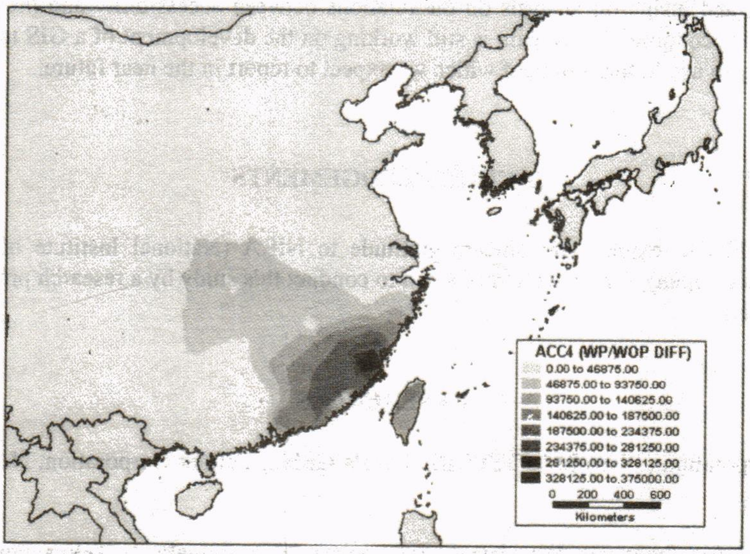

Figure 8. Accessibility Change from Direct Flights between China and Taiwan (b=0.0003)

Recalling equation 2, it is clear that there are two factors that affect accessibility levels: the weight of cities (in this case local share of GDP), and the cost of moving over the transportation network. In the present example, economic conditions are held constant so that the effect of new service is expected to be lower transportation costs. In effect, after introducing the new lines and conducting network analysis, we find that in general transportation costs are substantially lower for locations on both sides of the straits. The generalized cost between Beijing and Taipei, for instance, is 657 USD without project. However, after the new service has been introduced, the cost drops almost by half to 331 USD. Reduced costs lead to higher accessibilities, and the interest lies mainly in finding where do the accessibility gains concentrate. In what follows, we use ACC4 (setting b= 0.003) in order to emphasize the effect of cheaper long distance interactions. Figure 8 shows the regional accessibility gains due to the project (i.e. the difference of 'With Project' and 'Without Project' accessibilities), and it can be seen there that the effect is more important in the southeastern coast of China, and northwestern Taiwan.

5. CONCLUSIONS

In the present study, we have built a preliminary GIS database, which covers the Eastern Asia region, and the analysis tools needed to obtain international accessibility indicators. These indicators can be used to substantiate discussions of transportation, accessibility, and economic growth in the region. In the comparison of accessibility indicators, we have shown the usefulness of the local and regional accessibilities by changing the travel resistance parameter. The main application was to obtain accessibility indicators corresponding to the current situation of economic development and existing transportation infrastructure and services. Because of space constraints, in this paper we report only one application of future possible alternative plans of transportation development. However, all applications were confirmed to tease out various implications to the discussion as described in the case introduced in this paper. If more detailed data, such as economic production at the regional or local level was made available, the tools introduced in this paper could be used to conduct more varied and insightful analysis on the relations between accessibility and present/future regional/local economies. This team is still working on the development of a GIS tool and the methodology to use it, the results of which we expect to report in the near future.

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REFERENCES

Caliper Corporation (1999) **MAPTITUDE User's Guide**, Caliper Corporation, Newton MA, USA.

International Air Transport Association and Société Internationale de Télécommunications Aéronautiques (2000) **Passenger Air Tariff: Fares and Fare Rules – Eastern Hemisphere**, July 2000, Amsterdam.

Martellato, D. and Nijkamp, P. (1999) The Concept of Accessibility Revisited. In Aura

Reggiani (ed.), **Accessibility, Trade and Locational Behaviour**, Ashgate Publishing Ltd, England.

OAG Worldwide (2000) **Flight Guide Supplement: July-September 2000**, Colchester, UK.

Schürmann, C., Spiekermann, K. and Wegener, M. (1997) **Accessibility Indicators**, Berichte aus dem Institut für Raumplanung 39, Institute of Spatial Planning, University of Dortmund, Germany.

Spiekermann, K. and Wegener, M. (1997) Freedom from the Tyranny of Zones. In A.S. Fotheringham and M. Wegener (eds.) **Spatial Models and GIS – New Potential and New Models,** Taylor & Francis, London.