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GEOGRAPHICAL SIMULATION MODELING FOR EVALUATING LOGISTICS INFRASTRUCTURE: A MODEL FOR THE ASEAN ECONOMIC COMMUNITY

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ABSTRACT

Geographical Simulation Model (GSM) is an alternative decision support system to assess transportation, agglomeration, as well as economic growth behaviour according to logistics infrastructure improvement and development. This simulation model is based on spatial economics and includes seven economic sectors, including manufacturing and non- manufacturing. Traditional impact assessment methods like Computable General Equilibrium (CGE) model are often subject to limitations when providing analyses at the sub-national level. The available routes of highways, railways, and sea and air shipment are incorporated in the GSM model. The transaction cost within regions is modelled as determined by firms'choice to choose the course with the lowest trade costs. It also includes the estimates of some border cost measures such as tariff rates, non-tariff barriers, other border costs, etc. Enhancing ASEAN (the Association of Southeast Asian Nations) Economic Community by improving its infrastructure is used to demonstrate the GSM framework as a decision support system.

1 INTRODUCTION

In this era of enhanced regional economic integration, traditional economic analysis at the national-level has proven not to be adequate in providing useful analytical platforms and information for regional economic co-operation (Kumagai et.al 2011). In the European Union (EU), extensive research has been conducted on the relationship between economic integration and changes in the geographical structure of regional economies, especially the location of industries and income disparity (Midelfart-Knarvik, Overman, and Venables 2001; Midelfart-Knarvik et al. 2002; Maarten et al. 2010). In the East Asia, there exist some a limited number of research in the impacts of trade and transport facilitation measures that are based on CGE models (Siriwardana 2003, Urata and Kiyota 2005).

However, the dramatic increase in research on spatial economics in the last decade has coincided with globalization and regional integration of the world economy. Since the beginning of the 1990's, spatial economics, also called new economic geography, (NEG), a theoretical construct used to analyse the geographical distribution of economic activities has garnered much attention as a new frontier in the study

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of economics. The theory of NEG includes the concept of “space”that has traditionally not been handled well by mainstream economics and treats various geographic aspects of economic phenomena within the framework of general equilibrium (Kumagai et al. 2008; Kumagai et al. 2011). Therefore, Geographical Simulation Model (GSM), based on the spatial economics theory, can be animportant tool for understanding and forecasting such prominent phenomena, particularly in relation to the concentration of industries and population.In order to explain such situations, the understanding of the basis of increasing returns and the mechanism of agglomeration are indispensable.

2 GENERAL MODELLING FRAMEWORK

2.1. Spatial Economic and General Equilibrium Framework

This GSM model is based on spatial economics. It explains the spread of economic activities within a general equilibrium framework. The main components of spatial economics are: (1) increasing returns; (2) imperfect competition; (3) love of variety; and (4) endogenous agglomeration forces (Kumagai et al. 2008).

The balance of agglomeration forces against dispersion forces determines the distribution of economic activities, which is a key concept in spatial economic. There are many types of agglomeration and dispersion forces (see Table 1). Thus, the observed spatial configurations of economic activities have much variety, with exogenous shocks, the spatial structure is organized by itself, and the core-periphery structure evolves through structural changes.

Table 1: Balance of agglomeration forces against dispersion forces.

Desperation Forces	Agglomeration Forces
Transport Costs	Economy of Scale
Immobility of Labor	Larger Market
Higher Factor Prices	Intermediate Inputs

Krugman (1991) shows that a symmetric structure is maintained when transport costs reach a high enough level; core-periphery structures emerge when transport costs reach a low enough level. Formalizing, transport costs between regions are exogenous factors and express all distance resistance. Mobile workers choose a preference between regions based on wage rates and prices in both regions. When transport costs are high enough, the dispersion force overcomes agglomeration forces. Firms cannot afford to play highly competitive price games even in a somewhat larger market because profit from the distant market is small. Thus, economic activities disperse. However, as transport costs decrease to a low enough level, agglomeration forces surpass the dispersion force. Firms can enjoy large markets and low procurement costs even with harsh price competition by locating in a large market because the profits from such distant markets are large. Thus economic activities can agglomerate in the region (Kumagai et al. 2011).

2.2. IDE-GSM Formulation

The Geographical Simulation Model (GSM), also called IDE-GSM, was developed by The Institute of Developing Economies (IDE) and Japan External Trade Organization (JETRO). It has two major objectives: (1) to determine the dynamics of locations of populations and industries in East Asia in the long-term, and (2) to analyse the impact of specific infrastructure projects on the regional economy at sub-national levels. This model is grounded on multi- sector and country general equilibrium of NEG (Puga and Venables 1996). The model allows for the mobility of workers within each country and

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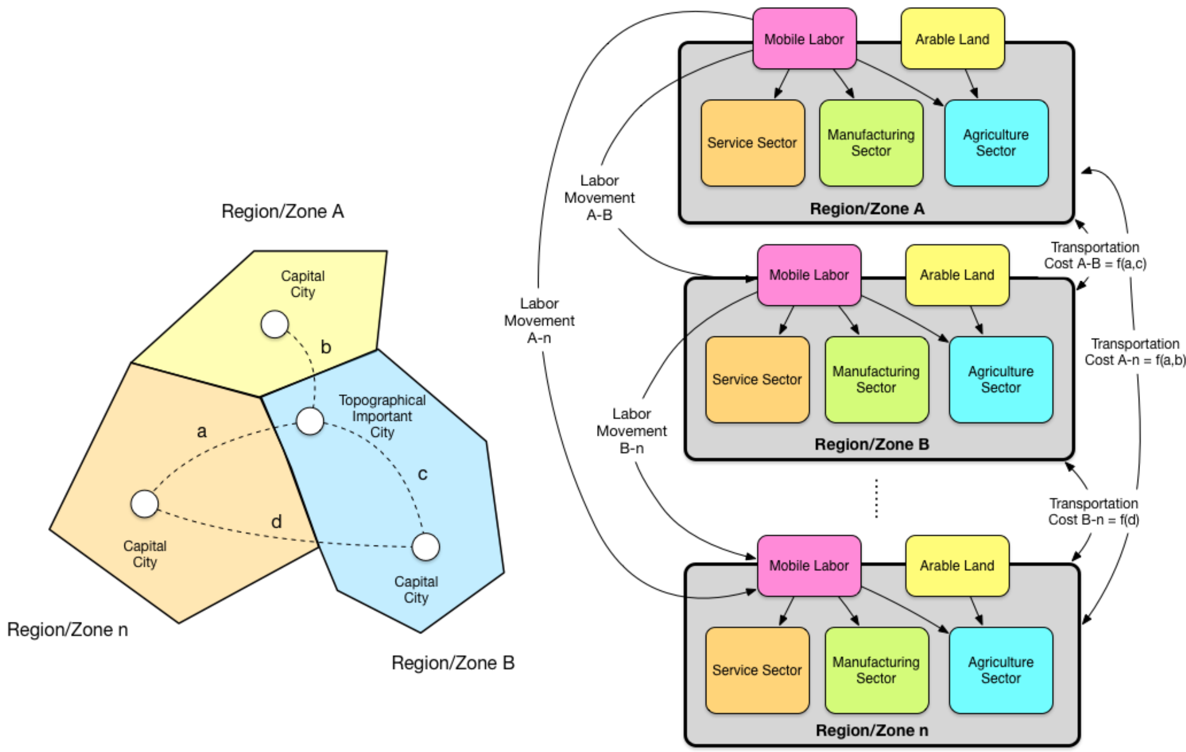

Figure 1: Schematic Diagram of Geographical Simulation Model (GSM).

between sectors. The explored sectors are agriculture, five manufacturing and service sectors (Kumagai at al. 2008). The schematic description of the model is found in Figure 1.

The IDE-GSM incorporates geography as its “topology” for cities and routes. This representation of geography has several advantages. It makes it possible to incorporate more realistic route choices of in logistics and the minimal distance between any two cities is calculated considering every possible route between them.

There are key regional/zone variables that are used such as nominal wage rates in three sectors, land rent, regional income, regional expenditure on manufactured goods, price index of manufactured goods and of services, average real wage rates in three sectors, population share of a location in a country and population shares of a sector in three industries within one location (Kumagai et al. 2011).

2.3. Key Assumptions

In GSM, the agriculture sector is assumed to be perfectly competitive and the production is depicted by the Cobb-Douglas function -- which typical can be shown as (1) -- of capital and labor, where the efficiency of production at a region is different. The transportation costs of agricultural good are assumed to be zero and the nominal wage rate to be the same within a region/zone and between sectors (Masahisa, Krugman, and Venables 1999; Kumagai 2011)

$$Y = AL^{\beta}K^{\alpha} \tag{1}$$

where:

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Y = total production (the real value of all goods produced in a year)
L = labor input (the total number of person-hours worked in a year)
K = capital input (the real value of all machinery, equipment, and buildings)
A = total factor productivity

and α and β are the output elasticities of capital and labor, respectively. These values are constants determined by available technology (Cobb and Douglas 1928).

In the manufacturing sector, monopolistic competitive environment is assumed and its technology is focused on increasing returns to scale, where labour and intermediate inputs of the same sector are required. The price index of intermediate inputs reflects all the sector's own distribution. These specifications depict circular causation which is based on agglomeration economies; the more firms are concentrated, the more workers migrate. Manufacturing products are different from agricultural goods, as they incur product specific-transportation costs, which are modelled in an iceberg manner. Firms choose the minimum transport route cost from various network connections and several transportation modes, such as road, ship, train and air. The GSM model includes the estimates of border cost measures such as tariff rates, non-tariff barriers, other border clearance costs, transhipment costs, etc. (Masahisa, Krugman, and Venables 1999; Kumagai et al. 2011).

In the service sector, the production function is characterized by increasing returns to scale technology with only labour input. Similarly to manufactured goods, service also incurs iceberg-type transportation costs.

Consumers are also assumed to possess the same utility function. This assumption is very conservative but there is currently no other proper assumption at this moment, given that the authors have not be able to adjust consumer utility function dynamically. Income effects are included in the GSM model, and the simulation results are relatively not sensitive to this assumption. This implies that the expenditure share of each good is the same among individuals. Regional incomes are depicted by regional GDPs, called Regional Gross Domestic Products (GRDPs). Land rent from agricultural sector is included in the regional income of the region where the land is located (Kumagai et al. 2011).

2.4. Labour Movement Decision

Migration decision of workers is characterized by real wage differences. The movement of workers ensures wage equalization among sectors. Among region, there is a migration dynamics difference. In the same region/zone, price index is assumed to be identical. When there is a nominal wage difference among sectors, workers in lower wage sector will move to higher wage sector. Among regions, price indexes are different. If there is real wage difference among regions, workers are assumed to move to the region of higher real wage.

Since each worker conceives real wage which reflects price index and nominal wage rate, when there is a region with higher real wage, some workers can enjoy higher real wage by moving there. As long as there is a real wage difference between any two regions, there will be migration between regions.

2.5. Data Framework

The data framework of the GSM simulation covers 17 countries, 1715 regions/zones, 4226 cities, and 7044 routes. Each country is subdivided into states/provinces/districts. Each state/province/district is represented by its capital city (See Figure 1). It also covers four modes of transports, such as air, land, sea, and rail. The data is based mainly on official data from national statistical data of each country. Regional GDP (RGDP) of agriculture, five manufacturing, and service sectors are derived. The five manufacturing sectors are agricultural and food processing, garment and textile, electronics, automotive and all others. The baseline data is for the year 2005. In order to capture the geographical spread of

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population and economic activities, the following figures show population density and GDP density is represented by GDP per square-km (see Figure 2).

2.6. Structure of Model and Calibration

GSM has been developed on Java^{TM} and object-oriented programming (OOP) technologies. The GSM model is able to forecast the dynamics of populations and industries at the sub-national level. It works in the following steps (Kumagai et al. 2008):

1. **Initialization & Calibration**: The data related to regions and routes are loaded from prepared data input files, e.g. CVS files. Regional data related to the routes between regions needs to be compatible. For example, names of cities on route data must appear in the regional data together with other attributions of the cities (regions), especially latitude and longitude.

   Each region and industry is set with its own "A(r)," the technology or efficiency parameter. Then the A(r) is calibrated to absorb the difference between theoretically computed nominal wage and the actual nominal wage in each region.

   For example, if actual GDP for a region is higher than theoretically estimated RGDP, then the "A(r)" in the region is calibrated to match the theoretical and actual GDPs. Furthermore, "A(r)" can reflect various industrial infrastructures in regions such as: Electricity, Water supply, Telecommunication, Human resources, Efficiency of Public sector, etc.
2. **Determination of Short-Run Equilibrium:** The GSM calculates the short-run equilibriumvalues of GDP by sector (equilibrium under a given population distribution), employment by sector, nominal wage by sector, price index, and other variables based on the distribution of population. The GSM uses iteration techniques to solve such multi-equation modelling.
3. **Population Dynamics Calculation:** Once short-run equilibrium values are found, the GSM calculates the dynamics of population or movement of labour based on differences in real wages among countries, regions, and industries. The GSM is then able to set the speed of adjustment for inter-country, inter-region, and inter-industry labour movements.
4. **Output Results** To examine related variables in time series, the GSM exports equilibrium values of GDP by sector, employment by sector, nominal wages by sector, price index, and other factors for every single year in several formats from database format to spatial presentation
5. **Repetition of Step 2.** Now, a new equilibrium under new distribution of population is found. The assumption is that this cycle is one year and then there is a need to return to Step 2. In the analysis presented in this paper, the typical simulation is run for 25 years.

3 ASEAN ECONOMIC COMMUNITY (AEC) MODEL

In this paper, ASEAN Economic Community is explored within the GSM framework to depict the interests of ASEAN countries, e.g. Indonesia, Malaysia, Philippines, Singapore, Thailand, Brunei, Myanmar, Cambodia, Lao PDR, and Vietnam. These member states have diverse policies, priorities and institutions. Enhanced ASEAN connectivity addresses the disadvantages of the ASEAN region and at the same time enables a more cohesive, competitive, investment-attractive, resilient, and dynamic economic community in Southeast Asia. To achieve this, there are three connectivity dimensions which are physical connectivity, institutional connectivity and people-to-people connectivity. ASEAN has put in place numerous program and initiatives for building and enhancing regional connectivity, and some good progress has been made. The main document is known as the Master Plan on ASEAN Connectivity (MPAC) (ASEAN Secretariat 2011).

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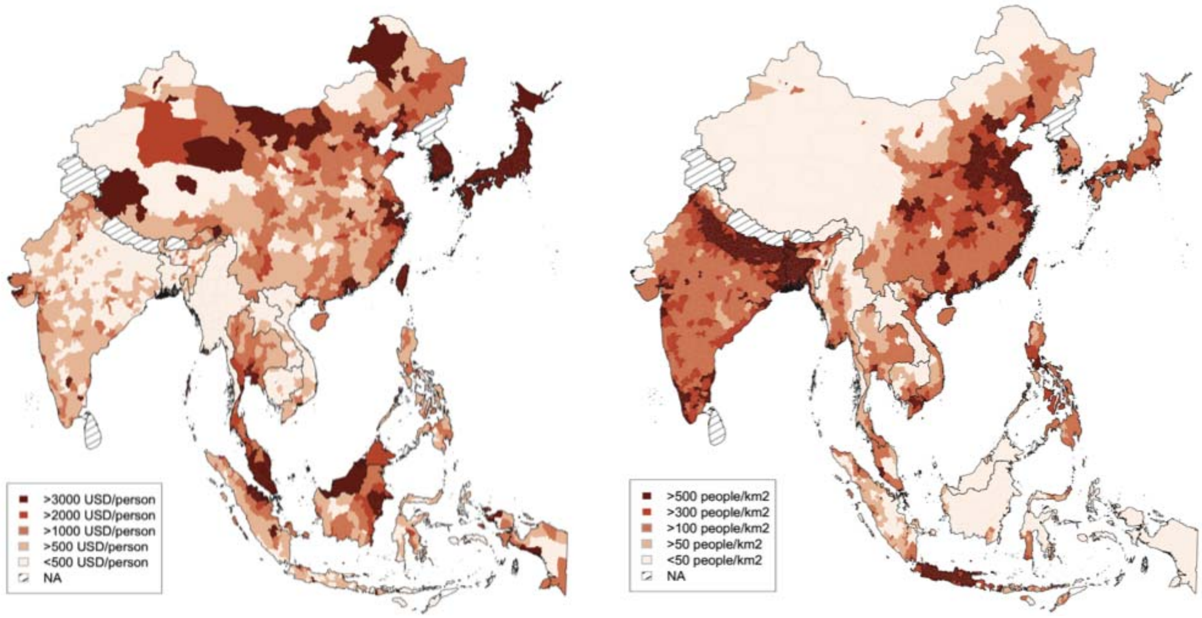

Figure 2: GDP and population density (year 2005).

Therefore, GSM can be used to simulate the impacts of connectivity improvement, particularly in reducing the direct and indirect cost due to the removal of physical and non-physical, such asenhanced transport and expanded interconnectivity linkedwith reducing tariff, non-tariff, social and cultural barriers. Figure 3 illustrates key components for direct and indirect costs of logistics between two locations. Some of MPAC's key initiatives are vital for the seamless movement of goods and tradable services within the region and to the rest of the world. This can be identified such as thecompletion of the ASEAN Highway Network, the accomplishment inimplementingthe Singapore Kunming Rail Link (SKRL) project, the establishment of an efficient and integrated inland waterways network, the accomplishment of an integrated, efficient and competitive maritime transport system, and the establishment of integrated and seamless multimodal transport systems to make ASEAN the main transport hub in the East Asia region (ASEAN Secretariat 2011).

3.1. Scenario Development

There are two key scenarios that are explored in this paper: 1) No AEC Development in Connectivity and 2) MPAC is fully implemented. The conditions of these two scenarios are shown as the following:

- No AEC Development: The conditions of routes in ASEAN are assumed as in the year 2005. There is no further development. Also, in 2020, the "congestion" at borders between neighbouring countries is reflected in the route data as an increase in border crossing time. Therefore, the time at border is assumed double in 2020. For tariff and non-tariff barriers among ASEAN countries are assumed to be the same as 2005. The reduction is found in tariffs and non-tariff barriers among non-ASEAN countries/between an ASEAN country and a non-ASEAN country continues.
- MPAC is implemented: the conditions of routes are updated at 2010, 2015, reflecting the development according to the MPAC. In 2020, the "congestion" at borders between neighbouring countries is reflected in the route data as an increase in border crossing time. (Time at border doubled in 2020 but halved by facilitation). Tariff and non-tariff barriers are updated according to various trade agreements including AEC.

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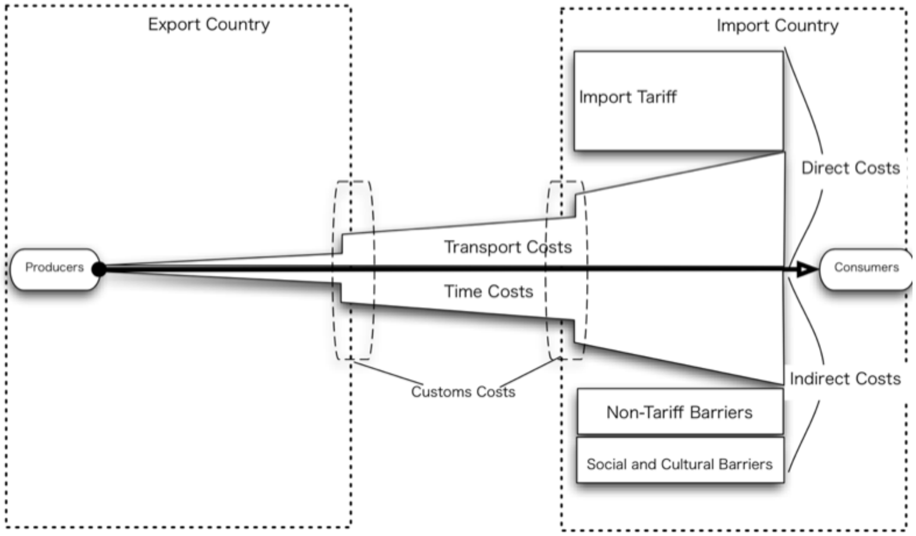

Figure 3: Key components of direct and indirect costs between two locations due to MPAC implementation.

3.2. Model Results

The simulation results show the impact to economic growth due to the MPAC implementation. Figure 4 and 5 reflects positive impacts on GDP growth around the region, particularly in Myanmar, Laos, the northern part of Indonesia, the eastern side of Malaysia, and the southern of Vietnam. However, it also shows the negative impacts on expected GDP growth is to the southern part of Indonesia, Cambodia, and northern Philippine. Table 2 illustrates the differences among ASEAN countries.

For Indonesia, Philippine, and Vietnam the negative growth refers to the move within growth poles within own countries or neighbouring one. This can benefit to the reduction of their nation disparity. However, for Cambodia, the regions near Laos border gain and the other parts lose. So, the southern corridor in the Greater Mekong Sub region (GMS) will compliment AEC development.

In 2030, the overall growth of ASEAN countries will be 0.32% better in 2030 when compare to their national estimate if the countries are able to fulfil all their MPAC commitments. The GSM simulation shows the % share of each ASEAN countries when implementing MPAC in Table 3 hereunder. The countries are ranked in descending order.

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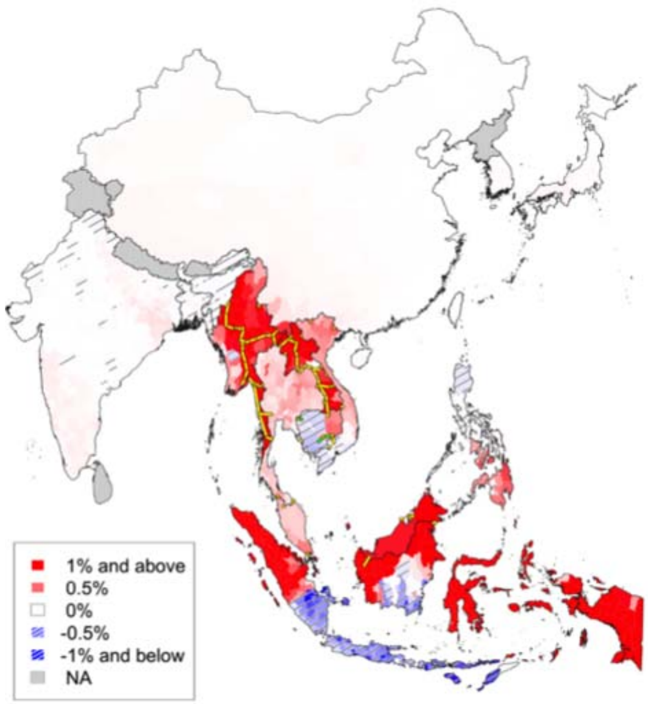

Figure 4: GDP growth differences between No AEC Development and AEC Development with MPAC Implemented from year 2015 to year 2030 (Overall).

Table 2: GDP growth differences between No AEC Development and AEC Development with MPAC Implemented from year 2015 to year 2030 in ASEAN countries.

Country	% GDP Growth
Myanmar	2.29
Brunei	2.12
Laos	1.16
Indonesia	0.39
Singapore	0.36
Malaysia	0.26
Thailand	0.05
Vietnam	0.05
Philippine	0.01
Cambodia	-0.02

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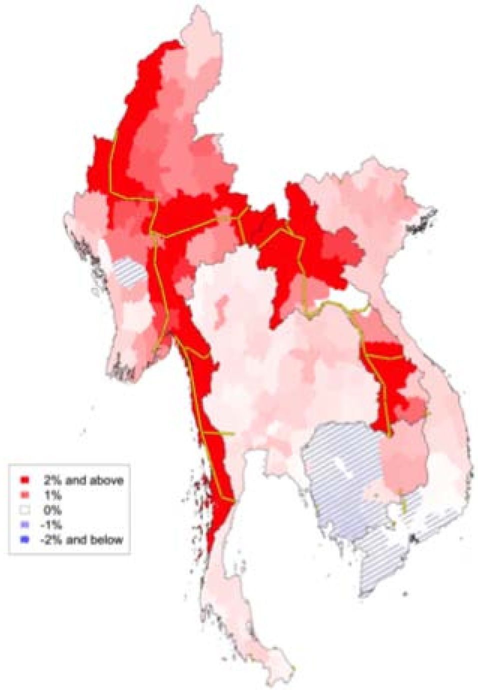

Figure 5: GDP differences between No AEC Development and AEC Development with MPAC Implemented in year 2030.

Table 3: Economic benefits when comparing no AEC Development with AEC Development under MPAC implemented from 2015 to 2030 in ASEAN.

Country	RGDP (M.USD)	% Share
Indonesia	12582	47.8
Myanmar	5876	22.3
Malaysia	2361	9.0
Singapore	2189	8.3
Thailand	1804	6.9
Laos	654	2.5
Vietnam	500	1.9
Brunei	316	1.2
Philippine	60	0.2
Cambodia	-45	-0.2

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4 SUMMARY

This Geographical Simulation Model (GSM) can be used as an alternative decision support system (DSS) tool to assess transportation, agglomeration, as well as economic growth behaviour according to the logistics infrastructure improvement and development. This simulation model is based on new economic geography (NEG). Nonetheless, this GSM model still needs to be refined and extended further. Some key parameters used in the test simulations are still based on assumptions. To conduct more precise analysis, each parameter will need be not only identified correctly but also based on empirical data.

However, the GSM test simulation does provide insights into the future and the benefits that can be accrued from regional economic integration. The derived findings do offer a clear idea of the benefits of using the GSM model when trying to better understanding the impact of logistics infrastructure within a regional economic integration framework. The scientific approach used in the GSM model development can provide regional and national policy makers with better informed decision when developing policies.

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