SPATIAL INEQUALITY IN THE SOUTHEAST ASIAN INTERCITY TRANSPORT NETWORK*

XINGJIAN LIU, LIANG DAI and BEN DERUDDER

ABSTRACT. Spatial inequality in transport access is both the driver and outcome of rising economic inequality in Southeast Asia. Unlike many regional disparity studies that focus on national economic indicators, this paper takes an urban network approach to assess the spatial inequality in Southeast Asian intercity transport network. We analyze urban connectivity in intercity road, rail, and air networks for a total of 47 Southeast Asian cities. Spatial inequality at the city and network level is revealed via centrality measures and community detection, respectively. Gini coefficients for individual centrality rankings point to a hierarchical degree distribution, a rather even distribution of closeness centrality, and a highly concentrated distribution of betweenness centrality. Four network communities are identified, reflecting the influences of entrenched uneven development, fragmented geography, and economic and political policies. *Keywords: Southeast Asia, network connectivity, transportation network, spatial inequality.*

Economic inequality has been rising in Southeast Asia in the past few decades (Yap 2014). Spatial inequality in transport access is both the driver and outcome of rising economic inequality. On the one hand, economic development in Southeast Asia has long been constrained by its "tyranny of geography" (Armstrong and Read 2006). The fragmented and tropical geography has inhibited efficient transportation and the formation of an integrated market (Hooper 2005). Areas with better physical infrastructure and transport access would benefit from lower transaction costs, larger market size, and higher chances of attracting foreign direct investment (Munnell 1992; Fujimura 2004; Walsh 2010). On the other hand, existing spatial inequality in transport access is conditioned on uneven economic growth, as improving physical connectivity requires substantial public investments.

Therefore, spatial inequality in transport access has always been high on regional and national agendas. For example, developing efficient and extensive transportation networks is highlighted in various Association of Southeast Asian Nations (ASEAN) initiatives (Goh 2008; Bhattacharyay 2009). More recently, Asian Development Bank and Asian Infrastructure Investment Bank are actively seeking to help Southeast Asian countries develop infrastructure networks. Flagship projects include Singapore to Kunming, China, railroads and high-speed rail networks in Thailand. National imperatives also feature predominantly in this

*The authors would like to thank the editor and anonymous reviewers for their valuable insights and suggestions, which have significantly helped to improve the manuscript. All errors remain our own. This study is supported by grants from the National Natural Science Foundation of China (41501177) and HKU Seed Funding Programme for Basic Research (201504159017). The usual disclaimer applies.

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process. Beyond economic functions, the development of transportation networks has been instrumental in social and political changes of ASEAN countries (Kuroda 2008), ranging from promoting national unification and integration (Kissling 1989; Raguraman 1997), to boosting labor migration (Pye and others 2012), to minimizing rural-urban inequalities (Sabandar 2007).

Rather than examining Southeast Asia as comprised of national political units and based on national statistics, this paper employs a network approach to explore the spatial inequality of transportation connections between Southeast Asian cities. Tim Bunnell suggests that this network approach would present an alternative geography of Southeast Asia as comprised of a network of cities and thus challenges the "methodological nationalism" in area studies (2013). Meanwhile, employing a network approach is consistent with the new network paradigm in the "urban system" literature (Camagni 1993; Castells 2001). The network paradigm departs from some of the conventional approaches of studying urban hierarchies in that the focus is no longer on the "characteristics" or "attributes" of cities in and by themselves (for examples, population size and number of companies; see, Tonts and Taylor 2010). Using data on intercity connections has become an increasingly popular way to examine urban hierarchies (Grubesic and others 2011). Still, we acknowledge the danger of upscaling "methodological nationalism" to "methodological regionalism" by conceptualizing Southeast Asia through the lens of transnational urban networks (Bunnell 2013). For example, intercity flows of capital, information, and goods are not confined within regional boundaries, thus problematizing the very regional framings such as "Southeast Asia" and "ASEAN." Nevertheless, Eric Thompson argues that regional entities such as "Southeast Asia" remain valuable in both practices and scholarship (2013).

Using an urban network perspective, our exploratory analysis focuses on the spatial inequality of transportation connections in two levels. First, we look into how well individual cities are connected by transportation networks—that is, inequality of network connections at the nodal level. This enables us to reveal the hierarchical geography of transportation connections produced by the layered economic, political, and social processes in Southeast Asia. For example, Pacific Rim cities such as Kuala Lumpur and Singapore are emerging as well-connected world cities (Perry and others 1997; Taylor and others 2000; Bunnell and others 2002), while cities like Phnom Penh are in dire need of adequate road infrastructure (Motomura 1996). Second, our analysis identifies groups of cities that are more densely connected to each other, revealing inequality of transportation connections at the network level. In the context of urban networks, groups of densely connected cities form network "clusters," where intracluster connections are stronger than intercluster linkages (Derudder and others 2003). These clusters correspond to network-based regions in economic geography and reflect functional (economic) integration across cities (Liu and others 2015). Regional integration policies—for example, Brunei

Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA)—are deemed important for reducing economic inequality in Southeast Asia, generating intercity traffic flows and fostering network-based city regions (Yap 2014).

Although several studies have examined individual cities' positions with Southeast Asian transportation networks, especially airline networks, they often analysed a limited set of cities (for example, O'Connor 1995); focus on one transportation mode (Bowen 2000); and/or were limited to one network indicator, such as degree centrality (Taylor and others 2000). Thus, the overall pattern of the connectivity of cities in transportation networks remained unclear (Yap and Thuzar 2012). Against this backdrop, we measure how major cities in Southeast Asian are connected in the ensemble of road, air, and rail transportation networks. More specifically, we explore the inequality of transportation connectivity across cities and look into which cities are important in Southeast Asian transportation networks based on a set of network centrality measures (inequality of transport access at the city level); and which groups of cities have greater intra-group connectivity, forming densely connected network-based subregions (inequality of transport access at the network level).

In the next section, we report the construction of a composite measure of urban infrastructural connectivity, as well as details the centrality measures and community detection algorithms employed to reveal network-based regions. The paper concludes with a discussion of major network patterns of intercity transportation networks in Southeast Asia, and points to avenues for future research.

Data and Methods

data

We analyze urban connectivity in intercity road, rail, and air networks for a total of forty-seven Southeast Asian cities (Figure 1). Countries under investigation included Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam (that is, all ten members of ASEAN, plus East Timor, which has submitted its bid to join). Cities were selected based on the following criteria: all metropolises with more than half a million residents (based on citypopulation.de's data); and all capital cities (for example Vientiane, Laos, and Dili, East Timor) were included regardless of their population size. The units of analysis were not cities proper, but metropolitan areas that often aggregate cities within geographic proximity (for example, Metro Manila is composed of the city of Manila and surrounding municipalities). We adopted this working definition of cities as many nearby cities are functionally connected and share infrastructures.

The data collection process thus creates a 47-by-47 matrix, capturing intercity transportation links for passenger flows between the selected forty-seven

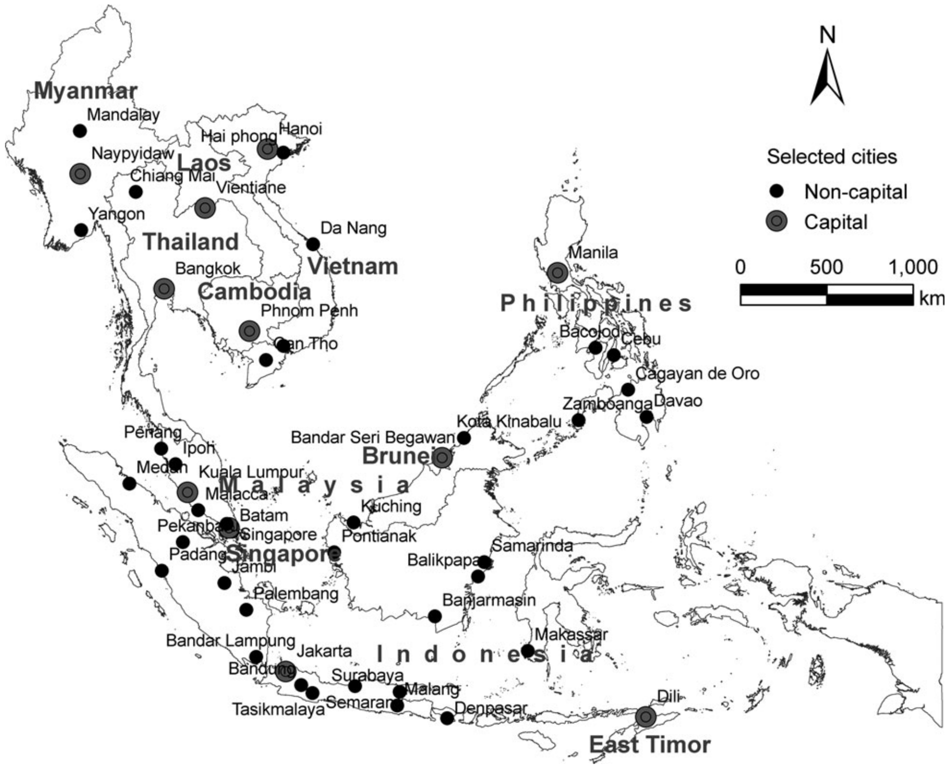

FIG. 1—Distribution of selected cities in Southeast Asia.

cities. The intercity transportation network is constructed as a composite network of three different layers: rail, road, and air connections. Each of the three layers contains 47 x (47-1) = 2162 valued dyads. Individual layers and the composite network are treated as symmetric by averaging the values of dyads between city-pairs. Dyadic values reveal the connectivity of Southeast Asian cities: the strength of connections between individual cities. A higher dyadic value corresponds to more connections, and vice versa. Individual transportation network data are then gathered, transformed, and aggregated into a composite network. The collection of individual network layers follows Liu and others (2015) and is summarized.

Intercity connectivity in the road network was approximated by the frequency of bus and ferry services. The intercity bus schedule was manually recorded from online ticketing systems of individual countries and cross-referenced with multiple sources. Ferry capacity was estimated and converted to bus-equivalent. The two busiest bus routes are between Kuala Lumpur-Johor Bahru (1673 weekly buses) and Singapore-Johor Bahru (1099).

Data about weekly trains were obtained from websites of railroad agencies and national railroad administrations for individual countries. The strongest rail connections are Kuala Lumpur-Ipoh, Kuala Lumpur-Penang, Kuala Lumpur-Johor Bahru (147, 119, and 63 weekly trains, respectively) in the densely connected Malay Peninsula, followed by Bangkok-Chiang Mai (56) in Thailand, Kuala Lumpur-Johor Bahru-Singapore (49), Jakarta-Semarang (49) in central Java, Indonesia, and Yangon-Mandalay (49) in Myanmar. Note that, due to the region's fragmented and tropical landscape, many cities in Laos, Philippines, and eastern Indonesia are not served by railroads (Nathan 2002).

The intercity airline network was estimated by the number of direct weekly flights based on SkyScanner's commercial flight search engine (http://www.skyscanner.com). SkyScanner provided information about both traditional and budget airline services. Charter flights were not included due to their rather idiosyncratic nature. Weekly flights data were also cross-referenced with other databases, such as Openflights.org. The strongest aviation connection is between Kuala Lumpur-Singapore (582 weekly flights), followed by Ho Chi Min City-Hanoi (522), and Jakarta-Surabaya (465).

All data were collected in the first week of February 2016. Information about the three individual transport networks was combined to produce a composite network. Applying the following equation normalized the logged dyadic values in each of the three layers: (original-min)/(max-min), where max and min denote maximum and minimum dyadic values in individual networks, respectively. All three networks thus have dyadic values ranging from 0 (no connectivity) to 1 (strongest connectivity). Links in the composite network were produced by averaging transformed dyadic values in individual networks. The end product of the data collection process is an intercity transportation network, which characterizes the connectivity among forty-seven major cities in Southeast Asia.

In comparison with previous studies of Southeast Asia cities (O'Connor 1995; Bowen 2000; Bhattacharyay 2009; Walsh 2010; Yap and Thuzar 2012), our data collection process measures multiple transportation networks and includes a larger array of cities; features a greater geographic coverage by including major cities from all ASEAN countries; and adopts a systematic approach, thus allowing for replication and longitudinal comparisons.

We acknowledge that our analysis of passenger flows represents a specific instance among multiple urban networks (Burger and others 2014). Empirical studies of other urban networks (for example, cargo flows; see Lee and Ducruet 2009) may or may not arrive at similar conclusions. Nevertheless, a composite measure of three passenger transportation networks is closely related to, among other things, labor mobility and external investment, thus providing a pertinent reflection of the uneven transport connectivity (Derudder and others 2014).

METHODS

We assessed the network hierarchy of individual cities with three network-centrality measures: degree, closeness, and betweenness. We also performed a network clustering analysis to reveal network-based city clusters. Centrality and community analyses examine the uneven distribution of transportation connections at the city and network level, respectively.

Following Arthur Alderson and others (2010), we illustrate the implications of these centrality measurements and the community detection algorithm with a "toy" network (Figure 2). To ease interpretation, the toy network is binary and all centrality scores are not normalized. Note that in the section on results, centrality scores are reported in a normalized fashion (that is, taking values between 0 and 1; see Borgatti and Everett 2006), to make results independent of network size; and incorporate network weights—different connectivity levels as detailed in the data construction section. Or, put differently: edges are treated as equal in the toy network, while in the real empirical setting they are weighted and represent different levels of connectivity. Our toy network depicts a hypothetical transport network among eleven Southeast Asian cities, whose degree, closeness, and betweenness centrality rankings are presented in Table 1.

Degree centrality reflects individual cities' direct connections to other cities. A city is more connected if it has more direct linkages with others. For example, in our toy example, Jakarta and Singapore are more connected with five linkages, whereas smaller Philippine cities such as Cebu and Davao have only two connections.

Closeness centrality measures the overall difficulty for a city to connect with all other cities in the network. Closeness centrality is operationalized by looking at individual cities' inverse (network) distances to all other nodes. In our toy example, Jakarta and Singapore have higher closeness centrality not only because they have the largest number of direct linkages, but also because all other cities are only three "steps" or "links" away. While degree centrality

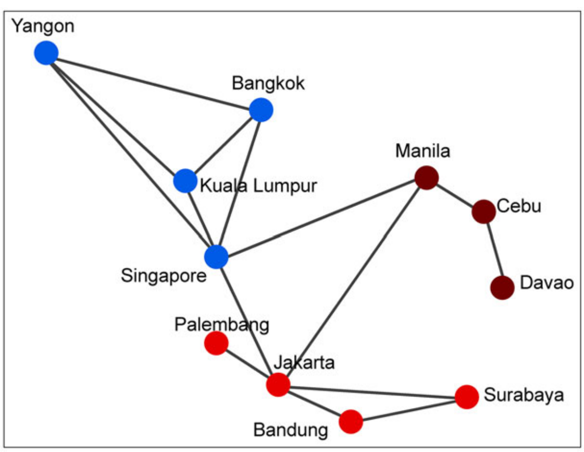

FIG. 2—The toy network (Cities are colour-coded to represent their community affiliation.)

TABLE 1—CENTRALITY RANKINGS FOR THE "TOY" NETWORK

RANK	CITY	DEGREE	CITY	CLOSENESS	CITY	BETWEENNESS
1	Singapore	5	Singapore	0.063	Jakarta	23
2	Jakarta	5	Jakarta	0.063	Singapore	21
3	Kuala Lumpur	3	Manila	0.059	Manila	16
4	Bangkok	3	Kuala Lumpur	0.043	Cebu	9
5	Yangon	3	Bangkok	0.043	Kuala Lumpur	0
6	Manila	3	Yangon	0.043	Bangkok	0
7	Surabaya	2	Surabaya	0.042	Yangon	0
8	Bandung	2	Bandung	0.042	Surabaya	0
9	Cebu	2	Cebu	0.042	Bandung	0
10	Palembang	1	Palembang	0.040	Palembang	0
11	Davao	1	Davao	0.030	Davao	0

measures the absolute number of connections, closeness centrality partly reflects the overall quality of connections—whether cities have the right connections to access the network at large. For example, while Palembang, Indonesia, and Davao, the Philippines, both have one connection in our toy network, Palembang has a higher closeness centrality and is therefore more integrated into the regional system. This is because Palembang's sole connection is with Jakarta, which has many connections and opens doors for Palembang to connect/be connected with other cities. In comparison, Davao's only direct linkage is with the less well-connected Cebu.

Betweenness centrality captures cities' brokerage function in the network—their capability of controlling connections between others. In the toy network, all connections between Davao and the other nine cities (except itself and Cebu) need to go through Cebu, thus giving Cebu a betweenness centrality of nine as it controls flows in and out of Davao. Within the larger regional context, Jakarta, Singapore, and Manila occupy similar brokerage positions for Indonesian cities, cities in the Indochina Peninsula, and Philippine cities, respectively.

Connections between cities are not random; cities with social, economic, and geographic proximity are more likely to be connected and form network clusters. Similar to the concept of "functional regions" (Derudder and others 2014)), a network cluster or community refers to a collection of closely connected cities whose intra-cluster connections exceed inter-cluster connections. Community detection algorithms build upon the connections between cities and partition the original network into relatively self-contained subcomponents. For example, in our toy example, most community detection algorithms would produce three communities (Figure 2): a community of cities on the Indochina Peninsula anchored by the city-state of Singapore; a Philippine community consisting of Manila, Cebu, and Davao; and a group of Indonesian cities centered on Jakarta. We tested a number of community-detection methods on our composite network and they produce largely consistent results. Therefore, we report community detection results from the "fast greedy modularity optimization method" (Clauset and others 2004). All data visualization and analyses were performed on the R platform (Csardi and Nepusz 2006).

Results and Discussion

centrality analysis

Centrality analysis reveals the inequality of transport access at the city level in Southeast Asia. Table 2 summarizes the three centrality rankings for the forty-seven Southeast Asian cities. Figure 3 visualizes the composite transportation network, where thickness of network links corresponds to connection strength, node size denotes degree centrality, and node colors are based on community affiliation.

We discern two initial observations from Table 2. First, network centralities differ significantly across cities. Singapore, Kuala Lumpur, Jakarta, and Bangkok rank consistently in the top five of all rankings (Bowen 2000). Unsurprisingly, cities in the sparsely populated fringe Indonesian and Philippine provinces occupy bottom spots in all rankings (Santosa and Joewono 2005). Second, although the rankings of cities point to a general theme (connectivity), there are sizable differences. Gini coefficients for individual centrality rankings point to a rather hierarchical distribution of degree centrality (with a Gini coefficient of 0.390), a relatively evenly distributed closeness centrality (0.118), and a highly hierarchical ranking of betweenness centrality (0.874).

Rather than examining the trajectories of individual cities, several major sets of processes underlying the uneven connectivity were identified: the uneven development that dates back to the colonial times, the region's fragmented and tropical geography, and more recent socioeconomic and political strategies.

First, the spatial inequality of transport connectivity dates back to the colonial era, when different Western powers coordinated development within their respective colonies (Dick and Rimmer 2003). In order to consolidate territorial control and facilitate the extraction of natural resources, colonial governments built transportation networks around strategically important cities (Saueressig-Schreu 1986; Sien 2003; Lange 2004). For example, the British linked cities along the Malay Peninsula with railroads (Nathan 2002), while tracks were laid by the French to connect Hanoi, Vietnam, with Kunming, China.

Second, individual cities' connectivity is affected by the region's "tyranny of geography," including the mountainous terrain, insularity, remoteness within the global context, as well as many archipelagic countries (Armstrong and Read 2006). This is most evidenced by the Philippine island cities in our analysis. The lack of rail and bus linkages has further "penalized" these cities when compared at the regional level.

Table 2—Centrality Rankings for forty-Seven Southeast Asian Cities (DC: Degree centrality; CC: Closeness centrality; BC: Betweenness centrality.)

RANK	CITY	DC	CITY	CC	CITY	BC
1	Singapore	1.000	Singapore	0.186	Jakarta	1.000
2	Kuala Lumpur	0.991	Kuala Lumpur	0.179	Manila	0.436
3	Jakarta	0.909	Jakarta	0.174	Singapore	0.399
4	Surabaya	0.677	Bangkok	0.167	Bangkok	0.362
5	Bangkok	0.632	Penang	0.152	Kuala Lumpur	0.355
6	Ho Chi Minh City	0.518	Johor Bahru	0.152	Ho Chi Minh City	0.281
7	Penang	0.494	Surabaya	0.151	Yangon	0.182
8	Bandung	0.483	Ipoh	0.150	Balikpapan	0.093
9	Johor Bahru	0.482	Denpasar	0.144	Surabaya	0.050
10	Semarang	0.426	Semarang	0.142	Denpasar	0.045
11	Manila	0.403	Malacca	0.140	Medan	0.010
12	Denpasar	0.400	Chiang Mai	0.139	Hanoi	0.008
13	Hanoi	0.389	Malang	0.134	Bandung	0.002
14	Medan	0.367	Phnom Penh	0.132	Palembang	0.002
15	Ipoh	0.353	Bandung	0.131	Penang	0.000
16	Malacca	0.309	Medan	0.129	Johor Bahru	0.000
17	Da Nang	0.303	Manila	0.128	Semarang	0.000
18	Batam	0.289	Ho Chi Minh City	0.127	Ipoh	0.000
19	Yangon	0.284	Batam	0.124	Malacca	0.000
20	Palembang	0.280	Pontianak	0.119	Da Nang	0.000
21	Chiang Mai	0.254	Bandar Lampung	0.117	Batam	0.000
22	Bandar Lampung	0.251	Vientiane	0.114	Chiang Mai	0.000
23	Balikpapan	0.248	Makassar	0.114	Bandar Lampung	0.000
24	Pekanbaru	0.246	Kota Kinabalu	0.113	Pekanbaru	0.000
25	Malang	0.233	Balikpapan	0.113	Malang	0.000
26	Makassar	0.210	Palembang	0.113	Makassar	0.000
27	Cebu	0.201	Hanoi	0.111	Cebu	0.000
28	Hai phong	0.195	Kuching	0.111	Hai phong	0.000
29	Phnom Penh	0.192	Yangon	0.111	Phnom Penh	0.000
30	Mandalay	0.181	Pekanbaru	0.110	Mandalay	0.000
31	Kota Kinabalu	0.170	Da Nang	0.109	Kota Kinabalu	0.000
32	Pontianak	0.164	Padang	0.109	Pontianak	0.000
33	Vientiane	0.151	Hai phong	0.106	Vientiane	0.000
34	Jambi	0.151	Banjarmasin	0.104	Jambi	0.000
35	Bandar Seri Begawan	0.151	Jambi	0.103	Bandar Seri Begawan	0.000
36	Naypyidaw	0.146	Cebu	0.101	Naypyidaw	0.000
37	Davao	0.135	Bandar Seri Begawan	0.100	Davao	0.000
38	Padang	0.133	Cagayan de Oro	0.099	Padang	0.000
39	Kuching	0.124	Davao	0.098	Kuching	0.000
40	Banjarmasin	0.118	Bacolod	0.097	Banjarmasin	0.000
41	Cagayan de Oro	0.104	Mandalay	0.096	Cagayan de Oro	0.000

(continued)

TABLE 2—CONTINUED

RANK	CITY	DC	CITY	CC	CITY	BC
42	Can Tho	0.092	Tasikmalaya	0.095	Can Tho	0.000
43	Zamboanga	0.092	Naypyidaw	0.095	Zamboanga	0.000
44	Bacolod	0.085	Zamboanga	0.092	Bacolod	0.000
45	Tasikmalaya	0.077	Can Tho	0.087	Tasikmalaya	0.000
46	Dili	0.031	Dili	0.077	Dili	0.000
47	Samarinda	0.024	Samarinda	0.073	Samarinda	0.000
Gini coefficient		0.390		0.118		0.874

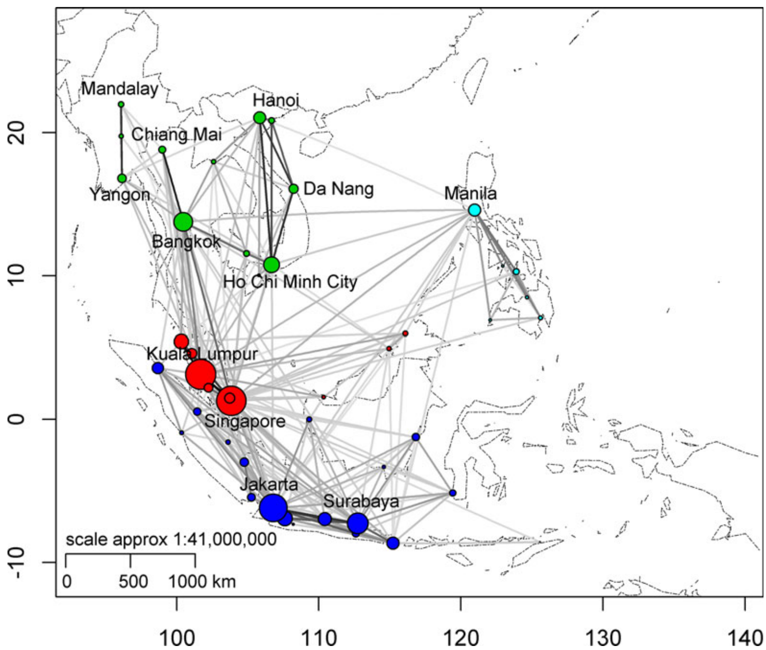

FIG. 3—Intercity transportation network between 47 Southeast Asian cities (The circle size reflects cities' degree centrality; link width and colors are proportional to linkage strength; and the circle colour corresponds to individual network communities.)

Third, intercity transport connections are oftentimes related to economic and political projects. For example, Singapore's drive to development high value-added services is supported by the city-state's reliable transportation connections (Lo and Yeung 1996; Yeung 2008) and the overprovision of air transportation capacity (Phang 2003). For the large archipelagic countries such as Indonesia and Philippines, national airlines help incorporate cities in remote areas into national development (Kissling 1989). Similarly, national policies also help shape connections around major cities in Vietnam (Doi Moi 1986; Durand and Anh 1996).

DEGREE CENTRALITY

Degree centrality summarizes a city's total connections with all others cities in the network. Having served as the region's gateway for a long time, Singapore attained the highest degree centrality. In addition to its role as an international air hub, Singapore's leading position benefits from its rail and road connections with mainland Southeast Asia. Facilitated by the city-state "Open Skies" policy and the emergence of low-cost airlines in recent years, Singapore has been increasingly connected with secondary cities in other countries: Surabaya and Denpasar in Indonesia, Penang in Malaysia, Chiang Mai in Thailand, and Cebu in the Philippines (Bowen 2000). These new connections help cement Singapore's position as the region's gateway city.

Oftentimes recognized as another world city in Southeast Asia, Kuala Lumpur ranked second in degree centrality (Gugler 2004). On the one hand, the government has strengthened east Malay's air connections to Kuala Lumpur to promote east Malay's economy and foster integration between the country's two halves. On the other hand, the Malaysian government has been aggressively redefining Kuala Lumpur's as a global hub for knowledge, trade, and foreign direct investment, emphasizing transportation infrastructures and communications projects (Rimmer and Dick 2009).

As the largest country in terms of both population and land size in ASEAN and with a relatively high urbanization level, Indonesia contains the most cities selected in the study. Indeed, in addition to Jakarta, large Indonesian cities such as Surabaya, Bandung, and Semarang rank in the top ten in terms of degree centrality. The leading positions of Indonesian cities could be ascribed to the large number of domestic connections, as evidenced by the dense rail, road, and air connections on Java Island. Similarly, the high ranks in degree centrality for Penang (ranked 7th) and Johor Bahru (ranked 9th) in Malaysia are due to dense domestic connections on the Malay Peninsula.

As a textbook example of a primate city (Sternstein 1984; McGee 1995), Bangkok accounts for almost a third of Thailand's urban population, as well as a significant share of the nation's transportation infrastructures (Douglass 2000). Bangkok ranks fifth in the degree centrality ranking. Though not well connected with secondary cities in Indonesia and Philippines, Bangkok's more northerly location makes it well situated to connect the Mekong river basin with other parts of Southeast Asia.

Having been Vietnam's commercial center since the 1800s, Ho Chi Minh City enjoys a higher rank (6th) in degree centrality than the nation's capital Hanoi (13th). Manila does not stand out in the degree centrality ranking, which could partly be explained by Philippines' island geography. Furthermore, Manila is increasingly integrated with Northeast Asia and has strong trade and investment activities with Japan, South Korea, and Taiwan (Rimmer, 2000).

CLOSENESS CENTRALITY

The closeness centrality ranking adds another dimension to the connectivity analysis by scrutinizing how "easy" it is to reach—via direct and indirect links —the other cities in the network. Given that most cities are fairly closely connected to one or more major gateways, the ranking is relatively "flat" (Table 2). This also resonates with the growth of low-cost carriers (that is, budget airlines), which improve the connectivity of small and medium cities and increase of the overall "closeness" scores for these cities (Hooper 2005; Zhang and others 2008). In addition to close connections with gateway cities, cities in several countries also form dense subregional networks (Jones 2002), which is associated with their geographic proximity and economic development. For instance, nine out of the twenty strongest connections (Table 3) concentrate along the western seaboard of the Malay Peninsula, and this dense subregional network covers roughly the areas of the "Straits of Malacca Economic Corridor" and the "Indonesia-Malaysia-Thailand Growth Triangle." Another case is the intensive connections along the Irrawaddy River in Myanmar (Figure 3), linking the country's largest port (Yangon) and its major inland economic center (Mandalay).

In addition, the formation of some densely connected urban regions is driven by political-integration strategies, as many Southeast Asian countries

TABLE 3—THE TWENTY STRONGEST DYADS

RANK	DYAD	CONNECTIVITY (MAX=1)
1	Kuala Lumpur - Singapore	0.900
2	Kuala Lumpur - Johor Bahru	0.896
3	Singapore - Johor Bahru	0.875
4	Kuala Lumpur - Penang	0.847
5	Bangkok - Chiang Mai	0.797
6	Ho Chi Minh City - Hanoi	0.748
7	Ho Chi Minh City - Da Nang	0.728
8	Jakarta - Surabaya	0.712
9	Jakarta - Semarang	0.709
10	Yangon - Mandalay	0.706
11	Hanoi - Da Nang	0.688
12	Ipoh - Singapore	0.683
13	Penang - Singapore	0.655
14	Yangon - Naypyidaw	0.633
15	Ho Chi Minh City - Hai phong	0.626
16	Kuala Lumpur - Ipoh	0.608
17	Ipoh - Johor Bahru	0.603
18	Semarang - Surabaya	0.599
19	Bandung - Surabaya	0.568
20	Penang - Johor Bahru	0.564

purposely pursued economic nationalism after their independence in the 1950s (Raguraman 1997). For example, attempting to promote national unification, north-south transportation was improved in Vietnam to connect the socialist north around Hanoi and the formerly capitalist south around Ho Chi Minh City. Furthermore, extensive highways were constructed in the central Malay Peninsula (Bunnel and others 2002), aiming to connect Kuala Lumpur with its satellite cities as well as facilitate transportation within major industrial regions (for example, the Multimedia Super Corridor and MSC). As for Indonesia, while national airlines were established for national integration on sprawling islands (Kissling 1989), the government has strived to promote the connections of secondary cities in recent years (Bunnell and Miller 2011). For instance, there are eleven direct flights every week between Balikpapan on Borneo and Singapore (Silas and Setijanti 1996).

BETWEENNESS CENTRALITY

Betweenness centrality highlights cities' brokerage functions for the interconnection of cities that are not directly linked. This ranking is much more hierarchical (Table 2). Notwithstanding an overall well-connected transport network, a few cities are still privileged with "gateway" functions and high betweenness centrality. Most notable examples include Jakarta, Manila, Singapore, Bangkok, and Kuala Lumpur.

Capital cities—Jakarta, Manila, Kuala Lumpur, Bangkok, and Ho Chi Minh City—tend to serve as gateways in their respective countries, as the Southeast Asian urban system has long been characterized by a high degree of primacy since the colonial era. With the region's four most populous countries as their hinterlands, Jakarta, Manila, Kuala Lumpur, and Ho Chi Minh City serve as major gateways for Indonesian, Philippine, Malaysian, and Vietnamese cities, respectively (Morshidi 2000; Bunnell and others 2002). Consider, many cities in Sumatra "use" Jakarta to connect to the wider network, making Jakarta a critical gateway for articulating Indonesian cities into the ASEAN economy (Bowen 2000). Although in recent years the Indonesian government has been actively developing decentralization schemes (Bunnell and Miller 2011), encouraging the development of low-cost budget airlines, and promoting international gateways other than Jakarta such as Surabaya and Denpasar, Jakarta international airport still accounts for the largest share of passengers and cargo within Indonesia.

Relatedly, although Bandar Seri Begawan, Brunei, is geographically closer to Cebu than to Manila, air travel between Bandar Seri Begawan and Cebu may well involve layovers in Manila, which thus acts as the Philippine gateway city.

In comparison, even without a large national hinterland, the city-state of Singapore emerges as a truly ASEAN transportation hub. This is consistent with Singaporean development strategies to project economic and political influence over the city-state's territorial neighbors (Yeung and Olds 1998;

Rodrigue 2006), as well as achieve growth through translocal economic activities (for example, international trade; see Rodrigue 1994; Taylor and others 2000). Later mimicked by many other countries in the region (Forsyth and others 2006), Singapore has long adopted policies such as "Open Skies" to proliferate the city's aviation connections (Oum 1998; Rodrigue and others 2013) and geared its soft (management and amenities) and hard (new airport terminals) infrastructures (Phang 2003) towards attracting layover passengers during long-haul intercontinental flights (Lohmann and others 2009). In addition, the planned Singapore-Kunming Railway Link and the ASEAN Highway Network could further boost the city-state's role as the gateway city.

COMMUNITY DETECTION

The community-detection algorithm identifies four network communities within the Southeast Asian intercity transportation network. These communities represent strong intracommunity connections and characterize the spatial inequality of transport connectivity at the network level. Our community-detection analysis identified a greater-Mekong community that anchored by Hanoi, Yangon, Bangkok, and Ho Chi Minh City; a greater-Malaysian community incorporating Singapore and Brunei; an Indonesian community organized around Jakarta; and a community of Philippine cities. Among the four communities, the greater-Malaysian community has the highest average-degree centrality of 0.430, suggesting the most-connected subregion in Southeast Asia. It is followed by the Indonesian community (0.292) and the greater-Mekong community (0.281), while the Philippine community only has an average-degree centrality of 0.175. As already implied, the delineation of these communities largely reflects the archipelagic geography of the region (Armstrong and Read 2006), boundary effects (Grundy-Warr and others 1999), as well as the legacy of national integration programs (Raguraman 1997).

Economically, the greater-Malaysian community is comprised of three countries with the highest GDP in the region: Singapore, Brunei, and Malaysia. The GDP per capita in 2010 for these three countries is about fifteen times higher than that in the region's less economically vibrant countries, including Cambodia, Laos, Myanmar, and Vietnam, (CLMV)). The three strongest dyads in our analysis are among Singapore, Johor Bahru, and Kuala Lumpur, owing to geographical proximity and economic complementarity. Despite the fact the Bandar Seri Begawan has direct flight connections with leading cities in other communities—Bangkok and Ho Chi Minh City in the Mekong subregion, Manila in Philippines, Jakarta, Surabaya, and Denpasar in Indonesia, Kuala Lumpur and Kota Kinabalu in Malaysia and Singapore—Brunei's capital city has far more links with Malaysian and Singaporean cities. The dense connections within this network community could also be ascribed to Malaysia's national policies to integrate east and west Malaysia.

The formation of Indonesian and the Philippine communities can be ascribed to the dense domestic connections with capital cities as major gateway cities, reflecting the primate urban systems in these countries (Bowen 2004; Huff 2011). The greater-Mekong network community consists of Thailand and other four least developed countries in our analysis (that is, CLMV). Except for Thailand being one of the five original ASEAN members, CLMV joined ASEAN after 1995. Recently, Thailand has played an increasingly critical role in reducing regional inequality through strengthening links and promoting subregional integration (Walsh 2010). Specifically, Thailand has actively promoted cross-border trade with neighboring countries, importing raw material and primary products, exporting manufactured goods, and becoming a major investor in CLMV. Thailand has provided much financial and technical assistance for basic infrastructure development in neighboring countries—the construction of roads, dams, and power plants—to support long-term economic development (Fujimura 2006).

Conclusions

According to neoclassical growth theory, urban connectivity in transportation networks is an important harbinger of economic development, as well as a facilitator of social and political cohesion (Bhattacharyay 2009). The development of intercity transportation networks in Southeast Asia has undergone several major phases, each of which is driven by different rationales, emphasizes different modes of transportation—airline networks in postwar era—and focuses on different geographic regions: the concentration of infrastructures around leading cities during colonial times as well as post-independence territorial integration targeting at remote areas. Over time, transportation networks in Southeast Asia became more integrated and cities were often able to form relationship with others, both nearby and afar. The coexistence of these local and translocal linkages calls for a network approach towards understanding the urban system in the ASEAN region. These overlapping developmental patterns create a complex and uneven geography of intercity transportation networks, requiring a network-explicit examination that covers multiple transportation modes and extensive geographic areas.

In this exploratory analysis, we created a composite intercity transportation network between forty-seven major Southeast Asian cities by integrating information about rail, road, and air transportation. Spatial inequality of transport connectivity at both the city and network levels was examined through the lens of centrality analysis and community detection. Gini coefficients for individual centrality rankings point to a hierarchical degree distribution, a rather even distribution of closeness centrality, and a highly concentrated distribution of betweenness centrality. With regard to accessibility at the city level, Singapore, Kuala Lumpur, and Jakarta were identified as the most dominant nodes in terms of all three centralities in Southeast Asia transportation network. Cities in the sparsely populated peripheral regions ranked at the bottom. With regard to accessibility at the network level, four network communities were detected to have denser intracluster connections: a greater-Mekong community surrounded around Bangkok, a Malaysia community together with Singapore and Brunei with Kuala Lumpur and Singapore as gateways, an Indonesian community articulated into the wider region by Jakarta, and a Philippine community centered on Manila. Our analysis also highlighted important geographic, economic, political, and social processes underlying the spatial inequality of transport access within Southeast Asia.

Our analysis points to several future research avenues. Firstly, future analyses would account for capacity of individual vehicles, airplanes, and trains (Yap and Thuzar 2012). Secondly, this paper focused on infrastructure networks that transport people, and a next step would involve measuring the movement of cargo and information (Bowen and Leinbach 2006). Thirdly, future studies would require a multiscale approach. For example, Bangkok is the only Thai city that exceeds the 0.5 million resident selection threshold, and future analyses would incorporate smaller Thai cities by looking at both domestic (Bangkok and other parts of the Thailand) and international connections. Lastly, our analysis suggests the transportation network of Southeast Asia is controlled by a handful of leading cities. However, national governments are pursuing strategies to increase domestic equality of connectivity as well as compete internationally for more strategic positions within the global transport network. The region's leading transportation hubs are also facing external competition. For example, Singapore is competing with Hong Kong and Dubai for stopovers on long-haul routes between Asia-Pacific and Europe (Lohmann and others 2009). We anticipate substantive changes will emerge in terms of centrality ranking and network communities, all pointing to the need of a longitudinal study.

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