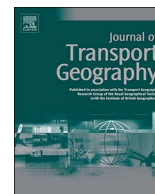




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# The evolving structure of the Southeast Asian air transport network through the lens of complex networks, 1979–2012

Liang Dai<sup>a</sup>, Ben Derudder<sup>a,\*</sup>, Xingjian Liu<sup>b</sup><sup>a</sup> Department of Geography, Ghent University, Krijkslaan 281/S8, Gent 9000, Belgium<sup>b</sup> Department of Urban Planning and Design, The University of Hong Kong, 8/F, Knowles Building, Pokfulam Road, 999077, Hong Kong

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## ABSTRACT

This paper presents a novel approach to investigating and understanding the evolving structure of the Southeast Asian air transport network (SAAN) over the period 1979–2012. Our approach captures the main topological and spatial changes from a complex network perspective. We find that the SAAN combines a relatively stable topological structure with a changing multilayered geographical structure. Statistical analysis indicates that the SAAN is a scale-free network with an increasing number of hub cities and has been characterized by small-world properties since 1996. Furthermore, the SAAN exhibits a recently intensified disassortative mixing pattern, suggesting an increasing dependence of small cities on hub-and-spoke configuration for better accessibility. A decomposition analysis is used to disaggregate the SAAN into a hierarchical core-bridge-periphery structure. The core layer consists of capital cities, the most economic vibrant secondary cities, and tourist destinations. This core layer is also densely interconnected with its center of gravity moving towards the north. The periphery layer, comprised of cities in remote areas, sustains a low significance with declining internal connectivity despite a rising number of cities being connected. The bridge layer lies in between both extremes, and is characterized by a high volatility over time. The connections and passengers between different layers increase, especially those between core and bridge after 1996. In our discussion, we trace these changes back to a series of socio-economic and politico-institutional dynamics in Southeast Asia.

## 1. Introduction

Air transportation has emerged as a key facilitator of economic development and social change as it greatly enables the flow of people, goods, capital, and information across space. This is particularly true for Southeast Asia (SEA), one of the most economically dynamic and strategically significant regions in the global economy (Sien, 2003). In 2015, SEA, which is commonly defined as including Cambodia, Laos, Myanmar, Vietnam (CLMV), Thailand, Malaysia, Singapore, Indonesia, Philippines, Brunei, and East Timor (formerly part of Indonesia) (cf. Rimmer and Dick, 2009), ranked third in Asia both in terms of its population of 633 million inhabitants (following China and India) and in terms of its economic size with a combined gross domestic product (GDP) of US\$2.45 trillion (following China and Japan) (ASEAN Secretariat, 2016). Important from the perspective of air transport, the region is much more geographically fragmented than, say, the European Union (EU) and North America. The archipelagic geography, further complicated by often-difficult terrain to cross in climatic and physiographic terms, endows air transportation with competitive

advantages over road, rail, and water transportation (Zhang et al., 2008). Or, as O'Connor (1995: 270) has pointed out: “air transportation is the only effective means for intercity links” in this region. For example, an express coach covering the 250 km trip from Ho Chi Minh City to Phnom Penh takes at least 5.5 h, whereas the flying time is only 45 min. Meanwhile, travelling by rail from Bangkok to Kuala Lumpur takes about 24 h compared to a 2-h flight. Similarly, a ferry trip between Singapore and Jakarta via Batam can last 26 h while a flight takes < 2 h. As a consequence, the importance of developing efficient and extensive air transport networks has been highlighted in various regional and national policy agendas (ASEAN Secretariat, 2011).

After several decades of fast-paced development, the Southeast Asian air transportation system has evolved into a complex network with mixed structures and large heterogeneities in capacity and intensity of connections. However, to date there has been no effort to engage in systematic complex-network analysis of the Southeast Asian air transport network (SAAN). Such a complex network approach has been shown to provide new insights into air transport systems at national (e.g., China; Wang et al., 2011), macro-regional (e.g., the EU;

\* Corresponding author.

E-mail addresses: [liang.dai@ugent.be](mailto:liang.dai@ugent.be) (L. Dai), [ben.derudder@ugent.be](mailto:ben.derudder@ugent.be) (B. Derudder), [xliu6@hku.hk](mailto:xliu6@hku.hk) (X. Liu).

Zanin and Lillo, 2013), and global (e.g., Guimera et al., 2005) scales. An analysis of the SAAN may or may not reach similar conclusions, as it entails very different sets of underlying geographic, institutional, and socioeconomic factors (Lordan and Sallan, 2017). To help filling this gap, in this paper we explore the structural evolution of the SAAN during 1979–2012 from a complex network perspective.

When examining a supra-national region such as the SEA region, one obviously risks falling into the 'territorial trap' (Agnew, 1994; Bunnell, 2013): it can be argued that the crux of the geographies of SEA's air transport connections are not simply confined to the SEA region, thus challenging the a priori framings such as SEA and ASEAN (cf. Taylor et al., 2013). Indeed, the 'openness' of SEA is clearly visible in the possible extension of the system to Hong Kong (Dick, 2005), or in the identified functional airline region by including neighboring China and Japan (Guimera et al., 2005). However, there has been no consensus on how closed a transport or urban system should be to make a regional framing tenable (Kratoska et al., 2005), while the liberalization/deregulation geography as circumscribed by the move towards open skies in the context of ASEAN Economic Community (AEC) and ASEAN Single Aviation Market (ASAM) does lend the region a certain coherence in this context (Liu et al., 2017; Thompson, 2013). Our analysis will therefore focus on airline connections originating and terminating within SEA.

The main contributions of our study are twofold. First, we conduct a statistical analysis to characterize the evolving topological structure of the SAAN over this 34-year period and compare the network metrics with some other major regional blocs. Second, a decomposition technique is employed to unveil the multilayered structure of the SAAN for the years 1979, 1996 and 2012, respectively. By doing so, we shed light on how the topological and geospatial architecture of the SAAN changes over time. To this end, the remainder of this paper is organized as follows: Section 2 reviews the literature, focusing on the application of complex network theory in the study of the geography of air transport networks. This is followed by a discussion of our methodological framework and data in Section 3. Section 4, then, presents the results of the complex network analysis of SAAN, after which the paper is concluded with an overview of our major findings, the limitations of our approach, and some avenues for further research.

## 2. Literature review

### 2.1. A growing air transport market in the context of regional integration

Southeast Asian countries have very different experiences with regional integration. It is well documented that regional economic integration in East Asia - including a large part of its Southeast Asian component - has been preceded by fast-paced industrial development in Japan and the emergence of newly industrializing countries (NICs) - South Korea, Taiwan, Hong Kong, and Singapore - since the mid-1960s (Yap, 2014). Consecutive waves of relocating labour-intensive industries then cascaded down to next-tier NICs - Indonesia, Malaysia, Thailand - and later to the Philippines after it introduced a transition towards more liberal economic policies from the early 1980s onwards (Coclanis and Doshi, 2000). Meanwhile, the three Indochinese economies (i.e. Vietnam, Laos and Cambodia) were trapped in conflicts and isolated from the SEA regional market for more than a decade after 1975. They subsequently embarked on a trajectory of regional economic integration through a fundamental shift in development strategy from a centrally planned economy to a market economy since the late 1980s, as exemplified by Vietnam's *Doi Moi* reforms (Hill and Menon, 2012). By 1993, CLMV countries had all embraced market mechanisms, emphasizing export promotion, welcoming foreign investment, and promoting tourism (Thant, 2012). The flows of trade and investment to these newcomers to regional integration led to the establishment of broader regional production networks. As a consequence, regional integration in SEA has been significantly accelerating since the early

1990s: Tanaka (2009) demonstrates that the intraregional trade has almost doubled over the past two decades and now constitutes a quarter of the region's total trade.

Enhanced intercity airline connectivity has been part and parcel of SEA's evolution towards greater regional integration and the development of a single economic market. Since the Association of Southeast Asian Nations (ASEAN) was founded in 1967, it has facilitated both improved regional economic integration and air transport connectivity, seeing both as being fundamentally intertwined. A key step was the agreement on an ASEAN Free Trade Area (AFTA) in 1992. The AFTA framework carried a commitment to further enhance regional co-operation by providing safe, efficient and innovative transportation and communications infrastructure networks. This boosted a series of sub-regional air liberalization initiatives, such as a joint agreement by Indonesia, Malaysia, and Thailand in 1994 to promote the development of air transport in ASEAN's Northern Growth Triangle. The agreement was later broadened to include the Philippines and Brunei, and was supplemented with a similar CLMV cooperation in 1998, which liberalized air transport between the four countries. Another important step was the 2003 agreement to building the AEC by 2015 in order to move SEA towards an integrated and globally competitive single market and production base. Under this umbrella, Southeast Asian governments have been engaged in concerted efforts to work out an open skies policy similar to the one realized in the EU, namely the ASAM. Against this background, the airline industry in SEA has been evolving from an assortment of individual and highly-protected companies into an increasingly integrated and liberalized system of regional business organizations.

According to data from the Official Airline Guide (OAG) database (<http://analytics.oag.com/>), SEA has witnessed substantial expansion in its regional air transport network over the past three decades. More than 60 new airports have been constructed and/or come into operation during the 1979–2012 period, while the number of direct intra-SEA air connections has nearly doubled from 330 to 602. In line with booming regional economic output and surpassing overall population growth, the total volume of scheduled air passenger traffic within SEA has increased dramatically from 23.9 million in 1979 to 234.9 million in 2012 (Fig. 1).

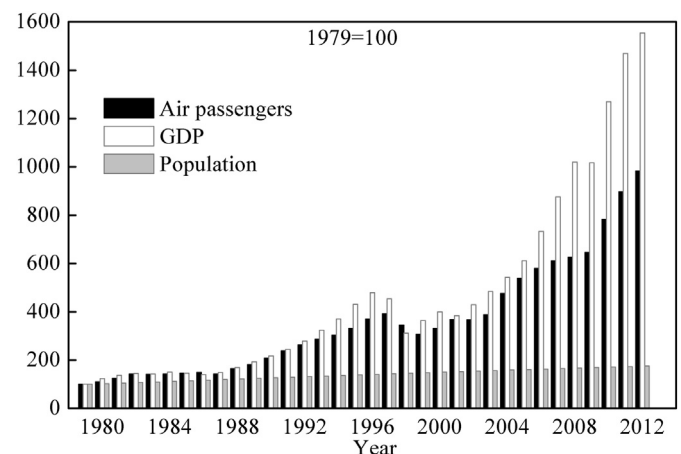


Fig. 1. Growth of scheduled air passenger traffic, GDP and population of Southeast Asia, 1979–2012 (Scheduled air passenger traffic from 1979 to 2012 was compiled from the OAG database. GDP and population data for each of the eleven Southeast Asian countries were gathered from World Bank (<https://data.worldbank.org/>). Since the World Bank GDP data of CLMV countries were incomplete, they were crosschecked and supplemented by data from <http://ivanstat.com>. Data from both sources were counted in current U.S. dollars (at 2015 prices). There was no GDP information for East Timor before 1999, since it was part of Indonesia. This confirmed the necessity to include it in our longitudinal study to keep geographic and statistical consistency although it has not become a formal ASEAN member yet.). The data in 1979 were standardized as 100 and those in other years were scaled according to this benchmark.

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