System Dynamics Framework for Sustainable Infrastructure Evaluation: Chiang Mai City and Impacts from Tourism

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Abstract

  Tourism consists of dynamic and complex activities. This industry has significant relationships to urban development. Tourism is also a key contributor to economic growth of the city; nevertheless, it effects to urban infrastructure carrying capacity of the city. A large number of tourists cause insufficient urban infrastructure, insufficient urban infrastructure effects the number of tourists. This relationship is dynamic and feedback; therefore, system dynamics approach is used for evaluation. The aim of this study is to develop the urban infrastructure evaluation model using system dynamics approach, as a key Decision Support System (DSS). This paper demonstrates the development of causal loop diagram and the framework model of Chiang Mai city, as a case study to analyse the impacts on urban infrastructure from tourists.

Keyword: System Dynamics, Sustainable Urban Development, Urban Infrastructure Evaluation, Chiang Mai City, Tourism Impacts.

1. Introduction and Background of Chiang Mai City

  Chiang Mai is the second largest province of Thailand. It is located in the north of the country, 700km north of Bangkok, as show in Figure 1. Chiang Mai has been attracting over 4 million visitors each year. The number of domestic tourists and international tourists in Chiang Mai are increasing since 2009, as shown in table 1. Because of the large number of tourist arrival in Chiang Mai, the revenue from tourism industry is the major economy of the city. In 2010, the revenue from tourism sector in Chiang Mai is 39,507.03 Million Baht while agriculture sector is 34,956 Million Baht (Chiang Mai Province Governor Office, 2013).

  Tourism generates many obvious advantages; for example, opportunities for employment, the demand for local products and industries. Nevertheless it generates many advantages, it can also have negative impacts on the environment and society that may effect to the sustainability of the city (Mai, Bosch, & Maani, 2011).

  The rapidly growth of Chiang Mai city is effected by tourism. In 2011, floating population in Chiang Mai municipality is approximately twice of registered urban population (Chiang Mai Municipality, 2011). People floating in Chiang Mai city because of many reasons, attractiveness from opportunities for employment is the one. Nowadays the rapidly growth of Chiang Mai city causes traffic congestion, environmental pollution, and insufficient resource and infrastructure.
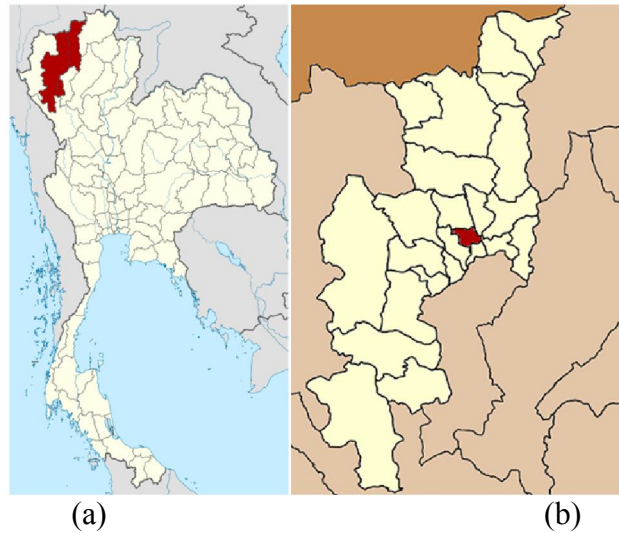
(a)   (b)

Figure 1 (a) Location of the province within Thailand (b) Location of the city within Chiang Mai Province

(Source: http://en.wikipedia.org/wiki/Chiang_Mai_Province and http://en.wikipedia.org/wiki/Chiang_Mai)

Table 1 Number of Tourists and Tourism Revenue of Chiang Mai Province: 2006 - 2012

Number of Tourists	Year						
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
International Tourists	1,876,300	1,583,837	1,470,802	1,241,300	1,695,288	2,039,162	2,192,322
Domestic Tourists	2,529,420	2,598,041	3,842,549	3,101,790	3,345,629	3,622,511	4,378,320
Total	4,405,720	4,181,878	5,313,351	4,343,090	5,040,917	5,661,673	6,570,642
Tourism Revenue (Million Baht)	39,785.06	38,894.25	38,135.33	32,605.79	39,507.03	43,070.24	53,863.72

(Source: Thailand National Statistical Office, Ministry of Information and Communication Technology)

Tourism consists of dynamic and complex activities (Mai et al., 2011). This industry has significant relationships to urban development. Tourism is also a key contributor to economic growth of the city; nevertheless, it effects to urban infrastructure carrying capacity of the city. A large number of tourists cause insufficient urban infrastructure, insufficient urban infrastructure affects the number of tourists. This relationship is dynamic and feedback; therefore, system dynamics approach is used for evaluation.

The aim of this study is to develop the urban infrastructure evaluation model using system dynamics approach, as a key Decision Support System (DSS). This paper demonstrates the development of causal loop diagram and the framework model of Chiang Mai city, as a case study to analyze the impacts on urban infrastructure from tourists.

2. The use of System Dynamics Approach in Sustainable Urban Infrastructure Evaluation

System dynamics is a methodology that can be used to model and facilitate analysis, communication and learning about real-world problems (Forrester, 1961; Goh & Love, 2012; Sterman, 2000).

Although it was first developed as a management discipline to understand result of the corporation policies (Forrester, 1996), but nowadays it has been used in wide various variety of applications, both in the social sciences and in engineering (Thompson & Bank, 2010; Xu & Coors, 2012).

In sustainable urban development area, there are many researches that using system dynamics approach; for example, to simulated the different sustainable development scenarios of the city (Duran-Encalada & Paucar-Caceres, 2009; Ho & Wang, 2005; Park et al., 2013), to estimate environmental carrying capacity of the city for a sustainable city management (Moon, 2002), to project the future CO_2 emission trends in the urban development (Fong, Matsumoto, & Lun, 2009). System dynamics also use to developed sustainable tourism model (Mai & Maani, 2010). System dynamics has also been used in applications related to urban infrastructure evaluation. Vo, Chae, and Olson (2002) developed Dynamic MCDM, an incorporation of MCDM and system dynamics approach, to use as an urban infrastructure decision making tool.

3. Conceptual Model for Chiang Mai City

In this study, Chiang Mai City model was developed by adding urban infrastructure sector to the URBAN1 dynamics model. The URBAN1 is a simplified three-stock version created by Alfeld and Graham (1976). The model consists of six sectors; population, business structure, housing, road and traffic, water supply and wastewater disposal, and solid waste disposal sectors. A causal loop diagram is constructed to represent Chiang Mai city and its components (in Figure 2).
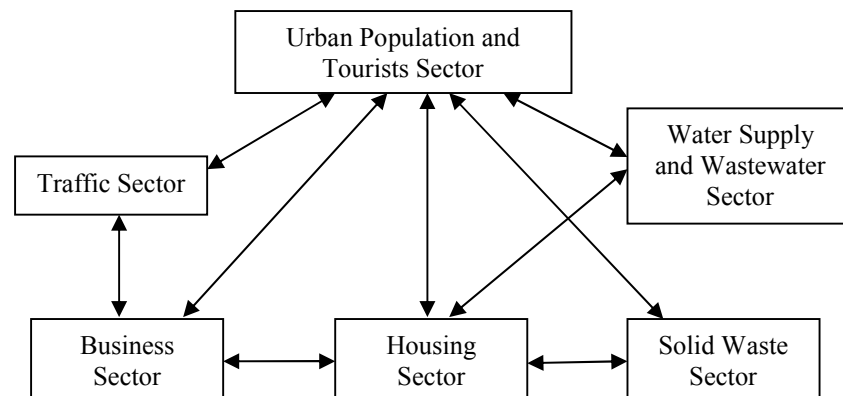

Figure 2 Conceptual Framework of Chiang Mai City Model

3.1 Urban Population and Tourists Sector

This sector outlines the relationship between total attractiveness of the urban and the population (urban population and number of tourists) as in Figure 3. The attractiveness of the urban is the attractiveness from urban components and infrastructure. It is composed of business sector, housing sector, traffic sector, water supply and wastewater disposal sector, and solid waste disposal sector. When the total attractiveness increases, urban population and number of tourists also increase.
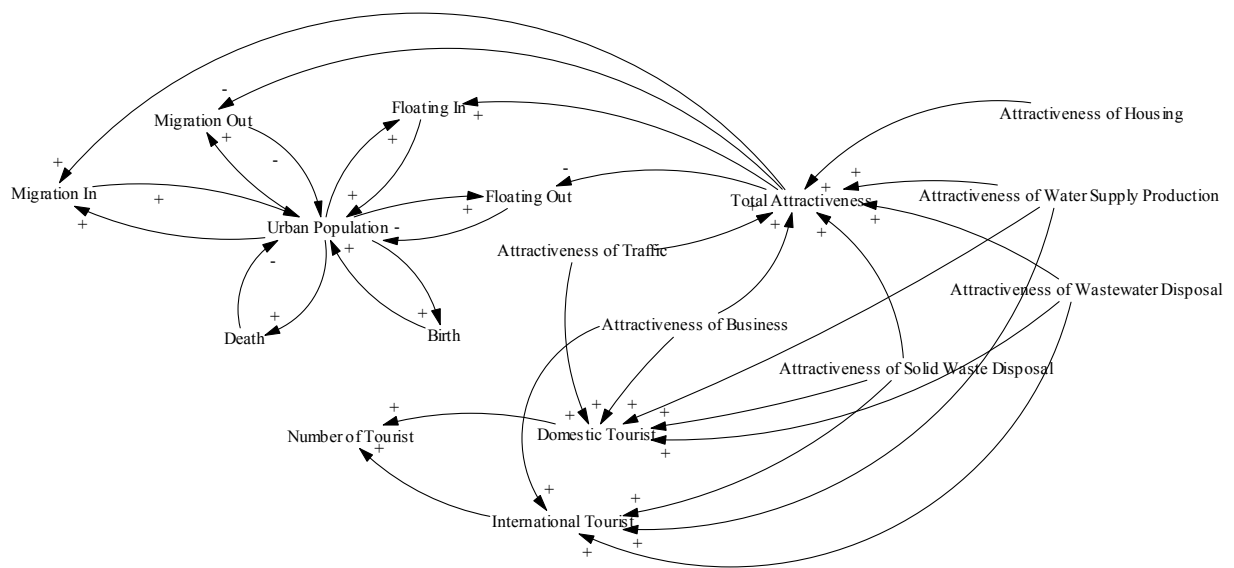
Figure 3 Causal Loop Diagram of Urban Population and Tourists Sector

3.2 Business Sector

The relationship between business structure of the city and urban population is shown in Figure 4. When the urban population increases, labor force and labor availability also increases. If the labor availability increases, it can drive construction of new business. When business construction increases, number of business structure and number of job also increases. When business structure increases, available land for business decreases. The decreasing of available land effects to the construction of new business. The construction of new business drives available jobs. The available job effects to the available labor. If available labor is insufficient, the attractiveness of job increases.
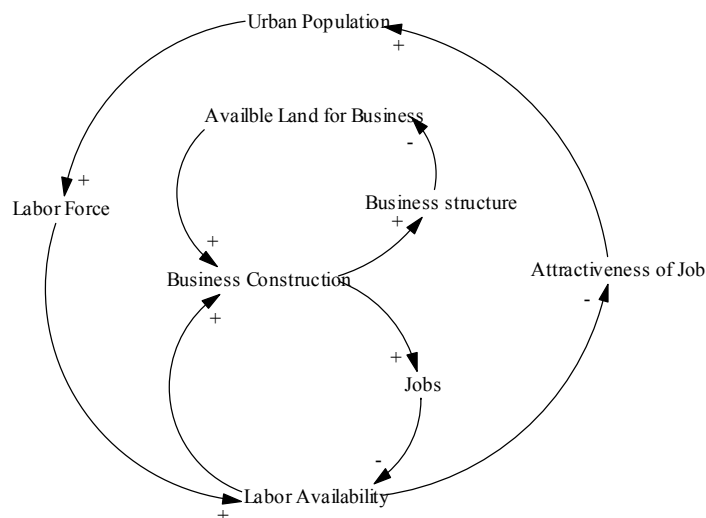

Figure 4 Causal Loop Diagram of Business Sector

3.3 Housing Sector

This sector outlines the relationship between urban population and housing as show in Figure 5. When the urban population increases, housing demand also

increases. If the housing available is sufficient, it can support housing demand. In the other hand, it drives the new construction of housing. Housing construction depends on land available for housing. The land available for housing effects housing price. Housing price also effects housing demand. If housing available increases, attractiveness of housing in the city also increases.
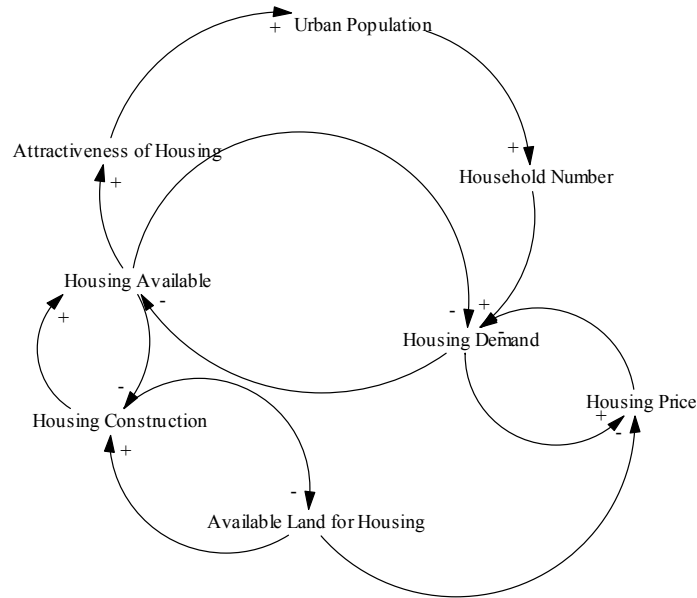

Figure 5 Causal Loop Diagram of Urban Housing Sector

3.4 Transportation Sector

Figure 6 demonstrates the relationship between urban population, number of car, and road capacity of the city. When urban population and number of domestic tourist increase, number of car also increases. The increasing of car is effect to car density and car running speed. Car running speed causes traffic congestion. The traffic congestion effect the urban attractiveness from traffic sector.
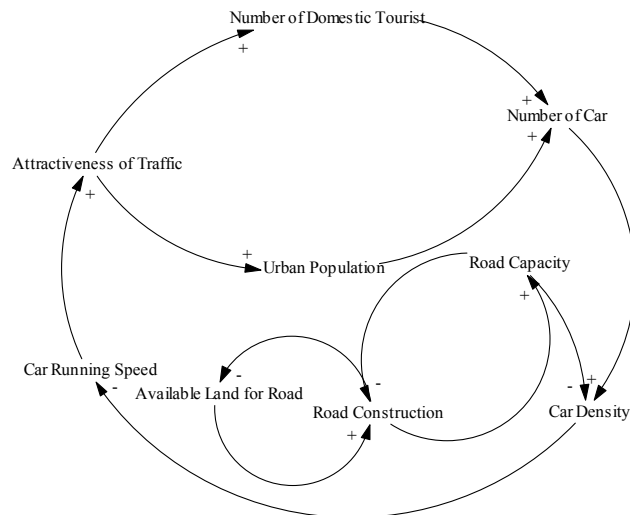

Figure 6 Causal Loop Diagram of Urban Traffic Sector

3.5 Water Supply and Wastewater Disposal Sector

The relationship between urban population, water supply production, and wastewater disposal is show in Figure 7. When urban population and the number of tourist increase, water supply consumption and wastewater also increases. Then water supply production system has to produce sufficient water supply for people in the city, similarly to wastewater disposal system. The lacking of water supply and wastewater disposal system decrease the urban attractiveness.
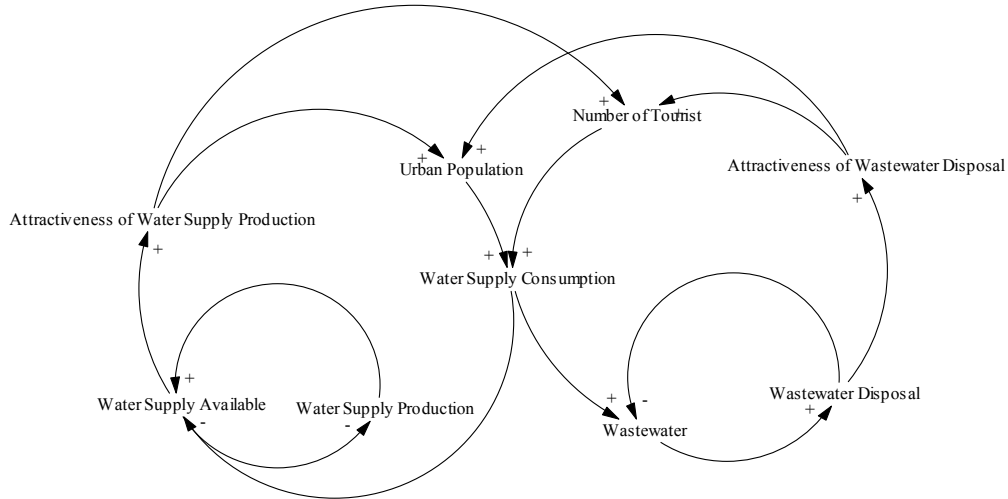

Figure 7 Causal Loop Diagram of Urban Water Supply and Wastewater Sector

3.6 Solid Waste Disposal Sector

Figure 8 demonstrates relationship between urban population and solid waste disposal. When urban population and the number of tourist increase, amount solid waste also increases. When the amount of solid waste increases, the performance of solid waste disposal system also increases. Therefore, the performance of solid waste disposal system effects to the urban attractiveness.
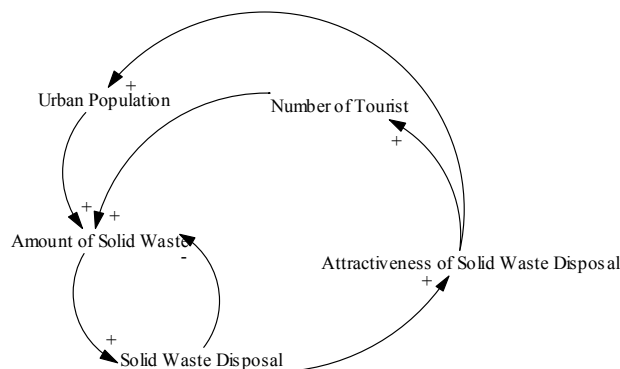

Figure 8 Causal Loop Diagram of Urban Solid Waste Sector

4. Dynamics Modeling Framework

From the conceptual model (Figure 2) and causal loop diagrams of six city components in Figure 3 – 8, the system dynamics modeling framework of Chiang Mai and impact of tourism is developed, as in Figure 9.
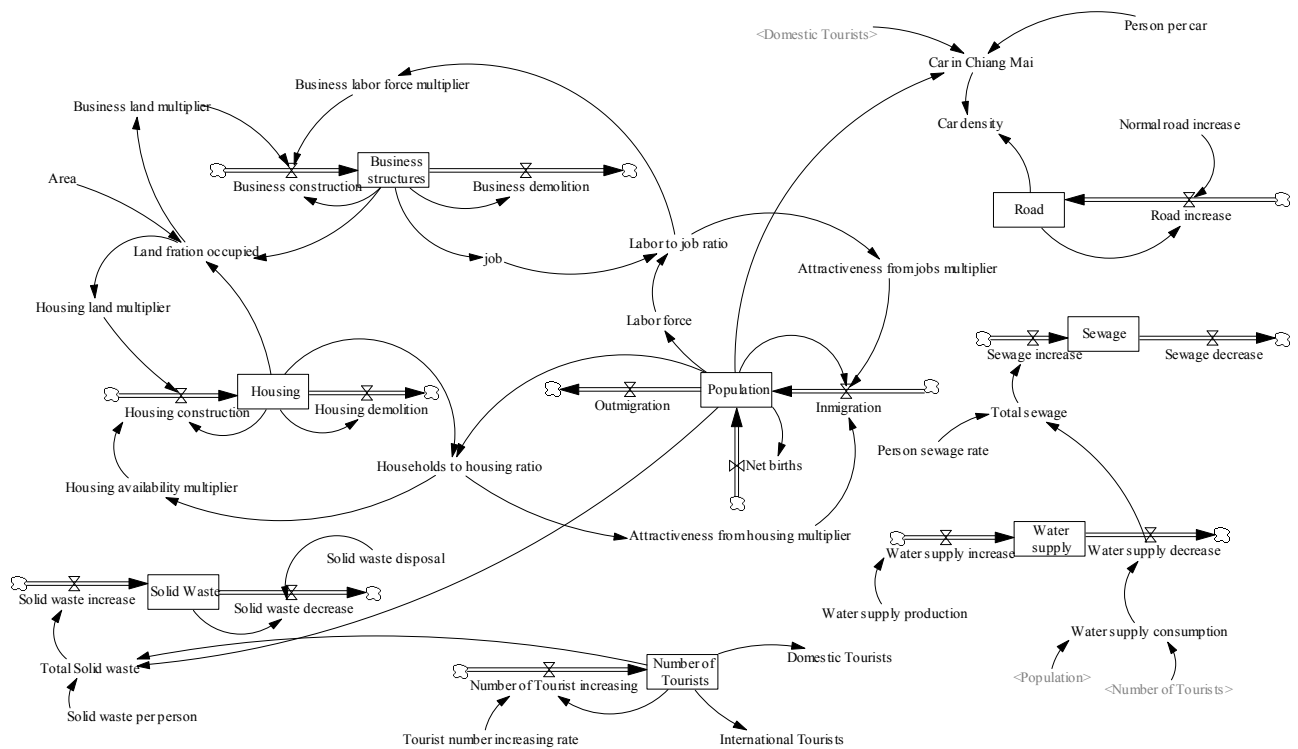
Figure 9 Stock and Flow Conceptual Model of Chiang Mai city and Impact of Tourism

5. Conclusion

The carrying capacity of basic urban infrastructure; such as, water and wastewater disposal system, solid waste disposal system, and transportation system, are dynamic. It has relationships to urban population. Tourism consists of dynamic and complex activities. This industry has significant relationships to urban development. Tourism is also a key contributor to economic growth of the city; nevertheless, it effects to urban infrastructure carrying capacity of the city. A large number of tourists cause insufficient urban infrastructure, insufficient urban infrastructure affects the number of tourists. This relationship is dynamic and feedback; therefore, system dynamics approach is used for evaluation. The aim of this study is to develop the urban infrastructure evaluation model using system dynamics approach, as a key Decision Support System (DSS). This paper demonstrates the development of causal loop diagram and the framework model of Chiang Mai city, as a case study to analyze the impacts on urban infrastructure from tourists.

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