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Design of industrial clusters and optimization of land use in an airport economic zone

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ABSTRACT

To increase the land utility and efficiency in an airport economic zone (AEZ) and to manage the corresponding transport demands, we propose a method to determine the structure and scale of the basic airport industry cluster based on the airport scale and its relationships to industries. The correlation coefficients between industries are calculated by the strengths of the logistical and non-logistical relationships. We use the system layout planning (SLP) approach to determine the location pattern of basic industries with the objective of maximizing the correlation coefficient of a unit distance. Finally, the employees' housing locations and service industries in the AEZ are determined using the Lowry model based on employees' choice behaviors regarding housing and consumer services. This study is helpful for planning the development of industrial clusters and optimizing the land use patterns in an AEZ.

1. Introduction

In the era of knowledge- and speed-based economies, the airport, as a node in a rapid and efficient transport system, has become a platform where the value of time and efficiency play important roles. Due to airport spillover effects, airport economic zones (AEZs) have become centers of urban and regional economic growth. The free trade zone of Shannon International Airport in Ireland was established as the world's first AEZ in 1959. In the following 50 years, the surrounding areas of certain hub airports have been gradually developed into critical AEZs (Cao and Zong, 1999). Normally, the airport directly or indirectly attracts relevant industries that rely on air transport, such as the aviation service, high-tech manufacturing, and modern service industries. The flows of information, technology, production, capital, people, and other factors between the airport and the associated industries promotes the development of more comprehensive functional facilities, such as residential, leisure, cultural, and medical facilities, eventually forming an AEZ with the attributes of an "Airport-Industry-City composite system (AIC system)" (Zhao et al., 2016).

The evolution process of the airport economy can be divided into four stages: 1) the embryonic period; 2) the growth period; 3) the prosperity period; and 4) the mature period. Similarly, the spatial evolution of an AEZ can be summarized as follows: the independent airport → the airport industrial park → the airport metropolis → the aviation town cluster (Hu and Li, 2014). To maximize the land utility in an AEZ and fully utilize air transportation with the airport as the key node, the scale and structure of the industrial clusters in an AEZ must be determined for different periods. Moreover, a popular topic is to identify the possibilities and time points of the formations of the independent airport, airport industrial park, airport metropolis and aviation town cluster around different airports. Furthermore, when optimizing the industrial cluster and land use pattern of an AEZ, the locations of the housing and living services for the employees should also be optimized to prevent the transport issue from becoming a growth bottleneck, which is induced by the transaction/communication between the industries and between the AEZ and home city.

In the 1990 s, China realized the concept of the airport economy, and certain Chinese cities with hub airports began to develop airport economies. Over the past 20 years, the airport economy has rapidly developed. By the end of 2014, China had constructed 67 AEZs around its large airports. However, many problems have been encountered in the planning, construction, and management of the AEZs at different stages and in different modes, such as the lack of industrial linkages, unreasonable industrial structures, and non-ideal spatial layouts. The root cause of these problems lies in the failure to follow the development law of AEZs and the construction principle of the AIC system to optimize the related land use. To avoid these problems, we regard AEZs as an "Airport-Industry-City integrating system (AIC system)". Based on a given airport site and the size of the basic airport industries, we build an industrial cluster distribution optimization model to optimize the

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location of industries and locate service industries in the AEZ. Thus, we provide a theoretical basis for planning AEZs.

In this study, referring to the experiences and processes of certain large airports around the world, we determine the categories and scales of the basic airport industry in an AEZ according to the flight-related industry chain and airport size. Using the system layout planning (SLP) approach, we analyze the strengths of the logistical and non-logistical relationships between basic airport industries and the airport itself according to the industry association intensity and their affinities to the airport and then calculate their correlation coefficients. We then optimize the spatial distribution of the basic industries with the objective of maximizing the unit distance correlation coefficient. Finally, we determine the housing locations of the employees and the service facilities in the AEZ using a land use model.

2. Literature review

The airport area has evolved from simply transportation infrastructure into a type of city. Conway (1980) proposed the concept of developing the industries of air transport, integrated logistics, commerce and business, leisure entertainment, and manufacturing to build complexes around airports. A key piece of literature on AEZ formation is the "fifth wave theory" of Kasarda (1991). According to this theory, with the emergence of large and high-speed jet aircrafts and rapid economic globalization, the manufacturing industry has become increasingly dependent on the rapid service of air transportation and has become gathered around airports. Kasarda (2000, 2001, 2006) predicted that economic globalization and the development of air transportation may induce a new urban form, namely, the Aerotropolis. Maurits et al. (2008) proposed the concept of an airport corridor, which is a functional combination of industry, commerce/business, housing and entertainment along the arteries between an airport and its home city. Guller (2003) presented the concept of an airport city, and Johanna (2010) defined the concept of Airea.

In 2011, the United States Congress issued an official definition of the airport metropolitan area in "The House of Representatives Bill 658, Aerotropolis Act", in which the airport metropolitan area is defined as an economic region around hub airports with an integrated cargo and passenger transport complex. The area is characterized by high economic effectiveness and sustainable development (United States Congress, 2011). Freestone and Baker (2011) compared the models of airport-oriented city planning under different concepts and stated that sustainable AEZs can be realized by coordinating the airport master plan and urban growth plan.

To interpret the airport economy and airport industry, Cambridge Systematics constructed a model to analyze their economic impacts and optimize land use based on data from over 20 airports. Neuwirth and Weisbrod (1993) summarized the types of industries that tend to be located near airports.

Correia and Silva (2015) analyzed several relevant aviation concepts, including the airport region, airport city, airport corridor, Aerotropolis and Airea, to evaluate whether the New Lisbon Airport area development process would be able to follow these modern aviation concepts.

Stevens et al. (2010) used the concept of Aerotropolis to analyze the interactions between Australian airports and corresponding home cities in terms of economic growth, land use, infrastructure and governance. Wang et al. (2011) summarized 30 key factors and 7 trends concerning the development of airport cities via interviews with a group of experts. In addition, they listed the industries suitable for Taiwan's Taoyuan International Airport using an industrial matrix analysis and verb-term coding. Kasioumi (2015) examined the recent evolution of spatial planning practice for the area around Paris' Charles de Gaulle Airport and identified the priorities of airport-centered urban development projects.

There are few corresponding studies on airport economies in China due to the delayed introduction of this field to the country. Cao and Zong (1999) began studying airport economies in 1999 and believed that production, technology, capital, trade and population would gather around airports to form multi-functional AEZs. In 2001, Li (2001) translated Cambridge Systematics' report to introduce foreign knowledge on the topic to China. Jin (2004) considered the airport city to be a comprehensive new town with an international hub airport supporting zonal development and air transportation-based industries. Li (2005) noted that the growth plan and functional orientation of an airport and the resource endowment and economic level of its home city affect the airport economy and provided suggestions for the layout design of the AEZ and the development of the airport economy at different levels. In terms of air transportation and industry clusters, Xiao (2006) noted that the airport economy is the result of industrial evolution and innovations in the transport system. Wang et al. (2006) studied the composition and regional economic attributes of airport industry clusters and analyzed the relationships between the airports and industrial clusters.

In terms of the spatial layout and industry selection, Cao et al. (2006) divided an AEZ into four layers: the airport operation area within 1 km of the airport; the airport business activity area located 1 km to 5 km of the airport; the area accommodating the airlines headquarters, financial and insurance companies, high-tech companies, exhibition centers, and headquarters of multinational companies located 5 km to 10 km from the airport or in an access corridor that is within a 15-minute drive to the airport; and the outer-ring area located 10 km to 15 km from the airport, which is the AEZ's boundary. Bai (2006) considered two key factors influencing the land use and industrial location in the area near Beijing Capital International Airport: airport market positioning and traffic accessibility. Hu and Wang (2009) studied the integration of the airport industry and urban space in the Tianjin Airport industrial zone and examined the layout of airport-related industries, which relies on an effective transport system, well-defined function areas, favorable investing conditions and a regulated scale of development.

Guan and Wu (2010) stated that the airport industry will become more similar to a leading industry with the progression of economic globalization, with the different airport industries exhibiting different location behaviors in an airport region.

Zhang et al. (2014) established a planning framework for AEZ development by accounting for relationships among industries, locations and transportation. Mao et al. (2014) examined the concept of integrating city growth and industrial production to realize intensive and efficient growth and verified its rationality and feasibility with the actual case of the Ming Yang industrial zone in Nanning. Guo and Mu (2014) analyzed the interactive elements and strategies for AEZ development and proposed a planning methodology considering the interactions among the functions, industries, land and traffic in the airport zone and home city.

Zhao and Cao (2013) noted that the cluster of the airport industry, high-tech industry and modern service industry should be developed with priority and analyzed their relationships and temporal priorities. Cao (2013) classified the airport industry and found that the industries accumulate in three ways: airport space extension, industrial transfer and regional industrial upgrading. Zhou and Han (2015) built a 5-dimensional industry selection model based on the indices of industry density, added value of products, easiness for cargo loading, time urgency for a product from the producer to the end user and the science and technology contents of a product or service to analyze the 66 advantage industries in 51 airport cities in China and selected the main industries for the Zhengzhou AEZ.

Previous studies on AEZs have mainly focused on the concept description, formation and growth mechanism, industry selection, spatial location, and their regional impacts. Current studies concerning the industry selection and land use planning of an AEZ are mainly qualitative descriptions and practical designs, which do not provide accurate analyses or quantitative optimizations. In fact, the industry selection