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A case study on the underground rapid transport system (URTS) for the international airport hubs: Planning, application and lessons learnt

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ABSTRACT

A large number of international airport hubs are now under expansion to have two or more terminals and additional satellites or midfield concourses under the pressure of quick and massive growth of air traffic volume. As a result, the problems of passengers' long walking between buildings, ground traffic congestion in the air side and low operational efficiency of transportation are becoming more and more prominent. Attributed to the merits of underground transport, the underground rapid transport system (URTS) has emerged as a sensible solution to provide a safe, accessible and pleasant way for passengers, reducing the congestions, flight delay and enhancing the operational efficiency as well. In order to better understand the merits of URTS and the way of its application in the airport hubs, this paper firstly explored the present status of URTS in airports around the world and the urgent need of URTS for the international airport hubs was addressed. Then, the lessons learnt from actual projects and recommendations were summarized and provided through a comprehensive case study of the planning and design of URTS in the expansion of Shanghai Pudong International Airport (SPIA). It is recommended that more importance should be attached to the URTS in the planning of airport expansion with a long-term view. The attempt, adopting the urban underground railway system into the URTS in the expansion of SPIA, could also provide a valuable reference for the development of URTS in other international airport hubs.

1. Introduction

Continually growing population strains the social environment by creating more traffic congestion and travel time (Besner, 2002; Cui and Lin, 2016). In order to cope with the corresponding demands for mobility and infrastructure, urban underground space is playing an important role in this field (Peng and Peng, 2018a, 2018b) and all the major metropolises in the word are building or expanding underground transport (Sterling et al., 2012; Qiao and Peng, 2016). The underground transport includes underground pedestrian, underground mass rapid transport system, underground expressway, underground logistic system and so on, freeing up more ground space for other uses, such as green spaces, sports ground, et al., which are vital for the urban development (Cui et al., 2013; Zhao and Künzli, 2016) and the local economy (Qiao et al., 2017).

As an indispensable modern transport means, the air traffic played an important role in our daily life and the passenger volume of air traffic has increased dramatically (Shuchi et al., 2018). Air traffic volumes began to grow rapidly in the 1960s–1970s with the appearance of turbojet passenger aircraft (Leder and Sproule, 2013). Fig. 1 illustrates the annual demands of air traffic passenger of the world, USA and China from 1970 to 2016 according to International Civil Aviation Organization (ICAO, 2016). Overall, the air traffic volume of the world and the two counties increased with time continually. In 1970, the global air traffic passenger was about 0.31 million, while in 2016, it became 3.69 billion, growing by twelve times (ICAO, 2016). The increase tendency of air passenger in China was similar with the world, maintaining a positive growth rates. In 2015, there were 800 million USA enplanements, a fivefold increase in the four decades since 1970 (ICAO, 2016).

Massive growth in air travel could impose adverse influences on performance of an airport, long wait time, airplane delay, and overall travel time and even missing a flight (Leder and Sproule, 2013). When further growth of passengers could no longer be served by the initial buildings and correlated facilities, the expansion of the airport was urgent (Hurley and NeSmith, 2014; Hoshii et al., 2016). However, the scale enlargement of passenger building or the newly-built midfield concourses would increase the distance from check-in counter to the boarding gates, which became a major concern of airport planners nowadays (Green, 2001; Shuchi et al., 2018). According to the recommendations of International Air Transport Association (IATA), this distance should not be longer than 300 m without any other auxiliary facilities (IATA, 2014).

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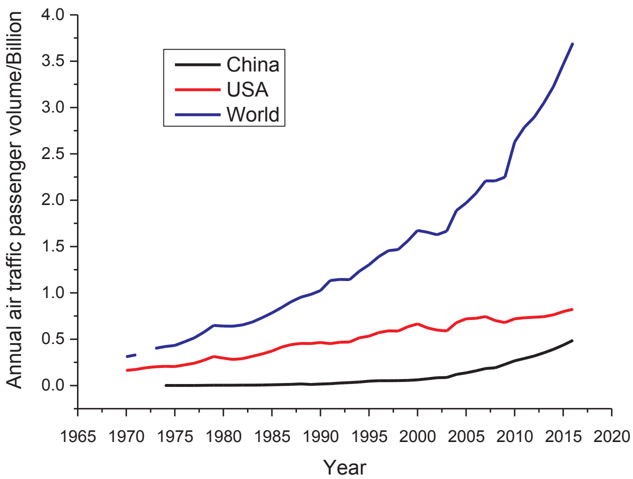

Fig. 1. Developments of annual air traffic passenger volume of the World, USA and China (Data sources: https://data.worldbank.org), https://data.worldbank.org/indicator/IS.AIR.PSGR?contextual=similar&end=2016&start=1970&type=shaded&view=chart&year=2016).

Sidewalks, one of the ways to handle the above problem, have the disadvantage of lower speed and the possibility of forming barriers to the cross-concourse passengers (Pennington et al., 2007). Shuttle buses and automated people mover (APM) were the two main methods transferring passengers between buildings. However, the shuttle buses generally provide low-quality services (Pennington et al., 2007). APM has become an effective technique to handle the increasing passenger volume. The first airport APM system was set at Tampa International Airport in 1971 and that in Seattle Tacoma international airport followed in 1972 (Leder and Sproule, 2013). However, almost all the shuttles and most of the APM system were operated above the ground. These at-grade vehicles and their correlated facilities share the right-of-way with aircrafts, baggage carts and other apron devices, aggravating the ground congestion in airports and road maintenance cost.

As a result, more and more reliances are placed on the underground transport technology, e.g. underground sidewalks, underground rapid transit system (URTS), etc., to free up more space for aircraft taxing and achieve high operational efficiency as well as the passengers' experience. A number of international airports have adopted the concept of underground transport (Leder, 2002; Pennington et al., 2007; Hoshii et al., 2016). Nevertheless, the necessity of URTS for the performance of international airport, especially for those with expansion, has not been analyzed adequately.

This paper explored the necessity and present status of URTS in the expansion of international airports. Then, the planning and design of URTS in the expansion of Shanghai Pudong International Airport (SPIA) were introduced in detail as a case study. The lessons learnt from this project and the corresponding recommendations were summarized. The aim of this paper is to present the underground transport planning in international airports promoting passenger mobility, which could provide a reference for the airport planner. Besides, since this is an emerging subject related to underground transport, it could also help underground space planner understand and analyze this new and specific application.

2. URTS in airport hub expansion

2.1. Necessity analysis

The development of airport passenger building configuration could be divided into four generations (Pitt et al., 2002), including (1) Linear Design, (2) Pier Configuration, (3) Satellite Concourse, (4) Midfield Concourse as shown in Fig. 2. The first two generations are in an acceptable scale for passengers walking with the assistance of moving sidewalks above grade, which can be used when the total length of passenger movement does not exceed 300–450 m (Leder, 2002). So, there were no demands for URTS overall in these two configurations.

In order to meet increasing air traffic volume and the demands of passengers, airport and its terminal facilities are becoming larger with satellites or mid-field concourses. The third generation of passenger building configuration was represented by Paris Charles de Gaulle international airport, as shown in Fig. 3, where seven satellites were around Terminal 1 in a radial style. Charles de Gaulle Terminal T1 used underground moving sidewalks connecting the landside passenger building with the airside satellites. Most of world-class airport hubs were expanded by building new midfield concourses or gates (Pitt et al., 2002), as the generation 4 shown in Fig. 2. These were located in the middle of the airfield, setting away from the landside terminal (Phua, 1995). Planners, designers and operators of airports face the challenges that how to move the passengers between buildings faster and more efficiently (Trans Solutions and University, 2012). Because of the large passenger volume and the need to cross the taxi way, the ground transport system will no longer provide a satisfactory level of service both in the capacity and time.

In order to meet the operational requirements of the airport, alleviating the ground congestion in airport, achieving acceptable passenger walking distance and raising the level of quality in service and passenger comfort, the URTS is becoming an essential consideration during the expansion of airports. The merits of URTS in airport expansion were summarized below.

(1) Improve operational efficiency and land use of the airport

Without the help of underground space, ground transportation would be the only link moving passengers between various terminals and concourses. As the scale of airports continues to expand, the delay of the flight is mainly caused by the airport ground movement congestion, resulting from the conflict between aircraft taxing, i.e. the movement of an aircraft on the ground under its own power, and ground passenger convey. The aircraft taxing could be free from the adverse influence of passenger convey by adopting URTS in airports which can separate these two traffic flows. Thus, it can alleviate flight delays and increase the operational efficiency significantly (Zhou and Jiang, 2015). Besides, URTS in airport expansion could free more space for aircraft parking. The aircrafts can be parked on all sides of the concourses by putting the vehicles of URTS underground. In other words, underground transit could mitigate the demanding airport ground land use and effectively improve land use rate, which is critical to cope with the long-term growth of airport traffic volume.

(2) Improve the safety and the comfort of passengers

Passengers' expectations and demands have been growing dramatically and their experience is one of the key issues in the airport planning (Yeh and Kuo, 2003). URTS in airport expansion could improve the safety and feeling of comfort by freeing them from the adverse effect of the weather. In contrast, ground transport system can be easily affected by the ground and weather conditions, thus is much more inefficient and uncomfortable than the underground transportation system. What's more, waiting times can often be unattractive to the passengers. The auto piloted rail vehicles in underground can be much more punctual than the manual-drive shuttles on the ground surface. Lastly, the trains of URTS generally run on the track, so passengers in it would feel much smoother than in the ground buses. Especially, the vehicles with tires on concrete track can work with lower noise and vibration.