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Analyzing the effect of aviation infrastructure over aviation fuel consumption reduction

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ABSTRACT

The purpose of this paper is to examine the effect of various aviation infrastructure dimensions over aviation fuel consumption reduction (AFCR) performance. This study is an effort that considers the role of dimensions collectively from all aspects belonging to aviation infrastructure. The relevance of dimensions and constructs for hypothesis development are based on extensive literature review. Exploratory factor analysis (EFA) and Confirmatory Factor Analysis (CFA) were performed in the consecutive purification processes. Also, hypothesis testing was conducted using Structural Equation Modeling (SEM). A customized questionnaire was developed for collecting data from both kinds of respondents: Aviation industry experts and academic experts. Out of 382 approaches through mail survey, a total of 194 valid responses were collected. Analysis of the results shows the positive and significant impact of various factors such as: airport design, airspace management and air traffic control over the aviation fuel consumption reduction. Maximum importance is adjudged on air traffic control (ATC) and airspace route flexibility. The results of this study will encourage airlines and airport development authorities to increase their insight over aviation infrastructure, also to perform deeper analysis and find out precise values for real life implications.

1. Introduction

There was a time when aircraft fuel availability and extraction cost had almost no effect over aviation industry growth. Today, however, the aviation industry is facing a lot of challenges which demands the need for conservation of aviation fuel. Commercial airliners are facing aviation fuel cost as a major expenditure out of their total operational cost. Airline fuel bills have crossed the previously highest labor cost to become 34% of the total operating cost (Lawrence, 2009). The early 1970s made it clear that the time of abundance and cheap fossil fuels was facing its end. Economies of aviation sector started to get affected significantly by fuel prices. After 1973 Arab oil embargo, market prices of fuel spiked, resulted in a prompt 400% increase in fuel price (ICAO, 2009). Over the next few decades, prices of aircraft fuel fluctuated a lot, raising concerns over aviation industry's profitability and sustainability. The increase in the cost of fuel forces airlines to go for higher ticket prices, resulting in pressure on the customer's wallet. Again in 2011, fuel prices severely spiked and reached an all-time high of 140 dollars per barrel in March 2011. Between March 2011, and March 2016, huge instability in aircraft fuel prices was seen in the global market as fuel prices shrunk to almost three times. Though, prices of aircraft fuel dropped from the level of 140 dollars in 2011 to today's level, which is close to 40 dollars per barrel (IATA, 2016). Airbus (2015) suggested prices of fuel will swell to a much higher level considering mid-to-long-term effects. After many consistent efforts by airliners, they are still facing huge difficulties to produce an increase in efficiency and revenue matching instability of fuel price. Top producers of fuel are oversupplying and oil demand of world aviation increased from 1.18 MB/day in 1971 to 4.9 MB/day in 2006 and it's about 11.2% of worldwide overall fuel demand (Mazraati, 2010). Additionally, CO_2 emissions are directly proportional to aviation fuel burning (Airbus, 2015). Concerns related to environmental degradation have increased over rapid escalation in the growth of air traffic. All initiatives and policies have failed to control a net increase of fuel utilization, and this leads to an increase in emissions with environmental impacts (Lee et al., 2001). A saving of 0.3 kg of aviation fuel can save almost a kg of CO_2

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emission, which in return also saves about 1.1 dollars (Tsai et al., 2014). Moreover, fuel reserves are depleting and there is dire need to look into the sustainability of the aviation industry. Supply-demand curves are showing an exponential gap. Tension between Middle East nations and huge demand of fuel from China is making the gap worse (Abdelghany et al., 2005). With this, airliners are confronting a challenge over maintaining their commercial viability, requiring a balance between increased fuel consumption and aircraft fuel cost. Furthermore, passengers mostly like to opt for airlines which have greater environmental consciousness (Hagmann et al., 2015). All these situations have encouraged airliners to explore efficient ways for aviation's fuel consumption reduction (AFCR).

Studies by (Drake, 1974; Linz, 2012; Barros and Wanke, 2015) suggest that the key steps towards this goal would be through socio-economic and political changes, improving alternative fuels (Alonso et al., 2014), improvising technological innovations and change in designs of aircraft (Dray, 2013). But, surprisingly previous studies have always subdued a key element like aviation infrastructure and its detailed impact on aviation fuel consumption. Lack of infrastructure and its operational efficiency leads to delays with congestions (this also works vice-versa). These delays and congestions increase fuel consumption and emissions. According to Eurocontrol (2013) delays at airports will rise from 1 min in 2012 to 5–6 min per flight by 2035, and this is considered a substantial increase and needs to be controlled. ICC (1992) strongly urged airport authorities and governments to make a timely and adequate amount of investment in airports, which is a portion of aviation infrastructure. Failing to do so would result in severe airspace and airport congestions. Large investments by developing nations in aviation infrastructures portray the importance of aviation infrastructure. Sarkar (2012) suggested that by improving the efficiency of aviation infrastructure, we can additionally reduce 4% emissions globally by 2020. This reduction could also be close to 10% for certain regions. Previous studies always lagged behind the precise solo collective effort of all the factors and sub-factors of aviation infrastructure over AFCR. This study attempts to touch almost all the sub-areas of aviation infrastructure in detail. In this article effort had been invested to connect all research gaps for a definitive conclusion regarding the options in the field of aviation infrastructure for aviation fuel consumption reduction.

2. Literature base for constructs and hypothesis development

Studies show that implementation of technologies and design is way behind schedule and fully depends on the wish of carriers, whether to invest on costly equipment's or not. Just as aircraft design, alternative fuels are also constrained by technological developments' timeline. Thus, investing time and money over them may not yield the required results in time. Moreover, there is a need for immediate action. Development and implementation of technology are constrained by its technology life cycle (TLC), which involves rigorous safety testings and also require engineering excellence. All this significantly increases the development cost and decreases implementation rate of technology (Ribeiro et al., 2007). So, the infrastructures emanate out to be the most predictable, and investing over it will produce predictable and satisfactory results with immediate effect. But investing in infrastructure to fill the gap between current and required is a huge one-time investment, so we must go for increasing asset utilization (Adler and Gellman, 2012) by investing in certain parts of infrastructure which will yield the most reduction in fuel consumption. With it comes the need to identify parts of aviation infrastructure which can assist the most in asset utilization.

While going through literature, we have to take into account propagation of delay i.e.; delay because of any reason transferred from one area to other areas (like a ripple effect) (Evans and Schäfer, 2011). Construct formation is based on the literature study. The research model of the current study is displayed in Fig. 1 and the development of the hypotheses are described in detail below.

2.1. Taxiway (TWY)

Development in the aviation industry is increasing ground operations complexity and causing problems throughout airport resource distribution. To increase the operational efficiency, we have to pre-plan taxiway paths (Zhou and Jiang, 2015). Research towards simulating a flight movement on taxi routes are going on so that one can predict aircraft movements step by step leading to minimizing conflicts. Conflict leads to delay and fuel burn. Jiang et al. (2013) studied taxiway safety separation for optimizing a path to be conflict free, by allowing one point of taxiway to permit only one aircraft pass at a time. In the case of peak hours, aircraft wait in departure queues for as much as 30 min. Practices breakaway thrusts to proceed, causing unnecessary fuel burn and emissions. Minimizing the taxing distance (Kazda and Caves, 2007) and incorporating rapid taxiways facilitate faster turnaround (Bradley, 2010) in airports; a significant amount of reduction in aircraft fuel burns can be achieved. Geometric component of a taxiway like number of turns and number of stops increases fuel consumption, because of differential thrust and throttle adjustments use in respective cases (Khadilkar and Balakrishnan, 2012). A study by Nikoleris et al. (2011) concludes 18% of fuel consumption is because of stop and go situations. Based on the above arguments, the following hypothesis is made:

H1: Taxiways have significantly positive impact on AFCR performance.

2.2. Terminal area (TMA)

As air transport is highly prone to changes for its efficiency improvement, Baltazar et al. (2014) took indicators, out of which passenger terminal area and cargo terminal area were efficiency indicators. FAA (2013) predicted an increase of 105% in passenger demand and 50% in flight operations for terminals areas from 2005 to 2040. This alarming data projects, how important terminal area infrastructure is for the efficiency of airports. Operations efficiency can greatly reduce fuel use, and what is the operational capacity of that airport will decide an airport's fuel saving capacity. According to Upham et al. (2003), operational capacity of an airport will be influenced by number of terminals and size of terminals in the airport. An increase in taxiing distance and terminal distance from runway lead to more distance to cover, causing more fuel consumption. Schlumberger (2012) found, location of terminal determines the extra greenhouse gas (GHG) emissions and similarly have an influence on fuel consumption. Based on the above arguments, the following hypothesis is made:

H2: Terminal areas have significantly positive impact on AFCR performance.

2.3. Apron (APRN)

According to Bradley (2010) MARS (Multi-aircraft ramping system) centerline and single centerline are very efficient. But, they have their own advantages and disadvantages and depend on the