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Methods for determining unimpeded aircraft taxiing time and evaluating airport taxiing performance

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Abstract The objective of this study is to improve the methods of determining unimpeded (nominal) taxiing time, which is the reference time used for estimating taxiing delay, a widely accepted performance indicator of airport surface movement. After reviewing existing methods used widely by different air navigation service providers (ANSP), new methods relying on computer software and statistical tools, and econometrics regression models are proposed. Regression models are highly recommended because they require less detailed data and can serve the needs of general performance analysis of airport surface operations. The proposed econometrics model outperforms existing ones by introducing more explanatory variables, especially taking aircraft passing and over-passing into the considering of queue length calculation and including runway configuration, ground delay program, and weather factors. The length of the aircraft queue in the taxiway system and the interaction between queues are major contributors to long taxi-out times. The proposed method provides a consistent and more accurate method of calculating taxiing delay and it can be used for ATM-related performance analysis and international comparison.

1. Introduction

Airport surface movement management has attracted extensive interests of US aviation community, given the increased airport surface delay in recent years and consequent excess fuel burn and emissions. While researchers dedicating efforts to develop systems to reduce surface delay, which are similar to airport collaborative decision making (A-CDM) implemented at some EU airports, how to evaluate the outcomes of those systems also needs careful consideration. Surface delay is

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widely used to indicate the performance of airport surface movement. It is defined as the excess time needed to taxi-in or taxi-out while compared to unimpeded time that flights take if there is no interference during their taxiing process. US airports are improving their equipment and system so that operational data can be recorded and played back to track taxiing process. Nevertheless, there is no automated tool for computing the unimpeded taxiing time and thus taxiing delay.

For flight operations at airports, "bottleneck" areas on the surface where congestion could occur include gates, apron area, taxiways, and runways–with the last two elements often referred to as the airport movement area. There are different perspectives in defining taxi-out times in this area of literature. On the one hand, an explicit definition of taxi-out time refers to the amount of time between an aircraft's pushback from the gate (off-block time) and its takeoff from the runway (wheel-off time). From an airlines' point of view, once an aircraft has left the gate, any excess time from an optimum unimpeded time that occurs before takeoff shall be considered as inefficient, regardless of its occurrence in the ramp or movement area. In addition, this definition only requires two time stamps: off-block time and takeoff time for each flight, which are both readily available in the aviation system performance metrics (ASPM) databases that the author used to obtain flight data. On the other hand, it is usually the airports or airlines themselves that control aircraft movement in the ramp area; air navigation service provider (ANSP) (e.g. the Federal Aviation Administration (FAA) in the U.S.) oversees the movement area. To evaluate the performance of each entity, aircraft movements in two areas need to be separately considered. For major airports with both a ramp control tower and an air traffic control tower, agreements are made on which spots to appropriately take over the control of aircraft from each other. For instance, only three out of 14 available spots on the surface of Philadelphia International Airport (PHL) are utilized between two towers to take over the control of flight movements.[1] The taxiing time for ANSP, according to this alternative definition, shall be the time that aircraft spend beyond the handover spots and before takeoff. Which definition to use is truly dependent upon research objectives and the availability of data. To evaluate taxiing performance by control areas would require more sophisticated data in additional to the available data for this study. Therefore, the taxi-out time in this study is defined as the difference between off-block time and runway takeoff time.

Unimpeded taxi-out time is defined as the travel time of an aircraft from pushback from the gate to takeoff on the runway without any interference of other traffic. This time variable is considered as the reference to estimate inefficiencies during the taxi-out phase. Whereas the U.S. and European systems have the same definition of unimpeded taxiing time,[2] methodologies used to derive this variable are different. The operational inefficiency during the taxiing phase, also defined in this research as additional taxiing time (or taxiing delay), is measured by the excessive time that aircraft take for the taxiing process in addition to the unimpeded reference time. Note that sometimes a certain amount of waiting in taxiing system is desirable for maximizing the utilization of other airside facilities, e.g. to avoid idle periods of runway usage so as to maximize runway throughput[1,2].

The objectives of this study are to: (1) Review existing methods of computing unimpeded taxiing time; (2) Compare the main existing methods for representative U.S. airports; (3) Propose new methods for determining unimpeded taxiing time; and (4) Discuss future research needs in this area.

The remaining of this paper is organized as follows: Section 2 reviews the literature and ongoing research on modeling taxiing times and defining unimpeded taxiing time; Section 3 compares the outcomes of existing methods for representative U.S. airports; Section 4 proposes different methods that can be used for estimating unimpeded taxiing time, including the methods combining visualization and statistical analysis and the method with refined econometric regression models. Section 5 concludes the study and provides recommendations for further study.

2. Literature review

2.1. Existing methods used by U.S. and EU ANSPs for estimating unimpeded taxi times

2.1.1. The U.S. APO method

The FAA Aviation Policy and Planning Office (APO) established a process for estimating unimpeded (nominal) taxiing times recorded in the ASPM database (see Appendix A). It is based on two linear equations, one for taxi-in and the other for taxi-out, and contains both taxi-in and taxi-out queue lengths.[3] The APO process seeks to build a numerical relationship between aircraft on the ground and taxiing time through a linear regression model. Model inputs are derived from the ASPM database. Note that aircraft are not recorded as either being in a queue or even outside the ramp area of the gates; the parameters recorded are a gate-out time and a wheel-off time. These values are used as surrogates for taxi-out time even though an aircraft may spend considerable time within the ramp area after a gate-out message is triggered. Appendix A describes the details of the APO method and Fig. summaries the methodology in a flow chart. The APO method explains taxiing time by departure and arrival queue lengths; however, it does not involve any other contributing factors such as runway configurations, weather conditions, or terminal/gate location. Also, APO method only applies to airline service quality performance system (ASQP) carriers (see Appendix C) and other airlines at airports are assigned with an average value.[4] As shown in Step 5 in Fig. 1, for obtaining the unimpeded taxi-out time, it usually set the number of departing aircraft to be 1 and arriving aircraft to be o.

2.1.2. Europe performance review unit (PRU) method

Namely, the PRU method developed by EUROCONTROL determines a common unimpeded taxi-out time for a group of flights that share similar characteristics (see Appendix B). Dependent upon data availability, these characteristics include aircraft class and pairs of departure stand and runway end, or aircraft class only (as in a simplified version of this method). A congestion index is calculated for every flight and a congestion index threshold is established for each group. After trimming flights by the threshold value on the congestion index, the truncated mean of remaining flights in the group (i.e. averaging taxi-out times between 10th and 90th percentiles) is calculated as the unimpeded taxi-out time for the group.

Due to data limitation of ASPM systems, there is no available record for runway or stand information. Hence, a

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