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Airport apron roundabout – Operational concept and capacity evaluation

Bojana Mirković [a,*], Vojin Tošić [a], Peter Kanzler [b], Michael Höhenberger [b]

[a] University of Belgrade, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, Belgrade 11000, Serbia
[b] Munich Airport, Postfach 231755, 85326 München, Germany

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ABSTRACT

The paper presents one of the initial steps in the evaluation process towards possible implementation of an innovative taxiway intersection design at Munich Airport apron. A roundabout is proposed as a potential solution for the 12-line intersection area expected at redesigned Apron 3. Although it is a common solution used in road transport for complex intersections, the roundabout has never previously been used for airport surface operations nor has its possible use been considered or analyzed. The paper presents preliminary design and operations concepts of the apron roundabout, followed by its capacity evaluation under Munich Airport operating conditions. The aim was to analyze whether a roundabout is suitable to replace a conventional intersection, in terms of capacity.

Introduction

The taxiway system is usually designed to provide a capacity that exceeds the capacity of the runway system and should not be observed as a factor limiting airport capacity. However, as taxiway system complexity increases, potential local bottlenecks can appear e.g. in the areas of taxiway intersections, points where taxiways cross an active runway, or where high-speed exits merge with taxiways (De Neufville and Odoni, 2002).

Usually, the appearance of the local bottlenecks at the taxiway system is not generated from the taxiway intersection design, but is caused by the departure and arrival flows and the way they interact through the intersections. Although rare, there are cases when the design itself can produce local capacity issues. Specifically, this would involve complex apron taxiway intersections, which appear as the secondary effect of solving a different problem. In order to enable smoother aircraft flow across the apron (aircraft passing, simultaneous push-backs, etc.) some airports introduce additional lanes for aircraft taxiing. That can result in more complex apron taxiway intersections.

Current airfield design and the plans for further development at Munich Airport (MUC) lead to appearance of an apron intersection consisting of 12 apron taxiways. A solution proposed, primarily from the safety reasons, but also to enable smoother flows through the intersection, is apron taxiway circle i.e. roundabout. Before it is taken into further consideration, it was necessary to examine whether the new solution might possibly generate unwanted bottlenecks in the apron area, providing lower throughput than conventional intersection under the same operating conditions.

* Corresponding author.
E-mail addresses: b.mirkovic@sf.bg.ac.rs (B. Mirković), v.tosic@sf.bg.ac.rs (V. Tošić), peter.kanzler@munich-airport.de (P. Kanzler), michael.hoehenberger@munich-airport.de (M. Höhenberger).

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This paper presents apron taxiway roundabout intersection concept and its evaluation in terms of capacity. It comprises the results from the project (Institute of the FTTE, 2006; Mirkovic and Tosic, 2006; Mirkovic et al., 2014) and findings from the thesis (Mirkovic, 2008).

Section 1 describes motivation for the possible introduction of a roundabout intersection at MUC and provides a detailed description of two intersection layouts, the conventional (current and future) and the roundabout.

Since the roundabout has never previously been used for airport surface operations nor has its possible use been studied, the model of roundabout operations (Section 2) was developed first and later used as the basis for simulation and analytical capacity models. The roundabout operations model is the core part of the capacity models. It consists of a set of rules for safe and smooth movement of aircraft through the intersection without violating separation requirements, under specific (MUC's) operating conditions. The taxiway intersection capacity concept and assumptions for capacity modeling are also discussed in this section. The same conceptual model that is described in Section 2 for roundabout intersection, also applies to the conventional intersection.

Simulation model for roundabout capacity analysis was developed using the Flexsim simulation tool from the roundabout operations model. It is described in Section 3, together with the results from four traffic scenarios, reflecting traffic patterns at MUC, followed by a discussion of the roundabout capacity evaluation under MUC operating conditions based on these results.

Further on, for comparison of the two apron intersections, an analytical model for apron intersection capacity analysis is developed and described in Section 4. It is based on a well known runway capacity model, modified to account for the specificities of the roundabout – primarily multiple entry/exit points to/from the intersection and more than one aircraft at the time is allowed in the intersection. The roundabout simulation model (Section 3) is used for analytical model validation. Based on the capacity results from analytical model for the same four traffic scenarios, the roundabout and conventional intersection are compared in terms of capacity and the conclusion is drawn from the perspective of the system as a whole i.e. accounting for their role, position and number, as well as the capacity of the runway system at MUC.

Section 5 gives some concluding remarks on models for taxiway intersection capacity estimation and summarizes the results.

1. Background and motivation for apron roundabout

The role of a taxiway system is to enable safe and efficient aircraft movements from the runway to aircraft stands and vice versa. An apron taxiway system should be designed to provide safe aircraft-to-aircraft and aircraft-to-objects separations. At busy airports, parallel apron taxiways are introduced to provide higher throughput by enabling aircraft passing in opposite directions, and greater possibilities (fewer restrictions) for simultaneous push-back operations. Two parallel taxiways are typically used at apron areas, even at the busiest airports.

In terms of apron taxiway system configuration, Munich Airport (MUC) is not a typical case. It operates with three parallel apron taxiways across all three aprons. Fig. 1 (source: DFS, 2004) shows the layout of Aprons 1, 2 and 3. Aprons, together with two terminals and one satellite building for baggage handling (currently under reconstruction), are located between the two parallel independent runways. The runway system operates in mixed mode (arrivals and departures) with a capacity of 90 operations/h.

At Apron 2 three parallel yellow taxiways allow simultaneous taxiing of the two largest aircraft (ICAO code letter F), or three smaller aircraft (up to C). In other apron areas, outer taxiways, orange and blue, may be used simultaneously only by smaller aircraft (A, B and C). The yellow central taxiway is used by larger aircraft (D, E or F). It cannot be used simultaneously with the blue and orange side lines. A greater number of apron taxiways leads to more complex taxiway intersections.

In the current state, the most complex intersection is located on the southern side of Apron 2 (black rectangle in Fig. 1) next to the unidirectional bridges, S7 and S8 (links between Apron 2 and the taxiway system related to the southern runway). The intersection consists of nine intersecting taxiways (three sides with three lines per side).

Following MUC development (a third parallel runway on the northern side and the expansion of the terminal complex eastwards, see Fig. 2) a 12-line intersection, four sides with three lines per side, was initially planned at the redesigned aprons.

Such an intersection is seen as a potential problem, due to ambiguous traffic patterns, crossings, etc. either for the apron controllers, or the pilots directly participating in the movement through the intersection. For this reason, a new potential design of the apron taxiway intersection area was sought out, aiming to provide a smoother flow than the conventional one, and at the same time, to allow capacity high enough to avoid the creation of local bottlenecks on the apron. The roundabout, a solution typically used for complex intersections in road transport, is proposed by MUC. An apron roundabout is not only an innovation for MUC, but an innovation in general, in terms of its purpose, design and location within the airport complex. MUC fully owns this roundabout solution for an apron intersection, both its technical and operational concepts, as the one to bring forth the idea first and to go through the evaluation process of its possible implementation.

The preliminary roundabout design is shown in Fig. 3. Dimensions, as given in Fig. 3, allow for three parallel yellow taxiways to be used simultaneously by three aircraft up to code letter C, or two larger aircraft (D, E, or F). The parallel orange and blue taxiways may be used simultaneously by two aircraft up to code letter C, while larger aircraft should use the central yellow taxiway and are not allowed to taxi simultaneously with any aircraft on the parallel blue or orange taxiways.

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