International Civil Aviation Organization

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Agenda Item 8: Airport Innovation and Technology

IMPLEMENTATION OF FOLLOW THE GREENS (FTG) OPERATIONS AT SINGAPORE CHANGI AIRPORT: TRIAL EXPERIENCE AND LESSONS LEARNT IN ENHANCING TAXIWAY SAFETY

(Presented by SINGAPORE)

SUMMARY

This paper presents Singapore Changi Airport's experience in the trial and implementation of Follow the Greens (FTG) operations as a taxiway safety enhancement measure, which has yielded positive results. It outlines the considerations leading to the adoption of FTG, the phased operational trial, implementation challenges, observed safety and operational benefits, and key lessons learnt that may be of value to airports and air navigation service providers considering similar initiatives.

1. INTRODUCTION

1.1 Singapore Air Traffic Control (ATC) and the Changi Airport Group work closely together to ensure safe ground movement including taxiing of aircraft at Changi Airport. These include the implementation of an Advanced Surface Movement Guidance and Control System (A-SMGCS), visual aids such as aerodrome markings and signage, and rigorous ATC procedures including surveillance monitoring and the use of standard phraseology. However, from time to time, taxi errors do occur. As part of the continuing efforts to enhance taxiway safety, Singapore ATC and Changi Airport explored additional mitigation measures to further enhance pilots' situational awareness and reduce the likelihood of route deviations. This led to the evaluation of technologies capable of providing direct and dynamic route guidance to pilots, complementing the existing safety measures and introducing an additional layer of defense against taxi errors.

1.2 One such technology evaluated was Follow the Greens (FTG), an advanced feature integrated into the A-SMGCS to provide visual routing guidance to aircraft during taxi operations.

2. DISCUSSION

Follow the Greens (FTG) Concept

2.1 The FTG concept is based on the Routing and Guidance modules of A-SMGCS. The Routing Service assists ATC in planning ground routes for aircraft and vehicles by generating routes based on predefined ATC routing preferences and prevailing operational conditions, such as taxiway closures and restrictions.

2.2 Building on the routing information, the Guidance Service provides visual guidance to aircraft during taxi operations by automatically controlling aerodrome lighting elements, including Taxiway Centreline Lights (TCL) and Taxiway Stop Bars (TSB), in accordance with ATC clearances. This enables individual aircraft to be guided along their assigned taxi routes through illuminated green TCL, providing intuitive routing guidance that can be updated in response to operational conditions and ATC requirements.

2.3 By providing pilots with continuous visual guidance along assigned taxi routes, FTG was expected to reduce the likelihood of route misinterpretation and provide an additional safety layer through the monitoring and prediction capabilities of the A-SMGCS. To evaluate these potential benefits and ensure the safe integration of FTG into existing operations, a phased operational trial programme was developed.

Trial Phase

2.4 To ensure the robust implementation of FTG operations and promote a thorough understanding of the system among operational users, the trial programme was conducted in phases. This phased approach provided structured training and familiarisation for both ATC and airside users, while allowing the FTG system and associated safety functions to be progressively evaluated under operational conditions.

- **Foundation Phase (2 months):** Conducted theoretical and simulator training to familiarise controllers with FTG concepts, A-SMGCS functions, operational procedures, and contingency handling.

- **Phase 0 – ATC Operational Familiarisation (6 months):** Enabled controllers to gain hands-on experience with FTG functions in a live operational environment while continuing to issue conventional verbal taxi clearances. Thise phase validated system performance and safety alerts across a broad range of traffic scenarios, including Runway 02 and Runway 20 operations.

- **Phase 1 – Night FTG Operational Trial (16 months):** FTG clearances were introduced during night operations with the participation from airlines and towing operators. This phase evaluated operational effectiveness, gathered stakeholder feedback, and supported system refinements leading to the operational implementation of night FTG operations on 6 August 2026.

- **Phase 2 – Day FTG Operational Trial:** Scheduled to commence in September 2026, this phase will extend FTG operations to daylight conditions to assess the effectiveness of visual guidance for pilots and towing crews, while continuing to gather operational feedback to support full implementation.

Challenges Encountered

2.5 The implementation of FTG operations presented several infrastructures, operational and system-related challenges which required close collaboration between the Air Navigation Service Provider (ANSP), airport operator, system provider and airside users.

2.6 One of the key infrastructure challenges was the existing TCL configuration at Changi Airport, where lights are designed in segments between stop bars. As a TCL segment can only be extinguished after an aircraft has fully vacated the segment, green lights may remain visible behind an aircraft after it has passed a substantial portion of the route. In addition, the bi-directional nature of the

TCLs meant that illuminated green lights could be visible to traffic approaching from the opposite direction, potentially leading to misinterpretation. To address these limitations, extensive stakeholder engagement was conducted to reinforce the principle of following only continuous green lights and stopping when a break in the green lights is encountered. This was supported through regular engagement forums, Electronic Direct Mailers (EDMs), and the publication of relevant information through NOTAMs, AIP and ATIS broadcasts.

2.7 Another infrastructure challenge involved towing operations. As FTG functionality relies on A-SMGCS surveillance data, tow tugs without transponders could not be detected by the system and therefore could not receive FTG guidance. To facilitate FTG towing operations, all tow tugs were required to be equipped with transponders. As such, FTG towing operations were only permitted for tow-tugs with serviceable transponders to ensure reliable surveillance tracking and guidance.

2.8 Operationally, ATC experienced an initial increase in workload during Phase 0 as controllers were required to input FTG functions into the A-SMGCS while continuing to issue conventional verbal taxi clearances. This was necessary to familiarise controllers with FTG operations in a live environment and validate system functionality while maintaining existing operating procedures. As the trial progressed to Phase 1, controller workload was reduced as taxi routing and guidance were provided through the A-SMGCS. This reduced the need for lengthy verbal taxi instructions and allowed controllers to focus on route amendments required for operational needs. In parallel, significant effort was devoted to stakeholder engagement to ensure that airlines, pilots, towing operators and ground handling agents understood the FTG concept, system limitations and operating procedures. Monthly engagement forums were conducted to gather feedback, review taxi error occurrences and discuss potential enhancements to both the system and procedures.

2.9 From a system perspective, the reliability of surveillance tracks and safety net functions was critical to the success of FTG operations. Continuous system tuning and software updates were required to minimise false tracks, improve track stability and enhance the performance of safety alerts. Considerable effort was also placed on stress-testing the system under varying traffic conditions. Operational experience further identified the need for greater route flexibility beyond the default system-generated routes. Subsequent enhancements were developed to provide controllers with alternate routing options to better accommodate different traffic complexities and operational scenarios, including single-runway operations.

Trial Outcome and Benefits

2.10 Following the introduction of FTG operations in March 2025, the normalised night-time taxi error rate showed a sustained downward trend, with taxi errors during night operations reducing by approximately 65% compared with the corresponding period in 2024. In contrast, the daytime taxi error rate remained relatively stable over the same period. While a small number of taxi errors continued to be observed during the trial, these were largely attributable to infrastructure limitations and human factors. The observed reduction in night-time taxi errors nevertheless demonstrated the potential of FTG to enhance taxiway safety and reduce route deviations during aircraft ground movements.

2.11 Beyond the safety benefits, FTG also demonstrated operational advantages for both pilots and ATC. The provision of intuitive visual routing guidance reduced reliance on lengthy and complex taxi clearances, resulting in fewer radio telephony (RTF) exchanges and a lower risk of route misinterpretation. The system also enabled more dynamic taxi operations, allowing route amendments to be reflected immediately through the illuminated TCL without the need for controllers to issue revised taxi instructions.

2.12 Feedback collected throughout the trial further reinforced the value of FTG operations. A stakeholder survey found that 93% of respondents considered FTG beneficial in enhancing safety and navigation on the airfield, while 92% of ATC respondents assessed FTG to be effective in reducing workload and found the system intuitive to use.

Future Considerations and Lesson Learnt

2.13 Changi Airport's experience in implementing FTG operations has demonstrated the potential of visual guidance technology as an effective taxiway safety enhancement measure to address taxi errors. Through a structured trial programme, FTG demonstrated positive safety and operational outcomes leading to the operational implementation of night FTG operations on 6 August 2026. The success of Phase 1 trial also provided the confidence to progress to the next stage of implementation, with Phase 2 Day FTG trial scheduled to commence in September 2026 to further evaluate the effectiveness of FTG under daylight operating conditions.

2.14 The implementation journey also highlighted several key lessons learnt. The effectiveness of FTG relies not only on technology, but also on continuous system enhancements, regular stakeholder engagement and user education to address operational challenges and infrastructure limitations.

2.15 Looking ahead, the trial highlighted the importance of infrastructure in maximizing the benefits of FTG operations. Future airport developments should consider infrastructure that better supports advanced surface movement guidance capabilities, such as single-lamp control and unidirectional TCL. A key lesson learnt from the implementation was that infrastructure and technology should be developed in tandem. Designing airfield infrastructure with sufficient flexibility to support future technological advancements will enable airports to more effectively leverage emerging safety and operational enhancement solutions.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matters as appropriate.

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