Exploring the Design of Dynamic Airspace Management Systems for Future Urban Low-Altitude Air Traffic

Objectives and Purpose

My future research will focus on the issues of competition and congestion in low-altitude airspace. With the rapid development of UAVs (Unmanned Aerial Vehicles) and AAVs (Autonomous Aerial Vehicles), low-altitude traffic is becoming an integral part of smart cities. (Guo et al., 2024) However, the surge in demand for low-altitude flights is intensifying competition and congestion in airspace. Commercial service aircraft like drone deliveries and air taxis will compete for limited airspace with public service aircraft such as police helicopters and medical rescue vehicles, leading to potential route interference and collisions that threaten urban public safety. (Shaheen, Cohen and Farrar, 2018) This research aims to explore innovative solutions for optimizing low-altitude airspace management and utilization through system and interaction design. The solution seeks to ensure the safe and efficient operation of aerial vehicles while advancing the sustainable development of urban low-altitude traffic.

Relevance of Past Research to Future Plans

In a previous project, I analyzed safety risks in China's tunnel transportation systems, particularly during emergencies such as fires. Factors like narrow tunnels and traffic congestion often lead to high mortality rates and severe social impacts. (Ma, Shao & Zhang, 2009) (Ren et al., 2019) Therefore, I designed a tunnel rescue system combining rail transport, smart devices, and remote-control technologies, to execute rapid firefighting and rescue operations. This intelligent system design significantly improved rescue efficiency and ensured safety. This experience deepened my understanding of the importance of traffic management in safety and efficiency. Based on this, I shifted my focus to the low-altitude domain of future transportation systems. By analyzing case studies such as U-space and Medifly, I identified challenges in coordinating airspace for diverse aerial vehicles and allocating resources in increasingly congested low-altitude. As low-altitude traffic becomes more widespread, competition for airspace will intensify. Therefore, I plan to adopt a systematic approach to explore ways to optimize low-altitude airspace resource allocation and management, offering innovative solutions to enhance the safety and efficiency.

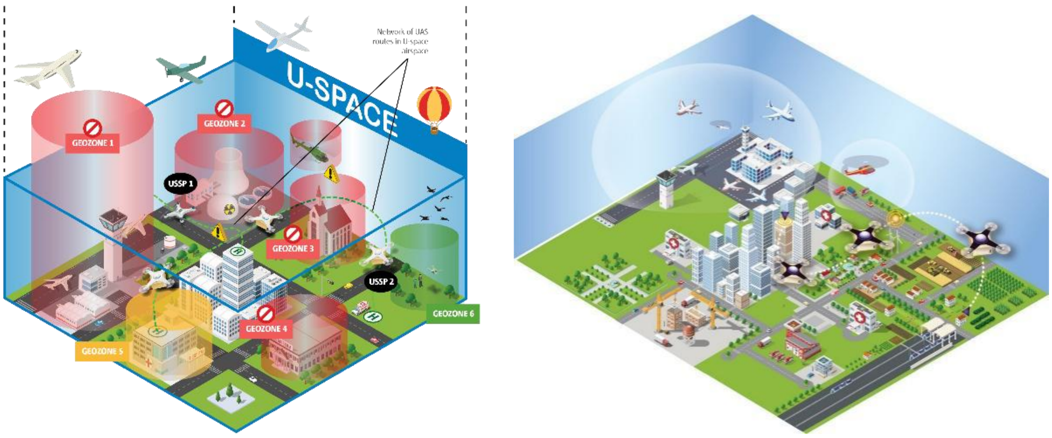

Figure 1&2: The EU's U-space ensures the safe, efficient integration of drones into airspace through digital automation. (European Union Aviation Safety Agency, 2022).

Figure 3&4: Germany's Medifly project highlights drones' potential for transporting emergency medical supplies in cities. (Medifly Hamburg, 2020).

Future Research Focus

1. Identifying And Analyze Core Issues in Low-Altitude Airspace

Through qualitative research and data analysis, I will explore the root causes of airspace competition and congestion. This process includes interviewing stakeholders such as residents, government agencies, emergency services, traffic control centers, and drone operators, as well as conducting scenario simulations to identify pain points in current management systems. The goal is to uncover potential conflicts among different aerial vehicles and provide data-driven theoretical insights for optimizing low-altitude airspace management.

2. Dynamic Airspace Coordination System Design

I will design a multi-layered airspace coordination and management system for future cities, using intelligent algorithms to optimize flight routes. Inspired by Singapore's Green Link Determining System, which reduces road congestion through intelligent traffic signal controls. (Land Transport Authority, n.d.) I plan to apply similar dynamic optimization strategies to low-altitude airspace. Flexibility will be a core design feature, enabling dynamic adjustments to aircraft priorities and routes based on real-time needs, ensuring safe coexistence between low-altitude vehicles and traditional air traffic.

3. User Experience Design and System Evaluation

Through prototype design and user testing, I will ensure the airspace management system features an intuitive interface. By incorporating user feedback, I will continuously optimize operational experiences and ensure ongoing optimization and efficiency.

Design Output and Impact

This research aims to advance low-altitude traffic management policies with forward-thinking measures. It will facilitate the orderly operation of low-altitude vehicles in urban airspace, reducing congestion and accident rates, and becoming more efficient and safer, thereby supporting the sustainable development of smart cities.

If admitted to RCA, I plan to expand the design concept of dynamic airspace management into a broadly applicable framework for intelligent transportation systems. Through interdisciplinary research combining interaction design, system design, and artificial intelligence, I aim to explore the adaptability of this framework in more complex societal and urban environments. I believe RCA's MDes Design Futures program, with its focus on systems thinking and future-oriented innovation, is ideal for my research. Courses like Complex Systems will enhance my logical reasoning ability to analyze and address the challenges of low-altitude traffic management using systematic thinking. Collaborating with diverse tutors and peers will enable me to integrate multidisciplinary knowledge into my designs, which will enhance the project's feasibility and innovation. I look forward to expanding my perspective at RCA, exploring the intersections of technology, design, and urban development, and contributing to innovative solutions for sustainable urban transportation systems of the future.

References

European Union Aviation Safety Agency (EASA), 2022. *Understanding how the new U-space will enable safe integration*. 20 October.

Guo, J., Chen, L., Li, L., Na, X., Vlacic, L. & Wang, F.Y., 2024. Advanced Air Mobility: An Innovation for Future Diversified Transportation and Society. *IEEE Transactions on Intelligent Vehicles*.

Ilić, D., Milošević, I. & Ilić-Kosanović, T., 2022. Application of Unmanned Aircraft Systems for smart city transformation: Case study Belgrade. *Technological Forecasting and Social Change*, 176, 121487.

Labib, N.S., Danoy, G., Musial, J., Brust, M.R. & Bouvry, P., 2019. A multilayer low-altitude airspace model for UAV traffic management. In *Proceedings of the 9th ACM Symposium on Design and Analysis of Intelligent Vehicular Networks and Applications*, pp.57-63.

Land Transport Authority (LTA), n.d. *Green Link Determining System*.

Ma, Z.L., Shao, C.F. & Zhang, S.R., 2009. Characteristics of traffic accidents in Chinese freeway tunnels. *Tunnelling and Underground Space Technology*, 24(3), pp.350-355.

Medifly Hamburg, 2020. *Successful demonstration of drone transport solution*. [online] 5 February.

Ren, R., Zhou, H., Hu, Z., He, S. & Wang, X., 2019. Statistical analysis of fire accidents in Chinese highway tunnels 2000–2016. *Tunnelling and Underground Space Technology*, 83, pp.452-460.

Shaheen, S., Cohen, A. & Farrar, E., 2018. The potential societal barriers of urban air mobility (UAM). n.p..

Wang, L., Deng, X., Gui, J., Jiang, P., Zeng, F. & Wan, S., 2023. A review of urban air mobility-enabled intelligent transportation systems: Mechanisms, applications and challenges. *Journal of Systems Architecture*, 141, 102902.