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Optimising and Analysing the Use of Drones in Healthcare

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ABSTRACT

Providing timely access to healthcare for all inhabitants of a country is extremely challenging, especially in rural areas and during crises. Digital innovations like telehealth or the use of drones can help to improve the access to care. Therefore, we have developed mathematical models to locate drones to transport defibrillators to out-of-hospital cardiac arrests as well as blood products to hospitals. The expected utilisation of these drones and the expected care improvements are evaluated within a discrete event simulation.

1 INTRODUCTION

In recent years, delivery drones, as one type of unmanned aerial vehicles, have received significant attention in the media as well as in research. In practice, drones could boost the realisation of several Sustainable Development Goals. While this is rather obvious for the climate related goal 13, drones can also help to provide better access to healthcare (goal 3 and infrastructure goal 9) as well as to create sustainable cities and communities (goal 11) (United Nations 2022). Especially in rural countries, providing timely access to healthcare for all patients is very challenging. This is even more the case for emergencies or during crises incidents. Drones could for example transport defibrillators to out-of-hospital cardiac arrests (OHCA) before the emergency medical services (EMS) arrive (Pulver and Wei 2018), transport vaccines (Matter and Potgieter 2021) or medical supply (Shi et al. 2022) or transport blood products from blood banks to hospitals (Ozkan 2022). Due to recent developments in technology and business models for drone operations, it can be expected that drones are likely to be deployed by various organisations in the next 2 to 5 years. Even though drones gain significant momentum in practice, research on drone logistics is still comparably scarce. A review on drone logistics as part of pre-EMS services can be found in Matinrad and Reuter-Oppermann (2022).

In the the two funded research projects "BISKIT" and "SPELL" we study the integration of drones into the healthcare systems of South Africa and Germany and develop location planning models as well as discrete event simulations to assess the solutions. In "BISKIT", we target the support and improvement of blood supply chain management in South Africa, especially during a crisis, by designing an information and decision support system. "SPELL" aims to design a platform offering AI-based services and data access to coordination centres and emergency services providers in Germany.

2 OPTIMISATION AND SIMULATION MODELS

In South Africa, meeting the demand for blood products is very challenging, not only during a crisis, but already on a daily bases. Therefore, one idea is to use drones to transport blood products on-time or in case of short-term demands, e.g. because of an emergency, making it possible to pool products longer and distribute them when the demand becomes known. We have built a two-stage stochastic programming

model that decides about drone locations as well as allocations to demand points simultaneously with the aim to transport blood products to hospitals in order to fulfill short-term demand. In an extension, the model additionally decides about locating battery swapping stations to extend the travel radius of drones. In order to analyse the utilisation of the drones and swapping stations as well as the expected fulfillment of demand we have implemented a discrete event simulation in the simulation software AnyLogic (The AnyLogic Company 2022). We have built test instances for the different regions in South Africa, based on the existing blood bank and hospital locations and modeled demand in relation to the number of inhabitants per area. It turns out that even with battery swapping stations, in some regions a significant number of hospitals still cannot be reached within the current flying range of drones, making it necessary to use trucks to transport sufficient blood products to those hospitals upfront.

As part of the "SPELL" project, we aim to improve and extend first responder apps in Germany and include the option of deploying drones to transport defibrillators to an out-of-hospital cardiac arrest. Therefore, we have built a bi-criteria multi-period model that decides about drone locations and allows relocations between periods to improve coverage. The model takes ambulance locations and static defibrillator locations into account to ensure an actual improvement in coverage by located drones. We solved the model for the German federal state of Hesse, showing that already by locating 24 drones, 54.7% of all inhabitants can be reached within 3 minutes, significantly increasing survival probabilities of OHCA patients.

3 CONCLUSION

Drones can play an important part in providing timely access to healthcare, especially in rural countries and during crises. For example, they can transport medicines, vaccines or blood products to hospitals or practices or defibrillators to out-of-hospital cardiac arrests.

In future work, we aim to extend the optimisation as well as the simulation models. One idea is to build an integrated approach for Germany to study the feasibility of combining different services for the same set of drones, e.g. transporting blood products or blood samples as well as defibrillators with one joint set of drones, in order to increase utilisation and benefit and reduce costs, while still ensuring short travel times to and high coverage probabilities for potential OHCA patients. For the blood logistics case, we want to build an integrated optimisation model deciding simultaneously about the quantities and routes of upfront transports by trucks as well as the short-term coverage by drones.

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REFERENCES

Matinrad, N., and M. Reuter-Oppermann. 2022. "A Review on Initiatives for the Management of Daily Medical Emergencies Prior to the Arrival of Emergency Medical Services". *Central European Journal of Operations Research* 30(1):251–302.

Matter, D., and L. Potgieter. 2021. "Allocating Epidemic Response Teams and Vaccine Deliveries by Drone in Generic Network Structures, According to Expected Prevented Exposures". *PloS one* 16(3):e0248053.

Ozkan, O. 2022. "Multi-objective Optimization of Transporting Blood Products by Routing UAVs: the Case of Istanbul". *International Transactions in Operational Research* 30:302–327.

Pulver, A., and R. Wei. 2018. "Optimizing the Spatial Location of Medical Drones". *Applied Geography* 90:9–16.

Shi, Y., Y. Lin, B. Li, and R. Yi Man Li. 2022. "A Bi-objective Optimization Model for the Medical Supplies' Simultaneous Pickup and Delivery with Drones". *Computers & Industrial Engineering* 171:108389.

The AnyLogic Company 2022. "AnyLogic Simulation Software". https://www.anylogic.com/, accessed 08.08.2022.

United Nations 2022. "Sustainable Development Goals". https://sdgs.un.org/goals, accessed 08.08.2022.