EINDHOVEN UNIVERSITY OF TECHNOLOGY

Research plan form - Graduation project AI&ES

Title graduation project: *Optimization of airport ground fleet charging infrastructure using Agent-Based Modelling*
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Date: *30-11-2023*

1. Background and already obtained results in the topic:

A rising number of airports are moving towards a carbon-neutral vehicle fleet to reduce emissions and become more sustainable. For example, Schiphol Airport aims to have an emission-free ground fleet by 2030. This can be achieved by completely switching to electric vehicles for the ground fleet of the airport. The ground fleet of an airport consists of a wide variety of vehicles, these vehicles include passenger-carrying apron buses and other utility vehicles such as baggage tractors and fuel trucks. The vehicles from the ground fleet are continuously in use and need to have a minimum amount of downtime for efficient ground handling operations. For this reason, the charging infrastructure in an airport and the challenges this brings will be of importance.

A critical gap exists in our understanding of how to effectively optimize the charging infrastructure in airport environments on an airport scale. The complex and numerous ground operations on the airport together with the value of time create a set of challenges which has not been addressed yet in current literature. In this research Agent Based Modelling (ABM) will be used to create a simulation model of the airport and with this model, the optimization of the routing of the electric ground vehicles will be investigated.

The importance of this research is emphasised by the need to meet sustainability goals and the efficiency of airport ground handling operations. An optimized charging infrastructure not only aligns with environmental objectives but is also crucial for maintaining the seamless functionality of airport ground fleets, reducing downtime, and supporting the continual flow of critical operations.

2. Literature survey

Ground Handling Operations have not been a prominent subject of studies when compared to other airport operations such as the Airport Ground Movement Problem (AGMP) where the movement of the aircraft on the tarmac is of interest [1]. However, there are multiple papers which have focused on the ground handling operations side of airports.

In one paper the goal is to optimize the ground-handling tasks on airports by proposing a new ground-handling management structure [2]. This is done by using a mathematical formulation of the Ground Support Equipment (GSE) and assignment problem which is generalized for most GSE types at the airport. Finally, by using a proposed strategy the solutions are gathered for a real airport scenario. The results show that the new ground-handling management structure outperforms existing strategies. The simulation results can be used to estimate the operation cost for example for different fleet sizes and traveling distances.

Another paper focuses on improving the efficiency and safety of airport aprons by optimizing the assignment of vehicles to apron operations [3]. This is again done by presenting a mathematical formulation of the problem and by using a fast sequential heuristic which can efficiently assign vehicles to apron by using real-time data on position and status. This new assignment policy reduces the travelled distance by 7.5% when compared to the assignments made by a regular dispatcher.

These previous papers focused only on optimizing ground-handling operations, however, other papers have focused on the electrification of the ground fleet. One paper aims to optimize the utilization of a mixed ground fleet consisting of electric and fuel-driven vehicles by using an objective function which minimizes the sum of time cost, energy cost and emission cost [4]. This problem is then solved using Adaptive Large Neighbourhood Search (ALNS) for two different case scenarios and the results indicate that the optimal fleet allocation strategy depends heavily on the scenario characteristics.

Finally, a couple of papers investigated the charging infrastructure on aprons for dynamic wireless charging for electric airport passenger buses [5] and for multiple vehicle types [6]. Currently, stationary conductive charging is the standard technology for vehicles. However, dynamic wireless charging offers an alternative where the vehicles can charge while moving, which is especially relevant for airport aprons. In these papers, the location planning problems related to the distribution of power supply in the road system are centred. To this end, an optimization model is developed and analysed. The results indicate that the resulting infrastructure is highly dependent on the overlap of the service requests of the different vehicle types.

3. Research questions

The main research question is as follows:

1. How can the charging infrastructure for electric ground fleets at airports be optimized to ensure both environmental sustainability and operational efficiency using Agent-Based Modelling?

To answer the main research question several sub-questions are defined:

a. What are the key operational parameters and constraints influencing the charging infrastructure requirements for electric ground fleets of airports?
b. How can the optimization of charging infrastructure be adapted to accommodate the continuous and time-sensitive nature of ground-handling operations at airports?
c. What role does the spatial distribution of charging stations play in optimising the charging infrastructure for a diverse ground fleet at airports?
d. To what extent can Agent-Based Modelling contribute to the development of adaptive and efficient charging infrastructure for electric ground fleets at airports?

4. AI&ES relevance

The problem at hand is an optimization problem which will be solved using a machine learning algorithm. Such a method of solving can be considered artificial intelligence. Additionally, artificial intelligence can potentially play a role in several steps of the project. For example, reinforcement learning can be utilized to train the agents in the simulation, this is done in a paper which focuses on the simulation of an electric fleet at a seaport [7]. Additionally, some form of a forecasting algorithm can be implemented if deemed useful.

5. Research methods

To answer the main research question and its sub-questions some data and tools are required. First of all, research needs to be done on the ground handling operations of an airport, for this project, Schiphol Airport will be utilized as a case scenario. This includes determining the size and content of the ground fleet and how these vehicles are routed on the airport grounds. Ideally, data is obtained that characterizes each ground vehicle type, these include the vehicle weight (with and without passengers), average speed, battery capacity and energy consumption. Additionally, the itinerary data for each vehicle type needs to be incorporated to accurately model the ground operations. Data on the charging infrastructure is required to optimize the routing of the electric vehicles, this data includes the power and efficiency of the chargers. Part of this data may be obtained by collaboration with the Netherlands Aerospace Center (NLR). All this data, together with a simplified layout of the airport, is used to make an accurate simulation model of the ground handling operations using Anylogic, which is a simulation modelling tool. Anylogic is used since it allows for agent-based modelling with the right amount of adaptability for this specific scenario.

Next, an optimization framework needs to be created. This framework consists of an objective function, which in this scenario could include minimizing the total energy consumption or reducing operational costs. The decision variables could be the locations of the charging stations. Additionally, constraints need to be considered, these can include but are not limited to spatial and operational constraints. To solve the optimization problem an optimization algorithm needs to be selected and integrated into the simulation model. After successfully integrating the algorithm into the simulation model it will be possible to extract and evaluate the results.

6. Expected outcomes of the project

The expected outcomes of the project are as follows. First of all, an optimal charging infrastructure layout for Schiphol airport for a specific ground fleet. However, the layout is most likely dependent on the size of the fleet, for example, to reduce operational costs a smaller fleet might be beneficial, so an optimal fleet size for this specific scenario can potentially also be an outcome of this project. These results could help with future infrastructure planning of airports and help with reducing energy consumption. The complete optimization framework itself is also one of the main outcomes of this project, ideally, this model will be versatile enough to be applied to other optimization problems in the future. Besides these expected outcomes of the project, the simulation model itself should also be considered a result. Together with a comprehensive documentation of the model it can be used for future research.

7. Time planning:

On the following page, a Gantt chart is shown with the general time planning of the project.

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Task name	Start date	End date	Assigned	Progress	WEEK 1	WEEK 2	WEEK 3	Christmas break	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	Carnival holiday	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15	WEEK 16	WEEK 17	WEEK 18	WEEK 19	WEEK 20	WEEK 21	WEEK 22	WEEK 23	WEEK 24	WEEK 25	WEEK 26	WEEK 27	WEEK 28	WEEK 29	Summer holiday	WEEK 30	WEEK 31	WEEK 32
Preparation phase	04-12-23	08-12-23		0%																																			
Define project and objectives	04-12-23	08-12-23		0%																																			
Literature review	04-12-23	08-12-23		0%																																			
Research plan	08-12-23	08-12-23		0%																																			
Prepare ABS model	11-12-23	12-01-24		0%																																			
Gather necessairy data	11-12-23	22-12-23		0%																																			
Process data	01-01-24	12-01-24		0%																																			
Get acquainted with simulation software	11-12-23	12-01-24		0%																																			
Simulation model development	15-01-24	09-02-24		0%																																			
Develop ABS model using Anylogic	15-01-24	02-02-24		0%																																			
Incorporate data	22-01-24	09-02-24		0%																																			
Conduct initial validation	29-01-24	09-02-24		0%																																			
Optimization framework integration	19-02-24	15-03-24		0%																																			
Devise optimization framework	19-02-24	01-03-24		0%																																			
Integrate optimization framework	26-02-24	07-03-24		0%																																			
Test the integrated model	04-03-24	15-03-24		0%																																			
Full-scale simulation and optimization	18-03-24	12-04-24		0%																																			
Execute optimization process	18-03-24	05-04-24		0%																																			
Evaluate the results and model	01-04-24	12-04-24		0%																																			
Analysis of findings	15-04-24	10-05-24		0%																																			
Intermediate report/presentation	10-05-24	10-05-24		0%																																			
Refinement and sensitivity analysis	13-05-24	07-06-24		0%																																			
Refine simulation and optimization model	13-05-24	24-05-24		0%																																			
Conduct sensitivity analysis	27-05-24	07-06-24		0%																																			
Finish final report	10-06-24	05-07-24		0%																																			
Final report	05-07-24	05-07-24		0%																																			
Presentation preparation and finalisation	02-09-24	20-09-24		0%																																			
Final presentation	20-09-24	20-09-24		0%																																			

8. References:

[1] Noortman, T. E. H. (2016). Agent-Based Modelling of an Airport's Ground Surface Movement Operation Understanding the principles and mechanisms of decentralized control. http://repository.tudelft.nl/.

[2] Alonso Tabares, D., Mora-Camino, F., & Drouin, A. (2021). A multi-time scale management structure for airport ground handling automation. Journal of Air Transport Management, 90. https://doi.org/10.1016/j.jairtraman.2020.101959

[3] Andreatta, G., Capanna, L., de Giovanni, L., Monaci, M., & Righi, L. (2014). Efficiency and robustness in a support platform for intelligent airport ground handling. Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 18(1), 121–130. https://doi.org/10.1080/15472450.2013.802160

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[5] Helber, S., Broihan, J., Jang, Y. J., Hecker, P., & Feuerle, T. (2018). Location planning for dynamicwireless charging systems for electric airport passenger buses. Energies, 11(2). https://doi.org/10.3390/en11020258

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[7] Brunetti, M., Campuzano, G., & Mes, M. (2022). Simulation of the Internal Electric Fleet Dispatching Problem at a Seaport: A Reinforcement Learning Approach. Proceedings - Winter Simulation Conference, 2022-December, 2675–2686. https://doi.org/10.1109/WSC57314.2022.10015516