Aalto University

MS-E2177 - Seminar on Case Studies in Operations Research D

Simulating and Optimizing a Multicar Shaft Elevator System
Interim Report

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1 Changes in the Project Scope and Updates

Due to time constraints and the programming workload, the project's scope has been adjusted during the interim phase. Instead of implementing all three planned simulation levels (basic, intermediate, and advanced), we will now focus on completing two: a basic simulation of a continuously moving Paternoster and an intermediate version with doors and a stopping mechanism. Our goal will remain to explore and optimize key performance metrics, including passenger waiting time, journey duration, and handling capacity for elevator up-peak morning traffic in a building of 10 floors plus the entrance floor. Passengers are assumed to arrive only during the up-peak traffic in the morning from the entrance floor (0) to the upper floors (1-10).

Given the complexity of building the simulators in Python, most of our efforts will be concentrated on development and testing. If time allows, additional effort will be directed toward optimizing passenger traffic in the elevators - particularly by fine-tuning the control logic to improve passenger distribution and reduce journey times across different traffic scenarios.

1.1 Template for the paternoster

We have created a Python-based simulation that models eight identical elevator cars moving up in one shaft and down in the other shaft, across 10 floors, without any overlap. We assume the floors are 5 pixels apart from each other, which corresponds to the 5-meter floor height assumed in the project plan. For visual clarity in the simulation, elevators are spaced at about half their length apart.

Each elevator moves at a speed of 0.5 m/s and can accommodate up to 8 passengers. Passenger arrivals follow a Poisson distribution with an average rate of 5 passengers per minute, totaling approximately 25 passengers during the 5-minute simulation period. This is in line with the assumptions made in the project plan.

The simulation aims to minimize the following for a single elevator traveling between floor i and floor $i + 1$:

$$C_1 \text{passenger waiting time [s]} + C_2 \text{duration of the journey [s]}.$$

Waiting time, journey duration, and the number of passengers are expressed in terms of the control variable, the pick-up/drop-off rate of passengers per second, which ranges between 0 and 8 (the maximum capacity for a single elevator). Currently, C_1 and C_2 are both set to 1.0, but these weights may be adjusted depending on the relative importance of each factor.

1.2 Stockmann excursion

Our group had the privilege of visiting one of the six working paternosters in Finland. There is a paternoster in the Stockmann building, in the city centre of Helsinki, where it is solely in use for the personnel of Stockmann. Marja-Liisa, our contact person, organized a visit for us with KONE, who have built the elevator and maintain it still. We rode the elevator and had a look at the machinery. The visit was a great help in visualizing our project, as we saw how the elevator works in real life.

2 Project Status

2.1 Completed Tasks

- **Meetings**:
  In addition to our regular meetings and collaborative coding and writing sessions, these are the main meetings so far:
  - Initial meeting with Marja-Liisa (January 23, 2025).
  - Initial meeting with our course professor Ahti (February 26, 2025).
  - Interim team meeting between members (March 5, 2025).
  - Stockmann excursion with Marja-Liisa (March 12, 2025).
- **Basic Simulation Framework**:
  - Implemented core movement for 8 paternoster cars.
  - Developed vertical motion with direction switching at the top and bottom.
  - Added passenger generation using Poisson distribution ($\lambda = 5/\text{min}$).
  - Built real-time visualization using `tkinter` canvas.
- **Real-time metrics tracking**
  - Average waiting and journey time.
  - Adjustable speed (1x, 3x, 5x, 10x simulation speed).

2.2 Ongoing Tasks

- Continuously improving the Python script.
- Contact Marja-Liisa for additional information if needed.
- **Intermediate Simulation Features**:
  - Extending per car capacity to 8 passengers.
  - Implementing door simulation mechanics.
  - Developing stopping mechanism when passengers board or leave.

2.3 Future Tasks

- Possible KONE excursion with Marja-Liisa during April.
- Schedule a meeting with Ahti (if necessary).
- **Advanced Simulation Development**:
  - Implementing independent car movement while maintaining safety distancing.
  - Adding floor to floor passenger journeys.
  - Analyze arrival patterns.

3 Updated Risk Management Plan

Table 1 presents the updated key risks associated with the project work. In this updated risk management plan, some clarifications have been made while the key risks have stayed relatively similar. This plan is expected to enable the management of relevant risks for the remaining project work.

Risk	**Likelihood**	**Consequences**	**Mitigation**
Unrealistic (too optimistic regarding the workload of relevant tasks) schedule.	Medium	Final goals may not be achieved on time. Increased disappointment and stress. Unsatisfied client.	Follow the planned schedule for meetings and the project's progression. If necessary, make adjustments. Communicate clearly.
Lack of programming skills for the more advanced simulator model.	Low	Inability to complete the last simulator models of the project.	Discuss the existing team resources in programming, particularly when challenges are encountered. Investigate the strengths of each project member, try to utilize those optimally for the programming, develop solutions, and if needed, use additional resources, like the internet or asking advice from friends.
Unrealistic or mediocre performance metrics (such as waiting, stopping, or journey times or system handling capacities) in the elevator simulation.	Medium	The results are not reliable for real-world scenarios.	Re-evaluate all the formulations. Review the literature carefully. Most importantly, ask for Marja-Liisa's and Ahti's advice.
Inactive project team members (due to e.g. lack of time or motivation).	Low-Medium	The workload is not balanced between all the members. The project goals may not be achieved. The project team dynamics may become worse.	Meet in person regularly. Make precise plans together with specific dates. Communicate. The project manager continues to observe the activity levels and tries to keep the team together.
The quality of the project work does not meet the client's expectations.	Low-Medium	Unsatisfied client. High disappointment for the team, because one of the most important goals is not achieved.	Ask for Marja-Liisa's feedback and meet her in person regularly. (What is well said? What should be improved? What could be changed even better?)

Table 1: The updated risk management plan.

Figure 1: Three photos from our Stockmann excursion on March 12, 2025, and the paternoster elevator, still in use by Stockmann's personnel.