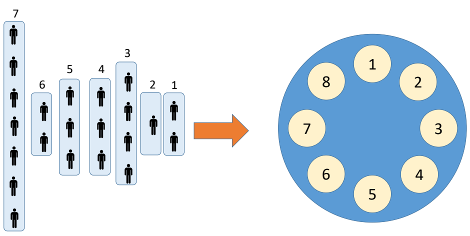
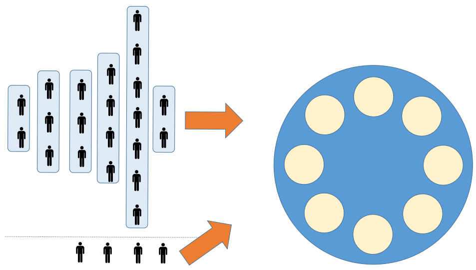
1 Problem description

An amusement park has one attraction that is so popular that it attracts large crowds of people, resulting in long waiting lines. Since people hate waiting in a queue, the CEO of the amusement park wants to take measures to improve the situation and make sure that waiting lines decrease significantly. He considers the option to add a so-called single-riders queue. We will explain the concept in more detail.

The attraction features boats with a capacity of 8 people. People arrive at the attraction in groups of varying sizes. The current policy is to fill the boats as much as possible on a first-come-first-served basis *without* splitting groups. An example is depicted in Figure 1(a), where the first three groups (of sizes respectively 2, 1, and 4) are able to board the boat. The boat will leave with an occupancy of seven people. Figure 1(b) depicts the new situation where an additional queue is added solely for groups of size one (single riders). The boarding policy is now as follows: the "regular queue" always has priority over the single-riders queue. This means that boats will be filled with the groups consisting of two or more people. However, whenever the next group does not fit entirely in the boat, the remaining places in the boat are filled with single riders (if available). In Figure 1(b) the boat will depart with the first group of two persons plus the four single riders.



(a) Current situation



(b) With a single rider queue

Figure 1: The two scenarios: (a) the current situation and (b) adding a single-rider queue.

Note that people arriving alone (i.e. in a group of size one) always join the single rider queue. They are not allowed to join the “regular queue” .

2 Main questions

The CEO of the amusement park wants you to write a clear report in which you address some (or all) of the following questions:

- Does the introduction of a single-rider queue lead to shorter queues?
- Does the introduction of a single-rider queue lead to a higher occupancy of the boats?
- To what extent does the variation in the group sizes play a role when answering the previous questions? For example, when 50% of the groups contain 1 person and 50% of the groups contain 5 people, the effect of adding a single-riders lane might be different than when groups are of size $1, 2, \ldots, 5$, each with probability $1/5$.

There is one last, very important question that you should address:

- Can you come up with another solution that might perform even better than adding a single-rider queue?

Please come up with a realistic, original solution that is an alternative to the single-rider queue. There is one restriction: it should not be too easy to implement. Before implementing this proposed solution, please verify with the lecturer if it is suitable for this assignment.

3 The model

You have to use a discrete-time model (which is also the easiest solution, by the way). In a discrete-time model, time is divided in intervals of the same length. For this application, it makes sense to choose as one time slot the time between the departures of two consecutive boats. For example: if there are 5 people waiting at the end of time slot $t-1$, and in time slot t one group arrives of size 2 and one group arrives of size 3, then the boat departing at the end of time slot t will be filled with 7 people (the 5 waiting people plus the group of two persons) and the queue length at the end of time slot t will be equal to 3. Be very clear about your model assumptions in your report!

4 Correctness of the results

In order to verify whether the results of your simulation are correct, please make sure to include the following situation somewhere in your report (this might be an appendix):

- The probabilities p_k that k groups arrive *in one time slot* are:

$$p_0 = 0.1, p_1 = 0.2, p_2 = 0.3, p_3 = 0.4.$$

- The probabilities q_m that an arbitrary group consists of m persons are:

$$q_1 = q_2 = q_3 = q_4 = q_5 = 0.2.$$

Include the following table in your report for this specific numerical example:

Performance measure	**Simulated value**	**Confidence interval**
Mean number of groups arriving per time slot		
Mean group size		
Model without single-rider queue		
Mean total queue length		
Mean occupancy of the boats		
Model with single-rider queue		
Mean total queue length		
Mean single-rider queue length		
Mean regular queue length		
Mean occupancy of the boats		

Note that the queue length is defined as the total number of people waiting (at the end of a time slot), *not* the number of groups.

This situation, with the given input parameters, should definitely not be the only case you analyse in your report. As indicated in Section 2, you should vary the distribution of the group sizes, but also try several arrival rates! This way you might be able to get more insight in the capacity of the system: how many people per time unit can this attraction handle?

5 More details

The assignment will be 25% of the final grade of the course 2WB50. The assignment is made in groups of two or three students. Each group should hand in a well-written report and the source code of their simulation programs. More detailed guidelines can be found in Canvas. Upload your report in PDF format before the deadline specified in Canvas. **This is a hard deadline**! Please include your source code as an attachment (uploaded as a **separate** ZIP file).