**Modeling assignment simulation: the dynamic bus station**

**Introduction**

In the past, a bus station would be made up of a large empty space where regional and city buses each had their own area. One or several bus lines always used the same platforms where they could let passengers get on and off. Thanks to the progress of technology, passengers can now see the arrival time and location for their buses on matrix display boards. As a result, the so-called rigid distribution (bus line 5 always arrives at platform 3) can be broken (bus line 5 arrives in 5 minutes at platform 3). With this type of technology, bus line 5 might arrive sometimes at platform 3 and other times at platform 5. Further, it is now thought unnecessary and even annoying to have buses occupying a platform space when they are not due to leave for some time. By assigning a separate alighting platform, from where the bus drives to a parking area (buffer), only moving to the departure platform a couple of minutes prior to departure.

These two pillars form the basis of the Compact Dynamic Bus station concept: dynamic distribution and separation of processes. According to logistics concepts for a better utilization of capacities, it is desirable to attempt the same process with fewer platforms. This is useful in where space is limited, expensive or required for other purposes. The core question for any town or city wishing to implement such a new bus station is: how many platforms are required in the new situation and how large does the buffer need to be? The answer depends strongly on the timetables and since a new bus station is a big investment, a simulation study is a very wise thing to do.

**Case description**

A city with 150,000 inhabitants has an outdated bus station and very little space. The City Council gives an order for a simulation study regarding a compact dynamic bus station. The aim of the study is to determine the number of platforms required and the size of the buffer.

All buses will go through the bus station, thus city buses, regional buses and special lines, such as school buses. In total, there are 37 lines, and each line is assigned a preferred platform. You may assume that the bus timetable is given. An example of the Monday rush hour, where it is assumed that there are 6 platforms and there is a given preferred platform is given (see `bus.xls`). Note that times are expressed in seconds.

In general we have \( n \) buses, where bus \( j \) has scheduled arrival time \( a_j \), scheduled departure time \( d_j \) and preferred platform \( p_j \).

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1 This is the problem given Case Study 7 Enterprise Dynamics educational suite.
Buses arriving more than 5 minutes before the departure time mentioned in the schedule let the passengers get off at a remote alighting location, which takes 30 seconds to complete. Afterwards, the buses drive to the buffer and wait there until 2 minutes before departure time. The buses then drive to the station, the area with the platforms, bus stops and passengers.

Buses arriving less than 5 minutes before the departure time drive on to the platforms directly. The alighting of passengers and the boarding of new ones then takes place simultaneously. This process takes 2 minutes, but buses do not leave before the time mentioned in the schedule.

As a result, buses combining boarding and alighting remain at the most 5 minutes at the station and other buses only 2 minutes. The time necessary to drive from the alighting location to the buffer and from the buffer to the station were kept outside this model, as well as the organization of the available space and the passengers’ behavior. A layout of the process is shown in Figure 1.

**Figure 1**

Each platform consists of two bus stops; so two buses can take position behind each other. The rear bus can only leave when the front stop is empty. Therefore, when the platform is empty, the first bus to arrive will take the front position. When the rear stop is occupied, the front stop cannot be reached. A bus on the rear stop does not move to the front stop if it subsequently becomes vacant.
For the passengers’ convenience, the bus lines have a preferred platform. If this platform is occupied, only the nearest platforms are used. So a bus with preferred platform 4 is only allowed to divert to platform 3 or 5. As far as the first and last platforms are concerned, only the single adjacent platform is used.

Questions

1. How can we make a calculation beforehand or a reasoned estimate of the number of platforms required? In the example bus.xls and how can you generalize this?
2. We consider the situation with a given number of platforms and a given preferred platform for each bus-line (as in the example). In this basic model, all time operations are temporarily constant (deterministic), which means that there are no disturbances as a result of, for instance, buses arriving too early or too late, or from longer or shorter boarding times. Describe an event-scheduling simulation model for this case.
   a. What is the state that has to be maintained during the simulation?
   b. What are the events and draw an event graph?
   c. What are the performance measures and how are they measured during the simulation?
   d. Describe the event handlers in words or pseudo-code.
3. Clearly the above case is too optimistic. Now suppose that the actual arrival times deviate from the scheduled arrival times, i.e. $AAT = SAT + \delta$, where $\delta$ follows a Normal Distribution with an average of 0 and a standard deviation of 1 minute. How does this change the above simulation model?
4. Suppose that we have a fixed number of platforms, but no preferred platforms. Determine a rule for the assignment of buses to platforms. How should this rule be included in the simulation model?