Lesson 1. Introduction to Simulation

1 What is simulation?

- **Simulation** is the imitation of a real-world system in order to obtain data that can be used to evaluate and improve the system's performance
- In this course, we will focus on simulations that are
  - **stochastic**: some aspects of the system are modeled using probability distributions
  - **discrete-event**: state of the system changes at discrete points in time triggered by **events**, e.g. the arrival of a customer, the completion of an activity

2 Why simulate?

- Real-world trial-and-error approaches are expensive, time consuming and disruptive
- Complex systems are often resistant to analytical models and solutions
  (e.g. limitations of linear programming, queueing theory)

3 An example

- Bank with a single drive-in window
- Time between customer arrivals (i.e. **interarrival time**) has the following probability distribution:

Interarrival time (min)	1	2	3	4	5
Probability	0.1	0.1	0.3	0.3	0.2

  - Assume that the arrival time of the first customer of the day also follows this distribution
- Time to serve a single customer (i.e. **service time**) has the following probability distribution:

Service time (min)	2	3	4	5
Probability	0.4	0.3	0.2	0.1

- Questions we might be interested in:
  - On average, how long does a customer spend at the drive-in window?
  - On average, how many customers are waiting on line at the drive-in window at any time?
- We can answer these questions by simulating the operation of the drive-in window

3.1 Sampling from probability distributions

- To perform this simulation, we need:
  - time of arrival of each customer
  - how long it takes to serve each customer
- Obtaining these requires **sampling** from the above probability distributions
- Idea: use a randomly generated number
  - 10 cards numbered 1 through 10
  - Cards shuffled, one card drawn at random
  - Card number corresponds to interarrival time as indicated below:

Card number	1	2	3, 4, 5	6, 7, 8	9, 10
Interarrival time (min)	1	2	3	4	5

    - $\mathbb{P}(\text{interarrival time} = 4) =$
    - $\mathbb{P}(\text{interarrival time} = 5) =$
  - Same idea for service time:

Card number	1, 2, 3, 4	5, 6, 7	8, 9	10
Service time (min)	2	3	4	5

3.2 Simulating the first three customers

- Using the above sampling technique, let's simulate the first three customers at the drive-in window

Customer (A)	Card no. (B)	Interarrival time (C)	Arrival time (D)	Begin service time (E)	Card No. (F)	Service time (G)	Departure time (H)	Total time at bank (I)

- Let time 0 = when the bank opens
- Arrival (D) = time when customer arrives =
- Begin service (E) = time when customer begins service =
- Departure (H) = time when customer leaves =
- Total time at bank (I) =