Department of Industrial Engineering
University of Stellenbosch

Simulasie 442 : Simulation 442
2025

Tut 1: Memorandum

Tutoriaal 1 *Tutorial 1*	Punt: 71 *Mark:*	Ingeedatum: **25-07-2025** (10:00) B3003 *Due date:*
Instruksies:	Formatteer alle syfers sinvol. Ontwikkel die model individueel. U mag in groepe van **twee** of minder werk om die vrae te beantwoord. Handig slegs een hardekopie van u antwoordstel in . Gebruik Tecnomatix en Excel vir u berekenings. **Hierdie tutoriaal en prakties is verpligtend**. **Indien u nalaat om die vereistes betyds na te kom, sal u die module sak**.	
Instructions:	*Format all numbers sensibly.* *Develop the model individually.* *You may work in groups of **two** or less when answering the questions.* *Submit one document only.* *Use Tecnomatix and Excel for your calculations.* ***This tutorial and practical are compulsory**.* ***You will fail the module if you do not comply with the requirements, on time**.*	

Question 1 [12]

Determine the type of the following variables. Also, justify your answer briefly.

(*E.g.*) The time between arrivals of customers at a drive-through is a continuous, stochastic variable.
Continuous: Time can be measured infinitely.
Stochastic: The exact time between two customer arrivals is uncertain and varies due to random human behaviour.

(a) Number of seats on a Boeing 737.

(b) The time it takes for a light bulb from the first time it works until it burns out.

(c) Required temperature to boil water (at a fixed pressure).

(d) Number of orders prepared at McDonald's.

(a) Discrete, deterministic variable. ✓
Discrete: The number of seats are countable. ✓
Deterministic: For any given aircraft, the number of seats is fixed and known. ✓

(b) Continuous, stochastic variable. ✓
Continuous: Time can be measured infinitely. There are infinitely many possible values within any time interval.✓
Stochastic: The exact time a specific light bulb will fail is uncertain and depends on probabilistic factors. ✓

(c) Continuous, deterministic variable. ✓
Continuous: Temperature can assume any numeric value and is measured on a continuous scale. ✓
Deterministic: The boiling point of water is known, it is exactly 100 °C. ✓

(d) Discrete, stochastic variable. ✓
Discrete: The number of orders are countable. ✓
Stochastic: The actual number of orders prepared in a given period is random and dependent on many factors. ✓

Question 2 [12]

The vehicle service division of a dealership plays a critical role in maintaining customer satisfaction and road safety. This department handles all service appointments, from routine maintenance to urgent repairs. Vehicles that arrive for service follow a structured process designed to ensure efficiency, compliance, and quality.

When a vehicle arrives at the dealership, it undergoes a multi-step process before it is returned to the customer. The dealership maintains service records, manages technician workloads, and ensures parts are available to minimize turnaround time. If a part is not in stock, the vehicle may be queued or scheduled for a return visit.

The key steps in the vehicle service process are:

- **Check-in:** The customer registers their vehicle, describing the issue or scheduled maintenance.
- **Diagnosis:** A technician performs a diagnostic assessment to identify service needs.
- **Approval:** The customer is informed of the findings, estimated cost, and timeline. Service proceeds upon approval.

- **Repair or Service:** Technicians perform the necessary tasks using available tools, parts, and service bays.
- **Quality Check:** A supervisor ensures all tasks were completed according to dealership standards.
- **Handover:** The vehicle is returned to the customer along with an invoice and a service summary.

This process depends heavily on resource availability (technicians, parts, bays) and condition-based decisions (part failure, workload, customer urgency).

(a) What is (are) the entity (entities) listed?

(b) Name two entity attributes.

(c) Name the resources in the process described.

(d) Name two conditions from this description.

(e) List three events in this description.

(f) List two state variables of the system described.

(a) Vehicles ✓[1]

(b) Car model ✓, service type ✓, technician skill level, appointment time [2]

(c) Service bays ✓, tools ✓, spare parts, technicians [2]

(d) Scheduled appointments ✓, availability of parts ✓[2]

(e) Car arrival ✓, service start ✓, diagnosis ✓, Repair, Quality check, Car pickup [3]

(f) Number of cars in line ✓, technician availability ✓, current stage of a vehicle [2]

Question 3 [20]

Christine is an ice cream maker based in Stellenbosch. She operates a small shop where she prepares and serves her handcrafted ice cream products. Throughout the day, she works alone and acts as the sole server in the system.

The table below provides the arrival times and service requirements (in minutes) for the first five customers to enter the shop. Each customer selects one of the following product options, each requiring a different preparation time:

- Soft serve (SS) – 2 minutes
- Two scoops (TS) – 5 minutes
- Waffle (W) – 6 minutes

- Milkshake (M) – 7 minutes

Explain, with detailed steps, how you would simulate the events occurring in the system with one teller between$t = 0$ and $t = 30$. Customers are treated as entities, denoted E_j, where j represents the customer number. You should make use of the simulation structures of Brunner *et al.*

Customer number:	1	2	3	4	5
Arrival Times:	4	6	12	18	20
Order Type:	W	TS	SS	TS	M

Half mark per line and maximum marks achievable is 20. Note that in discrete event simulation, nothing happens between the events, the model advances to the next event with only computer time that elapsed.

At t = 4: ✓

- E_1 is created and *active* (moved to resource) ✓
- E_1 is *time-delayed* and stored on the *Future Events List* ✓

At t = 6: ✓

- E_2 is created and *active* (can't move to resource) ✓
- E_2 is *condition-delayed* and stored on the *Delay List* ✓

At t = 10: ✓

- E_1 is *ready* and stored on the *Current Events List* ✓
- E_1 is *active* and disposed ✓
- E_2 is *ready* and stored on the *Current Events List* ✓
- E_2 is *active* (moved to resource) ✓
- E_2 is *time-delayed* and stored on the *Future Events List* ✓

At t = 12: ✓

- E_3 is created and *active* (can't move to resource) ✓
- E_3 is *condition-delayed* and stored on the *Delay List* ✓

At t = 15: ✓

- E_2 is *ready* and stored on the *Current Events List* ✓
- E_2 is *active* and disposed ✓
- E_3 is *ready* and stored on the *Current Events List* ✓

- E_3 is *active* (moved to resource) ✓
- E_3 is *time-delayed* and stored on the *Future Events List* ✓

At t = 17: ✓

- E_3 is *ready* and stored on the *Current Events List* ✓
- E_3 is *active* and disposed ✓

At t = 18: ✓

- E_4 is created and *active* (moved to resource) ✓
- E_4 is *time-delayed* and stored on the *Future Events List* ✓

At t = 20: ✓

- E_5 is created and *active* (can't moved to resource) ✓
- E_5 is *condition-delayed* and stored on the *Delay List* ✓

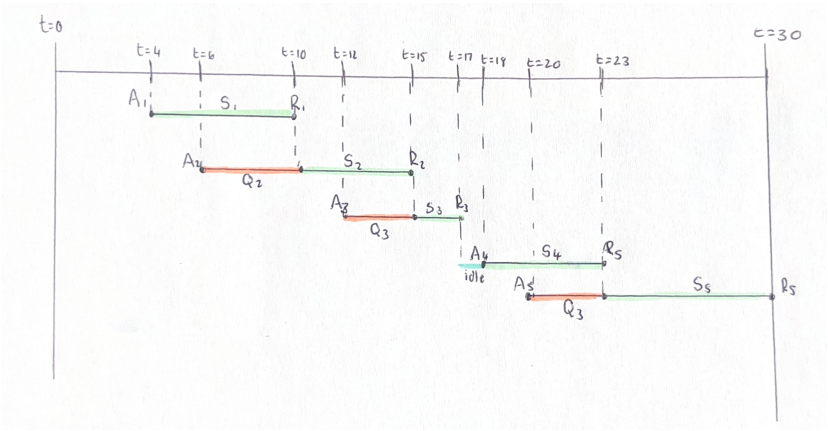
At t = 23: ✓

- E_4 is *ready* and stored on the *Current Events List* ✓
- E_4 is *active* and disposed ✓
- E_5 is *active* (moved to resource) ✓
- E_5 is *time-delayed* and stored on the *Future Events List* ✓
- E_5 is *ready* and stored on the *Current Events List* ✓

At t = 30: ✓

- E_5 is *ready* and stored on the *Current Events List* ✓
- E_5 is *active* and disposed ✓

All events realised



Question 4 [23]

During the summer time, Christine struggles to manage all the orders on her own. As a result, she asked her friend, Masindi, to help her. On a Saturday, they are particularly busy and need to work in parallel. Since Masindi only helps out, she does not know how to make milkshakes, and therefore, only Christine can complete milkshake orders. Assume Masindi takes the first order.

The arrival times and orders of the first six customers have been recorded in the table. Customer 1 enjoyed their ice cream so much that they came back to place the same order, after 8 minutes since they received their first order. Use this information to answer the following questions

(a) What is the total duration of the process, and at what time do Christine and Masindi finish (*i.e.* until the last order is completed)

(b) What is the total queue time of all customers?

(c) What is the queue time of customer 4?

(d) Was Christine or Masindi idle for longer, and how long were they idle?

(e) Which customers does Masindi serve?

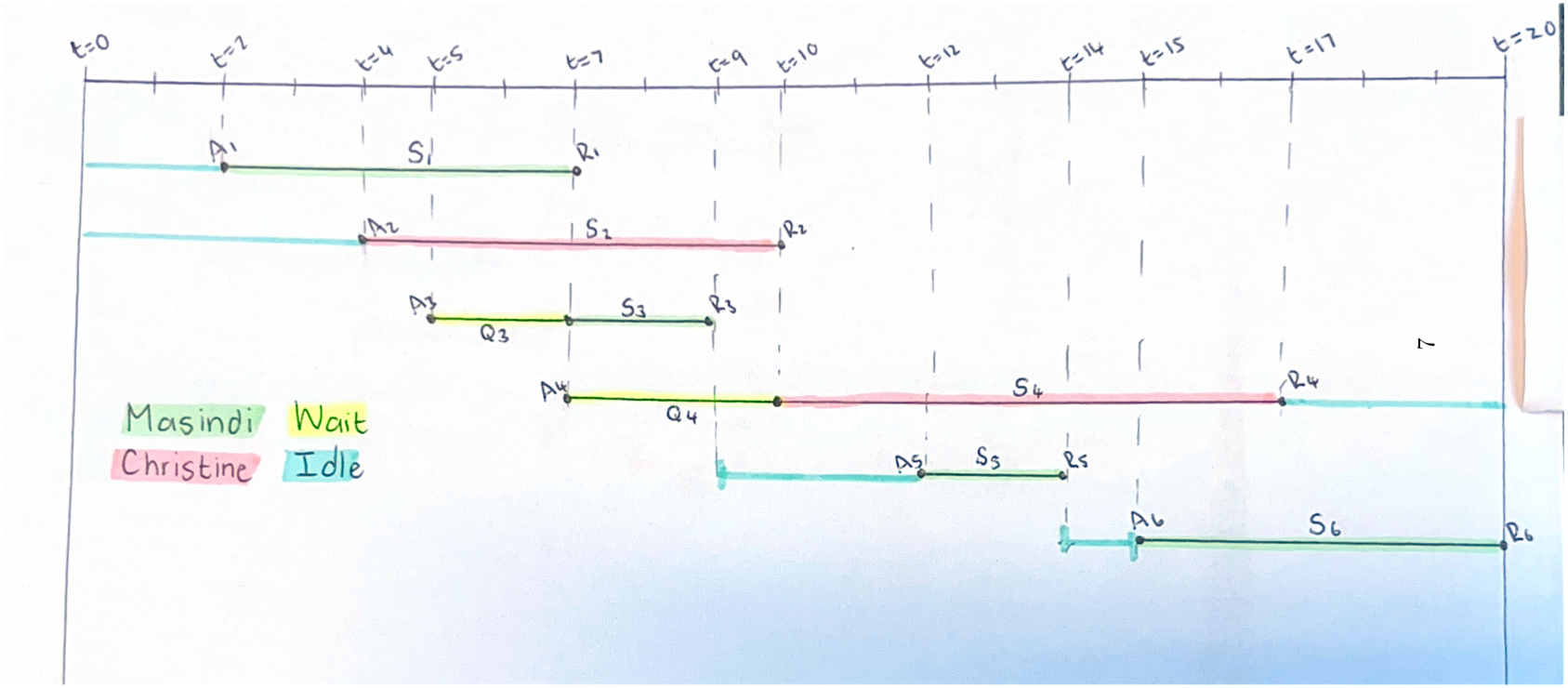
(f) List five system state variables of the system described.

(g) Explain the simulation world view of the ice cream shop and mention the entities that compete for resources under specific conditions, leading to events that change the system states as described in (e).

Customer number:	1	2	3	4	5
Arrival time:	2	4	5	7	12
Order Type:	TS	W	SS	M	SS

Hint: Construct a table using the format given, and systematically calculate the times using the data given.

Customer number	Arrival time	Queue time starts	Queue time ends	Queue duration	Service time starts	Service duration	Service ends


t=0
t=2
t=4
t=5
t=7
t=9
t=10
t=12
t=14
t=15
t=17
t=20
A1
S1
R1
A2
S2
R2
A3
Q3
S3
R3
A4
Q4
S4
R4
A5
S5
R5
A6
S6
R6
Masindi
Wait
Christine
Idle

Customer number	Arrival time	Queue time starts	Queue time ends	Queue duration	Service time starts	Service duration	Serivce ends
1	2	2	2	0	2	5	7
2	4	4	4	0	4	6	10
3	5	5	7	2	7	2	9
4	7	7	10	3	10	7	17
5	12	12	12	0	12	2	14
1	15	15	15	0	15	5	20
				5			**20 min**

The total queue duration and total preparation duration times receive full marks or no marks.

(a) Total duration is 20 min ✓
Christine ends at $t = 17$ ✓
Masindi ends at $t = 20$✓

(b) 5 min ✓✓✓

(c) 3 mim ✓✓

(d) Masindi was idle for 6 min ✓
Christine was idle for 7 min ✓
Therefore, Christine was idle for longer ✓

(e) Customers 1, 3, and 5 ✓

(f) Average time customer spends in system ✓
Average queue time of customer ✓
Average queue length ✓
Resource utilisation ✓
Number of customers served ✓

(g) In the simulation view of the Ice cream shop scenario, customers are entities.✓
Christine and Masindi serve as resources available to complete orders.✓
Customers compete ✓for the limited number of servers, with each customer order requiring a certain amount of time.
A critical condition in the simulation is the availability of servers; if both servers are occupied, customers must wait ✓until a server becomes available.
Additionally, specific requirements, ✓such as milkshake orders, can only be fulfilled by Christine specifically, introducing additional constraints on the assignment of orders to servers.

Events in the simulation are customer arrivals.✓Customer arrivals initiate orders, while an order being served allows the next customer in the queue to start their order if a server is available. These interactions among entities, along with the influence of various conditions, drive the dynamics of the ice cream shop operations during the simulation period and change the system state.

Question 5 [4]

Watch the video on STEMLearn, describing the modelling of a drive-through fast-food outlet. We introduce you to Tecnomatix Plant Simulation so that you get a feel for the practical work and modelling terminology. Let's call this MODEL 0. Use the video on STEMLearn and build the model in Tecnomatix Plant Simulation. Refer to Model 0 when answering the following question – you will not understand the theory (for now) explained from time 29:00 and on, but try the question.

What is the best number of cooks to deploy? Motivate your answer.

The best number of cooks to deploy is 3.✓If more are deployed ✓, we reach the point of diminishing return, *i.e.*, we add more cooks, but they do not increase the throughput significantly, yet cost more.✓✓

Total: Cross-check: 71
