



MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 420: SIMULATION MODELING

DATE:

TIME:

INSTRUCTIONS

- This paper contains FIVE questions
- Question ONE is **compulsory** and carries 30 Marks.
- Questions TWO – FIVE carries 20 Marks each.
- Answer QUESTION One and any other two questions.

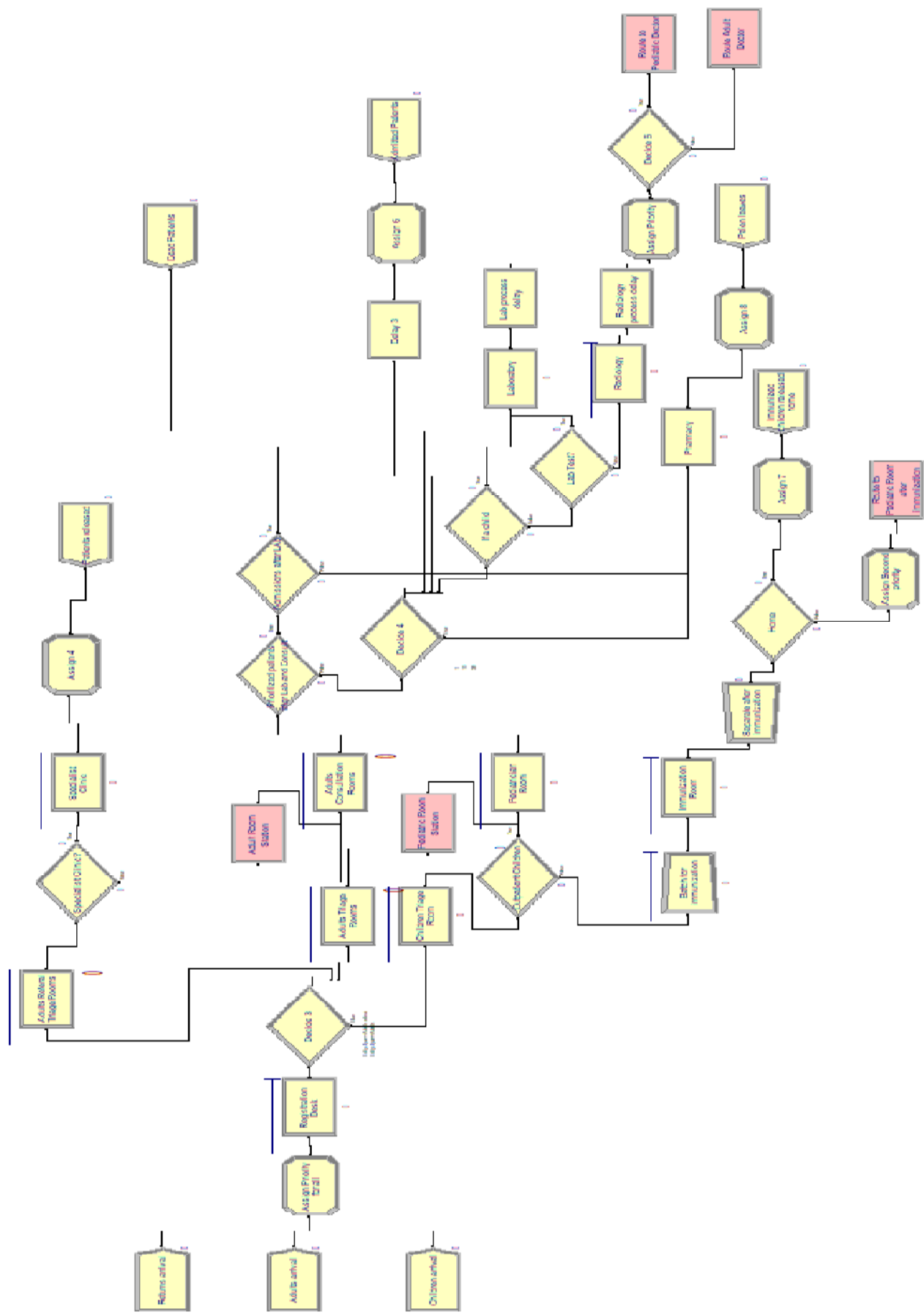
QUESTION ONE (COMPULSORY) (30 MARKS)

- a) (i) Define what is a discrete event simulation and state its characteristics. (3 marks)
- (ii) List any four components of a discrete event simulation Components of discrete event simulation (4 marks)
- b) Differentiate model verification and model validation (2 marks)
- c) Differentiate the functions of the Route and Station Arena modules. (2 marks)
- d) Outline four disadvantages of modelling and simulation. (4 marks)
- e) Outline the functions of the following modules as used in Arena simulation. (5 marks)

- f) The EXPOTTY hospital operates for 16 hours daily, where the outpatient department remains open from 8 am to 4 pm. The hospital deals with three categories of patients. The first category of patients are children, who arrive at the hospital following the schedule below. Among the children arriving, 75% of them are destined for outpatient services and 25% for immunization services. The immunization entails a vaccine that requires 3(three) patients to allow the execution. One vaccine is used on three patients incurring an average of 20 minutes. After the vaccination, there is a 10% probability that the child requires to be examined by the pediatrician. These children receive the second priority following ones that have test results.

The second category of patients are adults that are coming for outpatient services, and the third category is referral patients (adults returning for further treatment or check-up as a follow-up appointment), all of whose arrival rate is also based on the schedules below. 65% of the adult referrals' patients have appointments with the specialist clinic, while the rest are routed to the adult doctor consultation. The specialist clinic procedure commences with a triage incurring 15 minutes while the examination is made incurring 45 minutes per patient. All the patients examined by the specialist clinic are discharged to go home. The last category retains the patients admitted in the hospital in-patient facilities. A bed is available for admission every 1 hour and the admissible patients are held until the beds are available. After the consultation of the patients by the relevant doctors, 1% die, 10% are admitted to the hospital ward, 39% are subject to lab tests and 50% of the patients collect medicine at the pharmacy. A patient waits at the pharmacy for 15 minutes.

Of the patients requiring a lab test, 30% need radiology and the rest lab tests (blood etc.) which sampling takes 20 minutes. The hospital lacks X-ray facilities for children. Therefore, all children designated for the lab, undergo lab tests. The radiology is manned by a radiologist and Sample Data collected while evaluating the time patients spend in the radiology in minutes is as below. The processing of the results delay is equivalent to the lab result delay. After the lab tests, a delay of 45 minutes for the results to reach the doctors and the patients are prioritized to be seen by the doctor. After the second consultation, 10% of the patients who pass through the lab are admitted, the rest are discharged and collect drugs from the pharmacist and exit. The preliminary model is shown below.



- i) Outline three techniques/methods you model the delay a patient incurs waiting for the admission bed? (3 marks)
- ii) The Hospital collected data of the time intervals concerning the admissions beds availability. They generated a uniform probability distribution of a minimum of 1 hour and a maximum of 2.5 hours. Explain how you would incorporate this delay to ensure the patient waits for a signal when the bed is available. Briefly explain how you would model the prioritization of the patients visiting the doctor after undergoing the lab tests. Sketch the modules you will introduce. (4 marks)
- iii) The Operations team decides to model the two lab tests, i.e., Urine and Stool tests. After a study of the data available, it is determined that 25% of the lab tests are urine specific. Explain and sketch how you will model this aspect. (3 marks)

SECTION B (ANSWER ANY TWO QUESTIONS IN THIS SECTION)

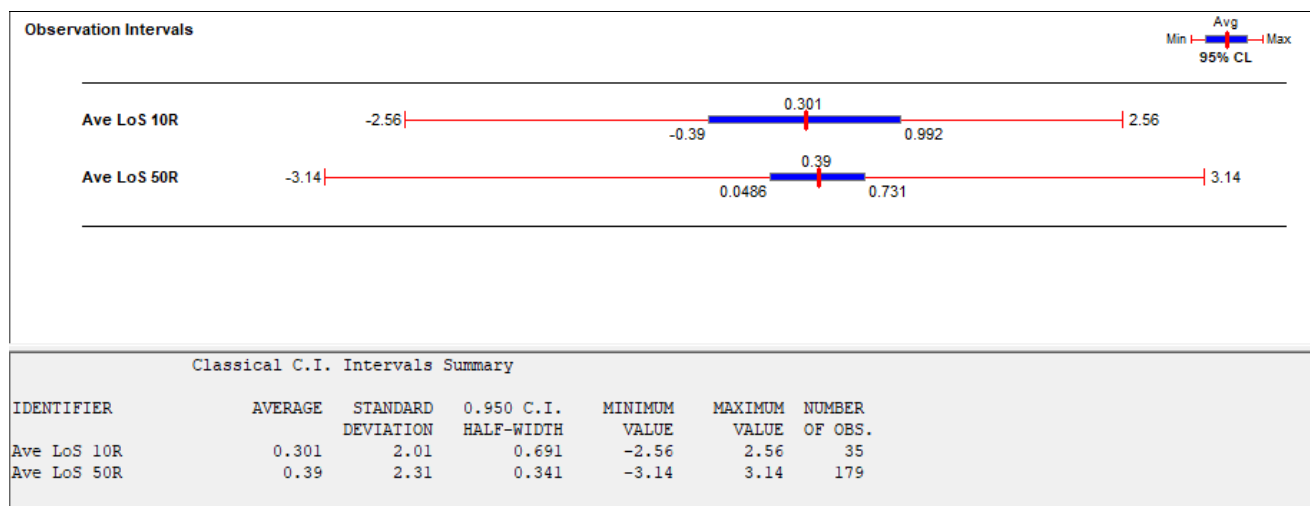
QUESTION TWO (20 MARKS)

A simulation was developed modelling the patient's arrival, treatment, and discharge from a hospital. The average time taken by a patient in the hospital is denoted as the Length of Stay (LoS). The simulation of the model using 1 replication generated the results below.

DISCRETE-CHANGE VARIABLES					
Identifier	Average	Half Width	Minimum	Maximum	Final Value
Adults.WIP	11.033	(Corr)	.00000	28.000	.00000
Adults referral.WIP	12.989	(Corr)	.00000	37.000	.00000
Children.WIP	12.644	(Corr)	.00000	33.000	2.0000
Specialist Doctor.NumberBusy	.81696	(Insuf)	.00000	1.0000	.00000
Specialist Doctor.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Specialist Doctor.Utilization	.81696	(Insuf)	.00000	1.0000	.00000
Radiologist.NumberBusy	.04464	(Insuf)	.00000	1.0000	.00000
Radiologist.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Radiologist.Utilization	.04464	(Insuf)	.00000	1.0000	.00000
Adult Doctor.NumberBusy	.68973	(Insuf)	.00000	2.0000	.00000
Adult Doctor.NumberScheduled	2.0000	(Insuf)	2.0000	2.0000	2.0000
Adult Doctor.Utilization	.34487	(Insuf)	.00000	1.0000	.00000
Adult Referral Triage Nurse.NumberBusy	.39732	(Insuf)	.00000	1.0000	.00000
Adult Referral Triage Nurse.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Adult Referral Triage Nurse.Utilization	.39732	(Insuf)	.00000	1.0000	.00000
Children Triage Nurse.NumberBusy	.14137	(Insuf)	.00000	1.0000	.00000
Children Triage Nurse.NumberScheduled	1.0000	(Insuf)	1.0000	1.0000	1.0000
Children Triage Nurse.Utilization	.14137	(Insuf)	.00000	1.0000	.00000
Registration Clerk1.NumberBusy	.55521	.27262	.00000	2.0000	.00000
Registration Clerk1.NumberScheduled	2.0000	(Insuf)	2.0000	2.0000	2.0000

- i) Why are the half widths for Radiologists.Utilization indicated "Insuf"? Explain why. "Insuf" (2 marks)

- ii) Why is the half-width for Adults.WIP indicated as “corr,” what does this mean and what is the reason for the occurrence. (2 marks)
- iii) Can we trust these results? Explain why and how the results could be improved. (3 marks)
- iv) Explain two ways in which this problem of half-width could be resolved. (4 marks)
- v) The model was simulated using 10 replications where the average length of stay was 7.658 ± 0.468 . Compute the number of replications that one would require to reduce the half-width to ± 0.25 minutes (3 marks)
- vi) The model was simulated using 10 and 50 replications, the performance measure LoS for the respective replications were compared generating the following results. Interpret the shown comparative results. (2 marks)

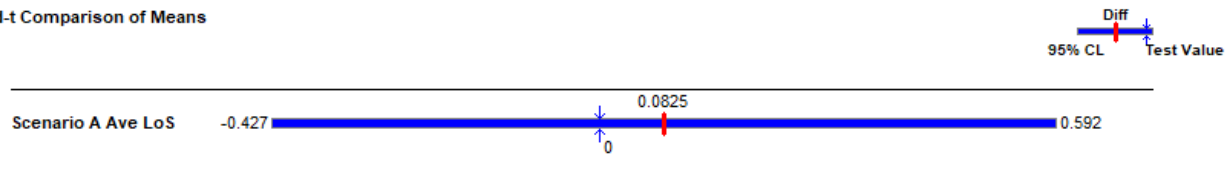


- g) Designing the model is a significant step in the modelling process. Outline the various tasks undertaken to design a model. (4 marks)

QUESTION THREE (20 MARKS)

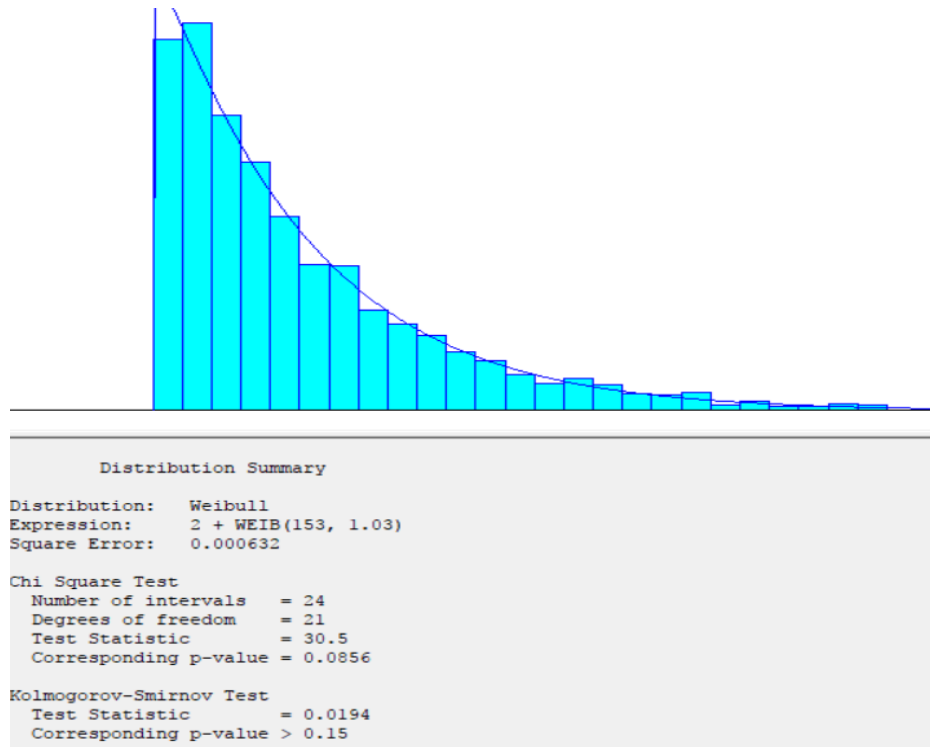
- a) Based on the current scenario (BASE) of the hospital simulation model, the operations team addressed some shortcomings and plan to import new vaccines that require 4 children per open dose. This change will extend the immunization time from 20 to 25 mins per dose opened. The facility layout has been re-designed, and the routing time significantly reduced from 15 to 5 minutes on average. New lab equipment is proposed to be installed that will reduce the radiology test processing and lab testing processes from 45 to 30 and 45 to 35 mins, respectively. The simulation was adjusted to have a new scenario A both using 50 replications. The results were analyzed using the output analyzer as below.

Paired-t Comparison of Means



Paired-T Means Comparison :						
IDENTIFIER	ESTD. MEAN DIFFERENCE	STANDARD DEVIATION	0.950 C.I. HALF-WIDTH	MINIMUM VALUE	MAXIMUM VALUE	NUMBER OF OBS
cenario A Ave LoS	0.0825	3.43	0.509	-3.13	3.14	177
				-3.14	3.14	177
FAIL TO REJECT H0 => MEANS ARE EQUAL AT 0.05 LEVEL						

- i) Explain what is being done here without interpreting the results (4 marks)
 - ii) Interpret the results (2 marks)
- b) Differentiate between a terminating and a steady-state simulation? Explain (2 marks)
- c) Describe the following two utilizations reported for each resource in modelling.(4 marks)
- d) In a simulation model, cycle times were measured and collected then fitted to a distribution using the input analyzer. The distribution shown was found to be the best fit.



- i) What is the function of the input analyzer in Simulation modelling? (2 marks)
- ii) Interpret the above results. (3 marks)
- iii) What does the shape and scale factors of the distribution imply in this specific expression?

$\gamma + \text{WEIB}(\eta + \beta)$ (3 marks)

QUESTION FOUR. (20 MARKS)

- a) Differentiate the functions of the Route and Station Arena modules. (2 marks)
- b) State and explain the three types of output statistics that can be contained in a report. (3 marks)
- c) What is System Dynamics modelling? (2 marks)
- d) Discuss four key assumptions predicated by System Dynamics modelling. (4 marks)
- e) Outline at least five techniques that can be utilized for model verification. (5 marks)

- f) In the previous question, the maintenance engineer sought to compare different scenarios using the Process analyzer. The exercise involved varying the vaccine type where a new

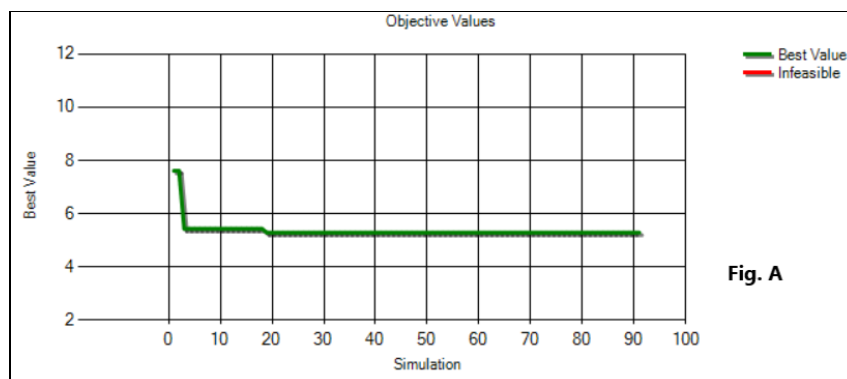
vaccine is proposed which would require 4 patients for one opened dose, but the process will take 25 minutes. Secondly, a new layout is proposed to reduce the routing time to 7 or 10 or 12 minutes.

	Scenario Properties				Controls			Response
	S	Name	Program File	Reps	VaccineBatch	ImmunizationTime	RouteTime	Ave LoS
1		Scenario 1	8 : Hospital M	50	3	10	7	5.154
2		Scenario 2	8 : Hospital M	50	3	10	15	7.557
3		Scenario 3	8 : Hospital M	50	3	10	10	6.087
4		Scenario 4	8 : Hospital M	50	3	10	15	7.557
5		Scenario 5	8 : Hospital M	50	4	25	12	6.783
6		Scenario 6	8 : Hospital M	50	4	25	15	7.671
7		Scenario 7	8 : Hospital M	50	4	25	7	5.109
8		Scenario 8	8 : Hospital M	50	4	25	15	7.671

Based on the above results, explain the process undertaken and interpret the results shown. (4 marks)

QUESTION FIVE (20 MARKS)

- Explain the two utilizations reported for each Resource in modelling. (2 marks)
- Distinguish the terms modelling and Simulation (4 marks)
- Steps in model validation (5 marks)
- Outline the steps you would take in building a Systems Dynamic simulation model. (3 marks)
- A hospital seeking to reduce the average Length of Stay (LoS) for patients in its Emergency Department has sought consultancy. The consultant considered immunization time, Vaccine batch size, Route time, Lab testing and Radiology process delay as the critical variables affecting the LoS. They generated the below report including Fig A and Table B using OptQuest.



Simulation	Objective Value	Status	Immunization Time	Lab testing process delay	Radiology process delay	Route time	Vaccine Batch
19	5.282436	Feasible	13	36	37	10	3
52	5.297184	Feasible	22	49	44	10	4
41	5.335458	Feasible	14	37	37	10	3
43	5.341097	Feasible	11	35	36	10	2
37	5.35293	Feasible	15	38	37	10	3
81	5.414095	Feasible	15	38	44	10	4
3	5.43408	Feasible	10	35	35	10	2
31	5.437171	Feasible	13	36	38	10	3
46	5.458725	Feasible	13	35	37	10	3
86	5.47013	Feasible	14	38	44	10	4
39	5.470349	Feasible	13	38	37	10	3
23	5.475808	Feasible	21	42	40	10	4
48	5.479514	Feasible	13	36	36	10	3
62	5.520887	Feasible	13	36	44	10	4

Table B

- (i) Describe the Figure A and Table B (3 marks)
- (ii) What were the steps the consultant took to generate this report? (3 marks)