NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

DEPARTMENT OF Civil, Mining and Process Engineering

QUALIFICATION : Bachelors of Engineering in Mining Engineering	
QUALIFICATION CODE: 08BMEG	LEVEL: 7
COURSE CODE: ORC 711S	COURSE NAME: OPERATIONS RESEARCH
SESSION: JUNE 2023	PAPER: THEORY
DURATION: 3 HOURS	MARKS: 100

SECOND OPPORTUNITY QUESTION PAPER	
EXAMINER(S)	Dr Lawrence Madziwa
MODERATOR:	Prof Mallikarjun Rao Pillalamarry

INSTRUCTIONS

1. Answer all questions.
2. Read all the questions carefully before answering.
3. Marks for each questions are indicated at the end of each question.
4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.

THIS QUESTION PAPER CONSISTS OF 7 PAGES (Including this front page)

1. The mine stores manager is concerned about the long queues of lorries waiting to deliver goods on the mine. Occasionally there are as many as 100 deliveries a week, and in some cases the lorry drivers have had to wait several hours before they can unload at one unloading bay. This has resulted in congestion at the warehouse and complaints from the lorry drivers. You have been asked to make recommendations for improving the situation and have collected delivery data as in the table below. [20]

Number of Lorries arriving per hour	**Number of hours**	**Unloading time (minutes)**	**Number of lorries**
0	7	0-20	38
1	10	20-40	26
2	8	40-60	10
3	8	60-80	3
4	5	80-100	2
5	2	100-120	1

Deliveries are allowed between 9am and 5pm, Monday to Friday. Any lorry that arrives after 5pm can join the queue awaiting unloading. Unloading crew can work overtime.

a. Explain the conditions which must be satisfied in order to apply the basic single server queuing model (M/M/1). [4]

b. Assuming that an M/M/1 model is appropriate, convert the data into suitable information for queuing. [4]

Number of Lorries arriving per hour (x)	**Number of hours (f)**	**xf**	**Unloading time (minutes)**	**y**	**Number of lorries f**	**yf**
0	7	0	0-20	10	38	380
1	10	10	20-40	30	26	780
2	8	16	40-60	50	10	500
3	8	24	60-80	70	3	210
4	5	20	80-100	90	2	180
5	2	10	100-120	110	1	110
	40	80			80	2160

c. Estimate how many lorries, on average are waiting to be unloaded and also the time that a lorry would expect to spend at the warehouse. [4]

d. The unloading bay is currently staffed by two employees who are each paid $100 for a 40 hour week, with any overtime being paid at a 4/3 rate. A suggestion has been made that a third person should be employed in the unloading ay which, it has been estimated, would result in saving of seven minutes in the average time to unload a lorry. This, it has been claimed, would not only reduce the lorry waiting time but would also produce a saving in cost to the mine. Analyse this suggestion and make a recommendation. [8]

2. A construction company has just made the winning bid of $5.4 million to construct a new plant for a major manufacturer. The manufacturer needs the plant to go into operation within a year. Therefore, the contract includes the following provisions:
• A penalty of $300,000 if the company has not completed construction by the deadline 47 weeks from start.

• To provide additional incentive for speedy construction, a bonus of $150,000 will be paid to the company if the plant is completed within 40 weeks.

a. The following details pertaining to the project. Construct the network diagram and compute the project completion time. [10]

Table 1: Activities description and predecessors

Activity	Activity Description	Immediate Predecessors
A	Excavate	—
B	Lay the foundation	A
C	Put up the rough wall	B
D	Put up the roof	C
E	Install the exterior plumbing	C
F	Install the interior plumbing	E
G	Put up the exterior siding	D
H	Do the exterior painting	E, G
I	Do the electrical work	C
J	Put up the wallboard	F, I
K	Install the flooring	J
L	Do the interior painting	J
M	Install the exterior fixtures	H
N	Install the interior fixtures	K, L

Table 2: Activity times

Activity	Optimistic Estimate *o*	Most Likely Estimate *m*	Pessimistic Estimate *p*
A	1	2	3
B	2	$3\frac{1}{2}$	8
C	6	9	18
D	4	$5\frac{1}{2}$	10
E	1	$4\frac{1}{2}$	5
F	4	4	10
G	5	$6\frac{1}{2}$	11
H	5	8	17
I	3	$7\frac{1}{2}$	9
J	3	9	9
K	4	4	4
L	1	$5\frac{1}{2}$	7
M	1	2	3
N	5	$5\frac{1}{2}$	9

Table 3:Time-Cost trade off data for the project activities

	Time		Cost	
Activity	Normal	Crash	Normal	Crash
A	2 weeks	1 week	$180,000	$ 280,000
B	4 weeks	2 weeks	$320,000	$ 420,000
C	10 weeks	7 weeks	$620,000	$ 860,000
D	6 weeks	4 weeks	$260,000	$ 340,000
E	4 weeks	3 weeks	$410,000	$ 570,000
F	5 weeks	3 weeks	$180,000	$ 260,000
G	7 weeks	4 weeks	$900,000	$1,020,000
H	9 weeks	6 weeks	$200,000	$ 380,000
I	7 weeks	5 weeks	$210,000	$ 270,000
J	8 weeks	6 weeks	$430,000	$ 490,000
K	4 weeks	3 weeks	$160,000	$ 200,000
L	5 weeks	3 weeks	$250,000	$ 350,000
M	2 weeks	1 week	$100,000	$ 200,000
N	6 weeks	3 weeks	$330,000	$ 510,000

b. What is the probability of completing the project in 40 days? [5]

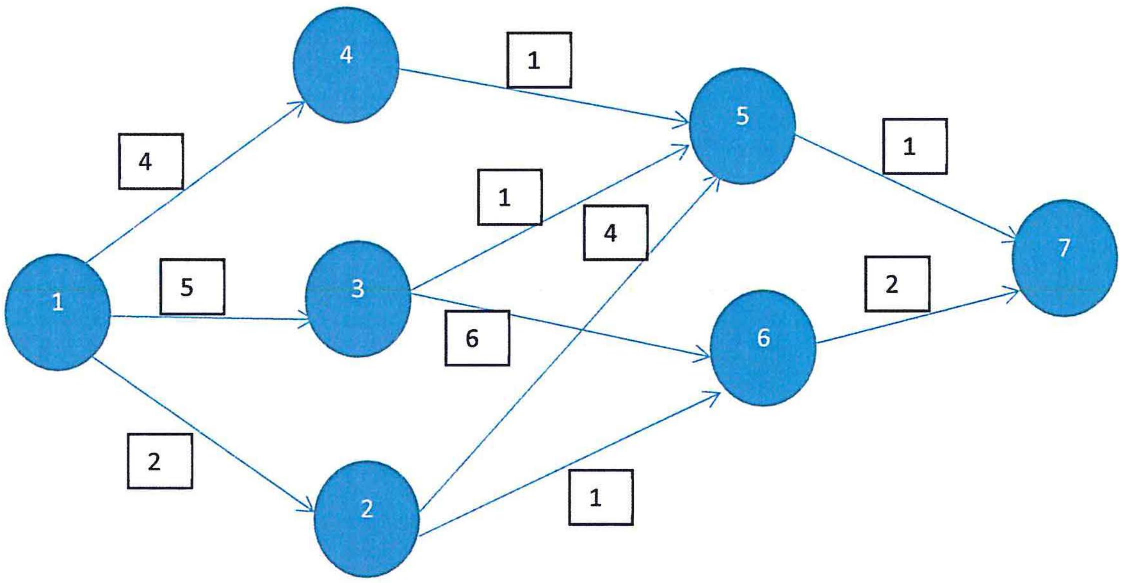
c. What is the probability of meeting the deadline of 47 days? [4]

d. Evaluate the option of working towards getting the bonus. What is your comment on this option? [5]

3. You are responsible for transporting four items on a limited space of 10 tons from Windhoek to Swakopmund. There are four different items that your company can transport between Windhoek and Swakopmund. Each item has a weight in tons, a net profit in thousands of dollars, and a total number of items that is available for shipping as shown in Table below. Use dynamic programming to determine how many of each item should be shipped to maximize profits. [20]

Item	Weight	Profit / Unit ($)	Number Available
1	1	3	6
2	4	9	1
3	3	8	2
4	2	5	2

4. You are responsible for transporting explosives through a network of towns and you have to minimize the travel distance between 1 and 7. Use an appropriate method to determine the minimal distance you need to travel. [10]
   a. Give examples of how networks are applied to solve problems in mining? [6]



5. One representation of economic order quantity (EOQ) inventory model is;

   $Q = \sqrt[2]{2CA/c}$

   Where Q is the economic order quantity

   C is the cost of placing an order

   A is the annual demand in units

   c is the cost of holding one unit in stock for one year

Data relevant to component K used at a mine in 22 different sections include;

- Purchase price: $15 per 100,
- Annual usage: 100,000 units ,
- Cost of buying office: fixed 15,575 per annum and variable is $12 per order,
- Rent of warehouse: $3,000 per annum,
- Heating: $700 per annum
- Interest: 25% per annum, insurance 0.05% per annum based on total purchases, deterioration has been expressed as 1% per annum of all items purchased.

Questions:

a. Calculate the EOQ for component K. [5]
b. Calculate the percentage change in total annual variable costs relating to component K if the annual usage was: (i) 125,000 units, and (ii) 75,000 units. [8]
c. Use the answers for question b above to comment on the sensitivity of the variable costs to changes in the annual usage. [4]
d. Describe two methods to help you modify your EOQ calculations if management decided that the expected total investment in stocks was 30% too high. [3]

(End of Exam)

QUEUING PERFORMANCE (m/m/s)

Average server utilization	p	$p = \dfrac{\lambda}{s\mu}$
Average number of customers in queue	L_q	$L_q = \dfrac{(\lambda/\mu)^s \lambda\mu}{(s-1)!\,(s\mu-\lambda)}$
Avg. number of customers in system	L	$L = L_q + \dfrac{\lambda}{\mu}$
Avg. time cust. spends waiting in queue	W_q	$W_q = \dfrac{L_q}{\lambda}$
Avg. time customer spends in system	W	$W = W_q + \dfrac{1}{\mu}$
Probability of zero customers	P_0	$P_0 = \dfrac{1}{[\sum_{k=0}^{s-1} \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k] + \frac{1}{s!}\left(\frac{\lambda}{\mu}\right)^s \frac{s\mu}{(s\mu-\lambda)}}$
Prob. there are n customers in system	P_n	$P_n = \dfrac{(\lambda/\mu)^n}{n!} P_0 \; for \; n \le s$ $P_n = \dfrac{(\lambda/\mu)^n}{s!\,s^{(n-s)}} P_0 \; for \; n > s$