NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF STATISTICS AND OPERATIONS RESEARCH

SORS6101: APPLICATIONS OF QUANTITATIVE ANALYSIS

MSc. OPERATIONS RESEARCH AND STATISTICS: PART II

NOVEMBER 2024 EXAMINATION

Time : 3 hours

Candidates should attempt **ANY FOUR** questions.

A1. The Bulawayo City Council is faced with the problem of high costs of supplying its residents with enough safe water daily to satisfy the citys average daily demand. The main contributing factor to this problem is the cost of pumping water from treatment plants situated at Sgodini and Nyamandlovu to the Bulawayo service reservoir from which water is then distributed to residents. The Bulawayo reservoir is currently being supplied by Nyamandlovu and Sgodini Pumping Stations. Sgodini Pumping Station has one pump while Nyamandlovu has 3 pumps: 2 Type-A pumps and 1 Type-B pump. Since pumping costs vary between day and night, with night time having less tariffs, the objective is to find how much capacity of each of the pumps available should utilized so as to satisfy average demand while minimising costs. The tariffs for the electricity per unite charge per kilo watt are given as: during the day 07 00 hrs in the morning to 00 00 hrs nidnight the charge is $50 and during the night 00 00 hrs midnight to 07 00 hrs in the morning the charge is $17.

Pump characteristics are given as: Sgodini treatment center has one pump which has a maximum output flow rate of 200m3 per hour. The corresponding power consumption will be 20 kilo Watt hour. Nyamadlovu treatment center which has 2 Type-A pumps and 1 Type-B pump which can be used in combinations shown in Table 1.

Pump Combination	Output Flow rate (m^3/h)	Power Consumption (Kwh)
A	300	80
B	100	30
A+B	390	110
A+A	550	160
A+A+B	622	190

Table 1: Pump combinations and their consumption rates

Formulate a linear programming model that would solve this problem in terms of the number of hours each pump is on that would minimise the total costs. Explain clearly all the variables used and how they can be obtained. [25]

A2. Wagner Fabricating Company is reviewing the economy feasibility of manufacturing a part that it currently purchases from a supplier. Forecasted annual demand for the part is 3200 units. Wagner operates 250 days per year. Wagner's financial analysts have established a cost of capital of 14% for the use of funds for investments within the company. In addition, over the past year $600 000 has been the average investment of the companys inventory. Account information shows that a total $24 000 was spent on taxes and insurance related to the companys inventory. In addition, it has been estimated that $9 000 was lost due to inventory shrinkage, which included damaged goods as well as pilferage. A remaining $15 000 was spent on warehouse overhead, including utility expenses for heating and lighting. An analysis of the purchasing operation shows that approximately 2 hours are required to process and coordinate an order for the part regardless of the quantity ordered. Purchasing salaries average $28 per hour, including employee benefits. In addition, a detailed analysis of 125 orders showed that $2 375 was spent on telephone, paper, and postage directly related to theordering process.

A one week lead time is required to obtain the part from the supplier. An analysis of demand during the lead time shows that lead time demand is approximately normally distributed with a mean of 64 units and a standard deviation of 10 units. Service level guidelines indicate that one stock out per year is acceptable. Currently the company has a contract to purchase the part from a supplier at the cost of $18 per unit. However, over the past few months, the companys production capacity has been expanded. As a result, excess capacity is now in certain production departments and the company is considering the alternative of manufacturing the parts itself. Forecasted utilization of equipment shows that production capacity will be available for the part being considered. The production capacity is available at the rate of 1000 units per month, with up to five months of production time available. It is felt that with a 2 week lead time,

schedules can be arranged so that the part can be produced whenever needed. The demand during the 2 week lead time is approximately normally distributed, with the mean of 128 units and a standard deviation of 20 units. Production costs are expected to be $17 per part.A concern of management is that set-up costs will be significant. The total cost of labour and lost production time is estimated to be $50 per hour, and it will take the whole 8 hour shift to set up the equipment for producing the part.

Managerial Report

Develop a report for management of Wagner Fabricating that will address the question of whether the company should continue to purchase the part from the supplier or should begin to produce the part itself. Include the following factors in your report:

1. An analysis of the holding costs, including the appropriate annual holding cost rate.
2. An analysis of ordering costs, including the appropriate cost per order from the supplier.
3. An analysis of setup costs for the production operation.
4. A development of the inventory policy was for the following two alternatives:

  (a) Ordering a fixed quantity, Q, from the supplier.

  (b) Manufacturing a fixed quantity, Q, from in plant production. Include the following in the policies of parts 4(a) and 4(b) above.

   (i) The optimal quantity Q.
   (ii) The number of order or production runs per year.
   (iii) The cycle time.
   (iv) The annual cost of the units purchased or manufactured.
   (v) The annual cost of the purchase policy and the total cost of the production policy.

5. Make your commendation as to whether the company should purchase or manufacture the part. What is the saving associated with your recommendation as compared with the other alternative? [25]

A3. NarePharm, a pharmaceutical manufacturing company, entered the pharmaceutical market 12 years ago with the introduction of six new drugs. Five of the six drugs were simply permutations of existing drugs and therefore did not sell very heavily. The sixth drug, however, addresses hypertension and was a huge success. Since NarePharm had a patent on the hypertension drug, it experienced no competition, and profits from the hypertension drug alone kept NarePharm in business.

During the past 12 years NarePharm continued a moderate amount of research and development but it never stumbled upon a drug as successful as the hypertension drug. One reason is that the company never had the motivation to invest heavily in innovative research and development. The company was riding the profit wave generated by its hypertension drug and did not feel the need to commit significant resources to finding new drug breakthroughs.

Now NarePharm is beginning to fear the pressure of competition. The patent for the hypertension drug expires in 5 years, and NarePharm knows that once the patent expires, generic drug manufacturing companies will swarm into the market like vultures. Historical trends show that generic drugs decreased sales of branded drugs by 75 percent.

NarePharm is therefore looking to invest significant amounts of money in research and development this year to begin the search for a new breakthrough drug that will offer the company the same success as the hypertension drug. NarePharm believes that if the company begins extensive research and development now, the probability of finding a successful drug after the expiration of the hypertension patent will be high. As head of research and development at NarePharm, you are responsible for choosing potential projects and assigning project directors to lead each of the projects. After researching the needs of the market, analysing the shortcomings of current drugs, and interviewing numerous scientists concerning the promising areas of medical research, you have that your department will pursue five separate projects, which are listed below:

Project Up: develop an antidepressant that does not cause serious mood swings.

Project Stable: Develop a drug that addresses manic-depression.

Project Choice: Develop a less intrusive birth control method for women.

Project Hope: Develop a vaccine to prevent HIV infection.

Project Release: Develop a more effective drug to lower blood pressure.

For each of the five projects, you are only able to specify the medical ailment that the research should address, since you do not know what compounds will exist and beeffective without research.

You have five senior scientists to lead the five projects. You know that scientists are very temperamental people and will work well only if they are challenged and motivated by the project. To ensure that the senior scientists are assigned to projects they find motivating, you have established a bidding system for the projects. You have given each of the five scientists 1000 bid points. They assign bids to each project, giving a higher number of bid points to projects they most prefer to lead. The following table provides the bids from the five individual senior scientists for the five individual projects:listed below:

Project Up: Develop an antidepressant that does not cause serious mood swings.

Project Stable: Develop a drug that addresses manic-depression.

Project Choice: Develop a less intrusive birth control method for women.

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Project	Dr. Ndou	Dr. Madziwa	Dr. Nare	Dr. Mguni	Dr. Chenjera
Project Up	100	0	100	267	100
Project Stable	400	200	100	153	33
Project Choice	200	800	100	99	33
Project Hope	200	0	100	451	34
Project Release	100	0	600	30	800

Table 2: Individual Bids for the Individual Projects

(a) Given the bids, you need to assign one senior scientist to each of the five projects to maximize the preferences of the scientists. What are the assignments given that Dr Nare must not be assigned to Project Release and also that Dr Ndava must not be assigned to Project Choice? [8]

(b) Dr. Chenjera is being courted by the Harvard Medical School to accept a teaching position. You are fighting desperately to keep her at NarePharm, but the prestige of Harvard may lure her away. If this were to happen the company would give up the project with the least enthusiasm. Which project should not be done? [10]

(c) You do not want to sacrifice any project, since researching only four projects decreases the probability of finding a breakthrough. You decide that either Dr. Madziwa or Dr. Mguni could lead two projects. Under these new conditions with just four senior scientists, which scientists will lead which projects to maximize preferences? [7]

A4. With thirty nine weeks to go for the students' SRC elections, an incumbent SRC member has decided not to run for re-election. Tom, a supporter of the incumbent and activist in the Faculty of Commerce for almost three semesters has been considering running for membership himself. Tom and his close friends met and decided on a set of campaign activities necessary to run a competitive campaign. Based on the years of their experience, they were able to determine a set of time and cost estimates for each of these activities. The budget for this campaign is shown in the following table:

Activity	Predecessors	Expected Time (Weeks)	Expected Cost($)	Forecasted Weekly Cost($)
A:	-	4	$2000	$500
B:	-	6	$3000	$500
C:	A	4	$4500	$1125
D:	A,B	6	$2500	$417
E:	D	2	$500	$250
F:	E	13	$13000	$1000
G:	E	1	$1500	$1500
H:	C,G	20	$6000	$300
I:	F	9	$7000	$778

Table 3: Budget for Campaign Activities

where activities A,B,C,D,E,F,G,H and I are Hiring campaign friends, Preparation of position papers, Recruiting volunteers, Raising funds, Filing candidacy papers, Preparing campaign material, Locating rooms of friends, Running personal campaign and Running magazine campaign, respectively.

Stanford, a confidante of Tom, ran an analysis and was able to determine that with a $4000 budget, the campaign would take 36 weeks. Given these estimates Tom took three weeks to make a decision and, to everyone's surprise, chose to enter the race. Following Tom's directions, 20 weeks into the campaign, Stanford prepared an assessment of progress to date and the financial outlook for the campaign, are shown in the following table below:

Work Package	Expenditures($)	Status	Forecasted weekly cost($)
A:	$2600	Finished	$500
B:	$5000	Finished	$500
C:	$3000	Finished	$1125
D:	$5000	Finished	$417
E:	$700	Finished	$250
F:	$5600	40% complete	$1000
G:	$700	Finished	$1500
H:	$2000	25% complete	$300
I:	$00	0% complete	$778

Table 4: Financial Outlook for campaign

Tom would want to know if the campaign is on target for completion in 36 weeks and if is progressing within budget. If it is not, he wants friends' recommendations for corrective action. What recommendations would you give in such a scenario? Advise. [25]

A5. Family Motor Alliance, a large automobile manufacturing company organises the vehicles it manufactures into three families: a family of trucks, a family of small cars and a family midsized and luxury cars. One plant outside Detroit, Michigan, assembles two models from the family of midsized and of luxury cars. The first model, The Family Thrillseeker, is a four-door sedan with vinyl seats, plastic interior, standard features, and excellent gas mileage. It is marketed as a smart buy for middle-class families with tight budgets, and each Family Thrillseeker sold generates a modest profit of $3600 for the company. The second model, the Classy Cruiser, is a two-door luxury sedan with leather seats, wooden interior, custom features, and navigational capabilities. It is marketed as a privilege of affluence for upper-middle-class families, and each Classy Sedan sold generates a healthy profit of $5400 for the company.

Rachel Rosencrantz, the manager of the assembly plant, is currently deciding the production schedule for next month. Specifically, she must decide how many Family Thrillseekers and how many Classy Cruisers to assemble in the plant to maximize profit for the company. She knows the plant possesses a capacity of 48 000 labour-hours during the month. She also knows that it takes 6 labour-hours to assemble one Family Thrillseeker and 10.5 labour-hours to assemble one Classy Cruiser.

Because the plant is simply an assembly plant, the parts required to assemble the two models are not produced at the plant. They are instead shipped from other plants around the Michigan area to the assembly plant. For example, tires, steering wheels, windows, seats, and doors all arrive from various supplier plants. For the next month, Rachel knows that she will be able to obtain only 20 000 doors (10 000 left-hand doors and 10 000 right-hand doors) from the door supplier. A recent labour strike forced the shutdown of that particular supplier plant for several days, and that will not be able

to meet its production schedule for the next month. Both the Family Thrillseeker and the Classy Cruiser use the same door part.

In addition, a recent company forecast of the monthly demands for different automobile models suggests that demand for the Classy Cruiser is limited to 3 500 cars. There is no limit on the demand for the Family Thrillseeker within the capacity limits of the assembly plant.

(a) Formulate and solve a linear programming problem to determine the number of Family Thrillseekers and the number of Classy Cruisers that should be assembled. [7]

Before she makes final production decisions, Rachel plans to explore the following questions independently except where otherwise indicated.

(b) The marketing department knows it can pursue a targeted $500 000 advertising campaign that will raise the demand for the Classy Cruiser next month by 20 percent. Should the campaign be undertaken? [5]

(c) Rachel knows she can increase next month's plant capacity by using overtime labour. She can increase the plant's labour-hour capacity by 25 percent. With the new plant capacity, how many Family Thrillseekers and how many Classy Cruisers should be assembled? [5]

(d) Rachel explores the option of using both the targeted advertising campaign and the overtime labour-hours. How many Family Thrillseekers and how many Classy Cruisers should be assembled using the advertising campaign and overtime labour-hours if the profit from each Classy Cruiser sold continues to be 50 percent more than for each Family Thrillseeker sold? [5]

(e) Knowing that the advertising campaign costs $500 000 and the maximum usage of overtime labour-hours costs $1 600 000 beyond regular time rates, is the solution found in part (d) a wise decision compared to the solution found in part (a)? [3]

A6. E-Education is a new start-up that develops and markets MBA courses offered over the internet. The company is currently located in Bulawayo and employs 150 people. Due to strong growth, the company needs additional office space. The company has the option of leasing additional space at its current location in Bulawayo for the next two years, but after that will need to move to a new building. Another option the company is considering is moving the entire operation to Lupane town immediately. A third option is for the company to lease a new building in Bulawayo immediately. If the company chooses the first option and leases new space at its current location, it can at the end of two years either lease a new building in Bulawayo or move to Lupane town. The following are some additional facts about the alternatives and current situation:

(a) The company has a 75% chance of surviving the next two years.

(b) Leasing the new space for two years at the current location in Bulawayo will cost $750 000 per year.

(c) Moving the entire operation to Lupane town would cost $1million. Leasing space would run only $500 000 per year.

(d) Moving to a new building would cost $200 000, and leasing the new building's space would cost $650 000 per year.

(e) The company can cancel the lease at any time.

(f) The company will build its own building in 5 years, if it survives.

(g) Assume all other costs and revenues are the same no matter where the company is located.

What should E-Education do?   [25]