# NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY 

## FACULTY OF INDUSTRIAL TECHNOLOGY

# DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING 

Masters in Engineering: Manufacturing Systems and Operations Management
Design, Analysis and Control of Manufacturing Systems - TIE 6111

## $1^{\text {st }}$ SEMESTER EXAMINATIONS DECEMBER 2011

Time allowed: 3 hours and 30 minutes reading time
Instructions: Answer Total of Four (4), THREE (3) questions, from each Section A and Compulsory Section B which carry 40 marks.

## SECTION A

## QUESTION 1

a) Develop an assembly line to produce one chair every 20 minutes for the job described by the Table 1.1.

Table 1.1

| Element | Time | Immediate Predecessors |
| :--- | :--- | :--- |
| A | 11 | - |
| B | 8 | A |
| C | 9 | B |
| D | 5 | B |
| E | 8 | C |
| F | 12 | C, D |
| G | 10 | E |
| H | 3 | F |

b) Three different material -handling units are available for moving items of material. The cost of these lifts are $\$ 3000, \$ 2500$ and $\$ 3300$ respectively. These units must make six moves. Data on the operating cost $\mathrm{W}_{\mathrm{ij}}$ and the operating time, $\mathrm{h}_{\mathrm{ij}}$ are given in Table 1.2. Determine which type of equipment should be used.

Table 1.2: Operating Cost and Operating time for material handling equipment

| Move | $\mathrm{W}_{\mathrm{ij}}$ | $\mathrm{h}_{\mathrm{ij}}$ | $\mathrm{W}_{\mathrm{ij}}$ | $\mathrm{h}_{\mathrm{ij}}$ | $\mathrm{W}_{\mathrm{ij}}$ | $\mathrm{h}_{\mathrm{ij}}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 1 | 10 | 0.8 | 40 | 0.5 | 80 | 0.7 |
| 2 | 60 | 0.7 | 70 | 0.3 | 50 | 0.8 |
| 3 | 70 | 0.4 | M | - | 30 | 0.9 |
| 4 | 80 | 0.5 | 100 | 0.3 | 60 | 0.2 |
| 5 | 100 | 0.1 | 50 | 0.2 | 40 | 0.1 |
| 6 | 40 | 0.2 | M | - | M | - |

## QUESTION 2

a) A gantry crane serves as the material handling system in a five -cell manufacturing facility as shown in Figure 2.1. The new monthly production forecast has been made. The corresponding from-to material flow chart is given in the Table 2.1 and Table 2.2. How should the five cells be rearranged to minimise the total travel distance of the gantry crane. Assuming that the cost of relocating the cells are negligible.


Two-way gantry crane

Figure 2.1: Layout
Table 2.1: Distance Matrix

| Cell | A | B | C | D | E |
| :--- | :--- | :--- | :--- | :--- | :--- |
| A | - | 15 m | 33 m | 53 m | 71 m |
| B |  | - | 18 m | 38 m | 56 m |
| C |  |  | - | 20 m | 38 m |
| D |  |  |  | - | 18 m |
| E |  |  |  |  | - |

Table 2.2: Frequency Matrix

| Cell | A | B | C | D | E |
| :--- | :--- | :--- | :--- | :--- | :--- |
| A |  | 250 | 0 | 25 | 100 |
| B | 25 | - | 0 | 225 | 50 |
| C | 0 | 0 | - | 100 | 0 |
| D | 300 | 0 | 50 | - | 0 |
| E | 50 | 0 | 100 | 0 | - |

b) Three jobs are to be scheduled in a five machine flow shop. Job data is shown in Table 2.3.
i) What is the sequence of we are to minimised makespan based on Machine D?
ii) Find the lowerbound on makespan for machine B.
iii) Construct a gnatt chart for job processing sequence ( $1,2,3$ ).

Table 2.3 Job Processing Times

|  | Machine |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Job | A | B | C | D | E |
| 1 | 2.0 | 4.5 | 1.0 | 3.2 | 4.1 |
| 2 | 0.5 | 2.4 | 0.2 | 0.1 | 2.8 |
| 3 | 1.2 | 0.3 | 0.5 | 1.4 | 8.2 |

## QUESTION 3

a) Briefly discuss one main types of material handling systems?
b) Give two advantages and two disadvantages for that type of material handling systems as applied to a case company of your choice.
c) Explain briefly one type of tool allocation policy in flexible manufacturing system and how applicable to is to a Zimbabwe situation.
d) An assembly system uses packing, assembly and inspection stations. There are two Packers, one automatic assembler and one inspector. Each worker is available 8 hrs per day. Table 3.1 contains the set of jobs ready to be produced. To avoid leaving kits exposed, a job must be completed the same day it is started. Which kits should be made today?

Table 3.1

|  |  | Processing Time (standard hours) |  |  |
| :--- | :--- | :--- | :--- | :--- |
| Job | Duedate | Packing | Assembly | Inspection |
|  |  |  |  |  |
| 1 | 1 | 10.5 | 2.4 | 0.5 |
| 2 | 4 | 3.5 | 1 | 0.6 |
| 3 | 1 | 5.7 | 0.6 | 0.6 |
| 4 | 2 | 2.3 | 0.3 | 0.4 |
| 5 | 4 | 23.9 | 4.2 | 3.5 |
| 6 | 1 | 4.5 | 1.2 | 1.5 |
| 7 | 1 | 2.3 | 1.1 | 0.8 |
| 8 | 2 | 4.1 | 0.6 | 3.5 |
| 9 | 3 | 12.4 | 4.6 | 7.2 |
| 10 | 1 | 10.4 | 2.4 | 0.1 |
| 11 | 3 | 18.9 | 5.4 | 4.5 |

## QUESTION 4

a) Describe the unit load concept in material handling.
b) Discuss briefly any two main questions to be considered in a specific checklist for material handling systems.
c) A job shop makes four types of products as described. Each product type includes several different stock-keeping items. Each item is produced a number of times each year. After completing an operation on a machine, the batch of the product goes to centralized storage. When the queue at its next machine is sufficiently small, the job is transferred to that machine. Currently the shop averages two weeks of work in centralized storage and one day's work waiting at each machine (shop works 8 hours per day and 5 days per week). The manufacturing manager is wondering if she should convert to a group technology layout utilizing cells. Jobs would enter a cell and not leave until all operations were completed. (ie no centralized storage, all jobs are transferred to their next machine). The annual inventory holding cost rate is 0.5 per year based on average inventory level. Jobs of the same product type require no changeover (no setup when switching between them). Otherwise all setups take 1 hour and machines cost $\$ 30$ per hour to operate, including labour. Material handling is currently by forklift. The forklift moves an average of 15 jobs per hour and costs $\$ 20$ per hour. It is estimated that handling system within a cell could be constructed that would result in a cost of about $\$ 0.50$ per inter-machine move. Fixed machine costs are $\$ 10000$ per year for machines 1 and 2 and $\$ 15000$ for the others. What do you recommend? State operations policies and cost as well as type of layout. Also give the following in Table 4.1 and Table 4.2.

Table 4.1: Production Costs

| Product | Annual Demand | Raw Material Cost \$ | Value Added \$ |
| :--- | :--- | :--- | :--- |
| 1 | 1000 | 20 | 30 |
| 2 | 2000 | 40 | 90 |
| 3 | 5000 | 10 | 50 |
| 4 | 2000 | 20 | 60 |

Table 4.2: Operation rate (Machine type, unit processing time)

| Product | Operation Data |
| :--- | :--- |
| 1 | $(1,0.1),(3,0.2),(2,0.5)$ |
| 2 | $(4,0.3),(3,0.2),(5,0.05)$ |
| 3 | $(5,0.02),(4,0.1),(3,0.07)$ |
| 4 | $(2,0.6),(1,0.2)$ |

## QUESTION 5

a) Visitors parking at NUST workshops is limited to five spaces only. Cars making use of this space arrive according to Poisson distribution at the rate of six cars per hour. Parking time is exponentially distributed with mean of 30 minutes. Visitors who cannot find an empty space immediately on arrival may temporarily wait inside the lot until a parked car leaves. That temporary space can hold only three cars. Others cars that cannot park or find a temporary waiting space must go elsewhere. Determine:
i) The probability of having $n$ cars in the system
ii) The effective arrival rate for cars that actually use the parking lot.
iii) The average number of cars in the lot.
iv) The average time a car waits for a parking space inside the lot.
v) The average number of occupied parking spaces.
vi) The average utilization of the parking lot.
b) Cars arrive at Esigodini toll gate according to a Poisson distribution with a mean of 90 cars per hour. The time for passing the gate is exponential with mean 38 seconds. Drivers complain of the long waiting time and the authorities are willing to reduce the average passing time to 30 seconds by installing automatic toll collecting devices, provided two conditions are satisfied: 1) The average number of waiting cars in the present system exceeds 5 and 2 ) the percentage of the gate idle time with the new device installed does not exceed $10 \%$. Can the new device be justified?

## SECTION B (40 marks)

QUESTION 6: Case Study MPorting

| Table A.1: M/M/C Queueing Results |  |  |
| :--- | :--- | :--- |
|  | $\mathrm{M} / \mathrm{M} / 1$ | $\mathrm{M} / \mathrm{M} / \mathrm{C}$ |
| L | $L_{s}=\frac{\lambda}{\mu-\lambda}$ | $L_{q}+\frac{\lambda}{\mu}$ |
| $\mathrm{L}_{\mathrm{q}}$ | $L_{q}=\frac{\lambda^{2}}{\mu(\mu-\lambda)}$ | $\frac{\rho(c \rho)^{c} p(o)}{c!(1-\rho)^{2}}$ |
| $\mathrm{~W}_{\mathrm{q}}$ | $\mathrm{W}_{q}=\frac{\lambda}{\mu(\mu-\lambda)}$ | $\frac{(c \rho)^{c} p(o)}{c!c \mu(1-\rho)^{2}}$ |
| W | $W_{s}=\frac{1}{\mu-\lambda}$ | $W_{q}+\mu^{-1}$ |
| $\mathrm{P}(\mathrm{o})$ | $P_{o}=1-\frac{\lambda}{\mu}$ | $\left[\frac{(c \rho)^{c}}{c!(1-\rho)}+\sum_{n-o}^{c-1} \frac{(c \rho)^{n}}{n!}\right]^{-1}$ |
|  | $\rho=\frac{\lambda}{\mu}$ |  |

End of Exam

