**Suryadatta Education Foundation’s**

**Suryadatta Institutes of Management and Mass Communication, Pune**

**MCA Department**

**MCA-I SEM-II**

**Subject: Optimization Techniques Chapter No:3**

**Chapter Name:** **Sequential model and related Problems**

**Assignment No:1**

1. A book binder has one printing press, one binding machine and manuscripts of 7 different books. The times required for performing printing and binding operations for different books are shown below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Book | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Printing time (hours) | 20 | 90 | 80 | 20 | 120 | 15 | 65 |
| Binding time (hours) | 25 | 60 | 75 | 30 | 90 | 35 | 50 |

Decide the optimum sequence of processing of books in order to minimize the total time required to bring out all the books.

2. Find solution of Processing 7 Jobs Through 2 Machines Problem

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Machine-1 | 3 | 12 | 15 | 6 | 10 | 11 | 9 |
| Machine-2 | 8 | 10 | 10 | 6 | 12 | 1 | 3 |

3 Find solution of Processing 5 Jobs Through 3 Machines Problem

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 |
| Machine-1 | 8 | 10 | 6 | 7 | 11 |
| Machine-2 | 5 | 6 | 2 | 3 | 4 |
| Machine-3 | 4 | 9 | 8 | 6 | 5 |

**Find the total Idle time on a machine & Total elapsed time.**

**4.**Find solution of Processing 5 Jobs Through 4 Machines Problem

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 |
| Machine-1 | 11 | 13 | 9 | 16 | 17 |
| Machine-2 | 4 | 3 | 5 | 2 | 6 |
| Machine-3 | 6 | 7 | 5 | 8 | 4 |
| Machine-4 | 15 | 8 | 13 | 9 | 11 |

**Find the total Idle time on a machine & Total elapsed time.**

5. Determine the optimal sequence of performing 5 jobs on 4 machines that minimizes total elapsed time. The machining of each job is required in the order ABCD and the process timings (in hrs.) are as follows: 55

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Job | M1 | M2 | M3 | M4 |
| J1 | 24 | 9 | 12 | 21 |
| J2 | 27 | 6 | 15 | 15 |
| J3 | 18 | 12 | 15 | 24 |
| J4 | 36 | 15 | 3 | 27 |
| J5 | 21 | 3 | 6 | 9 |

Find:1) Total elapsed time 2) Idle time

ANSWERS

**Q.1. .** A book binder has one printing press, one binding machine and manuscripts of 7 different books. The times required for performing printing and binding operations for different books are shown below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Book | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Printing time (hours) | 20 | 90 | 80 | 20 | 120 | 15 | 65 |
| Binding time (hours) | 25 | 60 | 75 | 30 | 90 | 35 | 50 |

Decide the optimum sequence of processing of books in order to minimize the total time required to bring out all the books.  
  
**Solution:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Job** | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **Machine *M*1** | 20 | 90 | 80 | 20 | 120 | 15 | 65 |
| **Machine *M*2** | 25 | 60 | 75 | 30 | 90 | 35 | 50 |

1. The smallest processing time is 15 hour for job 6 on Machine-1. So job 6 will be processed first.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 |  |  |  |  |  |  |

2. The next smallest processing time is 20 hour for job 1,4 on Machine-1 and for this jobs 30 is largest on Machine-2. So job 4 will be processed after job 6.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 | 4 |  |  |  |  |  |

3. The next smallest processing time is 20 hour for job 1 on Machine-1. So job 1 will be processed after job 4.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 | 4 | 1 |  |  |  |  |

4. The next smallest processing time is 50 hour for job 7 on Machine-2. So job 7 will be processed last.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 | 4 | 1 |  |  |  | 7 |

5. The next smallest processing time is 60 hour for job 2 on Machine-2. So job 2 will be processed before job 7.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 | 4 | 1 |  |  | 2 | 7 |

6. The next smallest processing time is 75 hour for job 3 on Machine-2. So job 3 will be processed before job 2.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 | 4 | 1 |  | 3 | 2 | 7 |

7. The next smallest processing time is 90 hour for job 5 on Machine-2. So job 5 will be processed before job 3.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 | 4 | 1 | 5 | 3 | 2 | 7 |

According to Johanson's algorithm, the optimal sequence is as below

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 6 | 4 | 1 | 5 | 3 | 2 | 7 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Job** | ***M*1 In time** | ***M*1 Out time** | ***M*2 In time** | ***M*2 Out time** | **Idle time *M*2** |
| 6 | 0 | 0 + 15 = 15 | 15 | 15 + 35 = 50 | 15 |
| 4 | 15 | 15 + 20 = 35 | 50 | 50 + 30 = 80 | - |
| 1 | 35 | 35 + 20 = 55 | 80 | 80 + 25 = 105 | - |
| 5 | 55 | 55 + 120 = 175 | 175 | 175 + 90 = 265 | 70 |
| 3 | 175 | 175 + 80 = 255 | 265 | 265 + 75 = 340 | - |
| 2 | 255 | 255 + 90 = 345 | 345 | 345 + 60 = 405 | 5 |
| 7 | 345 | 345 + 65 = 410 | 410 | 410 + 50 = 460 | 5 |

The total minimum elapsed time = 460  
  
Idle time for Machine-1  
=460-410  
  
=50  
  
  
Idle time for Machine-2  
=(15)+(175-105)+(345-340)+(410-405)+(460-460)  
  
=15+70+5+5+0  
  
=95

**Q.2 Find solution of Processing 7 Jobs Through 2 Machines Problem**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Machine-1 | 3 | 12 | 15 | 6 | 10 | 11 | 9 |
| Machine-2 | 8 | 10 | 10 | 6 | 12 | 1 | 3 |

**Solution:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Job** | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **Machine *M*1** | 3 | 12 | 15 | 6 | 10 | 11 | 9 |
| **Machine *M*2** | 8 | 10 | 10 | 6 | 12 | 1 | 3 |

1. The smallest processing time is 1 hour for job 6 on Machine-2. So job 6 will be processed last.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  | 6 |

2. The next smallest processing time is 3 hour for job 1 on Machine-1. So job 1 will be processed first.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 |  |  |  |  |  | 6 |

3. The next smallest processing time is 3 hour for job 7 on Machine-2. So job 7 will be processed before job 6.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 |  |  |  |  | 7 | 6 |

4. The next smallest processing time is 6 hour for job 4 on Machine-1. So job 4 will be processed after job 1.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 4 |  |  |  | 7 | 6 |

5. The next smallest processing time is 10 hour for job 2,3 on Machine-2 and for this jobs 12 is smallest on Machine-1. So job 2 will be processed before job 7.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 4 |  |  | 2 | 7 | 6 |

6. The next smallest processing time is 10 hour for job 3 on Machine-2. So job 3 will be processed before job 2.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 4 |  | 3 | 2 | 7 | 6 |

7. The next smallest processing time is 10 hour for job 5 on Machine-1. So job 5 will be processed after job 4.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 4 | 5 | 3 | 2 | 7 | 6 |

According to Johanson's algorithm, the optimal sequence is as below

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | 4 | 5 | 3 | 2 | 7 | 6 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Job** | ***M*1 In time** | ***M*1 Out time** | ***M*2 In time** | ***M*2 Out time** | **Idle time *M*2** |
| 1 | 0 | 0 + 3 = 3 | 3 | 3 + 8 = 11 | 3 |
| 4 | 3 | 3 + 6 = 9 | 11 | 11 + 6 = 17 | - |
| 5 | 9 | 9 + 10 = 19 | 19 | 19 + 12 = 31 | 2 |
| 3 | 19 | 19 + 15 = 34 | 34 | 34 + 10 = 44 | 3 |
| 2 | 34 | 34 + 12 = 46 | 46 | 46 + 10 = 56 | 2 |
| 7 | 46 | 46 + 9 = 55 | 56 | 56 + 3 = 59 | - |
| 6 | 55 | 55 + 11 = 66 | 66 | 66 + 1 = 67 | 7 |

The total minimum elapsed time = 67  
  
Idle time for Machine-1  
=67-66  
  
=1  
  
  
Idle time for Machine-2  
=(3)+(19-17)+(34-31)+(46-44)+(66-59)+(67-67)  
  
=3+2+3+2+7+0  
  
=17

Q.3 **Find solution of Processing 5 Jobs Through 3 Machines Problem**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 |
| Machine-1 | 8 | 10 | 6 | 7 | 11 |
| Machine-2 | 5 | 6 | 2 | 3 | 4 |
| Machine-3 | 4 | 9 | 8 | 6 | 5 |

**Solution:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Job** | 1 | 2 | 3 | 4 | 5 |
| **Machine *M*1** | 8 | 10 | 6 | 7 | 11 |
| **Machine *M*2** | 5 | 6 | 2 | 3 | 4 |
| **Machine *M*3** | 4 | 9 | 8 | 6 | 5 |

Since any of condition min{*T*1*j*}≥max{*Tij*} and/or min{*Tmj*}≥max{*Tij*}, for j=2,3,...,m-1 is satisfied.  
  
So given problem can be converted to 2-machine problem.  
  
Machine-G

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 13 | 16 | 8 | 10 | 15 |

Machine-H

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 9 | 15 | 10 | 9 | 9 |

1. The smallest processing time is 8 hour for job 3 on Machine-G. So job 3 will be processed first.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 |  |  |  |  |

2. The next smallest processing time is 9 hour for job 1,4,5 on Machine-H and for this jobs 10 is smallest on Machine-G. So job 4 will be processed last.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 |  |  |  | 4 |

3. The next smallest processing time is 9 hour for job 1,5 on Machine-H and for this jobs 13 is smallest on Machine-G. So job 1 will be processed before job 4.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 |  |  | 1 | 4 |

4. The next smallest processing time is 9 hour for job 5 on Machine-H. So job 5 will be processed before job 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 |  | 5 | 1 | 4 |

5. The next smallest processing time is 15 hour for job 2 on Machine-H. So job 2 will be processed before job 5.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 | 2 | 5 | 1 | 4 |

According to Johanson's algorithm, the optimal sequence is as below

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 | 2 | 5 | 1 | 4 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Job** | ***M*1 In time** | ***M*1 Out time** | ***M*2 In time** | ***M*2 Out time** | ***M*3 In time** | ***M*3 Out time** | **Idle time *M*2** | **Idle time *M*3** |
| 3 | 0 | 0 + 6 = 6 | 6 | 6 + 2 = 8 | 8 | 8 + 8 = 16 | 6 | 8 |
| 2 | 6 | 6 + 10 = 16 | 16 | 16 + 6 = 22 | 22 | 22 + 9 = 31 | 8 | 6 |
| 5 | 16 | 16 + 11 = 27 | 27 | 27 + 4 = 31 | 31 | 31 + 5 = 36 | 5 | - |
| 1 | 27 | 27 + 8 = 35 | 35 | 35 + 5 = 40 | 40 | 40 + 4 = 44 | 4 | 4 |
| 4 | 35 | 35 + 7 = 42 | 42 | 42 + 3 = 45 | 45 | 45 + 6 = 51 | 2 | 1 |

The total minimum elapsed time = 51  
  
Idle time for Machine-1  
=51-42  
  
=9  
  
  
Idle time for Machine-2  
=(6)+(16-8)+(27-22)+(35-31)+(42-40)+(51-45)  
  
=6+8+5+4+2+6  
  
=31  
  
  
Idle time for Machine-3  
=(8)+(22-16)+(40-36)+(45-44)+(51-51)  
  
=8+6+4+1+0  
  
=19

Q.4 **Find solution of Processing 5 Jobs Through 4 Machines Problem**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 |
| Machine-1 | 11 | 13 | 9 | 16 | 17 |
| Machine-2 | 4 | 3 | 5 | 2 | 6 |
| Machine-3 | 6 | 7 | 5 | 8 | 4 |
| Machine-4 | 15 | 8 | 13 | 9 | 11 |

**Solution:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Job** | 1 | 2 | 3 | 4 | 5 |
| **Machine *M*1** | 11 | 13 | 9 | 16 | 17 |
| **Machine *M*2** | 4 | 3 | 5 | 2 | 6 |
| **Machine *M*3** | 6 | 7 | 5 | 8 | 4 |
| **Machine *M*4** | 15 | 8 | 13 | 9 | 11 |

Since any of condition min{*T*1*j*}≥max{*Tij*} and/or min{*Tmj*}≥max{*Tij*}, for j=2,3,...,m-1 is satisfied.  
  
So given problem can be converted to 2-machine problem.  
  
Machine-G

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 21 | 23 | 19 | 26 | 27 |

Machine-H

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 25 | 18 | 23 | 19 | 21 |

1. The smallest processing time is 18 hour for job 2 on Machine-H. So job 2 will be processed last.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | 2 |

2. The next smallest processing time is 19 hour for job 3 on Machine-G. So job 3 will be processed first.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 |  |  |  | 2 |

3. The next smallest processing time is 19 hour for job 4 on Machine-H. So job 4 will be processed before job 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 |  |  | 4 | 2 |

4. The next smallest processing time is 21 hour for job 1 on Machine-G. So job 1 will be processed after job 3.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 | 1 |  | 4 | 2 |

5. The next smallest processing time is 21 hour for job 5 on Machine-H. So job 5 will be processed before job 4.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 | 1 | 5 | 4 | 2 |

According to Johanson's algorithm, the optimal sequence is as below

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 | 1 | 5 | 4 | 2 |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Job** | ***M*1 In time** | ***M*1 Out time** | ***M*2 In time** | ***M*2 Out time** | ***M*3 In time** | ***M*3 Out time** | ***M*4 In time** | ***M*4 Out time** | **Idle time *M*2** | **Idle time *M*3** | **Idle time *M*4** |
| 3 | 0 | 0 + 9 = 9 | 9 | 9 + 5 = 14 | 14 | 14 + 5 = 19 | 19 | 19 + 13 = 32 | 9 | 14 | 19 |
| 1 | 9 | 9 + 11 = 20 | 20 | 20 + 4 = 24 | 24 | 24 + 6 = 30 | 32 | 32 + 15 = 47 | 6 | 5 | - |
| 5 | 20 | 20 + 17 = 37 | 37 | 37 + 6 = 43 | 43 | 43 + 4 = 47 | 47 | 47 + 11 = 58 | 13 | 13 | - |
| 4 | 37 | 37 + 16 = 53 | 53 | 53 + 2 = 55 | 55 | 55 + 8 = 63 | 63 | 63 + 9 = 72 | 10 | 8 | 5 |
| 2 | 53 | 53 + 13 = 66 | 66 | 66 + 3 = 69 | 69 | 69 + 7 = 76 | 76 | 76 + 8 = 84 | 11 | 6 | 4 |

The total minimum elapsed time = 84  
  
Idle time for Machine-1  
=84-66  
  
=18  
  
  
Idle time for Machine-2  
=(9)+(20-14)+(37-24)+(53-43)+(66-55)+(84-69)  
  
=9+6+13+10+11+15  
  
=64  
  
  
Idle time for Machine-3  
=(14)+(24-19)+(43-30)+(55-47)+(69-63)+(84-76)  
  
=14+5+13+8+6+8  
  
=54  
  
  
Idle time for Machine-4  
=(19)+(63-58)+(76-72)+(84-84)  
  
=19+5+4+0  
  
=28

**Q.5 Find solution of Processing 5 Jobs Through 4 Machines Problem**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Job | 1 | 2 | 3 | 4 | 5 |
| Machine-1 | 24 | 27 | 18 | 36 | 21 |
| Machine-2 | 9 | 6 | 12 | 15 | 3 |
| Machine-3 | 12 | 15 | 15 | 3 | 6 |
| Machine-4 | 21 | 15 | 24 | 27 | 9 |

**Solution:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Job** | 1 | 2 | 3 | 4 | 5 |
| **Machine *M*1** | 24 | 27 | 18 | 36 | 21 |
| **Machine *M*2** | 9 | 6 | 12 | 15 | 3 |
| **Machine *M*3** | 12 | 15 | 15 | 3 | 6 |
| **Machine *M*4** | 21 | 15 | 24 | 27 | 9 |

Since any of condition min{*T*1*j*}≥max{*Tij*} and/or min{*Tmj*}≥max{*Tij*}, for j=2,3,...,m-1 is satisfied.  
  
So given problem can be converted to 2-machine problem.  
  
Machine-G

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 45 | 48 | 45 | 54 | 30 |

Machine-H

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 42 | 36 | 51 | 45 | 18 |

1. The smallest processing time is 18 hour for job 5 on Machine-H. So job 5 will be processed last.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | 5 |

2. The next smallest processing time is 36 hour for job 2 on Machine-H. So job 2 will be processed before job 5.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  | 2 | 5 |

3. The next smallest processing time is 42 hour for job 1 on Machine-H. So job 1 will be processed before job 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | 1 | 2 | 5 |

4. The next smallest processing time is 45 hour for job 3 on Machine-G. So job 3 will be processed first.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 |  | 1 | 2 | 5 |

5. The next smallest processing time is 45 hour for job 4 on Machine-H. So job 4 will be processed before job 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 | 4 | 1 | 2 | 5 |

According to Johanson's algorithm, the optimal sequence is as below

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 3 | 4 | 1 | 2 | 5 |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Job** | ***M*1 In time** | ***M*1 Out time** | ***M*2 In time** | ***M*2 Out time** | ***M*3 In time** | ***M*3 Out time** | ***M*4 In time** | ***M*4 Out time** | **Idle time *M*2** | **Idle time *M*3** | **Idle time *M*4** |
| 3 | 0 | 0 + 18 = 18 | 18 | 18 + 12 = 30 | 30 | 30 + 15 = 45 | 45 | 45 + 24 = 69 | 18 | 30 | 45 |
| 4 | 18 | 18 + 36 = 54 | 54 | 54 + 15 = 69 | 69 | 69 + 3 = 72 | 72 | 72 + 27 = 99 | 24 | 24 | 3 |
| 1 | 54 | 54 + 24 = 78 | 78 | 78 + 9 = 87 | 87 | 87 + 12 = 99 | 99 | 99 + 21 = 120 | 9 | 15 | - |
| 2 | 78 | 78 + 27 = 105 | 105 | 105 + 6 = 111 | 111 | 111 + 15 = 126 | 126 | 126 + 15 = 141 | 18 | 12 | 6 |
| 5 | 105 | 105 + 21 = 126 | 126 | 126 + 3 = 129 | 129 | 129 + 6 = 135 | 141 | 141 + 9 = 150 | 15 | 3 | - |

The total minimum elapsed time = 150  
  
Idle time for Machine-1  
=150-126  
  
=24  
  
  
Idle time for Machine-2  
=(18)+(54-30)+(78-69)+(105-87)+(126-111)+(150-129)  
  
=18+24+9+18+15+21  
  
=105  
  
  
Idle time for Machine-3  
=(30)+(69-45)+(87-72)+(111-99)+(129-126)+(150-135)  
  
=30+24+15+12+3+15  
  
=99  
  
  
Idle time for Machine-4  
=(45)+(72-69)+(126-120)+(150-150)  
  
=45+3+6+0  
  
=54