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| ***A) & B)*** |  |  |  |  |  |  |  |  |  |  |  |
| Cycle time,Tc = | | 1 | min |  |  |  |  |  |  |  |  |
| Number of failure (breakdown), N = | | |  | 10 |  |  |  |  |  |  |  |
| Number of stations, n = | | |  | 12 |  |  |  |  |  |  |  |
| Operating cycle, MTTF = | | |  | 225 | min |  |  |  |  |  |  |
| Repair cycle, MTTR = | | |  | 15 | min |  |  |  |  |  |  |
| Period of observation, AT = (MTTF +MTTR) \* N = (225+15) = | | | | |  | 2400 | min |  |  |  |  |
| Total down time of line , TD = Tc \* (MTTR) \* (n) \* (N) = | | | | |  | 1800 | min |  |  |  |  |
| Up time of the line, U = AT- TD = | | |  |  |  | 600 | min |  |  |  |  |
| Number of part produced = U/Tc = | | |  |  |  | 600 | parts |  |  |  |  |
| ***C) & D)*** |  |  |  |  |  |  |  |  |  |  |  |
| Failure rate,p = 1/MTTF =1/225 = | | | 0.0044 |  |  |  |  |  |  |  |  |
| Repair rate,r = 1/MTTR = 1/15 = | | | 0.066667 |  |  |  |  |  |  |  |  |
| station efficiency, % = r/(r + p) = | | | 93.75 |  |  |  |  |  |  |  |  |
| ***E)*** |  |  |  |  |  |  |  |  |  |  |  |
| Frequency of line stop for each station, *p* = N/Np = 10/600 = | | | | |  | 0.0167 |  |  |  |  |  |
| Upper bound frequency, Fu = 0.75 \* n \*p = 0.75 \*12 \* 0.0167 = | | | | |  | 0.15 |  |  |  |  |  |
| Lower bound frequency, Fl = 0.25 \*(1-(1- *p*)n *=* 0.25 \* (1- (1 - 0.0167)12 *=* | | | | | |  | 0.046 |  |  |  |  |
| Frequency of line stop for line, F =Fu+Fl = 0.0167+.046 = | | | | |  | 0.196 |  |  |  |  |  |
| Production time, Tp = Tc+ F \* Td = 1 + 0.083 \* 15 = | | | |  | 3.935 | min |  |  |  |  |  |
| 1- Production Rate, Rp = (1-Fl)/Tp = (1 - 0.024)/3.935 = | | | | | 14.5518 | pc/hr |  |  |  |  |  |
| 2- Line efficiency = Tc \* Rp = (1/60) \* 14.7888 = | | | |  | 24.25 | % |  |  |  |  |  |
| 3- Number of parts produced = AT \* Rp = (2400/60) \*14.7888 = | | | | | 582 | parts |  |  |  |  |  |
| 4- Number of defects = | | |  |  | 18 | parts |  |  |  |  |  |
| 5- Line cost = Operating cost(Co)/ Rp = 50/14.5518 = | | | | | 3.436 | SR/pc |  |  |  |  |  |
| ***F- Find the optimum number of the infinite buffers, and Line efficiency. Cost of buffer Cb =900 SR*** | | | | | | | | |  |  |  |
| **i) Two Stages: A Buffer after 6, n1 =6, n2 =6 - Number of buffer Nb=1** | | | | | | |  |  |  |  |  |
| **Stage 1, 2** | | | | |  |  |  |  |  |  |  |
| Frequency of failure per stop **F1 = F2 =6\**p*** |  |  |  | **0.1000** |  | ***This is the optimum since it give the minimum cost*** | | | | |  |
| Production Time, **(TP)=TC+F1\*Td =** |  |  | **2.5000** | **min** |  |  |  |  |  |  |  |
| Production Rate, **(RP)= 60/ TP =** |  |  | **24.000** | **part/hr** |  |  | stages | cost | Eff |  |  |
| Efficiency, ***(E1) = = E2= TC\*RP =*** |  |  | **40%** |  |  |  | 0 | 3.4360 | 24.25 |  |  |
| Number of parts Na = AT \* Rp = | | | **960** | **parts** |  |  | ***2*** | ***3.0208*** | ***40.00*** |  |  |
| Cost of line = Nbr \* (Cb)/Na + Co /Rp = | | | **3.02** | **SR/pc** |  |  | 3 | 3.1667 | 50.00 |  |  |
|  |  |  |  |  |  |  | 4 | 3.4271 | 57.14 |  |  |
| **ii) Three Stages: A Buffer after 4 & 8 , all has n =4 then all equal** | | | | | | | 12 | 6.6667 | 80.00 |  |  |
| **Stage 1,2, 3** | | | | |  | |  | | --- | |  | |  |  |  |  |  |
| Frequency of failure per stop **F1 =F2=F3= 4\**p*** |  |  |  | **0.0667** |  |  |  |  |  |  |  |
| Production Time, **(TP)=TC+F1\*Td =** |  |  | **2.0000** | **min** |  |  |  |  |  |  |  |
| Production Rate, **(RP)= 60/ TP =** |  |  | **30.000** | **part/hr** |  |  |  |  |  |  |  |
| Efficiency, ***(E1) =E2=E3= TC\*RP =*** |  |  | **50%** |  |  |  |  |  |  |  |  |
| Number of parts Na = AT \* Rp = | | | **1200** | **parts** |  |  |  |  |  |  |  |
| Cost of line = Nbr \* (Cb)/Na + Co /Rp = | | | **3.17** | **SR/pc** |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
| **iii) 4 Stages: A Buffer after 3 & 6 & 9 , all has n =3 then all equal** | | | | | | |  |  |  |  |  |
| **Stage 1,2, 3, 4** | | | | |  |  |  |  |  |  |  |
| Frequency of failure per stop **F1 =F2=F3= 3\**p*** |  |  |  | **0.0500** |  |  |  |  |  |  |  |
| Production Time, **(TP)=TC+F1\*Td =** |  |  | **1.7500** | **min** |  | |  | | --- | |  | |  |  |  |  |  |
| Production Rate, **(RP)= 60/ TP =** |  |  | **34.286** | **part/hr** |  |  |  |  |  |  |  |
| Efficiency, ***(E1) =E2=E3= TC\*RP =*** |  |  | **57%** |  |  |  |  |  |  |  |  |
| Number of parts Na = AT \* Rp = | | | **1371.429** | **parts** |  |  |  |  |  |  |  |
| Cost of line = Nbr \* (Cb)/Na + Co /Rp = | | | **3.43** | **SR/pc** |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
| **iii) 12 Stages: A Buffer after each station, all has n =1then all equal** | | | | | | |  |  |  |  |  |
| **Stage 1,2, 3, 4,…12** | | | | |  |  |  |  |  |  |  |
| Frequency of failure per stop **F1 =F2=F3= 3\**p*** |  |  |  | **0.0167** |  |  |  |  |  |  |  |
| Production Time, **(TP)=TC+F1\*Td =** |  |  | **1.2500** | **min** |  |  |  |  |  |  |  |
| Production Rate, **(RP)= 60/ TP =** |  |  | **48.000** | **part/hr** |  |  |  |  |  |  |  |
| Efficiency, ***(E1) =E2=E3= TC\*RP =*** |  |  | **80%** |  |  |  |  |  |  |  |  |
| Number of parts Na = AT \* Rp = | | | **1920** | **parts** |  |  |  |  |  |  |  |
| Cost of line = Nbr \* (Cb)/Na + Co /Rp = | | | **6.67** | **SR/pc** |  |  |  |  |  |  |  |

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| Part Family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |  |  |  |  |  |
| Weekly Demand | 22 | 25 | 30 | 50 | 30 | 15 | 14 | 18 | 20 | 30 |  |  |  |  |  |
| Subcontracting cost SR/unit | 800 | 620 | 700 | 1200 | 900 | 750 | 500 | 400 | 800 | 850 |  |  |  |  |  |
| Material cost SR/unit | 125 | 100 | 180 | 400 | 350 | 200 | 150 | 110 | 130 | 450 |  |  |  |  |  |
| Turning time, hr | 0 | 0.7 | 1.2 | 0 | 3 | 1.3 | 1.5 | 2.5 | 1.4 | 2.3 |  |  |  |  |  |
| Machining Center, hr | 2 | 1.2 | 1.7 | 1.6 | 0 | 1.6 | 1.5 | 0 | 2.2 | 2.2 |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Solution** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Available Time TA - M/c center, hr/week = 129.6 | | | | | |  |  |  |  |  |  |  |  |  |  |
| Available Time TA - turning, hr/week = 194.4 | | | | | |  |  |  |  |  |  |  |  |  |  |
| Process Cost = (process time of turning + process time of M/c centre) x 150, SR/unit | | | | | |  |  |  |  |  |  |  |  |  |  |
| Unit Saving, US = Purchase Cost - Material cost - Processes cost, SR/unit | | | | | |  |  |  |  |  |  |  |  |  |  |
| Total process time, TT = Process time x weekly Demand, hr/week | | | | | |  |  |  |  |  |  |  |  |  |  |
| Saving/hr, SH = unit saving/process time for a unit, SR/hr | | | | | |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Part family | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |  |  |  |  |  |
| Unit saving, US, SR/unit | 375 | 235 | 85 | 560 | 100 | 115 | -100 | -85 | 130 | -275 |  |  |  |  |  |
| Turning Total process Time, hr | 0 | 17.5 | 36 | 0 | 90 | 19.5 | 21 | 45 | 28 | 69 |  |  |  |  |  |
| M/c Centre Total process Time, hr | 44 | 30 | 51 | 80 | 0 | 24 | 21 | 0 | 44 | 66 |  |  |  |  |  |
| Unit saving/ unit process time, SR/hr | 187.5 | 123.7 | 29.3 | 350 | 33.3 | 39.7 | -33 | -34 | 36.1 | -61.1 |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Step 1, Order (rank):**,= 4, 1, 2, 9, 6, 5, 3 | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Step 2, Selection** | Turning Time, hr | | M/c Centre time ,hr | |  |  |  |  |  |  |  |  |  |  |  |
| used | Remain | used | Remain |  |  |  |  |  |  |  |  |  |  |  |
| 4 | 0 | 0 | 80 | 114.4 |  |  |  |  |  |  |  |  |  |  |  |
| 1 | 0 | 0 | 44 | 70.4 |  |  |  |  |  |  |  |  |  |  |  |
| 2 | 17.5 | 112.1 | 30 | 40.4 |  |  |  |  |  |  |  |  |  |  |  |
| 6 | 19.5 | 92.6 | 24 | 16.4 |  |  |  |  |  |  |  |  |  |  |  |
| 5 | 90 | 2.6 | 0 | 16.4 |  |  |  |  |  |  |  |  |  |  |  |
|  The set of part family to be produced **4,1,2,6,5** | | | | |  |  |  |  |  |  |  |  |  |  |  |
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| **Solution** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Max z for one batch = 28 | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tools slot require 12 slot this greater than 8, hence require batching. | | |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **First Trial:** | No. of parts | No. of slot used |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Batch 1: P1,P2,P3,P4,P5,P6,P7,P11,P12 | z= 19 | y =8 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Batch 2: P8,P9,P10 | z= 9 | y = 6 |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|  |  | **Table (3)** | | | | | | |  |  |  |  |
|  |  | Part | Weekly Demand | Operation | Machine Processing time, min | | | Tool type |  |  |  |  |
|  |  | A | B | C |  |  |  |  |
|  |  | a | 75 | 1 | 20 | 20 | - | T1 |  |  |  |  |
|  |  |  |  | 2 | 24 | 34 | 20 | T2 |  |  |  |  |
|  |  |  |  | 3 | - | - | 30 | T3 |  |  |  |  |
|  |  | b | 80 | 1 | - | 30 | 25 | T4 |  |  |  |  |
|  |  |  |  | 2 | 35 | - | - | T3 |  |  |  |  |
|  |  |  |  | 3 | 25 | - | 30 | T2 |  |  |  |  |
|  |  | c | 125 | 1 | 16 | 20 | 22 | T1 |  |  |  |  |
|  |  |  |  | 2 | - | 20 | 16 | T7 |  |  |  |  |
|  |  | Number of machines | | | 2 | 1 | 2 |  |  |  |  |  |
|  |  | Number of tool’s slot | | | 2 | 2 | 2 |  |  |  |  |  |
|  |  | Available time, hr/day | | | 12 | | |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  | Total slots | | 4 | 2 | 4 |  |  |  |  |  |
|  |  |  | Total time, min | | 7200 | 3600 | 7200 |  |  |  |  |  |
|  | Ittiration | a1 | a2 | a3 | b1 | b2 | b3 | c1 | c2 | Assigned Operation | Assigned Machine | Time remained, min |
|  | 1 | A,B | A,B,C | C | B,C | A | A,C | A,B,C | B,C | b2 | A | 4400 |
|  | 2 | A,B | A,B,C | C | B,C | 0 | A,C | A,B,C | B,C | a3 | C | 4950 |
|  | 3 | A,B | A,B,C | 0 | B,C | 0 | A,C | A,B,C | B,C | c1 | C | 2200 |
|  | 4 | A,B | A,B,C | 0 | B,C | 0 | A,C | 0 | B,C | c2 | C | 200 |
|  | 5 | A,B | A,B | 0 | B | 0 | A | 0 | 0 | b3 | A | 2400 |
|  | 6 | A,B | A,B | 0 | B | 0 | 0 | 0 | 0 | b1 | B | 1200 |
|  | 7 | A,B | A,B | 0 | 0 | 0 | 0 | 0 | 0 | a2 | A | 900 |
|  | 8 | A,B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35/75 a1 | A | 200 |
|  | 9 | B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45/75 a1 | B | 400 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | Utilization | |  |  |  |  |  |  |  |  |  |
|  |  | A | 97.22 |  |  |  |  |  |  |  |  |  |
|  |  | B | 88.89 |  |  |  |  |  |  |  |  |  |
|  |  | C | 97.22 |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |