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Solutions Manual for Manufacturing System Throughput Excellence 1st Tang

SOLUTIONS MANUAL SAMPLE PREVIEW

PUBLISHER
Wiley

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2024

RESOURCE TYPE
Solutions Manual

ISBN
9781394190324

Solutions Manual for Manufacturing System Throughput Excellence 1st Edition by Tang

ISBN: 9781394190324

Manufacturing System Throughput Excellence – Analysis, Improvement, and Design

Chapter 1: Throughput Concepts

1.1 A shift has 7.5 hours of planned production time. The actual production time in a shift was 6.8 hours. The shift experienced 0.15 hour of starved time, 0.25 hour of blocked time, 0.2 hour of equipment downtime, and 0.1 hour of work delay time. Calculate the operational availability and Toyota's formula availability for this shift.

Solution:

- $A = \frac{\text{Actual production time}}{\text{Planned production time}} = \frac{6.8}{7.5} = 90.7\%$
- $A_{\text{toyota}} = \frac{\text{Planned production time} - \text{Starved time} - \text{Equipment time} - \text{Work delay time}}{\text{Planned production time}}$
  $= \frac{7.5 - 0.15 - 0.2 - 0.1}{7.5} = \frac{6.9}{7.5} = 94.0\%$

1.2 A manufacturing system employs 320 people. Over one week, it utilized 13,400 labor hours and produced 4800 units. Calculate the productivity per employee and per hour for this week.

Solution:

- $\frac{\text{Produced units}}{\text{Number of employees}} = \frac{4800}{320} = 15.0 \text{ units/employee}$
- $\frac{\text{Produced units}}{\text{Production hours}} = \frac{4800}{13{,}400} = 0.358 \text{ units/hour}$

1.3 In one week, a shop incurred a direct labor cost of \$100 k, material cost of \$150 k, equipment cost of \$45 k, utility cost of \$7 k and overhead cost of \$13 k. Calculate the percentage of direct labor cost in the total cost.

Solution:

- $\frac{C_{\text{labor}}}{C_{\text{labor}} + C_{\text{material}} + C_{\text{equipment}} + C_{\text{utility}} + C_{\text{facility}} + C_{\text{overhead}}} = \frac{100}{315} = 31.7\%$

1.4 An operation has a known throughput time of 4.5 hours and a throughput rate of 50 jobs per hour. Calculate the average WIP level for this operation in the long run based on Little's Law.

Solution:

- $\text{WIP} = \text{TT} \times \text{TR} = 4.5 \times 50 = 225 \text{ (units)}$

Manufacturing System Throughput Excellence: Analysis, Improvement, and Design, First Edition. Herman Tang.

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1.5 A production line has eight workstations with cycle times of 58, 56, 57, 60, 59, 56, 55, and 59 seconds, respectively. Estimate the long-run average WIP for this production line.
Solution:

- $\text{TT} = 58 + 56 + 57 + 60 + 59 + 56 + 55 + 59 = 460 \text{ (seconds)} \approx 0.128 \text{ (hour)}$
- $\text{TR} = \frac{3600}{\max(58,56,57,60,59,56,55,59)} = \frac{3600}{60} = 60 \text{ (JPH)}$
- $\text{WIP} = \text{TT} \times \text{TR} = 0.128 \times 60 = 7.7 \text{ (units)}$

1.6 If a process has a cycle time of 48 seconds, estimate the corresponding theoretical throughput rate in JPH.
Solution:

- $\text{TR}_{\text{gross}} = \frac{3600}{\text{CT (seconds)}} = \frac{3600}{48} = 75.0 \text{ (JPH)}$

1.7 Based on the data from Exercise 1.1 and known production output of 480 units, calculate the standalone availability (A_{sa}) and standalone throughput rate (TR_{sa}).
Solution:

- $A_{\text{sa}} = \frac{\text{Actual production time}}{\text{Planned production time} - \text{Starved time} - \text{Blocked time}} = \frac{6.8}{7.5 - 0.15 - .025} = 95.8\%$
- $\text{TR}_{\text{gross}} = \frac{480}{6.8} = 70.59 \text{ (JPH)}$
- $\text{TR}_{\text{sa}} = \frac{A_{\text{sa}}}{A} \times \text{TR} = \frac{0.958}{0.907} \times 70.59 = 74.56 \text{ (JPH)}$

Chapter 2: System Performance Metrics

2.1 A shop had planned to produce 450 units during a standard eight-hour shift. However, it ended up producing 451 units in 8.5 hours. Calculate the shop's volume attainment (VA) and schedule attainment (SA) performance. Comment on the results.
Solution:

- $A = \frac{\text{Actual production time}}{\text{Planned production time}} = \frac{8.5}{8} = 106.25\%$
- $\text{VA} = \frac{\text{Actual produced units}}{\text{Planned output units}} = \frac{451}{450} = 100.22\%$
- $\text{SA} = \text{VA} \times \frac{\text{Planned production time}}{\text{Actual production time}} = \text{VA} \times \frac{1}{A} = 100.22\% \frac{1}{106.25\%} = 94.3\%$

2.2 A plant operates two shifts, six days a week. Each shift is 8.5 hours long, inclusive of a half-hour lunch break and three 15-minute breaks for nonproduction activities. The plant is designed to have a throughput rate of 60 units per hour. Over the week, the plant manufactured 4440 units, out of which 90 required repairs. Also, there were events leading to 12 hours of unplanned downtime. Calculate the plant's speed performance of the week.
Solution:

- $P(\text{unit based}) = \frac{\text{Actual units produced}}{\text{Planned units in uptime}} = \frac{4440}{((8.5-0.5-3\times0.25)\times6\times2-12)\times60} = 98.7(\%)$
- $\text{Desing CT} = \frac{3600}{\text{TR}} = \frac{3600}{60} = 60 \text{ (seconds)}$
- $\text{Actual CT} = \frac{((8.5-0.5-3\times0.25)\times6\times2-12)\times3600}{4440} = 60.81 \text{ (seconds)}$
- $P(\text{cycle time based}) = \frac{\text{Design CT}}{\text{Actual CT}} = \frac{60}{60.81} = 98.7(\%)$

2.3 A production line is designed to have a cycle time of 60 seconds, but it operates at 61.2 seconds. Estimate the throughput rate of this production line. If the production runs for 7.5 hours per shift, determine the number of units lost a shift due to the speed performance rate.

Solution:
- $P(\text{cycle time based}) = \frac{\text{design CT}}{\text{actual CT}} = \frac{60}{61.2} = 98.04(\%)$
- $\text{Lost TR} = 60 - \frac{3600}{61.2} = 1.18\ (\text{JPH})$
- $\text{Shift lost} = 1.18 \times 7.5 = 8.8\ (\text{units})$

2.4 Using the data provided in Exercise 2.2, calculate the OEE for the week.
Solution:
- $A = \frac{(8.5-0.5-3\times0.25)\times6\times2-12}{(8.5-0.5-3\times0.25)\times6\times2} = 86.21\%$
- $Q = \frac{4440-90}{4440} = 97.97\%$
- $\text{OEE} = A \times P \times Q = 86.21\% \times 98.67\% \times 97.97\% = 83.3\%$

2.5 A production system operated for 80 hours across five working days, with an OEE of 85%. Calculate its TEEP.
Solution:
- $\text{TEEP} = \text{OEE} \times U = 85\% \times \frac{80}{5\times24} = 56.7\%$

2.6 A quality improvement project can enhance the quality rate from 98.0% to 98.5%. It can also lead to a 0.1% improvement (92.0–92.1%) in operational availability and a 0.2% improvement (94.3–94.5%) in the speed performance. Compare the estimated OEE and calculated OEE (refer to subsection 2.2.3).
Solution:
- old $\text{OEE}_1 = A \times P \times Q = 92\% \times 94.3\% \times 98\% = 85.02\%$
- new $\text{OEE}_2 = A \times P \times Q = 92.1\% \times 94.5\% \times 98.5\% = 85.73\%$
- $\Delta\text{OEE} = \text{OEE}_2 - \text{OEE}_1 = 0.71\%$
- $\Delta\text{OEE} \approx \Delta A + \Delta P + \Delta Q = 0.1\% + 0.2\% + 0.5\% = 0.8\%$

2.7 For an operation, the significance of the three elements of OEE are assigned values of 7, 4, and 5, respectively. Over a week, these three elements were measured to be 91%, 99%, and 95%, respectively. Calculate the original OEE and the weighted OEE using the method introduced in subsection 2.3.1.2.
Solution:
- $\text{OEE} = A \times P \times Q = 85.59\%$
- $w_{\text{A}} = \frac{3\times7}{7+4+5} = 1.31$, $w_{\text{P}} = \frac{3\times4}{7+4+5} = 0.75$, and $w_{\text{Q}} = \frac{3\times5}{7+4+5} = 0.94$
- $\text{OEE}_{\text{w}} = (A^{w_{\text{A}}}) \times (P^{w_{\text{P}}}) \times (Q^{w_{\text{Q}}}) = 83.58\%$

2.8 Continuing from Exercise 2.4, assume a standalone availability of 96%. What would be the simplified standalone OEE? Compare this with the results obtained in Exercise 2.2.
Solution:
- $\text{OEE}_{\text{sa}-\text{simplified}} = A_{\text{sa}} \times P \times Q = 96\% \times 98.67\% \times 97.97\% = 92.8\%$

2.9 If a system's throughput is 0.5 JPH less than its target, and the unit profit is $1400, calculate the monetary loss for one week of production, assuming 75 working hours.
Solution:
- $-0.5 \times 75 \times \$1400 = -\$52{,}500$

Chapter 3: Bottleneck Identification and Buffer Analysis

3.1 A system comprises five workstations, each with cycle times of 52, 55, 58, 50, and 51 seconds, respectively. Estimate the throughput rates of the system and identify which workstation serves as the throughput bottleneck.

Solution:

- Station 3: $\text{TR} = \frac{3600}{\text{CT (seconds)}} = \frac{3600}{58} = 62.07$ (JPH) is the slowest workstation.

3.2 Four manufacturing subsystems, arranged in series, have active periods accounting for 95%, 89%, 91%, and 85% of the production time in a week, respectively. Determine which subsystem acts as the throughput bottleneck?

Solution:

- Subsystem 1, as it has the highest active time.

3.3 A system consists of seven operations. Their starved and blocked times (due to various reasons) over a week of production are listed in Table 3.3. Using the concept of a "turning point," identify the operation that is the bottleneck and provide a rationale for your choice.

Table 3.3

Operation	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Starved time (minute)	50	70	20	40	30	40	50
Blocked time (minute)	40	30	50	70	60	60	50

Solution:

- Operation 3, as it has the lowest combined starved and blocked time.

3.4 A conveyor, which has a transfer time of one minute between two systems with a cycle time of 55 seconds, is in operation. What would be the recommended minimum quantity of WIP units to support system throughput?

Solution:

- $Min = \frac{t_{\text{transfer}}}{\text{CT}} + 1 = \frac{60}{55} + 1 = 2.1$ (units)

3.5 A system that includes four subsystems arranged in series operates in a continuous flow. The five conveyors associated with these subsystems hold WIP units of 40, 65, 10, 20 and 32, respectively (refer to Figure 3.22). Identify the bottleneck in the system's throughput.

Solution:

- Subsystem 2, as its upstream conveyor has the highest WIP units.

3.6 A conveyor, with a capacity equivalent to 15 minutes of production time and typically filled to two-thirds of its capacity, is in operation. Determine the duration for which the conveyor can compensate for the downtime of its upstream and downstream systems.

Solution:

- (2/3) Cover up to ten minutes of the upstream system until the conveyor becomes empty.
- (1/3) Cover up five minutes of the downstream system until the conveyor becomes full.

3.7 A production line functions at a rate of 50 units per minute, and the WIP change alarm is set to activate at three-fourths of the production rate. If the number of WIP units on the conveyor drops by 120 units within three minutes, would the WIP change alarm be triggered?
Solution:
- Alarm: $\frac{3}{4} \times 50 = 37.5$ units/min
- $\frac{\Delta \mathrm{WIP}}{\Delta t} = \frac{120}{3} = 40$ (units/min) > 37.5

Chapter 4: Quality Management and Throughput

4.1 The implementation of an automated in-process inspection necessitates a new investment of $40,000, aimed at reducing the cost of internal failures. Given an estimated weekly cost saving of $1500 from internal failures and assuming no other changes in costs, calculate the break-even point for this investment.
Solution:
- Break–even $= \frac{\text{Total cost}}{\text{Total gains or savings}} = \frac{40{,}000}{1500} = 26.67$ (weeks)

4.2 An improvement project requires an investment of $15,000 and is projected to yield a cost saving of $3500 per quarter due to improved product quality over the next two years. The company's minimum acceptable rate of return (MARR) is set at 14%. Determine whether this project is worth undertaking.
Solution:
- Using Excel's rate() function: "=rate(2*4,3500,–15000)"
- Rate = 16.4% > MARR

4.3 An improvement project requires an investment of $15,000, and the company's MARR is 14%. Calculate the minimum expected cost saving per quarter from improved product quality over two years, which would make this project worthwhile.
Solution:
- Using Excel's pmt() function: "=pmt(0.14,2*4,–15000)"
- Saving = $3.33.55

4.4 A manufacturing system consists of eight workstations in series, with TPY values of 0.99, 0.98, 0.95, 0.97, 0.98, 0.95, 0.98, and 0.99, respectively. Calculate the RTY of the entire system.
Solution:
- RTY $= 0.99 \times 0.98 \times 0.95 \times 0.97 \times 0.98 \times 0.95 \times 0.98 \times 0.99 = 0.808$

4.5 A system comprises three parallel, identical subsystems, each with mean values of a quality attribute of 15.2, 14.5, and 13.7, respectively. Estimate the mean value of this quality attribute for the combined products from all subsystems.
Solution:
- $\mu = \frac{15.2+14.5+13.7}{3} = 14.47$

4.6 A system comprises two parallel, identical subsystems, each with similar mean values for a quality attribute but different variations. The standard deviations for this attribute are 5.5 and 7.3 for the two subsystems, respectively. Estimate the standard deviation value of this quality attribute for the combined products from both subsystems.

Solution:

- $\sigma = \sqrt{\frac{\sigma_1^2+\sigma_2^2}{2}} = \sqrt{\frac{5.5^2+7.3^2}{2}} = 6.46$

Chapter 5: Maintenance Management and Throughput

5.1 A robot has a failure probability of 0.0002 per hour. Calculate its reliability for eight hours of work. If the failure probability is reduced to 0.0001 per hour, what would be the improved reliability over eight work hours?
Solution:
- Using Excel's exp() function.
- =exp(−0.0002*8) = 99.84%
- =exp(−0.0001*8) = 99.92%

5.2 Over a three-month production period, the four most frequent failure modes (A, B, C, and D) occurred 10, 13, 9, and 8 times, respectively. The average downtime for these modes was 8, 3, 12, and 7 minutes, respectively. If the consequence rating is considered the same for all modes, which failure mode should be prioritized for maintenance?
Solution:
- Failure C has the highest severity, as $S_3 = F_3 \times D_3 \times C_3 = 108$

5.3 An assembly line encountered 92 failures over a three-month production period, amounting to 900 working hours. Determine the MTBF for this line.
Solution:
- $\text{MTBF} = \frac{\text{Total available time}}{\text{Number of failures}} = \frac{900}{92} = 9.78\ (\text{hours})$

5.4 The maintenance department spent 1050 minutes rectifying 92 failures on an assembly line over a three-month period. What is the MTTR for this line?
Solution:
- $\text{MTTR} = \frac{\text{Total down time}}{\text{Number of downtime or repair}} = \frac{1050}{92} = 11.41\ (\text{hours})$

5.5 If the MTBF of a production line is 15.5 hours for a given period, what would be the corresponding failure rate?
Solution:
- $\lambda = \frac{\text{Number of failures}}{\text{Total time}} = \frac{1}{\text{MTBF}} = \frac{1}{15.5} = 6.45\%$

5.6 If the MTBF and MTTR of a production line are 15.5 and 0.25 hours, respectively, for a given period, calculate the availability of this production line.
Solution:
- $A = \frac{\text{MTBF}}{\text{MTBF+MTTR}} = \frac{15.5}{15.5+0.25} = 98.41\%$

5.7 During a month's production, unplanned maintenance for downtime accounted for 125 out of the total 600 maintenance hours. What would be the PMP and the unscheduled downtime ratio?
Solution:
- $\text{PMP} = \frac{\text{Planned maintenance hours}}{\text{Total maintenance hours}} = \frac{600-125}{600} = 79.2\%$

5.8 A maintenance department incurred expenses of \$85 k and \$100 k on various maintenance tasks over two consecutive months. The estimated costs for throughput and quality for these two months were \$250 k and \$230 k, respectively. Calculate the total maintenance cost for these two months.

Solution:

- \$50 + \$250 = \$335 (k)
- \$100 + \$230 = \$330 (k)

5.9 A maintenance department adheres to the three elements of OEE to guide its maintenance activities. During a shift, three fundamental issues are reported, as listed Table 5.10. Due to resource constraints, the maintenance department can immediately address only two of these issues. Which two should be prioritized for immediate attention? (refer to Table 5.8 for the ratings)

Table 5.10

Issue	*A*	*P*	*Q*
1	Downtime = 4 minutes	Slow by 0.6 minute	None
2	None	Slow by 2.5 minutes	Defect = 1.9%
3	Downtime = 8 minutes	None	Defect = 0.3%

Solution:

Issue	R_A	R_P	R_Q	PI
1	8	3	1	24
2	1	5	4	20
3	9	1	2	18

Chapter 6: Throughput Enhancement Methodology

6.1 The TR data for a month exhibits a standard deviation of 2.7 and a mean of 56. Calculate the coefficient of variation (CV) for this data.

Solution:

- $\text{CV} = \frac{\text{Standard deviation}}{\text{Mean}} = \frac{2.7}{56} = 4.82\%$

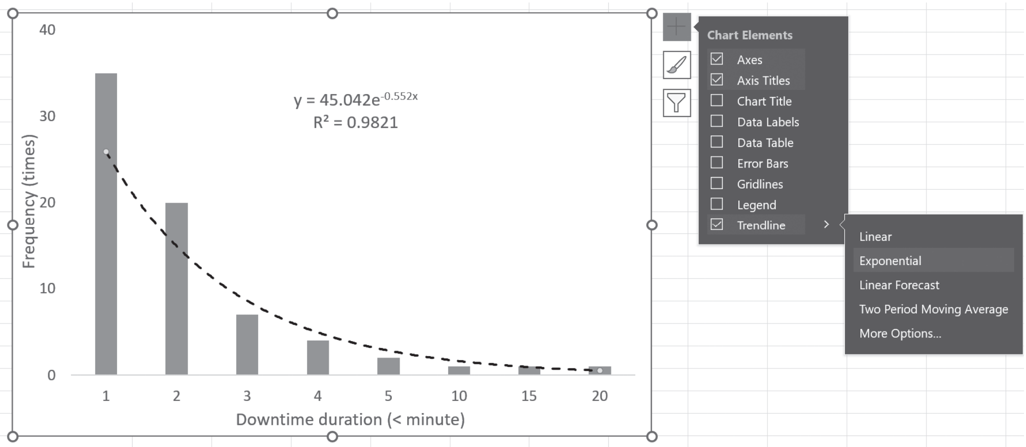
6.2 The table (Table 6.6) lists the downtime durations and corresponding frequencies of a system for one week. Utilize MS Excel or similar software to perform data curve fitting and analyze the overall characteristics of the system.

Table 6.6

Downtime (<minute)	1	2	3	4	5	10	15	20
Frequency (times)	35	20	7	4	2	1	1	1

Solution:

- Using Excel's trendline function:



6.3 A serial production line consists of five workstations, each with cycle times of 55, 58, 54, 57, and 52 seconds, respectively. Estimate the cycle time for this line.
Solution:

- $\text{CT}_{\text{serial}} \approx \text{Max}\{\text{CT}_{\text{op.1}}, \text{CT}_{\text{op.2}}, \ldots \text{CT}_{\text{op.}n}\} = \text{Max}\{55, 58, 54, 57, 52\} = 58$ (seconds)

6.4 A parallel manufacturing system comprises three identical legs, each with an equal production volume. The cycle times for these three legs are 85, 88, and 87 seconds, respectively. Determine the cycle time for this system.
Solution:

- $\text{CT}_{\text{parallel}} \approx \frac{\text{Average}\{\text{CT}_{\text{seg.1}}, \text{CT}_{\text{seg.2}}, \ldots, \text{CT}_{\text{seg.}n}\}}{n} = \frac{\text{Average}\{85,88,87\}}{3} = 28.9$ (seconds)

6.5 Three improvement project proposals have been rated (without weights) as shown in Table 6.7. Based on the three factors, determine which proposal should be prioritized for support. Provide a rationale for your choice.

Table 6.7

Proposal	(1) Benefits	(2) Technology	(3) Resources
A	3	4	2
B	3.5	3.5	3
C	4	2.5	3.5

Solution:

- Proposal B has the highest priority with an overall score of 36.75.

6.6 An internal survey was conducted to assess the levels of importance and agreement for various improvement tasks, as listed in Table 6.8. Based on the survey results, identify the top three tasks that should be prioritized.

Table 6.8

Task	Importance	Agreement
1	3.3	2.5
2	3.2	3.1
3	3.2	3.0
4	3.3	2.7
5	4.0	3.6
6	3.7	2.8

Solution:
- The top three tasks are 6, 1, and 4 with gaps of 0.9, 0.8, and 0.6, respectively.

Chapter 7: Analysis and Design for Operational Availability

7.1 A manufacturing system has seven workstations in series with reliability values of 0.98, 0.95, 0.97, 0.98, 0.95, 0.98, and 0.98, respectively. Calculate the theoretical reliability of the system.
Solution:
- $R_{\text{system}} = 0.98 \times 0.95 \times 0.97 \times 0.98 \times 0.95 \times 0.98 \times 0.98 = 80.7\%$

7.2 A manufacturing system has two parallel subsystems, each with five workstations with a reliability of 0.98. Determine the system's reliability when operating at full capacity (both subsystems working) and at half capacity (only one subsystem working).
Solution:
- $R_A = R_B = 0.98^5 = 90.4\%$
- $R_1 = R_A \times R_B = 81.7\%$ at full capacity
- $R_2 = R_A \times (1 - R_B) + (1 - R_A) \times R_B = 17.4\%$ at half capacity

7.3 A manufacturing system comprises two parallel subsystems and one serial subsystem, each with five workstations, as shown in Figure 7.30. The workstation reliability values in the parallel subsystems *A* and *B* are 0.97, and those in the serial subsystem *C* are 0.98. All subsystems have five workstations. Calculate the system's reliability when operating at full capacity (all subsystems working) and at half capacity (one parallel subsystem working with the serial subsystem). (Refer to Table 7.6 for a parallel system analysis.)

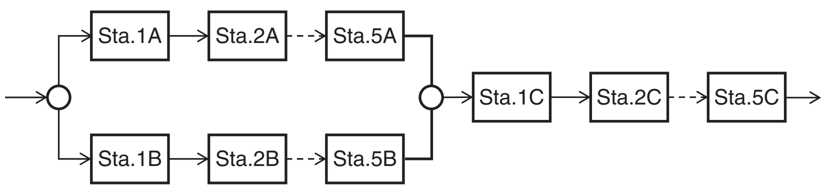


Figure 7.30

Solution:
- $R_A = R_B = 0.97^5 = 85.9\%$

- $R_C = 0.98^5 = 90.4\%$
- $R_1 = R_A \times R_B \times R_C = 66.7\%$ at full capacity
- $R_2 = (R_A \times (1 - R_B) + (1 - R_A) \times R_B) \times R_C = 21.9\%$ at half capacity

7.4 A manufacturing system has seven workstations in series with reliability values of 0.98, 0.96, 0.97, 0.98, 0.95, 0.98, and 0.99, respectively. Identify the workstation most critical to system throughput in production.
Solution:
- $R_{\text{system}} = 0.98 \times 0.96 \times 0.97 \times 0.98 \times 0.95 \times 0.98 \times 0.99 = 82.4\%$
- $I_5 = \frac{R_{\text{sys}}}{R_5} = \frac{82.4\%}{95\%} = 0.868$
- Station 5 has the highest relative importance.

7.5 A process has a reliability of 85% and a gross TR of 80 JPH. If a slow manual backup with a TR of 60 JPH can be designed for the process to improve its reliability, what is the TR of the process with backup over an extended period? What is the TR if the manual back is only 80% reliable?
Solution:
- $\text{TR}_{\text{w backup}} = \text{TR}_{\text{gross}} \times R + \text{TR}_{\text{backup}} \times (1 - R) = 80 \times 85\% + 60 \times (1 - 0.85) = 77.0$ (JPH)
- $\text{TR}_{\text{w backup}} = \text{TR}_{\text{gross}} \times R + \text{TR}_{\text{backup}} \times (1 - R) \times R_{\text{backup}} = 80 \times 85\% + 60 \times (1 - 0.85) \times 80\% = 75.2$ (JPH)

7.6 A process has a reliability of 0.85. To improve its reliability, an identical process is designed as an automated backup with a switch reliability of 0.97 and integrated into the operation. What is the improved reliability of the operation?
Solution:
- $R_{\text{improved}} = R + [(1 - R) \times R_{\text{backup}} \times R_{\text{switch}}] = 0.85 + (1 - 0.85) \times 0.85 \times 0.97 = 97.4\%$

Chapter 8: System Design for Throughput Assurance

8.1 Two lines, linked in series with no buffer between them, have individual throughput rates of 55 and 56 JPH and operational availabilities of 92% and 90%, respectively. Estimate the throughput capacity at the end of the second line.
Solution:
- $\text{TR} = \text{Min}\{\text{TR}_1 \times A_1, \text{TR}_2 \times A_2\} = \text{Min}\{55 \times 0.92, 56 \times 0.90\} = 50.4$ (JPH)

8.2 Two systems have TRs of 55 and 56 JPH and operational availabilities of 92% and 90%, respectively. A buffer between them has impact factors $B_1 = 1.037$ and $B_2 = 1.045$. Estimate the throughput capacity at the end of the second system.
Solution:
- $\text{TR} = \text{Min}\{\text{TR}_1 \times A_1 \times B_1,\ \text{TR}_2 \times A_2 \times B_2\} = \text{Min}\{55 \times 0.92 \times 1.037, 56 \times 0.90 \times 10.45\} = 52.47$ (JPH)

8.3 A manufacturing line has seven workstations with a design CT of 50 seconds. The design CT for each workstation is 45, 42, 47, 50, 38, 40, and 43 seconds, respectively. Calculate the range of workloads for all workstations.

Solution:

- Range = Max{45, 42, 47, 50, 38, 40, 43} – Min{45, 42, 47, 50, 38, 40, 43} = 12 (seconds)
- Range = Max{90.0%, 84.0%, 94.0%, 100.0%, 76.0%, 80.0%, 86.0%} – Min{90.0%, 84.0%, 94.0%, 100.0%, 76.0%, 80.0%, 86.0%} = 24 (percentage points)

8.4 A manufacturing system has six workstations with a required net TR of 60 JPH. The design results are the gross TR and availability for each operation, listed in Table 8.6. Check the projected net TR for each workstation and determine if the system design meets its throughput requirement. What is the net TR range across all operations?

Table 8.6

Workstation	1	2	3	4	5	6
Design gross TR	61	65	64	65	66	62
Availability (%)	99	92	95	93	96	98

Solution:

- Net TR: 60.39, 59.80, 60.80, 60.45, 63.36, and 60.76 for the six workstations, respectively.
- As net TR_2 = 59.80 < 60 (JPH), the design does not meet the requirement.

8.5 The individual availability (reliability) values of workstations in a production line are listed Table 8.7. If the net TR is required to be at least 80 JPH, what is the maximum permissible CT for each workstation? (Hint: calculate required gross TR, then CT)

Table 8.7

Workstation	1	2	3	4	5	6	7	8
Reliability (%)	94	98	97	94	96	95	99	94

Solution:

- Using: gross TR = $\frac{\text{net TR}}{A}$
- Using: CT = $\frac{3600}{\text{gross TR}}$

Workstation	1	2	3	4	5	6	7	8
Gross TR	85.11	81.63	82.47	85.11	83.33	84.21	80.81	85.11
Max CT allowed	42.3	44.1	43.7	42.3	43.2	42.8	44.6	42.3

8.6 A manufacturing system has six workstations with different OEE capabilities, listed in Table 8.8. The design objective for the system is a net TR of at least 60 JPH. To achieve a good balance for the throughput performance, calculate the design CT for each operation.

Table 8.8

Workstation	1	2	3	4	5	6
OEE (%)	93	88	90	89	92	91

Solution:

- Using: gross TR $= \frac{\text{net TR}}{\text{OEE}}$
- Using: CT $= \frac{3600}{\text{Gross TR}}$

Workstation	1	2	3	4	5	6
Gross TR	64.52	68.18	66.67	67.42	65.22	65.93
Target CT	55.8	52.8	54.0	53.4	55.2	54.6