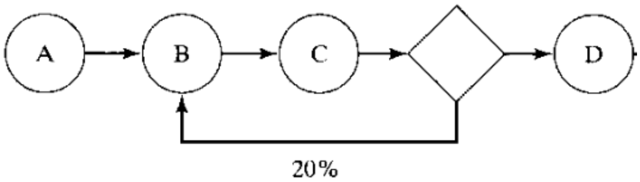
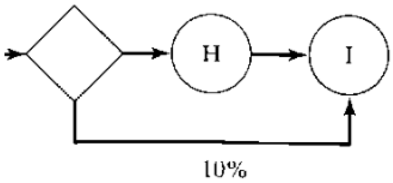
Laguna, M., & Marklund, J. (2013). Business process modelling, simulation, and design. Chapter 5: Managing Process Flows – This book is in the reading list			Book pg no
Lecture 7: Analysing Process Flows		Slide pg no	
Process Throughput	**Process Throughput** ▪ Inflow and Outflow rates typically vary over time (see figure on next slide) – $R_i(t)$ = Arrival/Inflow rate of jobs at time t – $R_o(t)$ = Departure/Outflow rate of finished jobs at time t – IN = Average inflow rate over time – OUT = Average outflow rate over time ▪ A stable system must have IN = OUT = λ – λ = the process flow rate in – λ = the process flow rate out – **λ = process throughput**	9	149
Work-In-Progress	**Work-In-Process ("WIP")** ▪ WIP(t) comprises all jobs that have entered the process but not yet left it – including jobs waiting for the previous batch to be completed ▪ WIP(t) = Work in process at time t – WIP(t) increases when $R_i(t) > R_o(t)$ – WIP(t) decreases when $R_i(t) < R_o(t)$ ▪ WIP = Average work in process over time 	12	150
Cycle Time	**Process Cycle Time** ▪ The difference between a job's departure time and its arrival time = **cycle time** – One of the most important attributes of a process – Also referred to as **throughput time** ▪ The cycle time includes both value adding and non-value adding activity times – Processing time – Inspection time – Transportation time – Storage time – Waiting time ▪ Cycle time is a powerful tool for identifying process improvement potential	16	152
Little's Law Formula	**Little's Formula**: WIP = $\lambda \cdot$CT	17	153
Turnover ratio (Inventory)	**Turnover ratio = 1/CT**	17	153

<table>
<tr><td>Rework</td><td>

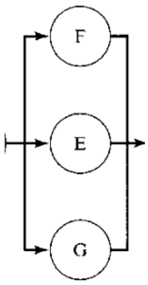
- Assuming a job is never reworked more than once

$CT = (1+r)T$

- Assuming a reworked job is no different than a regular job

$CT = T/(1-r)$</td><td>22</td><td>155</td></tr>
<tr><td>Multiple Paths</td><td>

- Assume that **m** different paths originate from a decision point
  - p_i = The probability that a job is routed to path i
  - T_i = The time to go down path i

$CT = p_1T_1+p_2T_2+\dots+p_mT_m= \sum_{i=1}^{m} p_iT_i$</td><td>28</td><td>156</td></tr>
<tr><td>Parallel Activities</td><td>

- M process segments in parallel
- T_i = Average process time for process segment i to be completed

$CT_{parallel} = Max\{T_1, T_2, \dots, T_M\}$</td><td>31</td><td>157</td></tr>
<tr><td>Cycle Time Efficiency</td><td>$\text{Cycle Time Efficiency} = \dfrac{\text{Theoretical Cycle Time}}{CT}$</td><td>33</td><td>159</td></tr>
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Capacity Needs and Utilization, I	**Step 1 – Calculate unit load for each resource** ▪ The total resource time required to process one job – N_i = Number of jobs flowing through activity i for every new job entering the process – T_i = The processing time for activity i in the current resource – M = Total number of activities using the resource Unit load for Resource = $\sum_{i=1}^{M} N_i \cdot T_i$	42	163
Capacity Needs and Utilization, II	**Step 2 – Calculate the unit capacity** ▪ The number of jobs per time unit that can be processed Unit capacity for resource j = 1 / Unit load for resource j **Step 3 – Determine the resource pool capacity** ▪ A resource pool is a set of identical resources available for use ▪ Pool capacity is the number of jobs per time unit that can be processed – Let M = Number of resources in the pool Pool capacity = M*Unit capacity = M / Unit load	44	163
Capacity Needs and Utilization, III	Capacity is related to resources not to activities! ▪ The process capacity is determined by the **bottleneck** – The bottleneck is the resource or resource pool with the **smallest capacity** (the **slowest** resource in terms of jobs/time unit) – The slowest resource will limit the process throughput **Capacity Utilization** ▪ The theoretical process capacity is obtained by focusing on processing times as opposed to activity times – Delays and waiting times are disregarded $\Rightarrow$ ***The actual process throughput*** $\leq$ ***The theoretical capacity***! $\text{Capacity Utilization} = \frac{\text{Actual Throughput}}{\text{Theoretical Process Capacity}}$	46	164