LECTURE 3
PROCESS ANALYSIS

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WHERE ARE WE

Lecture 1 - 2 Introduction and Operations Strategy

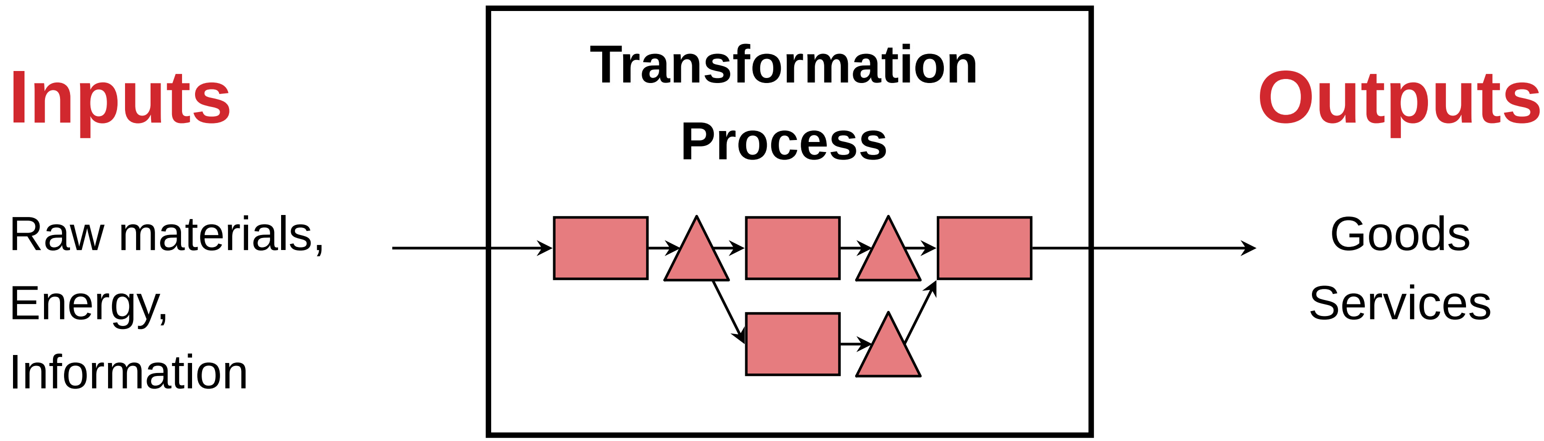
- What is operations management and why study OM
- What is operations strategy
- Competitive dimensions, order qualifiers, order winners
- Tradeoffs, efficient frontiers

Lecture 3 - 6 Process Analysis

LEARNING OBJECTIVES FOR TODAY

- **Basic flow charting of processes**
- **Key measures of a process**
- **Bottleneck analysis**
- **Little's Law**
- **Classification of production (manufacturing) process**
- **Classification of service process**
- **Modeling processes with queuing theory**

PROCESS VIEW OF AN ORGANIZATION



A process is any part of an organization that takes inputs and transform them into outputs that are of greater value to the organization than the original inputs.

EXAMPLES

- **Products**

Honda Motors assembles the Accord in a plant in Marysville, Ohio. The assembly plant takes in parts and components that have been fabricated for the plant.

McDonald's, at each of its restaurants, uses inputs such as hamburger meat, lettuce, tomatoes, and potatoes.

- **Services**

In the hospital, specialized equipment and highly trained doctors, nurses, and technicians are combined with another input, the patient.

The airline uses airplanes, ground equipment, flight crews, ground crews, reservation personnel, and fuel to transport customers between locations all over the world.

WHAT DO WE CARE ABOUT PROCESSES?

- **If you run a fast-food restaurant, you care about how many customers will go by your shop.**
- **If you apply for a mortgage, you care about how many days to take before your application gets approved.**
- **If you run a hospital, you want to know how many beds are required for the inpatients.**

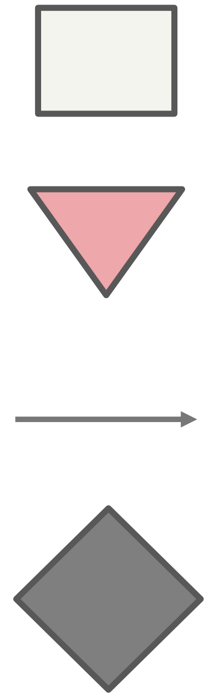
PROCESS FLOW CHARTING

Task/Operations

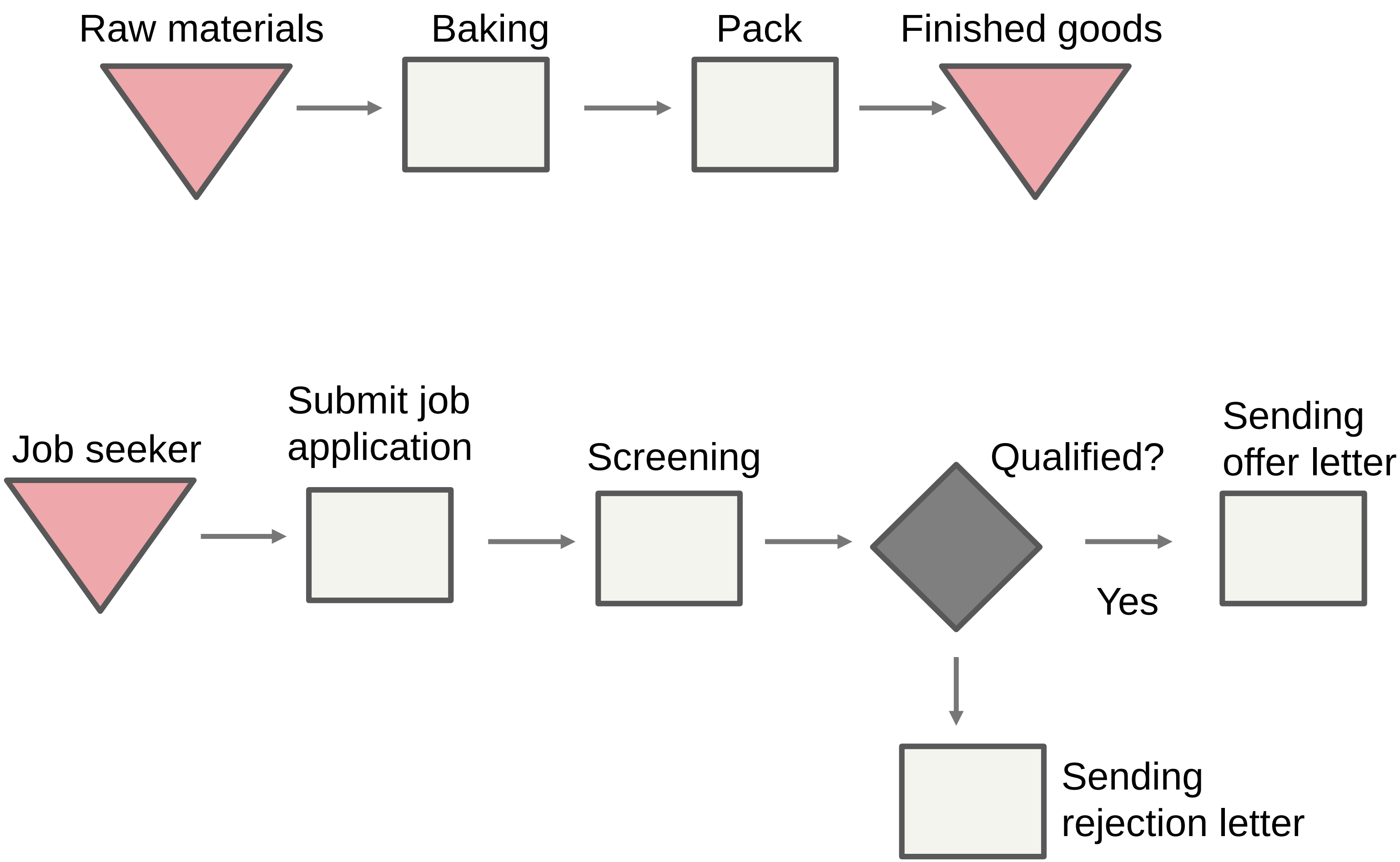
Storage of goods (Inventory)

Flow of goods/customers

Conditional / question

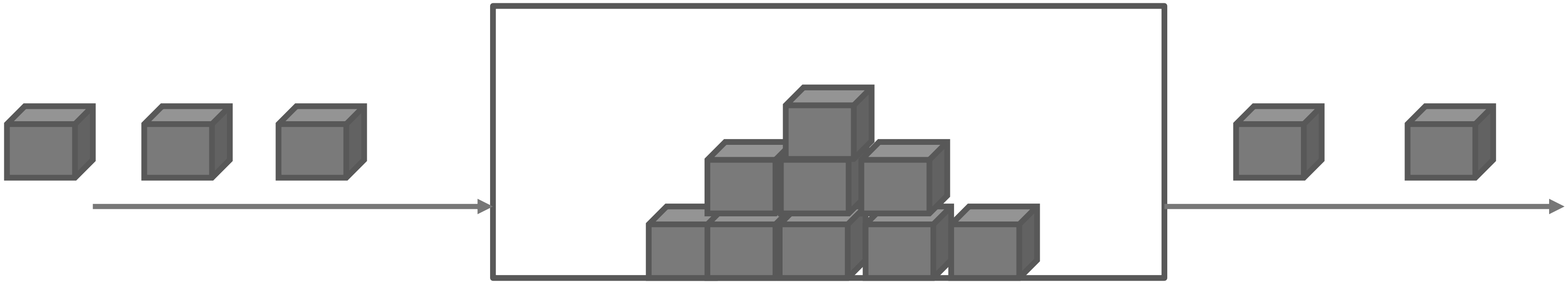


PROCESS FLOW CHARTING



BASIC QUESTIONS OF PROCESS ANALYSIS

- On average, how much time does a typical flow unit spend within process boundaries (flow time)?
- On average, how many units will pass through the process per unit of time (throughput rate)?
- On average, how many units can pass through at most (capacity rate) ?
- On average, how many flow units are within process boundaries at any point in time (inventory)?
- How can we improve the efficiency of a process?



BASIC PROCESS MEASURES

Input rate

- Rate at which inputs are arriving at the system
- e.g., arrival of flights at YYZ, 1200 arrivals/day

Throughput rate

- Rate at which finished products/customers leave
- Also called output rate
- e.g., departure of flights at YYZ, 1200 departures/day

Utilization (ρ)

- Ratio of time a resource is used relative to the time it is available (dimensionless quantity).

$$\rho = \frac{\textit{How often is the resource being used } (\textit{time})}{\textit{Total availability } (\textit{time})}$$

THE PHYSICS OF PROCESS FLOWS

Identify "flow units":

- Cars, sandwiches, passengers (airport security screening)

Flow Times (Time spent in process)

- How long does it take me to produce one product?

Flow Rates

- Capacity: Maximum rate at which units can leave the system
- Input: Rate at which units are arriving to the system
- Output: Rate at which units are leaving the system

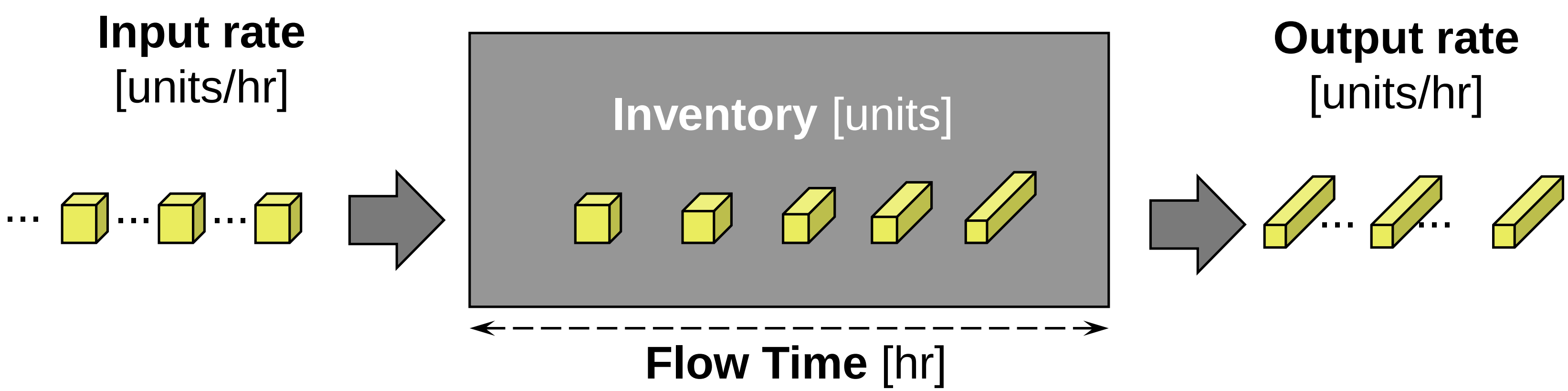
Stocks (Inventory build-up)

- How many units in the system
- e.g. number of customers in a restaurant

BASIC PROCESS MEASURES IN PRODUCTION AND SERVICE OPERATIONS

	Production process	Service process
Flow unit	Materials	Customers
Input rate	Raw material releasing rate (e.g., iron ore)	Customer arrival rate
Output rate	Finished goods output rate	Customers departure rate (service completion rate)
Flow time	Time required to turn materials into a product	Time that a customer is being served
Inventory	Amount of work-in-process	Number of customers being served
Capacity (rate)	Maximum output rate	Maximum service completion rate

SINGLE STAGE, SINGLE MACHINE/SERVER



- **Capacity of the whole process** = 1 / FlowTime ***[units/hr]***
  - Only for single stage, capacity of a stage = capacity of the whole process
  - The maximum possible output rate that can be achieved.

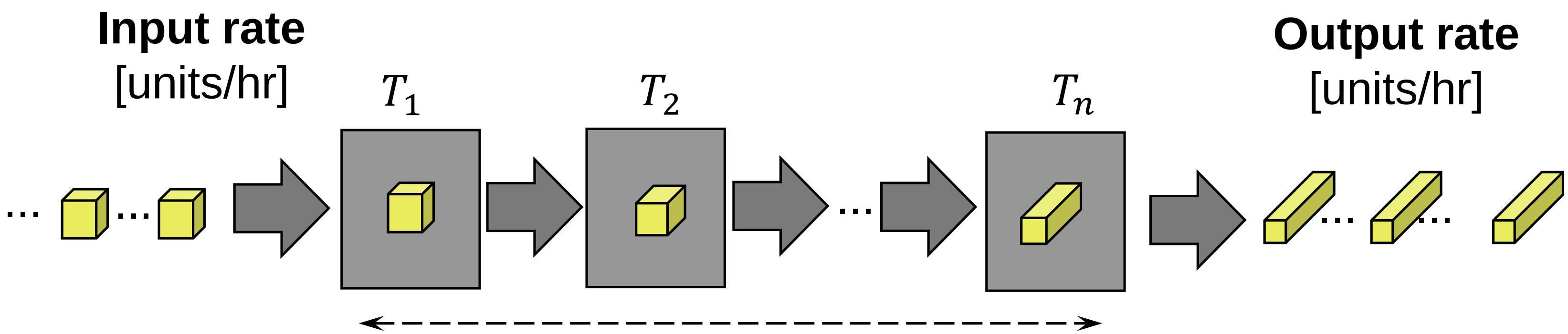
- **Output rate** = *min{Input Rate, Capacity}*
  - In the long run. Also called the ***throughput*** rate.

- **Utilization** = Throughput Rate / Capacity

  = *min{Input Rate, Capacity} / Capacity*

  = *min{Input Rate / Capacity, 1}*

MULTIPLE STAGES, SINGLE SERVER/STAGE



Flow Time $= T_1 + T_2 + \cdots + T_n$ [hr]

- **Capacity of the whole process**
- = 1 / $max\{T_1, T_2 \cdots, T_n\} = \min\{1/T_1, 1/T_2 \cdots, 1/T_n\}$**[units/hr]**
  - The maximum possible output rate that can be achieved

- **Output rate** = $\min$ {Input Rate, Capacity}
  - In the long run
  - Also called the ***throughput*** rate
  - Cycle time = 1 / throughput rate

- **Utilization of Stage n** = Throughput Rate / Capacity of Stage n
  = Throughput Rate · T_n

PROCESS EXAMPLE (1)

Consider the process of making cakes:

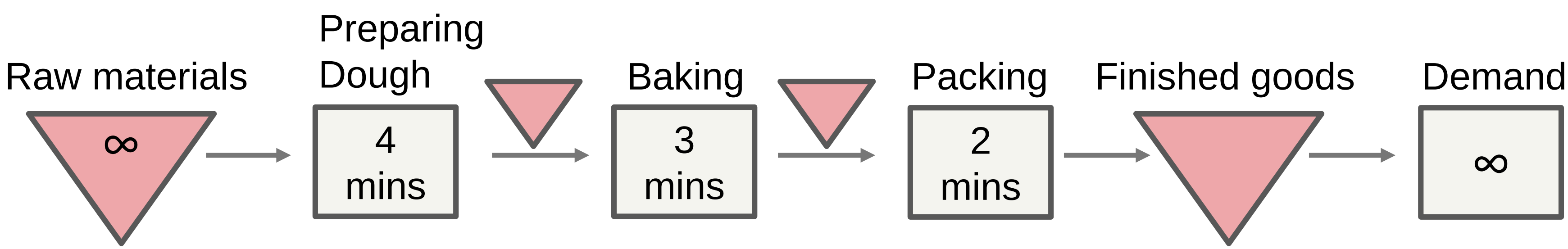
(1) First we need to prepare the dough (生面团) (4 mins)

(2) After that, we need to bake (3 mins)

(3) After that, we need to pack (2 mins)

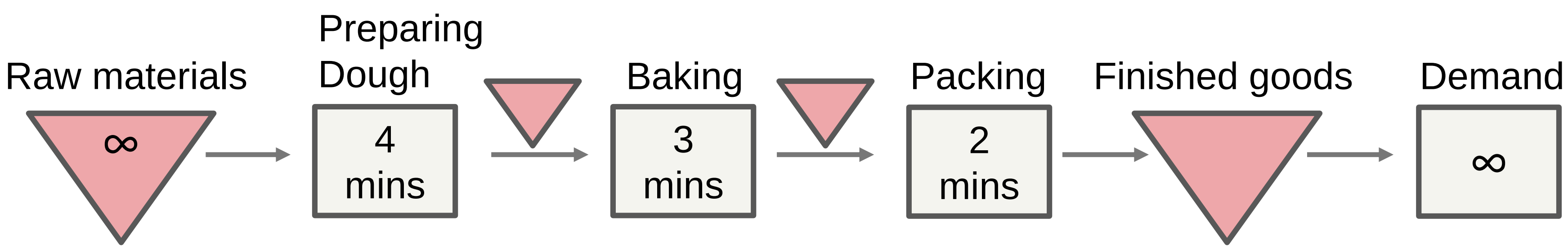
Assume that for each step, there is one worker doing the job

PROCESS ANALYSIS



- **How much time to make one cake (flow time) ?** **9 mins**
- **How many cakes can we make per hour (capacity rate of the process, or throughput rate) ?** **15 / hour**
- **How much time between completion of two units? (cycle time)** **4 mins**
  - Cycle time = 1 / throughput rate

PROCESS ANALYSIS

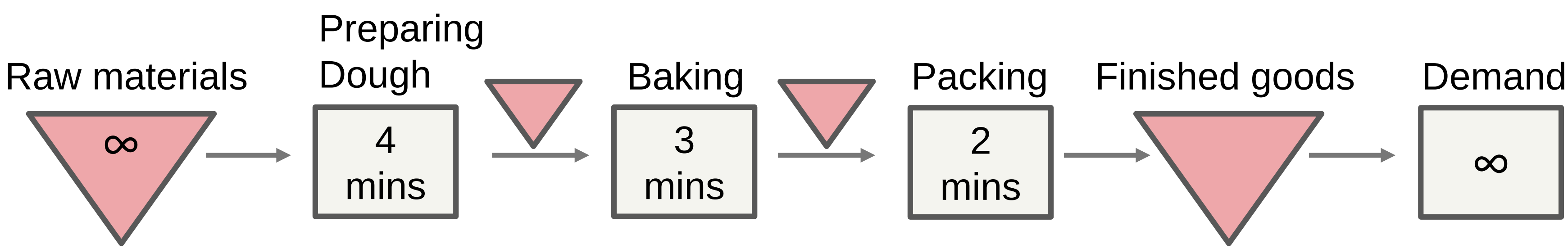


- **Which step determine the speed of the whole process?**

Preparing the dough

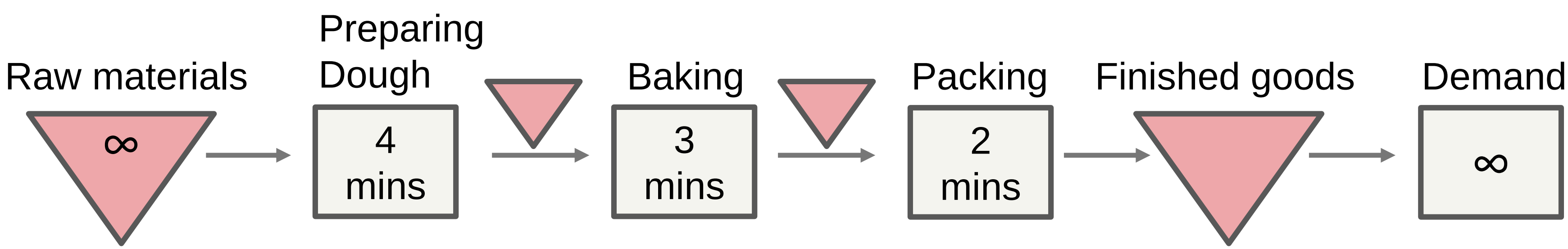
  - We call this step the bottleneck
- **What shall we do if we want to improve the overall efficiency of the process?**

PROCESS ANALYSIS



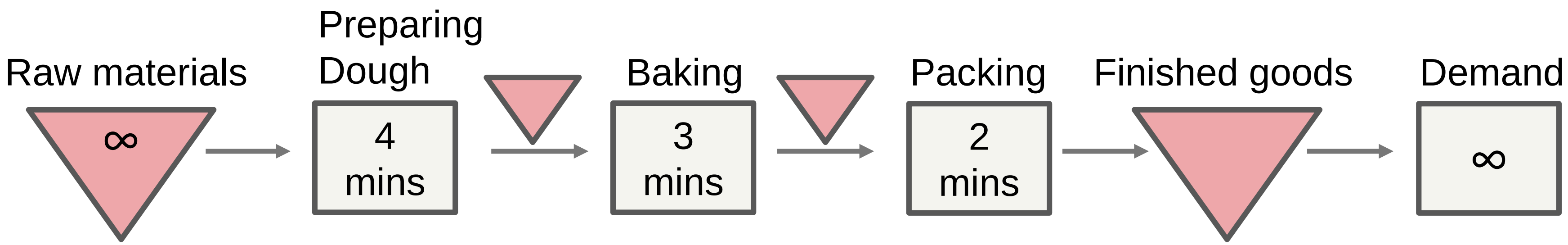
- **Utilization rate is the percentage of the time that one stage is busy**
  - Utilization rate = time activated / time available
  - What are the utilizations for the guys at the three stages?

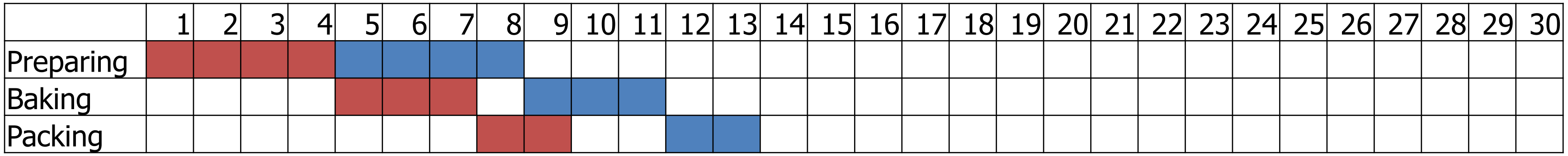
PROCESS ANALYSIS – GANTT CHART



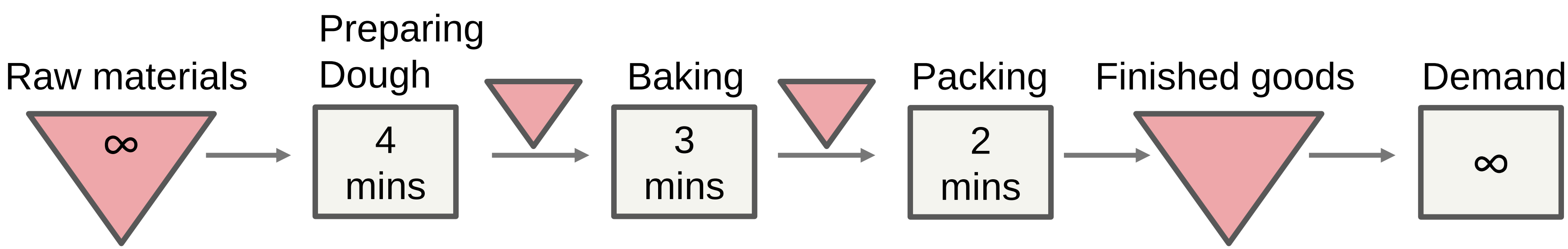
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Preparing																														
Baking																														
Packing																														

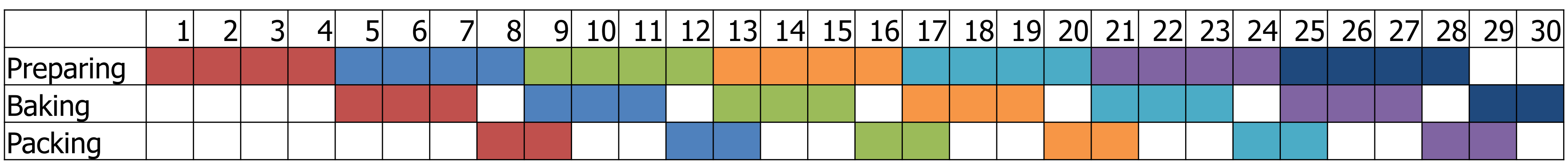
PROCESS ANALYSIS – GANTT CHART





PROCESS ANALYSIS – GANTT CHART

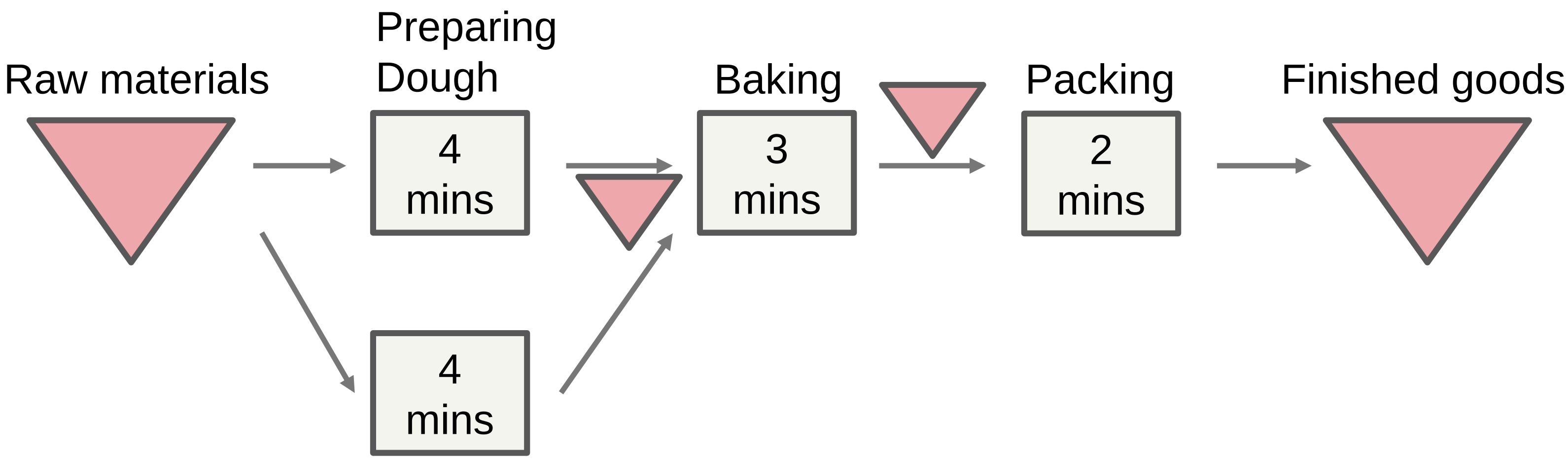




Flow time = 9 min
Cycle time = 4 min
Throughput = 15 / hour

Utilization of Prep station = 100%
Utilization of Baking station = 75%
Utilization of Packing = 50%
Average utilization = (100% + 75% + 50%) /3 = 75%

PROCESS ANALYSIS



- **What will happen if we add an additional worker at the first stage?**
  - Flow time, throughput, cycle time, utilization?
  - Flow time = 9 mins
  - Throughput rate = 20/hr
  - Cycle time = 3 mins
  - Utilization = 2/3, 1, 2/3
  - Average Utilization = (2/3*2+1+2/3)/4 = 75%

PROCESS EXAMPLE (2)

Consider the process of going to the hospital:

(1) First we need to triage(1 mins)

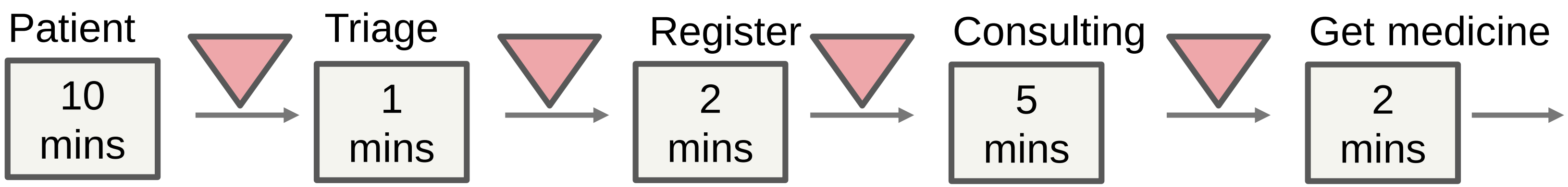
(2) After that, we need to register (2 mins)

(3) After that, we need to consult the doctor (5 mins)

(4) After that, we need to collect the medicine (2 mins)

Assume that for each step, there is one worker doing the job, and one worker can only work for one patient at the same time

PROCESS ANALYSIS



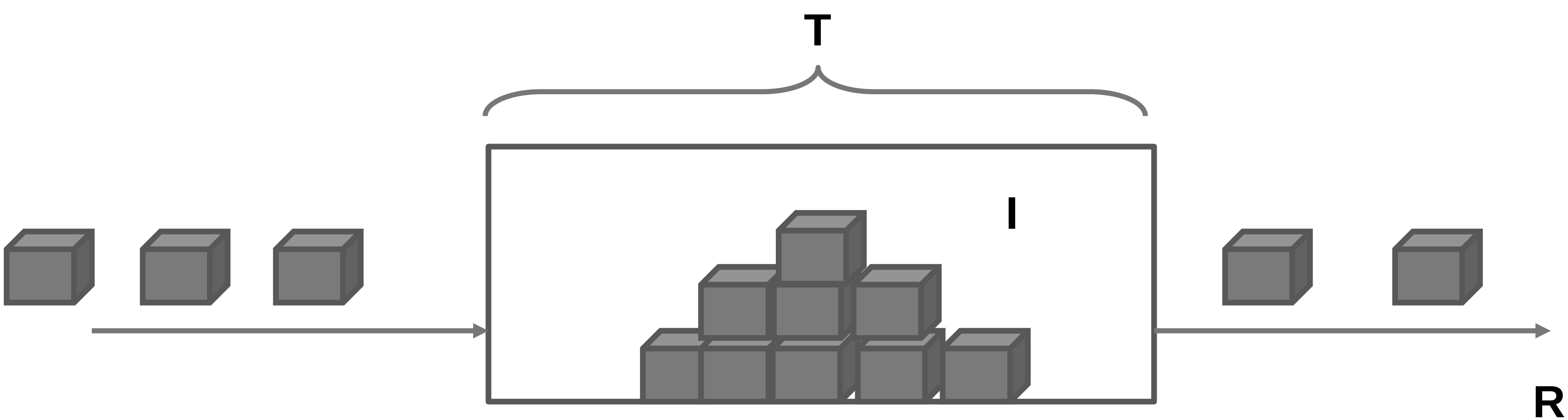
- **How much time for one patient to complete the whole process(flow time) ?** **10 mins**
- **What is the throughput?** **6 / hour**
- **How much time between completion of two units? (cycle time)** **10 mins**
    - Cycle time = 1 / throughput rate
- **What is the capacity rate of this hospital?** **12 / hour**
- **What if 1 patient comes every minute?**

STARVING AND BLOCKING

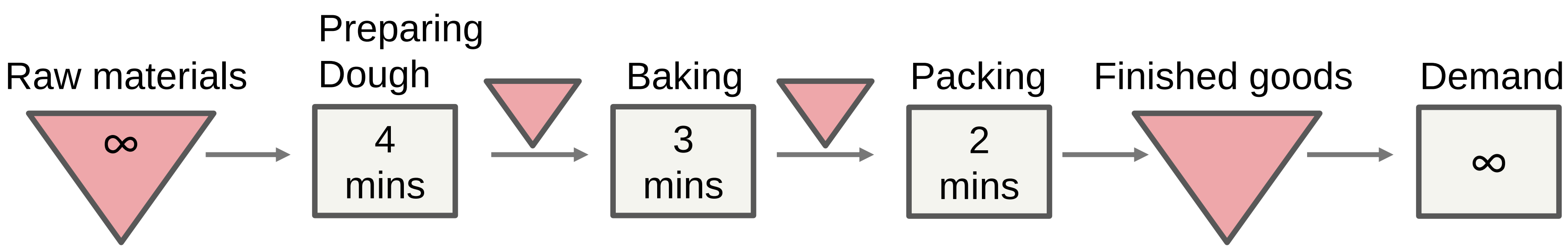
- **Starving** occurs when the activities in a stage must stop because there is no work
- **Blocking** occurs when the activities in the stage must stop because there is no place to deposit the item just completed

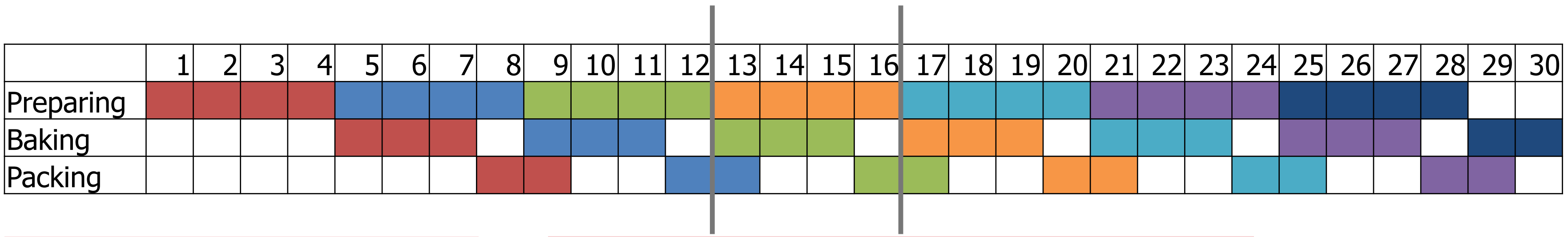
LITTLE'S LAW

- **It relates three important measures:**
  - **Inventory**: How many units are within the boundary of the process
  - **Throughput** : How many units are flowing through the process per unit of time
  - **Flow time**: How much time is needed for one unit to flow through the process
  - Works only when the process is **stable**
- **Inventory (I) = Throughput (R) x Flow time (T)**



LITTLE'S LAW

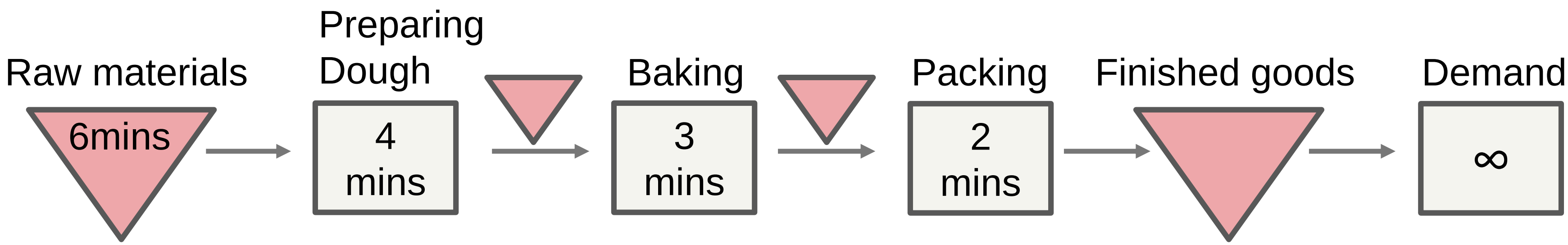


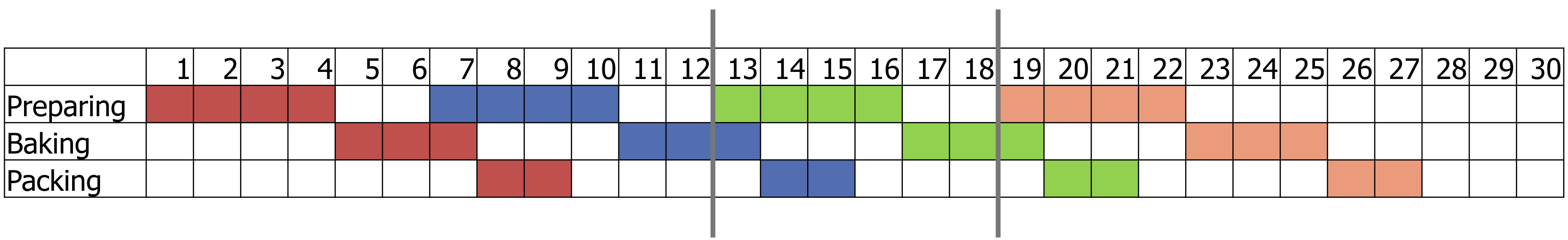


Flow time = 9 min
Cycle time = 4 min
Throughput = 15 / hour

Inventory = Flow time * Throughput
= 9 min * 15 / hour
= 9 / 60 hour * 15 / hour
= 2.25

LITTLE'S LAW





Flow time = 9 min
Throughput = 10 / hour

Inventory = Flow time * Throughput
= 9 min * 10 / hour
= 9 / 60 hour * 10 / hour
= 1.5

LITTLE'S LAW EXAMPLE

Job Flow: The Travelers Insurance Company processes 10,000 claims per year. The average processing time is 3 weeks. Assuming 50 weeks in a year, what is the average number of claims "in process?"

Answer: 600

Cash Flow: Motorola sells $300 million worth of cellular equipment per year. The average accounts receivable in the cellular group is $45 million. What is the average billing to collection process cycle time?

Answer: 0.15 year

LITTLE'S LAW EXAMPLE

Customer Flow: The above fast-food restaurant processes on average 1,500 customers per day (15 hours). On average there are 75 customers in the restaurant (waiting to place the order, waiting for the order to arrive, eating etc.). How long does an average customer spend at the restaurant?

Answer: 45 min

LITTLE'S LAW EXAMPLE

The birth rate for the local hospital is about 5 births per day. 90% of the mothers stay in the hospital for 2 days and 10% of the mothers stay in the hospital for 7 days. If one nurse can take care of 3 mothers at the same time. How many nurses do we need on average?

Solution: The average stay time (flow time) = 2 x 90% + 7 x 10% = 2.5 days, Throughput = 5 births per day. So the average number of mothers staying in the hospital = 2.5 x 5 = 12.5. So we need 12.5 / 3 = 4.2 nurses on average

LITTLE'S LAW EXAMPLE

Can you give a rough estimation of how many people are born each year in the world?

LITTLE'S LAW

Assume birth-death is stable

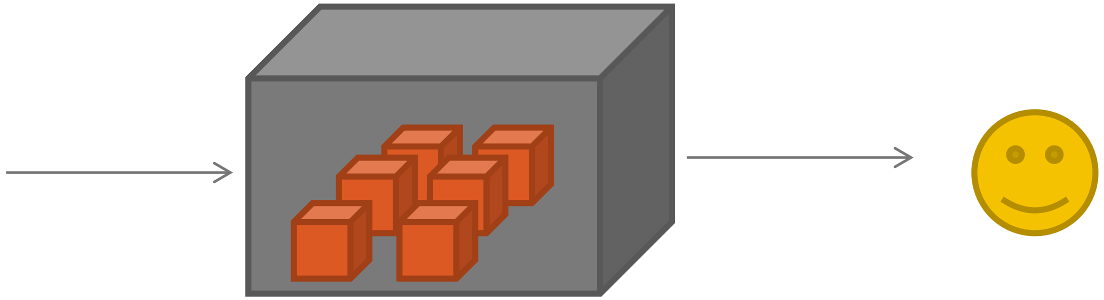
World population = 7 billion (Inventory)

Average life span = 70 years (flow time)

Throughput = 7 billion / 70 years = 100 million per year

INVENTORY MEASURES

The process of retailing:



- The retailers often keeps inventory to meet customer demand
- However, the inventory often occupy a lot of capital and will cause a loss in terms of opportunity cost
- It is crucial for the retailer to keep an inventory as low as possible

INVENTORY MEASURES

Inventory sometimes is measured in

- **Inventory turnover （存货周转率） = Throughput / Inventory = 1 / Flow time**
  - Throughput = 1000 units per year, Inventory = 10 units
  - Inventory turnover = 1000 / 10 = 100 (turns)
- **Days of Supply = Inventory / Throughput (per year) * 365**

  = Inventory / Throughput (per day)

  = Flow time (in days)

  Days of Supply = 10 / 1000 * 365 = 3.65 days

TURNS AND DAYS-OF-SUPPLY AT WAL-MART IN 2010*

Walmart

I **= Inventory = $33,160**

R **= COGS = $304,657**

** All figures in $Million from 2010 balance sheet and income statement*

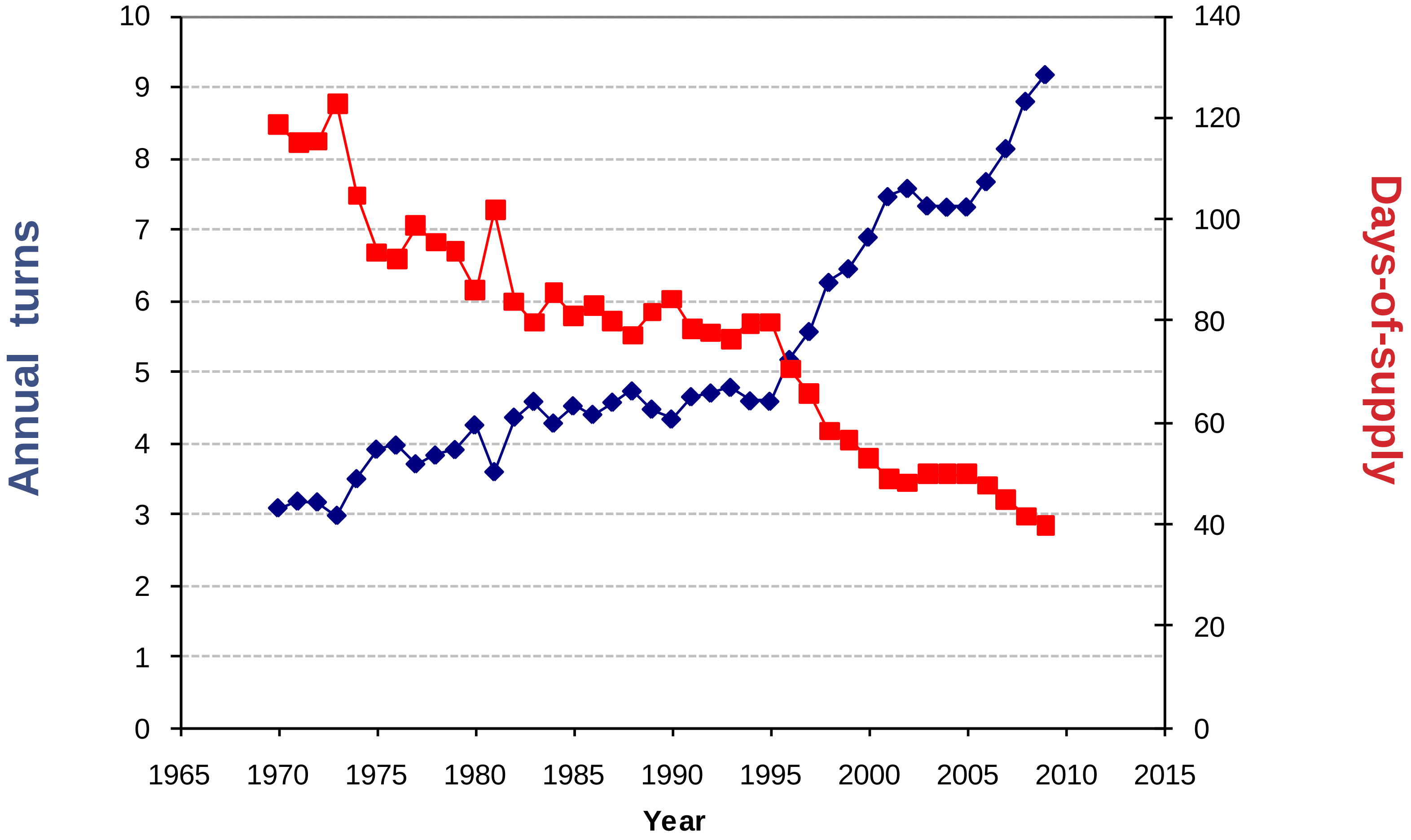
COGS = Cost of Goods Sold = Flow Rate

- The Flow Rate is <u>not</u> Sales (which was $405,046) because inventory is measured in the cost to purchase goods, not in the sales revenue that may be earned from the goods.
- Note: Some companies use the term “Cost of sales” to mean COGS

Annual turns = $304,657 / $33,160 = 9.19

Days-of-supply = $33,160 / $304,657 * 365 = 39.7

WAL-MART'S TURNS CHANGE FROM YEAR TO YEAR



PROCESS FLOW TIME REDUCTION

Perform the activities in parallel

A classic example is product development, where the current trend is toward concurrent engineering. Instead of forming a concept, making drawings, creating a bill of materials, and mapping processes, all activities are performed in parallel by integrated teams. Development time is reduced dramatically, and the needs of all those involved are addressed during the development process.

Change the sequence of activities

Documents and products are often transported back and forth between machines, departments, buildings, and so forth. For instance, an item might be transferred between two machines a number of times for fabrication and inspection. If the process can be streamlined, it may be possible to perform all of the fabrication before the inspection, thus eliminating the waiting associated with the back and forth transfer.

Coordination between steps

Get the customers involved

SOMETIMES WE DO NOT WANT TO REDUCE FLOW TIME

The coffee shop owner agreed that it was indeed his goal to make more money at the shop. Further, he explained that the consultant needs to understand that it is during this pause provided while waiting in line and prior to pouring coffee that patrons peer into the pastry case, and decide they want a coffee and a pastry! The consultant was amazed at the coffee shop owners perfect logic and very effective process.

SUMMARY

- **Process Flow-charting**
- **Performance measures of processes**
  - Flow time, throughput, cycle time, capacity rate
- **Little's Law (when the process is stable)**
  - Inventory = Throughput x Flow time
- **Process Flow time reduction**