Operations Management 1st edition Cachon Solutions Manual

SKU: 9781259142208-SOLUTIONS

CHAPTER 2

INTRODUCTION TO PROCESSES

CONCEPTUAL QUESTIONS

1.

Answer: **C. Number of customers.**

Feedback: The number of workers, cash registers, and suppliers are unlikely to change much over the course of a month and do not "flow" through the process of the hardware store.

2.

Answer: **D. The number of patients.**

Feedback: Physicians, beds, and square footage are unlikely to change much over the course of a month and do not "flow" through the process of a hospital.

3.

Answer: **The flow rate is 1,000 passengers per day and the flow time is 5 days.**

4.

Answer: **The inventory is 15 voters.**

Feedback: The flow rate is 1,800 / 10 = 180 per hour, or 180 / 60 = 3 per minute. The flow time is 5 minutes.

5.

Answer: **B.**

Feedback: The flow rate into a process must equal the flow rate out of a process.

6.

Answer: **False.**

Feedback: Little's Law applies even if there are fluctuations in inventory, flow rates, and flow times.

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PROBLEMS AND APPLICATIONS

1.

Answer: **D.**

Feedback: The number of customers is the appropriate flow unit for process analysis. The employees are resources, and the other two measures are unlikely to change from week to week.

2.

Answer: **B.**

Feedback: The number of tax returns completed each week reflects the main operation of the accounting firm during tax season. The accountants are resources; the customers with past-due invoices reflect the accounts receivable process and not the main operation; and the reams of paper received are a result of the firm's purchasing policies and not necessarily the main operation.

3.

Answer: **A and D are correct**

Feedback: The gasoline pumps and employees are resources, not flow units.

4.

Answer: **0.4 callers per minute**

Feedback: 8 calls divided by 20 minutes = 0.4 calls per minute.

5.

Answer: **4 minutes**

Feedback: To calculate the flow time of the callers, subtract the callers departure time from his or her arrival time. 32 total minutes divided by 8 callers = 4 minutes.

6.

Answer: **0.1667 customers per minute**

Feedback: Flow rate = 10 customers divided by 60 minutes = 0.1167.

7.

Answer: **8.6 minutes**

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Feedback: To calculate the flow time of the customers, subtract the customers departure time from his or her arrival time. 86 total minutes divided by 10 customers = 8.6 minutes.

8.

Answer: **4 minutes**

Feedback: To solve this problem, use Little's Law. Inventory = Flow rate × Flow time.
10 people in line (average inventory) = 2.5 flow rate x flow time
Flow time = 4 minutes
The flow rate is 300 customers divided by 120 minutes = 2.5

9.

Answer: **90,000 wafers**

Feedback: 100 per second x 60 seconds per minute x 15 minutes = 90,000

10.

Answer: **360 skiers**

Feedback: 1,800 skiers divided by 60 minutes per hour (flow rate) x 12 minutes (flow time) = 360 skiers

11.

Answer: **8,539 visitors**

Feedback: Flow rate = 3,400,000 visitors divided by 365 days = 9,315.07 visitors per day

Flow Rate = 22 hours/ 24 hours per day = .9167 day

Inventory = 9,315.07 (flow rate) x 0.9167 (flow time) = 8539.12 visitors per day

12.

Answer: **900,000 patients**

Feedback: 6 months (flow time) x 150,000 new patients per month = 900,000 patients

13.

Answer: **20 chat sessions**

Feedback: Flow rate = 240 chats divided by 30 employees = 8

Flow time = 5 minutes divided by 60 minutes = 0.833 hour

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Inventory = Flow Rate x Flow Time, 8 x 0.833= 0.6667 x 30 employees = 20 chats

14.

Answer: **840 units**

Feedback: 4,200 units divided by (12 minutes/60 minutes) = 840 units

15.

Answer: **120 skiers**

Feedback: 1,200 beds divided by 10 days = 120 new skiers per day.

16.

Answer: **7.5 minutes**

Feedback: To solve this problem, use Little's Law. Inventory = Flow rate × Flow time. 30 people in line (average inventory) = 240 customers/ 60 minutes (flow rate) x flow time. Flow time = 7.5 minutes

17.

Answer: **8 years**

Feedback: 120 associates = 15 new employees x flow time. Flow time = 8

CASE

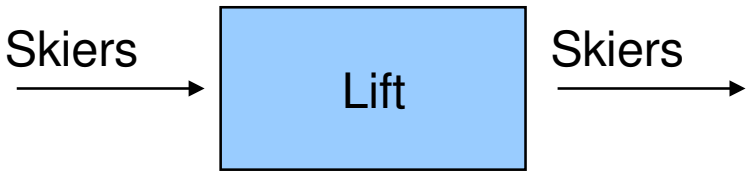
Although the analysis of the case is relatively simple, the intuition is not always easy to grasp – many students will intuitively believe that the capacity of the faster lift should be greater than the capacity of the slower lift. The main lesson in this case is to get students to understand why that intuition is not correct.

To begin the case discussion, ask the students their opinion as to who is correct, Mark (unloading capacity should be twice as high on the detachable lift) or Doug (the unloading capacity should be the same on the two lifts). Hopefully there are students who support each opinion.

To resolve the question, begin with the simple process flow diagram:

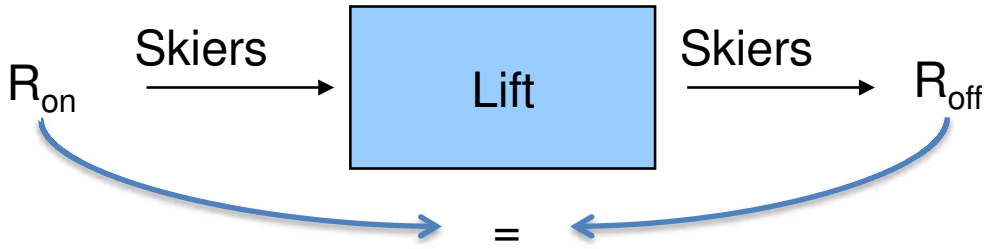
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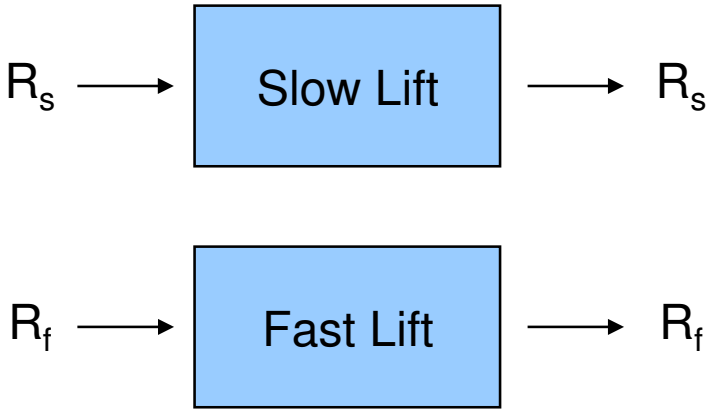


Ask the question "Do all of the skiers that get on the lift at the bottom get off the lift at the top?" Of course, the answer is "We would hope so!". So "What does that mean about how the rate of skiers getting on the lift, R_{on}, is related to the rate of skiers getting off the lift, R_{off}?" And the answer there must be that they are equal! If the rate on where faster than the rate off, the number of people on the lift would grow and grow and grow. We know that can't happen. Similarly, if the rate off exceeded the rate on, then the number of people on the lift would shrink and shrink and shrink, leaving the lift eventually with nobody. Which also doesn't happen.

So we can add to our process flow diagram:



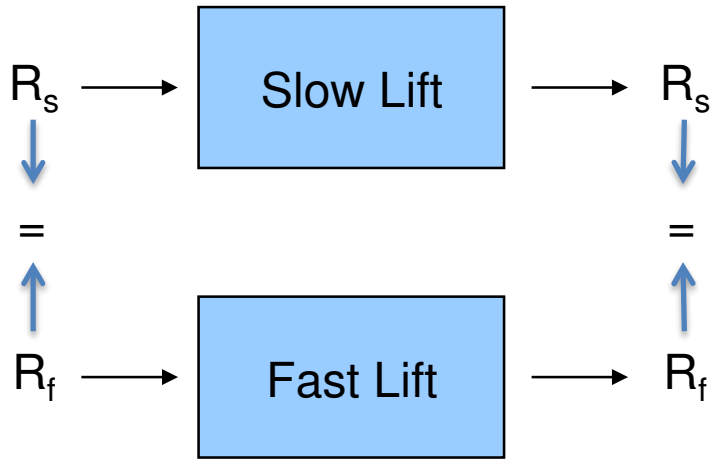
Now it is time to compare the two lifts. We can draw the process flow for each of them, emphasizing that the rate on for each must equal the rate off:



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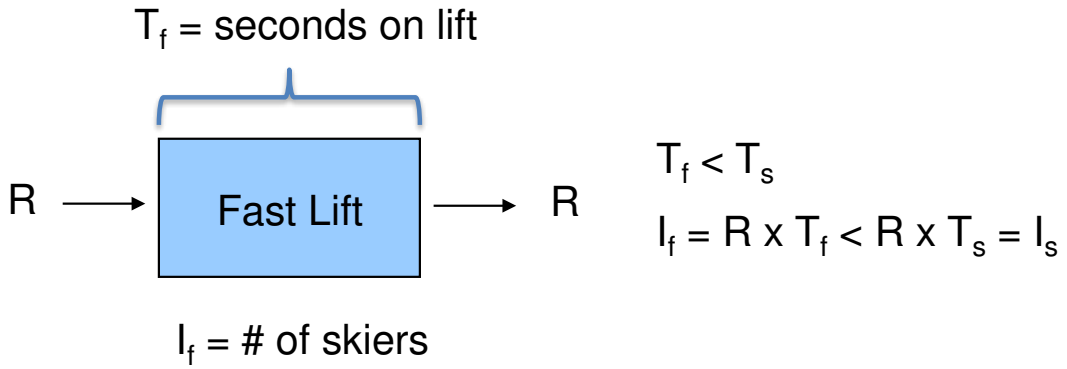
Now ask students "How can we compare the rates across the two types of lifts?" The answer is given in the case – we are told that the rate skiers load onto the slow (fixed grip) lift is the same as the rate they load onto the fast (detachable) lift. That means that $R_s = R_f$. And that means that the rates that they onload skiers at the top must be the same!



Thus, Doug is correct – both lifts have the same capacity to unload skiers at the top even though one is faster than the other.

And this brings us to Jessica's question – so what is the difference between the two lifts? If you ask students this question, the likely first response is that skiers spend less time on the faster lift. And that is correct. But are there other differences? Actually, there are two additional differences worth mentioning. The first comes from Little's Law and the 2nd one requires a deeper understanding of this process.

The first obvious difference is the number of skiers on the lift. According to Little's Law, I = R x T. So if the two lifts have the same R, but the faster lift has a smaller T, then the faster lift must have a smaller I as well:



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So fewer people are on the faster lift and they spend less time on the lift but the faster lift and the slower lift bring skiers to the top at the same rate.

If students can't get the next difference between the two lifts, then you can prompt them with the following question "If the faster lift has fewer skiers than the slower lift, then where are the additional skiers?" Or put another way: "If the ski area attracts a certain number of skiers but the faster lift has fewer skiers on it, then where are the other skiers?" The answer is that they are on the slopes! That means that adding a faster lift takes skiers off the lift but they don't disappear. Instead, they are on the only other place they can be, the slopes. Which means, somewhat counter-intuitively, that adding a faster lift makes the slopes more crowded (holding the total number of skiers fixed).

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Chapter 2 – Teaching Plan

Introduction to Processes

Specific Learning objectives

LO2 - 1: Identify an appropriate flow unit for a process

LO2 - 2: Distinguish among the three key process metrics (flow rate, flow time and inventory) and evaluate average flow rate and flow time from departure and arrival data.

LO2 - 3: Use Little's law to evaluate the three key process metrics

What Students Learn in this Chapter

Operations management is largely about managing processes. Hence, the goal of this chapter is to start students thinking in terms of processes. We begin with the basic definitions of a process and its components (e.g., a resource, a flow unit, etc.). Next, we introduce three key process metrics: inventory, flow rate and flow time. Not only will we use these metrics in this chapter, they will appear in many of the subsequent chapters. Finally, we explain how these three metrics are linked, via Little's Law. The relationship I = R x T is relatively simple to understand but very powerful for understanding processes. In particular, it emphasizes that operations is often about tradeoffs. For example, if inventory is increased (to give better availability to customers) then so will flow time.

Many examples are used in the chapter. In one, students are shown a table of departure and arrival times for patients to the Interventional Radiology unit. With those data we are able to demonstrate several of the key process metrics, thereby linking plausible and realistic data to actual process analysis.

Relationship to other Chapters

The chapter is the foundation for the other chapters that directly deal with processes: Process Analysis (Chapter 3), Process Improvement (Chapter 4), Process Analysis with Multiple Flow Units (Chapter 5), and Process Interruptions (Chapter 7). The issues and methods in this chapter are also relevant for Introduction to Inventory Management (Chapter 10), Supply Chain Management (Chapter 12), Inventory Management with Steady Demand (Chapter 12), Inventory Management with Frequent Orders (Chapter 13), Service Systems with Patient Customers (Chapter 16) and Service Systems with Impatient Customers (Chapter 17).

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Proposed Time Line

A lecture can be used to introduce this material to students but then it is probably best to have them do some hands on exercises to become comfortable with the ideas. Better yet would be to intersperse these exercises between sections of the lecture. For instance, give students the example of a process and ask them to define an appropriate flow unit, or to evaluate average inventory, etc. Through a series of examples (which could also be taken from the solved problems in the chapter), students begin to see the power of a process view and especially of Little's Law. The class can close (say 20 minutes) with a discussion of the chapter's mini case. The case is seemingly simple when in fact it isn't – the "answer" is not intuitive to most students.

Students should be able to master this material over a single 80 min session. If you have advanced students, this session could be combined with the material in the Introduction to Inventory Management chapter.

Potential cases / Exercises / Props

Besides the mini-case in this chapter, most cases and exercises will cover more material than in this chapter. For example, the "snowflake" exercise allows students to use the material in this chapter plus the Process Analysis (Chapter 3) and Process Improvement (Chapter 4) chapters.

Teaching suggestions for the mini-case

This case:

- Requires students to apply Little's Law
- Tests their understanding of the difference between processing time and process rate.
- Reinforces the concept that the average output of a process must equal its average input.

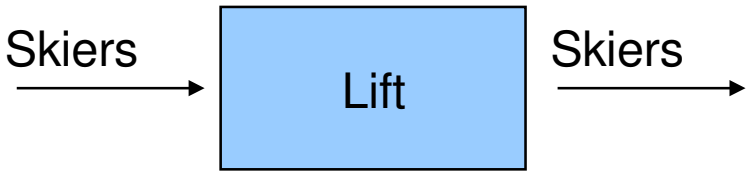
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To begin the case discussion, ask the students their opinion as to who is correct, Mark (unloading capacity should be twice as high on the detachable lift) or Doug (the unloading capacity should be the same on the two lifts). Hopefully there are students who support each opinion.

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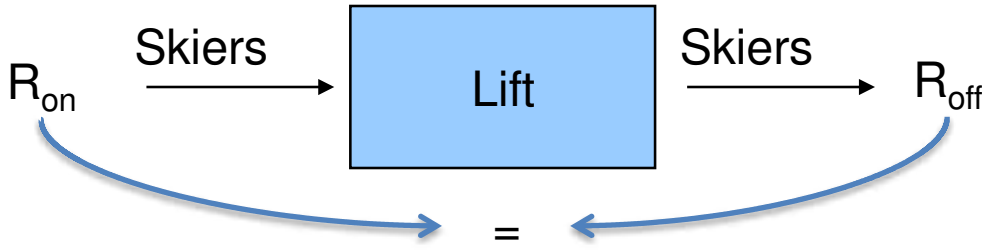
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To resolve the question, begin with the simple process flow diagram:



Ask the question "Do all of the skiers that get on the lift at the bottom get off the lift at the top?" Of course, the answer is "We would hope so!". So "What does that mean about how the rate of skiers getting on the lift, R_{on}, is related to the rate of skiers getting off the lift, R_{off}?" And the answer there must be that they are equal! If the rate on where faster than the rate off, the number of people on the lift would grow and grow and grow. We know that can't happen. Similarly, if the rate off exceeded the rate on, then the number of people on the lift would shrink and shrink and shrink, leaving the lift eventually with nobody. Which also doesn't happen.

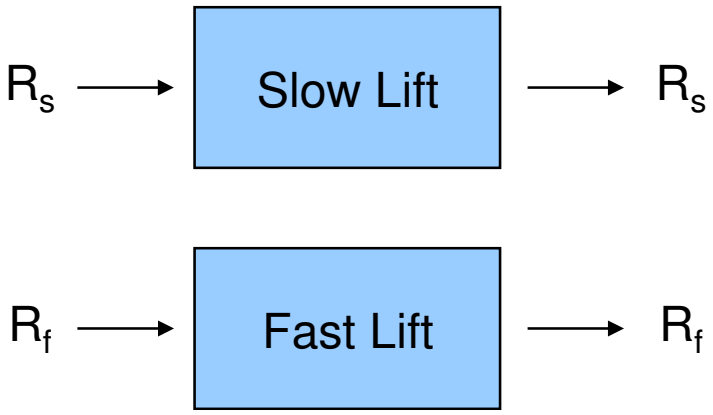
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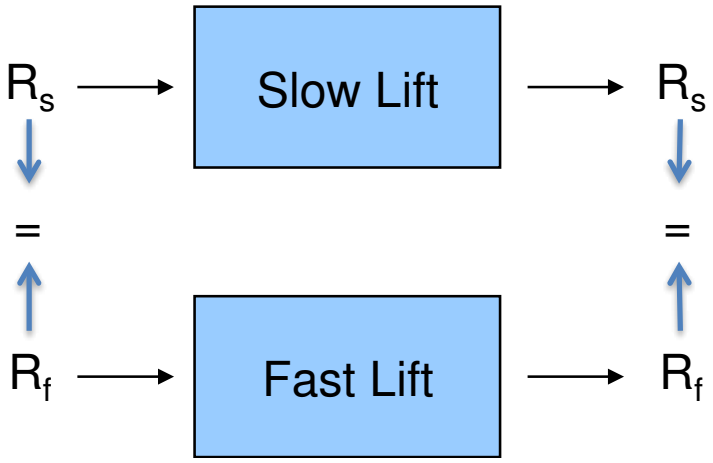
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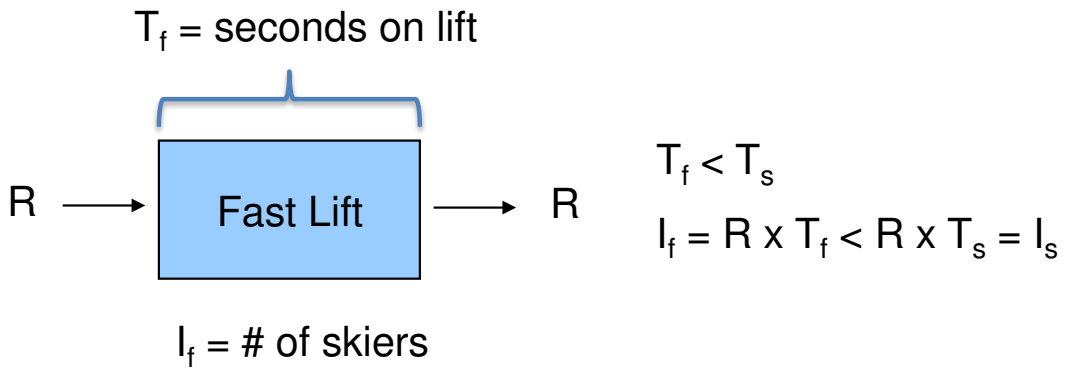
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Chapter 2

Introduction to Processes

Operations Management, 1st Edition

Gerard Cachon and Christian Terwiesch

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Chapter Learning Objectives

Learning Objectives for Chapter Two

- **LO2-1.** Identify an appropriate flow unit for a process
- **LO2-2.** Distinguish among the three key process metrics and evaluate average flow rate and flow rate time from departure and arrival time
- **LO2-3.** Use Little's Law to evaluate the three key process metrics.

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Introduction

You cannot manage what you cannot measure

If you do not know how to measure a process then it is difficult to know how to improve a process.

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Process Definition, Scope, and Flow Units
LO2-1

What should the manager measure to determine if the process is performing well?

- **Process** – A set of activities that take a collection of inputs, perform some work or activities with those inputs, and then yield a set of output

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Process Definition, Scope, and Flow Units

Managers face the same question everyday

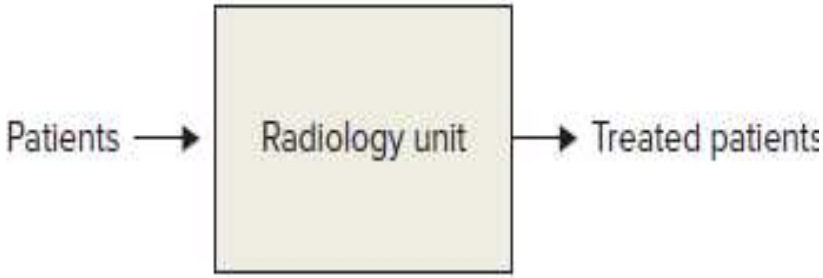
- Is the process performing well?
- How can we make the process better?
  - The first step measure the performance of the employees
  - Need a plan for making those employees better at what they do

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Process Definition, Scope, and Flow Units

- Process Flow Diagram
  - Resources – group of people/equipment that transforms inputs into outputs (See figure 2.1)

Figure 2.1
A simple process flow diagram of the radiology unit at Presbyterian Hospital



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Process Definition, Scope, and Flow Units

Process – A set of activities that take a collection of inputs, perform some work or activities with those inputs, perform some work or activities with those inputs, and then yield a set of outputs

Process flow diagram – A graphical way to describe the process. It uses boxes to depict resources, arrows to depict flows, and triangles to depict inventory location.

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Process Definition, Scope, and Flow Units

- **Process Scope** – The set of activities and processes included in the process

- **Flow Unit** – the basic unit that moves through a process.

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Check Your Understanding

Which of the following is an appropriate flow unit for a roller coaster at an amusement park?

A . Seats on the roller coaster.

B. Riders.

C . Employees.

D . Miles per hour (as in the speed of the roller coaster).

E . Operating time (as in the number of hours operated per day).

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Check Your Understanding
Answer

The correct answer is?

B

Explain…

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Rules to Define Flow Unit

1. Choose flow unit that corresponds to what you want to track and measure (with respect to the process).

2. Stick with the flow unit you define.

3. Choose a flow unit that can be used to measure and describe all of the activities within the process.

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Key Process Metrics
LO2-2

Process Metric – something we can measure that informs us about the performance and capability of a process.

1. **Inventory** – number of units within a process.
2. **Flow Rate** – the rate at which flow units travel through a process.
3. **Flow time** – the time a flow unit spends in a process, from start to finish.

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Key Process Metrics

Inventory tells us how much "stuff" is in the process

Inventory takes up space and cost money

Flow Rate - tells us how much time spends in the process

More units flowing through a process is generally more desirable because the point of the process is to produce output.

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Check Your Understanding

Question:

Over the course of an eight - hour day, a dentist's office treats 24 patients. What is the flow rate of patients in this dentist's office per hour?

Answer Flow rate = 24 patients ÷ 8 hours = 3 patients per hour

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Little's Law
Linking Process Metrics together
LO2-3

Little's Law – the law that describes the relationship between three key process metrics:

Inventory = Flow rate Multiplied by Flow time

I = R Multiplied by T

Flow Rate = R

Flow Time = T

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Little's Law
Continued

If you know (or observe) any of the two key process metrics, you can use Little's Law to derive the third

Inventory = Rate Multiplied by Time

I = R Multiplied by T

I = R(T)

Little's Law tells us the *average* time a flow unit spends in the process

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Check Your Understanding

Question:

During a typical Friday, the West End Donut Shop serves 2400 customers during the 10 hours it is open.

Each customer spends (an average) 5-minutes in the shop.

On average, how many customers are in the shop simultaneously?

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Check Your Understanding
Answer

Answer for Flow Rate :

2,400 customers ÷ 10 hours = Flow Time (5minutes).

240 customers ÷ hour = Flow Time (5minutes).

4 customers ÷ minute = Flow time (5 minutes).

4 customers per minute multiplied by 5 minutes = 20 customers.

I = R Multiplied by T

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Review

Ten customers visit Candy Haven Bakery from 8am to 10am. The customers spend 10, 15, 20, 11, 8, 12, 5, 18, 29 and 32 minutes in the bakery. What is the average flow rate of customers in this bakery per hour?

A . 16.

B . 10.

C . 8.

D . 5.

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Review
Answer

Answer: D

Breakdown,

I = 10 customers ÷ 2hours (8am to 10am).

T = average of time all customers spent in bakery

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