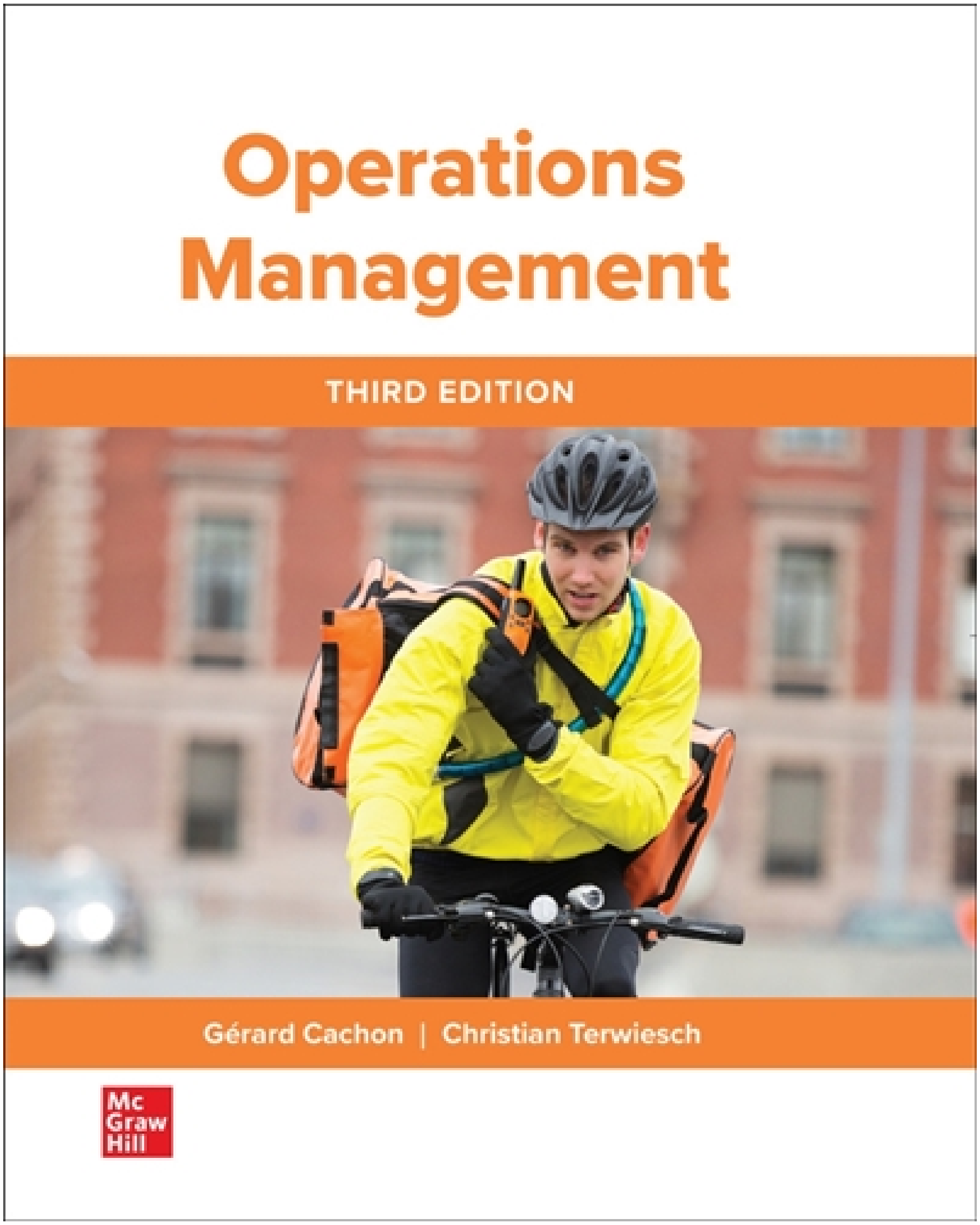
Solutions for Operations Management 3rd Edition by Cachon



Solutions

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(R), flow time(T), and inventory(I)) 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(I), flow rate(R), and flow time(T). 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. This relationship I = R × 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 flow time will also increase

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 11), Inventory Management with Steady Demand (Chapter 12), Inventory Management with Frequent Orders (Chapter 14), Service Systems with Patient Customers (Chapter 16), and Service Systems with Impatient Customers (Chapter 17).

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 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 Case

Cougar Mountain

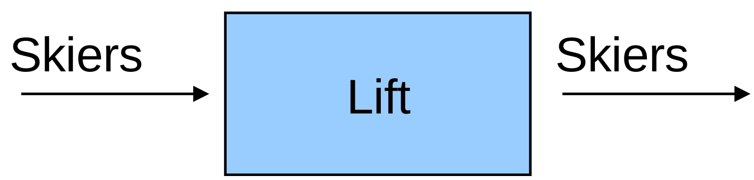
This case:

- 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. This represents a stable process.

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.

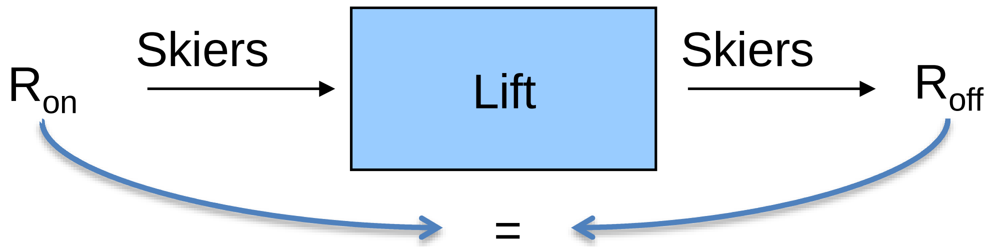
To begin the case discussion, ask the students their opinion as to who is correct, Mark (unloading capacity should be twice as high on the detachable lift) or Doug (the unloading capacity should be the same on the two lifts). Hopefully there are students who support each opinion.

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

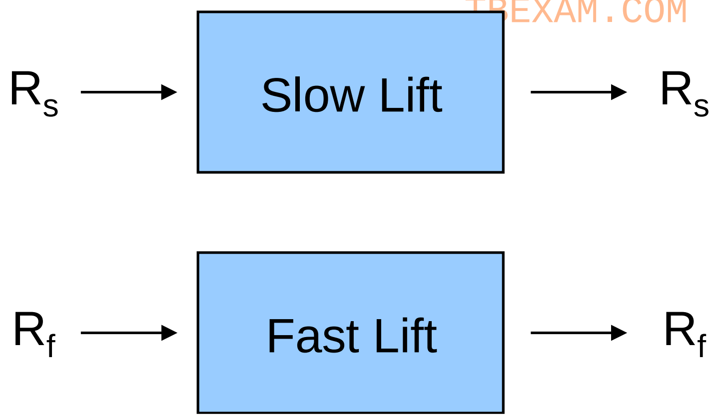


Ask the question "Do all of the skiers that get on the lift at the bottom get off the lift at the top?" Of course, the answer is "We would hope so!" So "What does that mean about how the rate of skiers getting on the lift, R_{on}, is related to the rate of skiers getting off the lift, R_{off}?" And the answer there must be that they are equal! If the rate on were faster than the rate off i.e $R_{on} > R_{off}$, 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 i.e $R_{on} < R_{off}$, 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.

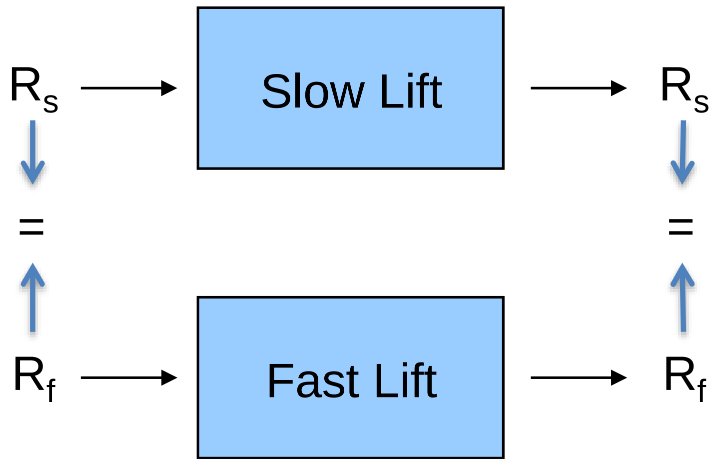
So we can add to our process flow diagram:



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:



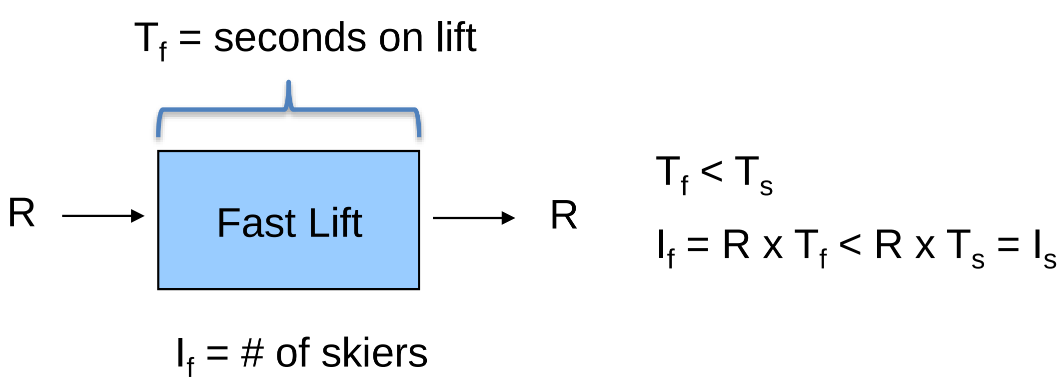
Now ask students "How can we compare the rates across the two types of lifts?" The answer is given in the case—we are told that the rate skiers load onto the slow (fixed grip) lift is the same as the rate they load onto the fast (detachable) lift. That means that $R_s = R_f$. And that means that the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



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).

CHAPTER 2

INTRODUCTION TO PROCESSES

CONCEPTUAL QUESTIONS

1. From the perspective of process analysis, which of the following could be appropriate flow units for a hardware store?

> *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. Over the course of a month, which of the following is most likely to describe an appropriate flow unit for a process analysis of a hospital?

> *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. At a cruise ship terminal, each day on average 1000 passengers embark on ships. On average, passengers spend 5 days on their cruise before returning to this terminal. If the flow unit is a passenger, then what are the flow rate and flow time of this process?

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

4. It is election day and 1800 voters vote in their precinct's library during the 10 hours the polls are open. On average, there are 15 voters in the library and they spend on average 5 minutes in the library to complete their voting. What is the inventory of voters, the flow rate, and the flow time for each voter?

> *Answer:* **The inventory is 15 voters (this is given), the flow rate is 180 voters per hour or 3 voters per minute and the flow time is 5 minutes.**

5. Over the course of a day, fans pour into a NASCAR venue at the rate of 8000 people per hour. The average rate at which fans leave the venue _______.

> *Answer:* ***B.* must be exactly 8000 people per hour**
> *Feedback:* The flow rate into a process must equal the flow rate out of a process (for the process to be stable).

6. A computer server experiences large fluctuations in the amount of data requests it receives throughout the day. Because of this variation, Little's Law does not apply. True or false?

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

PROBLEMS AND APPLICATIONS

1. For the purpose of process analysis, which of the following measures would be considered an appropriate flow unit for analyzing the operation of a coffee shop? **Instructions:** You may select more than one answer.

> *Answer:* ***D.* Number of customers served each week**
> *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. For the purpose of process analysis, which of the following measures would be considered an appropriate flow unit for analyzing the main operation of a local accounting firm? **Instructions:** You may select more than one answer.

> *Answer:* ***B.* Number of tax returns completed each week**
> *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. For the purpose of process analysis, which of the following measures would be considered an appropriate flow unit for analyzing the main operation of a gas station? **Instructions:** You may select more than one answer.

> *Answer:* **A (sales dollars) and D (number of customers served per day) are correct**
> *Feedback:* The gasoline pumps and employees are resources, not flow units.

4. What is the flow rate of callers from 8:00 a.m. to 8:20 a.m.?

> *Answer:* **0.4 callers per minute**
> *Feedback:* 8 calls divided by 20 minutes = 0.4 calls per minute.

5. What is the flow time of callers from 8:00 a.m. to 8:20 a.m.?

> *Answer:* **4 minutes**
> *Feedback:* To calculate the flow time of the callers, subtract the caller's departure time from his or her arrival time. (4+5+2+3+5+8+3+2 = 32) so, 32 total minutes divided by 8 callers = 4 minutes.

6. What is the flow rate of customers from 9:00 a.m. to 10:00 a.m.?

> *Answer:* **0.1667 customers per minute**
> *Feedback:* Flow rate = 10 customers divided by 60 minutes = 0.1167 customers per minute.

7. What is the flow time of customers from 9:00 a.m. to 10:00 a.m.?

Answer: **8.6 minutes**
Feedback: To calculate the flow time of the customers, subtract the customers departure time from his or her arrival time. (6+15+12+5+8+7+8+6+15+4 = 86) 86 total minutes divided by 10 customers = 8.6 minutes.

8. What is the average amount of time that a customer spends in process?

Answer: **4 minutes**
Feedback: To solve this problem, use Little's Law. Inventory = Flow rate × Flow time.

The flow rate is 300 customers divided by 120 minutes = 2.5.

10 people in line (average inventory) = 2.5 flow rate x flow time

Flow time = 4 minutes

9. How many wafers does the cooling tube hold, on average, when in production (in other words, don't count the time they are not in production)?

Answer: **90,000 wafers**
Feedback: Inventory = flow rate x flow time = 100 per second x 60 seconds per minute x 15 minutes = 90,000 wafers

10. How many skiers are riding on the lift at any given time?

Answer: **360 skiers**

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

11. Last year, on average, how many visitors were in the park simultaneously?

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. How many patients are taking this drug on average at any given time?

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

13. On average, how many chat sessions are active (i.e., started but not completed)?

Answer: **20 chat sessions**
Feedback: Flow rate = 240 chats divided by 30 employees = 8 chats per employee

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

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

14. How large of an oven is required so that the company is able to produce 4200 units of bread per hour (measured in the number of units that can be baked simultaneously)?

Answer: Each oven should have a capacity of **840 units**
Feedback: 4,200 units multiplied by (12 minutes/60 minutes) = 840 units

15. How many new skiers are arriving, on average, in LaVilla every day?

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

16. How long did the average passenger have to wait in line?

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. How long is the average associate employed at the consulting company?

Answer: **8 years**
Feedback: 120 associates = 15 new employees per year x flow time. Flow time = 8 years.

CASE Cougar Mountain

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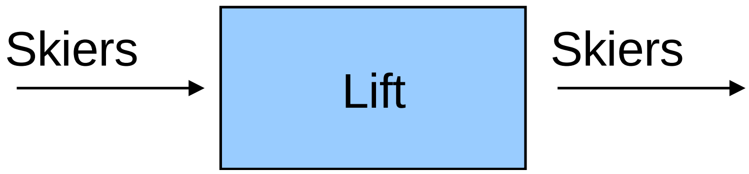

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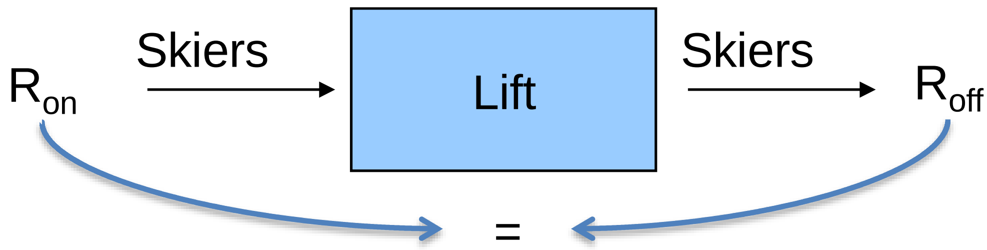

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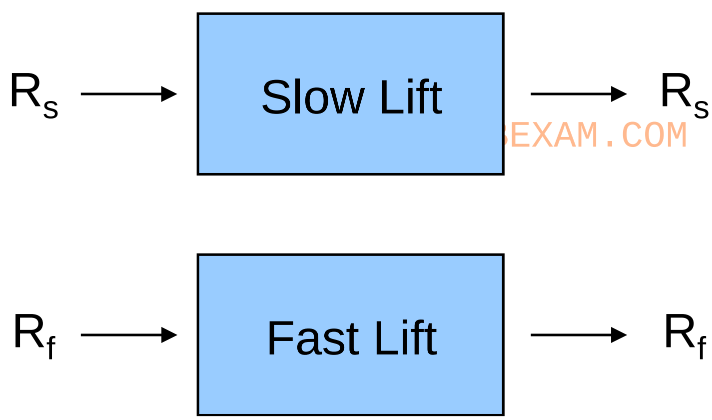

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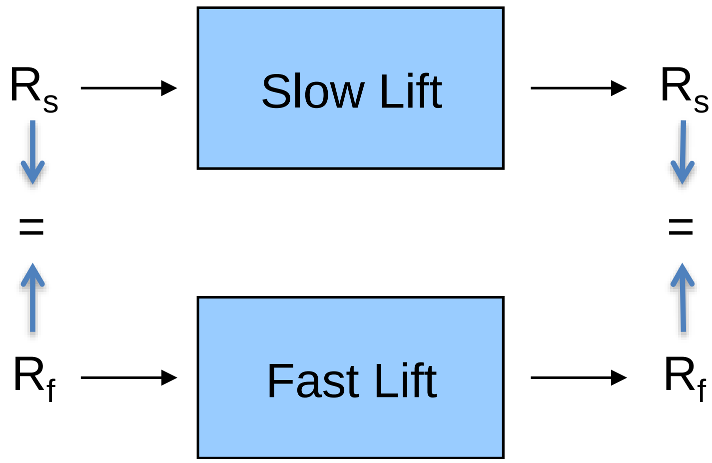

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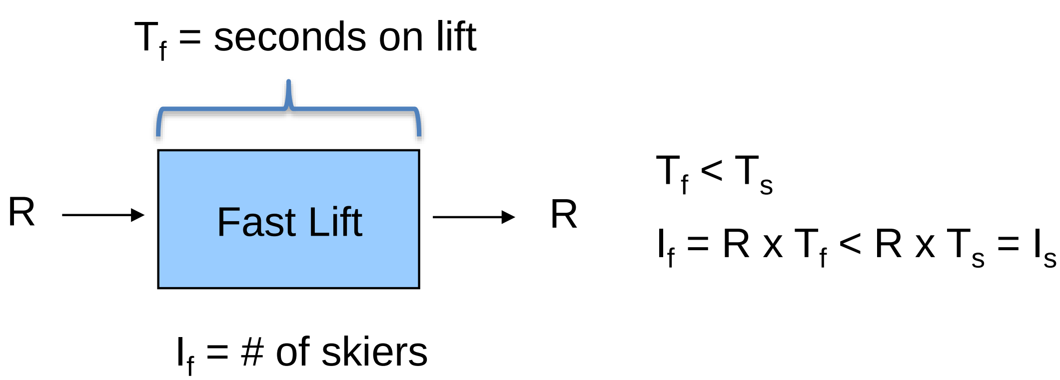

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