Manage Productivity to Maximize Profit

Course No: K08-005

Credit: 8 PDH

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By

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COURSE OVERVIEW

This course is for people wanting a basic understanding of the design and management of efficient work processes in any environment for any product. Public organizations will benefit as much as private because work efficiency and productivity is essential to both. The concepts presented here are universal whether processing legal documents or building toasters on an assembly line.

Plenty of practice exercises (with answers following) give students the opportunity to understand the concepts of production planning, equilibrium, and efficiency and apply them in their own work. Students will be able to measure existing production capacity and forecast future demand while analyzing data to determine breakeven points for equipment purchase or leasing and creating optimal staffing strategies with full or part-time help.

Profitability (efficiency in the public sector arena) only comes when we make the most efficient and effective use of our existing resources and available data.

LEARNING OUTCOMES

Participants in this self-study course will learn to:

1. List the elements needed for effective goals
2. Identify measurable work performance goals
3. Analyze floor plans for optimal work flow
4. Analyze work flows to determine their current efficiency
5. Explain and apply the principles of 'production equilibrium'
6. Determine work process flow adequacy
7. Revise workflows to improve efficiency
8. Explain the concept of 'cycle time'
9. Create optimal production cycle timing
10. Analyze work flows looking for improved efficiency and productivity
11. Analyze expected work flows to determine equipment and staffing needs
12. Learn to calculate the existing costs and production capacity of an existing workforce
13. Apply the skills learned to practice exercises within the course
14. Analyze historical data with a variety of statistical tools
15. Forecast our ability to meet future business opportunities
16. Analyze existing staffing and production needs to devise the most economical mix of full and part-time employees
17. Determine production equilibrium across work stations in a production flow to maximize production while minimizing costs
18. Determine how efficiently employees are working
19. Discover if they are being "productive" or "busy"
20. Predict future demand and capacity with more confidence using historical data
21. Conduct break-even analyses to select the best use of resources
22. Use historical data effectively to support financial proposals
23. Use weighted data effectively to forecast future trends
24. Quickly prioritize a list of group options for decision making

PRODUCTIVE OR BUSY?

Do you think a person can be very busy but not very productive? How could this happen?

It is because task requirements are not always well defined. Sometimes people are just "busy" because they were not told all three elements of productivity. But, when you focus a task with the three critical performance standards of productivity, they will include "how much" (**quantity**), "how well" (**quality**) and "by when" (**time**), you establish goals and they become productive.

The light bulb in a lamp is physically the same as a laser beam.

However, the laser has all of its energy narrowly focused upon a particular point that gives it incredible power. How could you compare parts of your workday to the light bulb and the laser beam?

When do you feel more satisfied with your work: *when you are acting like a light bulb or a laser beam?*

Which condition(s) ultimately makes your job more enjoyable and your work more productive?

How can you use the light bulb and laser beam example in a discussion with your employees?

Why would you want to do that?

PRACTICE EXERCISE #1

Are these situations productive or busy?

Read each situation and put a checkmark under the appropriate "Productive" or "Busy" column. Remember, we define "productive" as having all three elements of **how much (quantity)**, **how well (quality)**, and **by when (time)** present in a situation. (Answers are given below.)

The Situation	Productive	Busy	If "busy", what is missing?
Grant has been pushing the cart loaded with statements up and down the hall for the past 45 minutes.			
Logan has processed 200 documents in the past 3 hours.			
Murphy has the machine running items at a speed of 375/hour and a reject rate of .82%			
Cindy completed 3 hours of classes at night school this past quarter.			
Describe a typical activity of yours that is busy but not productive because you have not been told the three components of productivity; **quality, quantity, and time**. **Which of the three components is missing?** What will you do about it?			

- ✓ Grant is just busy. Nothing has been accomplished. What is the QUALITY measurement?
- ✓ Logan is busy. She has processed 200 documents but are they the correct ones? Where they processed accurately? There is no QUALITY component.
- ✓ Murphy has been productive. The QUALITY component is the "reject rate".
- ✓ Cindy has been busy. She completed the courses but what was her grade: i.e., the QUALITY of her participation? If she failed, she was technically productive. But if the quality is below acceptable, it is a waste of resources or negative productivity. If she received an "A", she would be more productive than if she received a "C".

THE VALUE OF SETTING MEASURABLE GOALS

There are at least four reasons why you should set *measurable* goals:

1) **Knowing where you are going will help you plan to get there.**

   How do you plan your vacations?

   a) Start planning with the ultimate destination and work backward budgeting time and money necessary to make it happen (Time and money are measurables)
   b) Just leave the house on the first day of vacation and see where you end up?

2) **Measurable goals (milestones) along the way to your ultimate destination help you track your progress.**

   Just as mileage signs along the interstate help you track your progress toward your goal, creating personal milestones help you track your progress.

3) **Planning helps you prevent problems**

   If you plan your vacation well enough, you will have enough money and time to get to where you want to go, spend time there enjoying your vacation, and afford to come back home afterward. (Or would you prefer to stay until your time and money runs out and see what happens next?)

4) **Measurable goals help you enjoy your life at work more**

   Having measurable goals helps you focus your efforts on their accomplishment and not have to *guess* whether you are doing what *you hope* will make your boss happy.

   How does this lack of clarification affect you and your work?

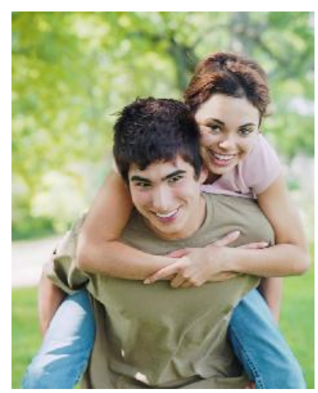
   It probably undermines your confidence and keeps you from going "all out" because you fear you may have to undo some work.

THE ELEMENTS OF MEASURABLE GOALS

An effective, measurable goal requires at least these elements:

- ✓ ***Realistic*** *(in the mind of the person doing the work)* – The person must feel they have some chance of success or they will not bother trying.
- ✓ ***Quantifiable*** – It must tell the person **HOW MUCH (**Quantity**), HOW WELL (**Quality**),** and **BY WHEN (**Time**)**. This knowledge helps them gauge their own progress toward the ultimate goal.
- ✓ ***Job Related*** – He/she must understand how his/her personal goals support the goals of the department, which support the goals of the division.
- ✓ ***Doable*** – They must involve his/her *doing something* that can be observed and measured. A goal that calls for *"Understanding how work flows through the IP Department"* is useless. It only becomes useful if he/she must ***do something*** that demonstrations his/her understanding such as **explain** the work flow or **identify** a specific work area in the flow such as Balancing.

PRACTICE EXERCISE



Devise a scaled reward system for the family's two teenagers to *"be more helpful around the house".* Just define specific tasks with quality, quantity, and time. Give a basic (good) level of expectation, a better one and the top level.

Here is one example. You may make up as many as you think appropriate. You can defend it because it is available to both, expected of both, and both know what the expectations are.

Activity - "Cleaning the floors"	**Reward= $x**
1. Vacuum the carpets: all rooms and all floors where there is carpet.	1.00X
2. All of #1 and vacuum everywhere there are hardwood floors	1.25X
3. All of #2 above, damp mop all bathroom tile floors, spray polish wood floors	1.50 X

The activities for the teenagers are certainly measurable – you can visually inspect to see that they did those tasks – **but are they productive?**

Technically speaking, they are NOT because there are no time or quality criteria specified. (Of course, they are implied but since teenagers and employees are not mind readers, you cannot be sure their definition of "vacuum the carpets" means the same as yours does.)

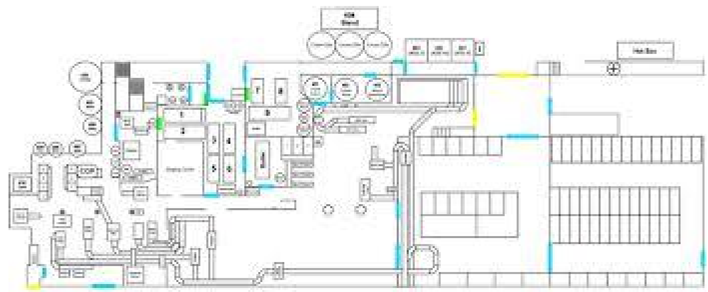
You would make them technically productive by specifying what "vacuum the carpet" means in terms of residue picked up: i.e., **QUALITY**.

> Do you want a "get on your hands and knees and get every possible piece of lint, pet hair, dust, and dirt out so it's spotless" kind of result or is "run the vacuum slowly over it and pick up what it can get in one pass " satisfactory?

Next, how much **TIME** do they have to do it? Obviously, vacuuming the room at the desired quality level in ten minutes is more productive than doing it in fifteen minutes.

ANALYZING YOUR FLOOR PLANS

The floor plan in your production area is an obvious but often "hidden" consideration when analyzing productivity.



Many times people who are trying to improve productivity get caught up in looking at machine speeds, length of work hours, or steps they can eliminate in the production process without considering how the layout of everything may be a significant factor in the ability to produce.

The production layout determines how smoothly material flows through the process. "Smoothly" is influenced by work delays, production sequence, stops and starts of machinery or employees, the morale of the employees doing the work, the ability of the manager to define expectations so the employee can work confidently, or whether it gets "bumped" for a higher priority.

Use the grid on the next page to sketch one of your work areas. Be sure to include how and from where materials for processing arrive into this area; the shapes, sizes, and locations of the production machinery; how and where finished products leave this area; walkways for employees; walkways for anyone "passing through" if not working on production; and anything else associated with the production.

Use dotted lines to show the flows of materials or where workers have to walk. Do any paths cross? Are the flows following the shortest possible lines? Are there any obvious opportunities for improvement?

Figure 1

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Analyzing Your Work Flows

After you look at the floor layout, the next step is to look at the work processes, themselves. You should look at every segment of the assembly line whether you work in a factory producing automobiles or an office producing finished documents. However, before starting to look at the work process and the employees doing it, you should be aware of a phenomenon discovered in the late 1920s

The **Hawthorne Studies** (or experiments) were conducted from 1927 to 1932 at the Western Electric Hawthorne Works in Chicago by a researcher from the Harvard Business School. The studies grew out of preliminary experiments at the plant from 1924 to 1927 on what factors or changes would influence productivity. In particular, they wanted to find out what effect fatigue and monotony had on job productivity and how to control them through such variables as rest breaks, work hours, temperature and humidity.

They discovered more than they anticipated. The more they adjusted the length of work hours and breaks up and down, *the more productivity increased*. The more they diminished illumination, the *more productivity increased*. In short, productivity increased in *every situation* until exhaustion or too little illumination in the factory physically prevented more production.

They discovered that the singling out a particular group of employees for special attention (even if it was for longer hours and diminished lighting) made the employees feel special which made them increase productivity to get more attention! (You can read more about this experiment at http://en.wikipedia.org/wiki/Hawthorne_effect.)

The reason we mention the Hawthorne Studies in this section on analyzing workflows is that you may unintentionally influence the workflow just by watching the employees work. Their production times *may be* much different than normal. We suggest you make several observations as unobtrusively as possible and average the times.

PRACTICE EXERCISE: ANALYZING WORK FLOW

Department: _Accounts Payable___ Date Observed: __June 23-24____

Job Observed: ___Reimbursing expense reports __________________

Observer: Logan Grant

OBSERVATION CODES

W = Working (doing what they are paid to do) **M** = Moving from work station

I = Idle (any time waiting or not working) **F** = Filing (Or storing something)

What comments can be made about improving the workflow based on this example?

Step #	Describe the Step	Code	Distance in feet	Time in min/sec	Comments
1.	Goes to incoming mail area to get expense reports and returns to work station (desk)	M	70' r/t	0:45	(next page)
2.	Opens envelope, organizes receipts.	W	-	1:15	
3.	Notices some expense code fields are empty, looks up proper codes.	W	-	2:10	
4.	Completes authorization to reimburse form on PC and send to the shared printer.	W	-	0:15	
5.	Goes to shared printer to get form	W	25	0:10	
6.	Waits while admin assistant finishes printing new parking policy.(Admin assistance goes to get more paper.)	I	- 60' r/t for admin	2:15	
7.	Takes printed form to boss for review and approval.	M	45'	0:20	
8.	Boss on the phone – clerk waits	I	-	3:15	
9.	Goes to copier to make 2 copies of approved form	W	35'	0:25	
10.	Copier toner low. Must find new cartridge and refill	W/I	-	3:50	
11.	Makes copies and back to desk	W	35'	0:20	
12.	Cuts reimbursement check and places it into I/O envelope.	W	-	2:00	
13.	Starts at step 1 again				

Summary: Time for 1 complete work cycle: ___**16:50 minutes**__

Take a few minutes to consider each step. Then list some questions that you would ask about each step in this situation. At this point, we are not ready to make any recommendations for change: we are just asking questions to make sure we clearly understand the situation.

(We have listed some on the next page.)

COMMENTS ABOUT THE WORKFLOW

Step #	Describe the Step	Code	Distance in feet	Time in min/sec	Comments
1.	Goes to incoming mail area to get expense reports and returns to work station (desk)	M	70’ r/t	0:45	Can we bring mail to them?
2.	Opens envelope, organizes receipts.	W	-	1:15	
3.	Notices some expense code fields are empty, looks up proper codes.	W	-	2:10	Print most common codes on the form? On-line reference?
4.	Completes authorization to reimburse form on PC. Sends to the shared printer.	W	-	0:15	
5.	Goes to the shared printer to get form	W	25	0:10	
6.	Waits while admin assistant finishes printing new parking policy. (Admin assistance goes to get more paper.)	I	- 60’ r/t for admin	2:15	Store paper at printer? Dedicated printer for accounts payable?
7.	Takes printed form to boss for review and approval.	M	45’	0:20	Authorize clerks to OK up to a threshold?
8.	Boss on the phone – clerk waits.	I	-	3:15	
9.	Goes to copier to make 2 copies of approved form.	W	35’	0:25	
10.	Copier toner low. Must find new cartridge and refill.	W/I	-	3:50	Check all copiers at end of day for toner and paper to be ready for next day?
11.	Makes copies and back to desk.	W	35’	0:20	
12.	Cuts reimbursement check and places it into I/O envelope.	W	-	2:00	
13.	Starts at step 1 again.				

ESTABLISHING PRODUCTION EQUILIBRIUM

"Production Equilibrium" is another way of saying, *"what combination and sequence of tasks gives us maximum production in the least amount of time?"*

Production line supervisors and managers must always look for the ***maximum production possible*** with ***the least amount of idle time*** at any workstation along the production cycle.

(The time it takes to make one complete product on your assembly line is called **CYCLE TIME.)**

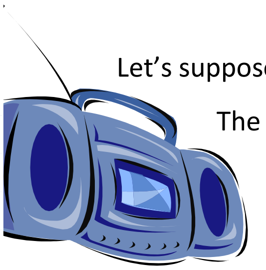
The two factors of cycle time we must consider are:

- ✓ **ADEQUACY –** Can our production line meet the demand within the required standards of time and quality? "Is it ADEQUATE for the task?"

- ✓ **EFFICIENCY –** Have we minimized "idle" time at every workstation along the assembly line? (Remember, "assembly line" can also refer to a paperwork process.)

We will spend the rest of the course looking at many aspects of these two factors.

DETERMINING LINE ADEQUACY



Let's suppose we work for the Big Sound Radio Manufacturing Company.

The company designed a new model, called the Big Blaster that they think will be a big seller. Based on the drawings, it looks like there are eight steps in the production process with an estimated time (in seconds) how long each step should take.

This is the sequence of tasks and the length of time to do each. (Time expressed in seconds)

Work Station	Process	Task Time (seconds)
1	**Receive the new radio shell, clean it, and place on conveyor belt. (Do this first.)**	12
2	**Install internal speakers**	45
3	**Install AM & FM receivers**	120
4	**Solder all electrical connections - melt weld all plastic connections**	30
5	**Attached the 120 v. electrical cord to the radio**	42
6	**Attach the back to the radio (only after all internal work is done)**	25
7	**Test the radio on AM & FM receivers.**	15
8	**Place in box and send to shipping dept. And ready for next. (This must be done last.)**	8

This is what we must determine: (come back and answer these as we move through the lesson.) **The answers begin on page 19** Error! Bookmark not defined.

✓ If we set up the production line with the eight steps and times shown above, what will be the **cycle time** per radio? ________ (We define **CYCLE TIME** as the time it takes to make one complete product on your assembly line.)

- ✓ If we set up the production line with the eight steps and times shown above, what will be our **production capacity** for each eight-hour shift? ____

- ✓ If we set up the production line with the eight steps and times shown above, what will be our **production efficiency** for each eight-hour shift? _____

- ✓ What is the **best production equilibrium** (this term becomes evident in a few minutes) we can achieve each shift? (You will see which choice is best.) This is how we will find the answers to these questions.

We will look a little closer at the proposed production schedule.

Work Station (w/s) #	Process	Task Time	Longest time for any task	Idle time waiting for next w/s
1	Receive the new radio shell & clean it. (This must be done first.)	12		
2	Install internal speakers	45		
3	Install AM & FM receivers	120		
4	Secure all connections	30		
5	Attach the 120 volt cord	42		
6	Attach the back (internal work must be completed first.)	25		
7	Test the AM & FM receivers	15		
8	Place in box for shipping. **(This must be last.)**	8		
	Time in seconds	297		

These are typical questions to consider in a production environment.

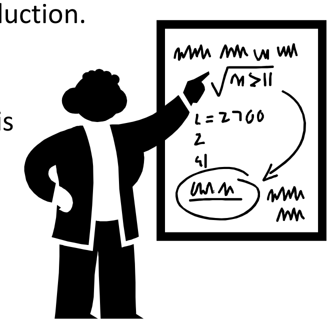
- ✓ What is the longest time for any single task? _______
- ✓ Write this amount in each cell in that column. Why should we do that? (This becomes evident soon, also.)
- ✓ Can additional tasks be completed and moved before the longest task is finished? ___________
- ✓ What impact does that "longest task" have on the whole work cycle? (Everything else stops until this part is completed)
- ✓ Write in the amount of idle time at each station while waiting for the longest task to be completed.

- ✓ **Some questions we can ask at this point:**
- ✓ Is this the only sequence that we can have? (**Answer:** The step at station #1 must come first.
- ✓ Steps 2 & 3 can be reversed if we attach the receivers to the speakers instead of the speakers to the receivers.
- ✓ Step 4 can only come after we make the connections.
- ✓ Step 5 must have something inside the radio to which we can attach the cord.
- ✓ Step 6 must come now because we cannot put on the back until everything is placed inside.
- ✓ Step #8 must be last because it goes to shipping after assembly.
- ✓ The only flexibility we have is reversing steps 2 & 3 if that would help.)
- ✓ What is the longest time spent at any workstation? (**Answer:** 120 seconds at step 3.)
- ✓ What happens to the whole assembly line while step #3 occurs? (**Answer:** The whole line stops and waits.)

This is what production actually looks like when we take into account delays while longer processes are completed.

Work Station #	Process	Task Time	Longest time for any task	Idle time waiting for next w/s
1	Receive the new radio shell & clean it. (This must be done first.)	12	120	108
2	Install internal speakers	45	120	75
3	Install AM & FM receivers	120	120	0
4	Secure all connections	30	120	90
5	Attach the 120 volt cord	42	120	78
6	Attach the back (we must complete internal work first.)	25	120	95
7	Test the AM & FM receivers	15	120	105
8	Place in box for shipping. **(This must be last.)**	8	120	112
	Time in seconds	297	960	663

There are important considerations that must not be overlooked when looking at production.



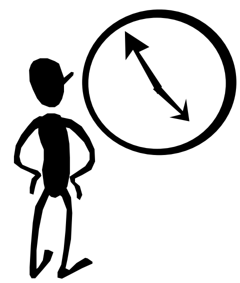
- ✓ The longest time spent at any workstation delays every workstation once the line is "full" and each station is engaged in production.

- ✓ **"Cycle Time"** is the total of task time + idle time.

(297 seconds task time + 663 seconds wait time = **960 seconds of cycle time.)**

More Questions

- ✓ If we set up the production line with the eight steps and times shown above, what will be the cycle time per radio?

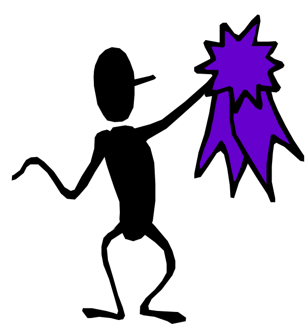


"Cycle Time" is the total of task time + idle time. (297 seconds task time + 663 seconds wait time = **960 seconds of cycle time.)**

- ✓ If we set up the production line with the eight steps and times shown above, what will be our production capacity for each eight-hour shift?

We have seen that it takes 960 seconds for a complete "cycle" in the assembly of one radio. Since our answer for cycle time is expressed as seconds, we must convert our 8-hour work shift to seconds so we are dealing with similar amounts.

The 8-hour shift has 60 minutes in each hour with 60 seconds in each minute. Therefore, 8 x 60 x 60 = 28,800 seconds per shift. If it takes 960 seconds to build a radio and we have 28,800 seconds on the shift, we can build 28,800 ÷ 960 = **30 radios per shift**.



- ✓ If we set up the production line with the eight steps and times shown above, what will be our production efficiency for each eight-hour shift?

We found the cycle time to be 960 seconds. During this time, work is being done for only 297 seconds: the rest of the cycle is idle time waiting for the longest task to be completed so the line can move again.

The efficiency of the line is determined by dividing the total work time <u>within a cycle</u> by the <u>length of the cycle</u>. **This is 297 ÷ 960 = 30.9% efficient.**

✓ What is the **best production equilibrium** we can achieve each shift?

We will rearrange the tasks slightly to reduce as much idle time as possible. We will still acknowledge the sequence requirements (which step must come before any others) as we do this.

Figure 2

Work Station #	Process		Task Time	Longest time for any task	Idle time waiting for next w/s
1	Receive the new radio shell & clean it. (This must be done first.)		12	120	108
2	Install AM & FM receivers		120	120	0
3	Install internal speakers	45			
	Secure all connections	30			
	Attach the 120 volt cord	42			
	Total time at this workstation =		117		
	Attach the back (internal work must be completed first.)	25			
	Test the AM & FM receivers	15			
	Place in box for shipping. **(This must be last.)**	8			
	Total time at this workstation =		48	120	72
	Time in seconds		297	480	183

These are sequence priorities.

Put the longest task as close to the front as you can while still acknowledging sequence priorities.

Put the next longest task next.

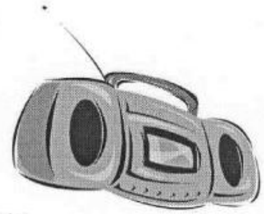
We collapsed eight separate steps into four. This means we can save money on purchasing workstations and hiring workers for each station. **Work time** remains at 297 seconds because it still takes the same amount of work to build each radio. However, we have reduced the waiting time significantly. This means the **cycle time** is lower, too. This means we can produce more radios during each shift.

If it now takes 480 seconds to build a radio and we have 28,800 seconds on the shift, we can build 28,800 ÷ 480 = **60 radios per shift**. **Efficiency is now 297 ÷480 = 61.9%.**

The next page contains a sample of how a spreadsheet and charts would look as we compare the current production with our proposed.

This is the current process with 8 workstations.

THE CURRENT PROCESS OF PRODUCING RADIOS



Note: When we do these calculations, we are looking for *very close approximations, not exact amounts*
We do not measure the time spent as the first few products move into the assembly line and fill all the work stations (w/s) nor the time spent as the production line empties at the end of the day.

All times are in seconds

Work Station #	Task	Time to do the task and move it to the next w/s	Longest time any one task	Idle time waiting for the longest task to end.
1	Receive the new radio shell, clean it, place on conveyor belt. (This must be done first.)	12	120	108 seconds waiting after the production line is "full"
2	Install internal speakers	45	120	75 seconds waiting after the production line is "full"
3	Install AM & FM receivers and connect to speakers	120	120	0 seconds waiting after the production line is "full"
4	Solder all electrical connections - melt weld all plastic connections	30	120	90 seconds waiting after the production line is "full"
5	Attached the 120 v. electrical cord to the radio	42	120	78 seconds waiting after the production line is "full"
6	Attach the back to the radio (only after all internal work is done)	25	120	95 seconds waiting after the production line is "full"
7	Test the radio on AM & FM receivers.	15	120	105 seconds waiting after the production line is "full"
8	Place in box and send to shipping dept. And ready for next. (This must be done last.)	8	120	112 seconds waiting after the production line is "full"
	Seconds of actual work to to produce a radio →	**297**	**960**	**663** ← This is the time each radio spends waiting through the production line.

This is the actual cycle time needed to move one radio through all of the work stations. (960)

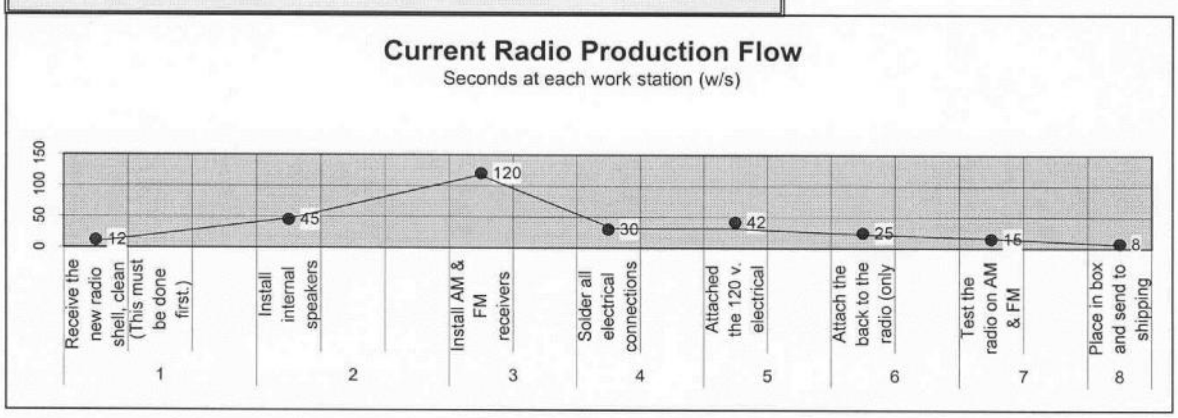
Given information			
shift/hrs.	min/hr.	sec/min	seconds of work per shift
8	60	60	**28,800**

$$\text{Efficiency \%} = \frac{\text{Work Time}}{\text{Cycle Time}} \quad \text{or} \quad \textbf{E\%=WT/CT} = \frac{297}{960} \quad \textbf{30.9\% Line Efficiency}$$

$$\text{Radios produced/shift} = \frac{28{,}800 \text{ seconds in a shift}}{960 \text{ seconds to produce each radio}} = \textbf{30} \text{ radios/shift}$$

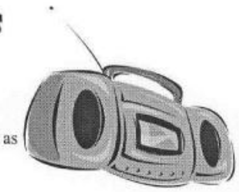
Check your calculations!!
TOTAL CYCLE TIME SHOULD EQUAL WORK TIME + WAITING TIME.

Work time =	297
Wait time =	663
Total cycle time =	960



This is the recommended process with 4 workstations.

THE PROPOSED PROCESS OF PRODUCING RADIOS



We will put as many tasks at each station as possible with these limitations:

1. We acknowledge the tasks that must be first and last by putting them first and last.
2. **We put the longest task as close as we can to the front of the line.**
3. We group all other tasks which to do have a prerequisite in descending assembly time at each station so long as assembly time at each w/s does not exceed the LONGEST task in the whole line.

All times are in seconds

Work Station #	Task		Time to do the task and move it to the next w/s	Longest time any one task	Idle time waiting for the longest task to end.
1	Receive the new radio shell, clean it, place on conveyor belt. (This must be done first.)		12	120	108 seconds waiting after the production line is "full"
2	Install AM & FM receivers Note: We still connect speakers and receivers at w/s #3		120	120	0 seconds waiting after the production line is "full"
3	Install internal speakers and connect to receivers Solder all electrical connections - melt weld all plastic connections Attached the 120 v. electrical cord to the radio	45 30 42	117	120	3 seconds waiting after the production line is "full"
4	Attach the back to the radio (only after all internal work is done) Test the radio on AM & FM receivers. Place in box and send to shipping dept. And ready for next. (This must be done last.)	25 15 8	48	120	72 seconds waiting after the production line is "full"
	Seconds of actual work to to produce a radio →		**297**	**480**	**183** ← This is the time each radio spends waiting through the production line.

This is the actual cycle time needed to move one radio through all of the work stations.

Given information			
shift/hrs.	min/hr.	sec/min	seconds of work per shift
8	60	60	**28,800**

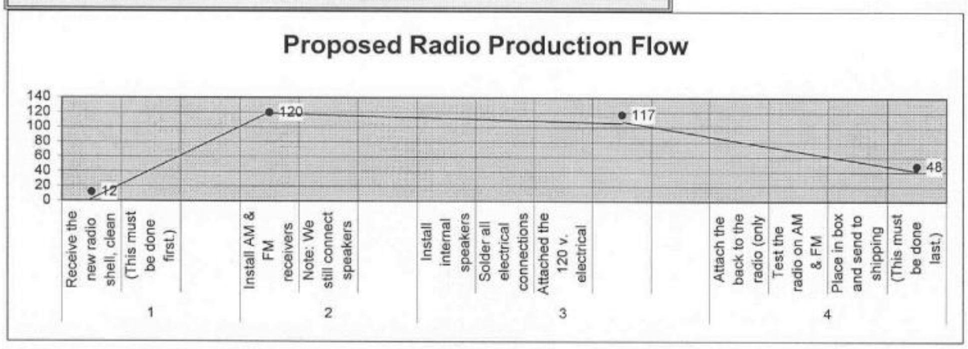
$$\text{Efficiency \%} = \frac{\text{Work Time}}{\text{Cycle Time}} \quad \text{or} \quad \mathbf{E\%=WT/CT} = \frac{297}{480} \quad \mathbf{61.9\%\ \ Line\ Efficiency}$$

$$\text{Radios produced/shift} = \frac{28{,}800 \text{ seconds in a shift}}{480 \text{ seconds to produce each radio}} = \mathbf{60} \text{ radios/shift}$$

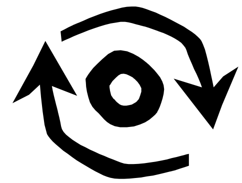
Check your calculations!!

TOTAL CYCLE TIME SHOULD EQUAL WORK TIME + WAITING TIME.

Work time =	297
Wait time =	183
Total cycle time =	480



PRODUCTION PLANNING



Sometimes we have to plan for new production instead of trying to improve an existing process. We must calculate for these considerations:

- ✓ How long does it take to complete this product and what are the steps that make up that completion time?
  Think about the radios we assembled earlier. We had to know how many different steps were involved, what sequence of priorities there were (if any) and how long did we think it will take to complete each step?

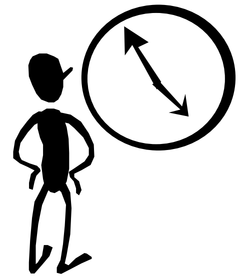
- ✓ How many workstations (and employees at those stations) will we need as a minimum? We will calculate this in a few minutes.

- ✓ What is the maximum cycle time can we spend on each product?
  The maximum amount of cycle time for each product will determine the least amount of workstations we will need.

  For example, if we had all day to finish a product, we may only need 1 workstation. But if we were required to finish fifty products a day, we may need more than 1 workstation.

- ✓ Will we have the capacity to meet the demand without adding extra shifts or overtime? We will take these in order and you will see how easy it is to plan production.

PRACTICE ACTIVITY



Sometimes the designer of the product prototype can help you find this information. Other times, you have to talk with an expert who may be producing it already somewhere else. For our example, we will assume we are going to start production of a document in our department that we have never handled before. We talked to "experts" (people familiar with this kind of document processing) and this is what we learned.

OPENING NEW CUSTOMER ACCOUNTS

Task	Tasks	Prerequisite Task	Task Time (seconds)
A	Open the envelope & take out the application	-	5
B	Verify the customer signed and dated the application.	A	8
C	Enter the customer's information from the form into the tracking system	B	145
D	Make three copies of the customer's application.	B	45
E	File one copy of the application with the billing department.	B	20
F	File one copy of the application with the marketing department.	B	20
G	File one copy of the application with the verifications department.	B	20
H	Send the original application to the records department	B	20
I	Resort the computer's database after you have entered the customer's information.	C	30
	End this cycle		313

✓ How long does it take to complete this product and what are the steps that make up that completion time?

We see from the chart above there are 9 steps (A-I) and the total task time is **313 seconds**.

✓ How many workstations and employees at those stations will we need as a minimum?

We learned earlier in this lesson when we assembled radios that we must look for two things first:

- The longest time to complete a single task
- Are there are any priorities on sequencing?

In this example, we see the longest single task ("C") is 145 seconds. Also, the only priorities are that "A" must come first; make sure the customer signed and dated it "B" and task "I" cannot be completed until task "C" is finished. We can rearrange the tasks into a sequence like this to minimize cycle time. (Can you suggest any other arrangements?)

Note: Although technically tasks "A" & "B" are separate steps, we know that we can open the envelope, take out the application and verify if the customer signed and dated it at this one workstation.

PRODUCTION LAYOUT "A" (Wkstn = Work Station)

Wk stn		Tasks & Completion Time in seconds		Prerequisite Task	Task Time (seconds)	Longest task time	Delay Time
#1	A	Open the envelope & take out the application	5	A	13	145	132
	B	Verify the customer signed and dated the application.	8				
#2	C	Enter the customer's information from the form into the tracking system = 145 seconds		B	145	145	0
#3	D	Make three copies of the customer's application.	45	B	125	145	20
	E	File one copy of the application with the billing department.	20				
	F	File one copy of the application with the marketing department.	20				
	G	File one copy of the application with the verifications department.	20				
	H	Send the original application to the records department	20				
#4	I	Resort the computer's database after you have entered the customer's information = 30 seconds		C	30	145	115
	End this cycle				313	580	267

We see that the least number of workstations that we need is 4.

What is the efficiency of this arrangement?

313 seconds (total task time)/580 seconds (total cycle time) = 53.9% efficient

- ✓ How many documents could we produce in an 8-hour shift? **49**
  - 8 hours x 60 minutes/hr. x 60 seconds/minute = 28,800 seconds in the workday

    We convert this to seconds because the cycle time is expressed in seconds.
  - 28,800 seconds in the work day/580 seconds to complete 1 document = **49.65** documents/day.
  - We round it down to 49 since we probably would not leave a partially completed document to the next day.

What if we modified the previous process sequence to add step "I" to the previous workstation, reduced workstations from 4 to 3, and lengthened the task period at that station by 10 seconds?

Would that improve our efficiency? How could you prove it?

PRODUCTION LAYOUT "B"

Wk stn		Tasks & Completion Time in seconds		Prerequisite Task	Task Time (seconds)	Longest task time	Delay Time
#1	A	Open the envelope & take out the application	5	-	13	155	142
	B	Verify the customer signed and dated the application.	8	A			
#2	C	Enter the customer's information from the form into the tracking system		B	145	155	10
#3	D	Make three copies of the customer's application.	45	B	155	155	0
	E	File one copy of the application with the billing department.	20	C			
	F	File one copy of the application with the marketing department.	20				
	G	File one copy of the application with the verifications department.	20				
	H	Send the original application to the records department	20				
	I	Resort the computer's database after you have entered the customer's information.	30				
End this cycle					**313**	**465**	**152**

Although we prefer to place the longest tasks at the front of the production line, we must acknowledge priorities first.

Here, step "C" obviously must occur before step "I".

We see that the least number of workstations that we need is three.

- ✓ What is the efficiency of this arrangement? **67.3 %**

  313 seconds/465 seconds = 67.3%

- ✓ How many documents could we produce in an 8-hour shift? **61**

  28,800 seconds/465 seconds cycle time = 61.9 documents/day.

- ✓ How much have (%) we improved our productivity using layout "B" instead of "A"? **24.4%**

  Layout "A" = 49 whole documents/day   Layout "B" = 61 whole documents/day.

  (61-49)/49 = 24.4% increase.   Or, 61/49 = 1.24 Either way it is expressed, we have gained a 24.4% increase.

How Many Workstations and Employees Will We Need?

First, we will calculate the maximum cycle time we have available to complete each product. It is easy to do; here is how:

1. Calculate the amount of available work time you have in **a work period.** This may be expressed as a "day" or a shift.

2. **Make sure you clarify how you define a "day"**: is it 8 hours, 10 hours or the product of all three shifts?

3. Determine the **demand** (how many products you must produce) during that work period. "Products" may be radios, tee shirts, or completed documents.

4. Divide the available work time by the number of products you must finish to discover the maximum cycle time available to produce each unit.

Practice Exercise

We are considering placing a bid on a contract to produce 150 documents in a day. How many workstations and employees will we need?

We will break it down step-by-step.

We have an 8-hour day during which we must process 150 documents. We divide the available time to produce it (8 hours) by the amount of products we must make. This becomes 8 hours ÷ 150 products = .053 hours maximum cycle time per product.

Although this is mathematically correct (.053 hours), we can express it more clearly. We will convert the 8-hour day to minutes and see what we get.

8 hours in the work period x 60 minutes in an hour = 480 minutes

Let us calculate the maximum cycle time again. 480 minutes ÷ 150 products = 3.2 minutes maximum cycle time per product.

It is getting clearer because we can understand 3.2 minutes per product cycle time much easier than .053 hours. Let us take it another step and see if it gets any better:

480 minutes in the work period x 60 seconds in a minute = 28,800 seconds

28,800 seconds ÷ 150 products = 192 seconds maximum cycle time per product.

Now we have something we can easily work with. We see that we only have **192 seconds** to produce each product if we are to achieve our requirement of 150 per work period.

Look back at our calculations on production layouts "A" and "B". We first calculated we would need **580** seconds to process a document with **four workstations** using layout "A". Then we combined tasks into **three workstations** on layout "B" and calculated we could reduce production time down to **465** seconds.

PRODUCTION LAYOUT "A"

If we need **580** seconds to produce a document with layout "A" (with four workstations) and must complete a document within **192** seconds, we must have 580 ÷ 192 = 3.02 layouts like "A".

However, since we cannot have less than a complete work process (the ".02" remainder), we must have 4 layouts like "A" and realize that we are not getting maximum use out of the 4th one. Four workstations mean four employees must be hired for each type "A" layout. Four layouts mean the company will have to hire 16 people. That can be expensive!

PRODUCTION LAYOUT "B"

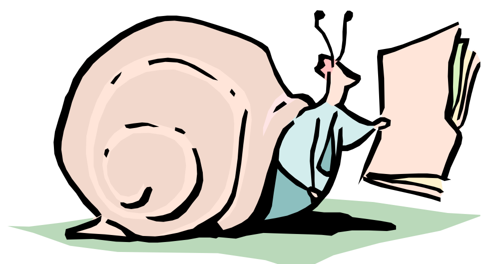
If we need **465** seconds to produce a document with layout "B" (with three workstations) and must complete a document within **192** seconds, we must have 465 ÷ 192 = 2.4 layouts like "B".

But, since we cannot have less than a complete work process (the ".4" remainder), we must have 3 layouts like "B" with 3 workstations each and realize that we are not getting maximum use out of the 3rd one.

Three new layouts mean three employees must be hired for each type "B" layout. This means we will have to hire 9 employees. *This is certainly better than hiring 16 as we would with the type "A" layout.*

HOW EFFICIENTLY ARE YOUR EMPLOYEES WORKING?

This section will be deceptively short because you have already learned how to determine employee efficiency!



Look back to the production layouts "A" and "B" where we calculated efficiency for each production plan. We calculated efficiency by dividing the time spent actually working within the entire cycle time required to make the product.

Layout "A's" efficiency rating was **53.9%**: "B's" was **67.3%**. That is how you determine an employee's efficiency. Ideally, you want to get as close to 100% as possible, which would mean there was no idle time within a production process.

That is virtually impossible in reality but you can use 85% as a typical benchmark of an efficient operation.

How Productively Are Your Employees Working?

Essentially, productivity requires measurements of **quality**, **quantity**, and **time** being present. *Without all three measures included, employees are only "busy" but not productive.*

For example, an employee processing 875 documents an hour at an accuracy of 98.6% is being **productive** because you have quantity (875), quality (98.6% accurate), and time (hour).

(Whether 875 an hour is productive *enough* for the company's standards is a matter between the employee and his supervisor.) If we told the employee to process 875 documents in an hour without reference to the quality standard, he would just be **busy.** If we cannot use the documents he processed because of high errors, he has "produced" nothing of value and only wasted time.

Take a minute to think about your job. Name a task that you do that clearly has defined measurements of quality, quantity, and time. What does it do for your job satisfaction and level of confidence knowing exactly what is expected of you?

If you are not sure or cannot name tasks that have all three elements clearly defined, what does that do to your motivation to work? **(It reduces motivation.)**

What does that for your confidence if you are not positive about what your supervisor expects from you**? It reduces it.**

What conversation should you have with your supervisor as soon as you leave this class? **Get your work expectations clarified in terms of quality, quantity, and time.**

If you have employees who are not working to your expectations, is there a chance they have similar confusion about **your expectations of them** as you may have about **your supervisor's expectations of you**?

PRODUCTION CAPACITY TODAY AND TOMORROW

Production managers face these questions daily

- ✓ "How many products can we produce at our maximum efficiency?"
- ✓ "How much will that cost us?"
- ✓ "If we get a chance to bid on a new project, will we be able to handle it?"
- ✓ "Will we need additional resources?"

We have already learned how to analyze existing workflows to see if there are opportunities to reduce cycle time, delays, or movement. We will do another exercise here to work our way through this situation.

You have looked at assembly lines to see if we could rearrange the sequence of tasks or group tasks to reduce cycle time and the number of workstations and employees while increasing efficiency. Now we will assume that we have rearranged the assembly lines to their most efficient.

Our company has an opportunity to bid on a project that **could make a lot of money for us**. However, if we do not do our homework first, *it could cost us a lot of money instead.* This next analysis will give us a clear picture of what we can or cannot do and help us select the best action among several choices.

Staff and Equipment Capacities

Let us calculate the existing cost and production capacity of our workforce in the department we are analyzing. Before we can begin looking ahead to tomorrow, we must be sure we have a confident understanding of where we are today. (Note: FT = full time, PT = part time)

Here is the worksheet we completed about our current situation.

Current Staff Capacity and Cost

November 13

Cindy Huntley

Account Processing

Line #	Employee Position	Processor (FT)	Processor (PT)
1	Hourly production minimum	10 accounts	7 accounts
2	Hrs. per production period	8	8
3 (lines 1x2)	Production/ employee /period	80	56
4	Annual production periods /employee	236	250
5 (lines 3x4)	Annual production /employee	18,880	14,000
6	Hourly cost /employee	(FT)	$8.25
7 (lines 2x4x6)	Annual cost /employee	$18,750	$16,500
8	Number of these employees	8	5
9 (lines 7x8)	Total annual employee cost	$150,000	$82,500
10 (lines 5x8)	Total annual production	151,040	70,000
11 (lines 9/10)	Current staff cost / product	**$0.99**	**$1.18**

Why is this less than FT? (Typically PT has lower skill levels)

Why is this more than FT? (PT does not get vacations)

Why did we not put a number here? (FT is on a salary, not hourly rate)

How could we reduce the cost per item produced by the PT employees? (One way is to devise a training program to increase their skills.)

We must also consider the equipment capacity and cost of production. This is how we do it.

Current Equipment Capacity and Cost

Row 2: This is at normal operating speed.
Row 5: Machines can run 24/7 (include maintenance periods)
Row 7: Any cost except the employee assigned to the machine. This can include depreciation, maintenance, electricity, and materials the machine uses.

1	Equipment	Laser printer	Processing machines
2	Hourly production capacity	60	550
3	Hrs. per production period (a work shift)	8	8
4 (rows 2x3)	Production capacity/ machine /period	480	4400
5	Annual prod periods/ machine	250	250
6 (rows 4x5)	Annual production/ machine	120,000	1,100,000
7	Hourly cost/ machine	$0.65	$1.09
8 (rows 3x5x7)	Annual cost/ machine	$1,300.00	$2,180.00
9	Number of these machines	8	1
10 (rows 8x9)	Total annual machine cost	$10,400.00	$2,180.00
11 (rows 6x9)	Total annual production capacity	960,000	1,100,000
12 (row 10/11)	Current cost / product	$0.01	$0.0020

Annual production periods per machine require some explanation. The example above with row #5 (annual prod periods/ machine) = “250” derives from this assumption:

- ✓ The company is open for one “shift” per day
- ✓ 365 days in a year minus 10 holidays the company is closed = 355 days
- ✓ The company is also closed on weekends. This is 2 days every week and there are 52 weeks in the year = 104 days. From the line above, 355 days – 104 weekend days = 251 days of productivity. (We rounded this to 250 for ease of calculation in the example.)

If the company were open 24/7, the number of production periods would be greater.

PRACTICE ACTIVITY

- ✓ **How many <u>more</u> <u>full time</u> employees could we hire at their current production rates before exceeding the production capacity of the printers we currently have?**

  Total printer capacity = 960,000 Current FT staff capacity (figure 11) = 151,040;

  PT staff capacity = 70,000 151,040 FT + 70,000 PT = 221,040 staff capacity.

  Printer capacity unused = 960,000 – 221,040 = 738,960. 738,960/18,800 (each FT capacity) = 39.3 or **39 new FT employees without exceeding the printers' capacity**.

- ✓ **How many <u>more</u> <u>part-time</u> at their current production rate?**

  Total printer capacity = 960,000 Current FT staff capacity (figure 11) = 151,040;

  PT staff capacity = 70,000 151,040 FT + 70,000 PT = 221,040 staff capacity.

Printer capacity unused = 960,000 – 221,040 = 738,960. 738,960/14,000 (each PT capacity) = 52.7 or **52 new PT employees without exceeding the printers' capacity**

- ✓ **What would be the most cost effective combination of full or part-time employees to get as much of the printer capacity as possible without exceeding it?**

  Total full time = 960,000/18,800 = 51.06 FT employees (round down to 51.0)

  51 FT employees x 18,800 capacity each = 958,800 produced

  958,800/960,000 = **99.875% of max printer capacity**

  Total P/T = 960,000/14000 = 68.57 PF employees

  68 PT employees x 14,000 = 952,000

  952,000/960,000 = **99.17% of max printer capacity**

  What % of maximum printer capacity would we be using?

- ✓ **Full Time employees = 99.9**%
- ✓ **Part Time employees = 99.27%**

Practical Application Challenge

Our company has a chance to become a parts supplier for an automobile manufacturer that is building a new plant in our state. We already make a product similar to the one they need so we will not have to modify any equipment. This is our present situation:

Current Staff Capacity				
Number of employees	Job Assignment	Hourly production each	Hourly cost each	Their annual cost each (2000 hrs)
6	Assembly Line Workers (ALW)	850	$14.50	$29,000
4	Assembly Machine Operators (AMO)	1,500	$16.50	$33,000

Current Equipment Capacity				
Number of Machines	Equipment Description	Hourly production each	Hourly cost each	Their annual cost each
4	Assembly Machine (AM)	1,500	N/A	N/A

Why are we not concerned with cost in this example? (We want to know if we can produce them. We are not considering the cost now.)

Other information that may be useful:

- ✓ If we hire more full time employees, they will be at the same pay rates as above. Since we have a strong "new hire training program", we anticipate they will meet those same production numbers quickly. They will work 8-hour periods, 5 times a week, and get 2 weeks vacation starting their first year. We pay over time at time-and-a-half but restrict it to 2 hours at a time.
- ✓ We can hire an unlimited number of part-time employees as ALWs and AMOs. Their productivity in both positions is typically 70% of a full-timer's. They cost $10.75/hr., must work a minimum of 2 hours if we call them to work. They do not earn overtime nor get benefits or vacations.
- ✓ The potential client requires us to be able to produce a minimum of **13,750,000** assemblies a year.

They questions we face are:

- ✓ Do we currently have enough machine and staff capacity to do that?
- ✓ If not, what will be the least expensive way to achieve that capacity without having to set up additional shifts?

This work sheet will help you visualize the situation. Calculate the open cells.

	Staff Capacity and Cost Calculations				
Row 1:	Specify full (FT) or part-time (PT) to eliminate possible confusion.				
Row 2:	This amount is defined as the minimum acceptable level of productivity and contains measurables of quality, quantity, and time requirements.				
Row 3:	A normal workday or shift length				
Row 5:	Assume the FT employees get 2 weeks vacation and there are 10 company holidays per year when the plant is closed.				
1	**Employee Position**	**FT AL Workers**	**FT AM Operators**	**PT AL Workers**	**AM Operators OT**
2	Hourly production minimum	850	1,500	595	1,500
3	Hrs. per production period	8.00	8.00	8.00	2.00
4 (rows 2x3)	Production/ employee /period				
5	Annual prod periods /employee				
6 (rows 4x5)	Annual production /employee				
7	Hourly cost /employee				
8 (rows 3x5x7)	Annual cost /employee				
9	Number of these employees				
10 (rows 8x9)	Total annual employee cost				
11 (rows 6x9)	Total annual production				
12 (row 10/11)	Current staff cost / product				

The answers are placed later in the course.

Current Equipment Capacity and Cost

Row 2: This is at normal operating speed.
Row 5: Machines can run 24/7
Row 7: Any cost except the employee assigned to the machine.

1	**Equipment**	**AL Machine**	**AL Machine OT**
2	Hourly production capacity	1,500	1,500
3	Hrs. per production period	8.00	9.25
4 (rows 2x3)	Production/ machine /period	12,000	13,875
5	Annual prod periods/ machine	250	250
6 (rows 4x5)	Annual production/ machine	3,000,000	3,468,750
7	Hourly cost/ machine	We are not calculating machine costs here so we do not include this in the problem. We are focused on **total production capacity** regardless of the cost.	
8 (rows 3x5x7)	Annual cost/ machine		
9	Number of these machines	4	4
10 (rows 8x9)	Total annual machine cost	N/A	N/A
11 (rows 6x9)	Total annual production	12,000,000	13,875,000
12 (row 10/11)	Current cost / product	N/A	N/A

Practice Exercise

Staff Capacity & Requirements		Machine Capacity & Requirements	
Annual requirement	**13,750,000**	**Annual requirement**	**13,750,000**
Assembly Line Workers (ALW)		**Assembly Line Machine (ALM)**	
Current total FT ALW capacity	9,628,800	Current total ALM capacity	12,000,000
Capacity surplus/shortage?	**shortage**	Capacity surplus/shortage?	**shortage**
Extent of surplus/shortage	4,121,200	Extent of surplus/shortage	1,750,000
Current capacity of individual FT ALW.	1,604,800	Current capacity of individual ALM.	3,000,000
FT ALW needed	**2.6 = 3.0**	**ALM needed**	**0.6 = 1.0**
Extent of surplus/shortage	4,121,200		
Expected capacity of individual PT ALW	1,123,360		
PT ALW needed	**3.7 = 4.0**		
Assembly Machine Operators (AMO)			
Current total FT AMO capacity	11,328,000		
Capacity surplus/shortage?	**shortage**		
Extent of surplus/shortage	2,422,000		
Current capacity of individual FT AMO.	2,832,000		
FT AMO needed	**0.9 = 1.0**		
Extent of surplus/shortage	2,422,000		
Expected capacity of individual PT AMO	1,982,400		
PT AMO needed	**1.2 = 2.0**		

They questions we face are:

- ✓ Do we currently have enough machine and staff capacity to do that? **No**.
- ✓ If not, what will be the least expensive staffing method to achieve that capacity without having to set up additional shifts? **(The answers in green above)**

BREAK EVEN ANALYSIS

A "break even" analysis is probably nothing new to you.

If you ever got tired of getting your old car repaired and decided to buy a new one, you made a "break even" analysis although it may not have been totally based on economics.

Or you may have thought, "instead of renting this (insert anything "rentable" here), I'll probably save money if I just buy one!"

There is a mathematical way to determine when it is smarter to pick one alternative over another. That is what we will learn next.

Your department is going to start making a product that requires monthly steam cleaning of the production floor. You can either rent a steam cleaner for $45/day or buy a new one for $475.

You estimate you will not need it more than a day at a time. However, you realize at some point it will be smarter to buy the machine than keep renting it.

QUESTION: **When does it become smarter to buy instead of rent?** (Answer = It will pay for itself just before the 12th use.)

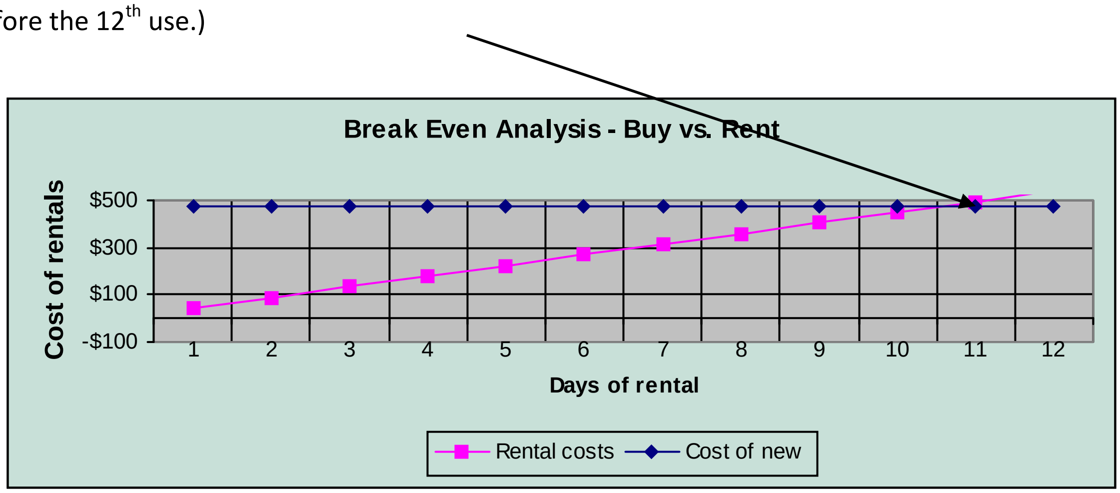


Figure 3

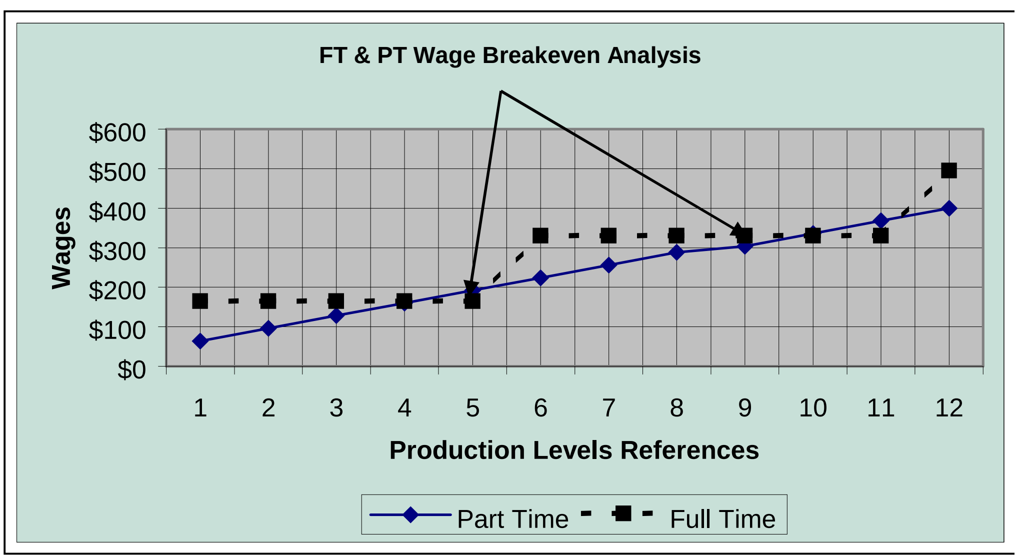
BREAK EVEN PRACTICE EXERCISE

You are the manager of the production department and have been given the required production schedule below. You have permanent employees who can produce 150 items per hour. Part-time employees are also available but they typically produce 70% of what you can get from the permanents. Permanents cost $165 day and you must pay them for full-day periods only. Part-timers cost $16 per hour. They must work in whole-hour increments.

Figure 4 **Fill in the rest of the data table.**

Required Production Amounts	FT hourly production = 150		PT production @ 70% = 105		
	FT/Hrs Needed	Cost/day FT	70% PT/Hrs	PT Full Hours	Cost/hr PT
					$16.00
400					
600					
800					
1000					
1200					
1400					
1600					
1800					
2000					
2200					
2400					

Here is a chart showing breakeven points at various production levels.



Answers to the table on the previous page.

This is what our data looks like.

Required Production Amounts	FT hourly production = 150		PT production @ 70% = 105		
	FT/Hrs Needed	Cost/day FT	70% PT/Hrs	PT Full Hours	Cost/hr PT
					$16.00
400	2.7	$165	3.8	4	$64.00
600	4.0	$165	5.7	6	$96.00
800	5.3	$165	7.6	8	$128.00
1000	6.7	$165	9.5	10	$160.00
1200	8.0	$165	11.4	12	$192.00
1400	9.3	$330	13.3	14	$224.00
1600	10.7	$330	15.2	16	$256.00
1800	12.0	$330	17.1	18	$288.00
2000	13.3	$330	19.0	19	$304.00
2200	14.7	$330	21.0	21	$336.00
2400	16.0	$330	22.9	23	$368.00
2600	17.3	$495	24.8	25	$400.00
2800	18.7	$495	26.7	27	$432.00
3000	20.0	$495	28.6	29	$464.00
3200	21.3	$495	30.5	31	$496.00
3400	22.7	$495	32.4	33	$528.00

Answers to problem on page 38

Staff Capacity and Cost Calculations

1	**Employee Position**	**FT AL Workers**	**FT AM Operators**	**PT AL Workers**	**AM Operators OT**
2	Hourly production minimum	850	1,500	595	1,500
3	Hrs. per production period	8.00	8.00	8.00	2.00
4 (rows 2x3)	Production/ employee /period	6,800	12,000	4,760	3,000
5	Annual prod periods /employee	236	236	250	236
6 (rows 4x5)	Annual production /employee	1,604,800	2,832,000	1,190,000	708,000
7	Hourly cost /employee	$14.50	$16.50	$10.75	$24.75
8 (rows 3x5x7)	Annual cost /employee	$29,000	$33,000	$21,500	$49,500
9	Number of these employees	6	4	4	4
10 (rows 8x9)	Total annual employee cost	$174,000	$132,000	$86,000	$198,000
11 (rows 6x9)	Total annual production	9,628,800	11,328,000	4,760,000	2,832,000
12 (row 10/11)	Current staff cost / product	$0.02	$0.01	$0.02	$0.07

Use the data sheet below to make these worker selection decisions.

✓ If the production demand for an upcoming client will be 400 items, should we hire a new full time employee or a temp? Why?

Use the same question format to produce these volumes:

Demand	FT or PT?	Reason
500	PT	Select $80 PT for 5 hours of work instead of $165 for 4.5 hours since FT must get paid for all day.
1150	FT	Select FT because 1200 produced in 8 hours = $165 while PT needs 11 hours to produce that at a cost of $176.
1500	PT	Select PT because will cost $240 to produce vs. $330 for FT.

Work Hours	FT Produces @ rate of 150	PT Produces @ rate of 105	FT Wages at this volume	PT Wages at this volume
1	150	105	$165	$16
2	300	210	$165	$32
3	450	315	$165	$48
4	600	420	$165	$64
5	750	525	$165	$80
6	900	630	$165	$96
7	1050	735	$165	$112
8	1200	840	$165	$128
9	1350	945	$330	$144
10	1500	1050	$330	$160
11	1650	1155	$330	$176
12	1800	1260	$330	$192
13	1950	1365	$330	$208
14	2100	1470	$330	$224
15	2250	1575	$330	$240
16	2400	1680	$330	$256

In this length of time....

...they produce this much...

Write a description here that explains what the DATA is telling you about the breakeven points.

If we knew what the desired production was *and we were not concerned with time*, we could staff for the most cost-effective production runs like this:

- ✓ Part-time hours are cheaper up to 10 full hours (9.5 on the graph) where we can produce up to 1,000 items.
- ✓ Full-time is cheaper from 1,000 to 1,399 items
- ✓ Part-time is cheaper from 1,400 to proportionally between 2,000 and 2,200 items. (Actual amount is 2,171 using expression 304 : 2000 :: 330 : X = 330*2000=304x = 660,000/304x=2,171)
- ✓ Full-time is cheaper from 2,200 (actually 2,172) to 2,400
- ✓ Part-time is cheaper from 2,600 to just under 3,200

PREDICTING FUTURE DEMAND

We can make reasonable predictions about the future if we have kept good records of the past. The more past data we can review, the greater the chances our predictions will be close. (We never expect them to be 100% because there is always an element of random chance in our lives.)

We can make "educated guesses" about future events that may not be measurable such as *"what will the market want us to produce this time next year?"* or like, *"how much volume do you think we'll process this time next year?"*

We will look at one method of collecting non-measurable data and then at how to use past data for confident future predictions.

PRIORITIZING OPINIONS BY A "FORCED CHOICE" METHOD

(Use this for non-measurable predictions. It is also called "Nominal Group Method".)

Suppose you gather a group of company experts with long experience and knowledge about your industry. You want to find out what they think are the most likely products the market will want this time next year.

You set ground rules that everyone must reply but no one else can object or argue. An assistant will post their ideas on a board or flip chart.

You go around the table in order. Each person must give an answer or say, "pass". When all have passed, you will stop. Then number the responses.

Before the meeting, prepare a sheet that looks like this. We have listed from 1-5 but you can list more if you expect many answers.

1 2

1 2
3 3

1 2 3
4 4 4

1 2 3 4
5 5 5 5

Let us assume we are in the book-publishing field and we asked our staff for ideas on future products. Since we cannot attempt all of them at once, we want to prioritize them

This is the list of ideas:

1. Every book title on a CD they can play in their car
2. More techo-thrillers
3. Larger print in paperbacks
4. Electronic books they can download at home for a price
5. Shorter stories – not over 250 pages most popular

Next we will vote!

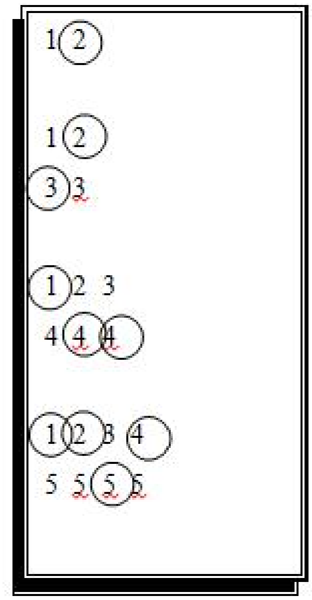
It would be very confusing for people to consider all five choices at once and expect them to select a priority order. We can make it easier for them by asking them to select a preference from between two choices at a time. That is what we have done with the layout above. If you look carefully at the numbers, they are pairs of all the combinations possible.

Now ask people to look only at each pair of choices, decide which they prefer, **make no comments (just raise their hands)**, and be sure that everyone votes.

Here is an example of how it would work.

- You say, "Look at choices 1 and 2 only. All of those who prefer choice #1, raise their hands." You count the hands.
- Then say, "All those who prefer #2, raise your hands." You circle the number that gets the biggest count.
- Then say, "Let's compare numbers 1 and 3. All in favor of #1, raise your hands." You count the hands in the air. "Now all in favor of #3 raise your hands."

- You work your way through the chart until you have voted on every pair and your charts looks like this.



Then add up the times each was selected:

1 = 2

2 = 2

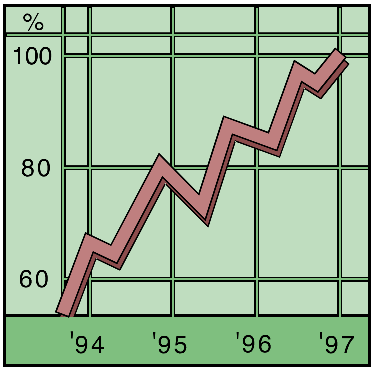
3 = 1

4 = 3

5 = 1

According to your panel, they think choice #4 (with 3 votes) is most likely to happen. If you must break the tie between any of the others, use the same method we just did.

Measurable Forecasting Methods



We will look at some simple but powerful methods of predicting future measurable trends.

Remember that **measurable** predictions are based on past data while **non-measurable** predictions are usually "best guess" thoughts based on experience and educated opinion.

We will look at four prediction methods and you will quickly understand when to use each.

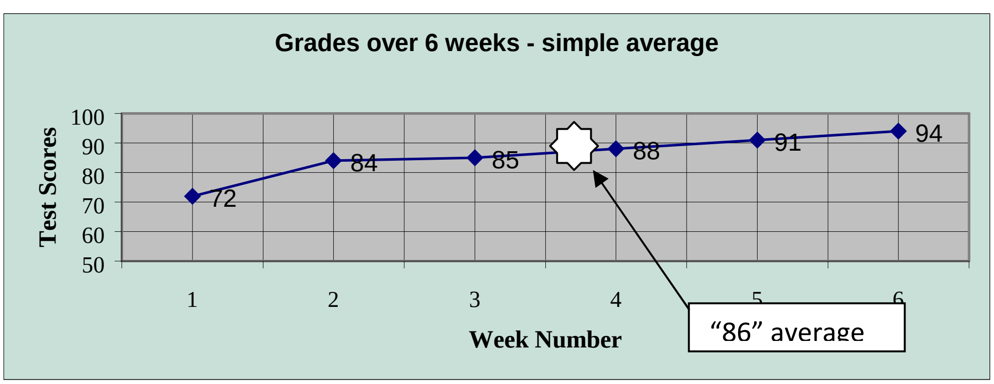
Simple Average ("SA")

This is what we used in grade school to determine how we would do on the next report card.

Although the report card was in our future, **it only told us about our past.**

For example, if we received these scores on our weekly tests, 72, 84, 85, 88, 91, and 94 over the past six weeks, we would add them up (514), divide by 6 (the number of scores), and expect an average grade of **86** (85.66) on our report card.

Look at our scores. Do you see a trend over the past six weeks? **What is it? [Steadily increasing]**

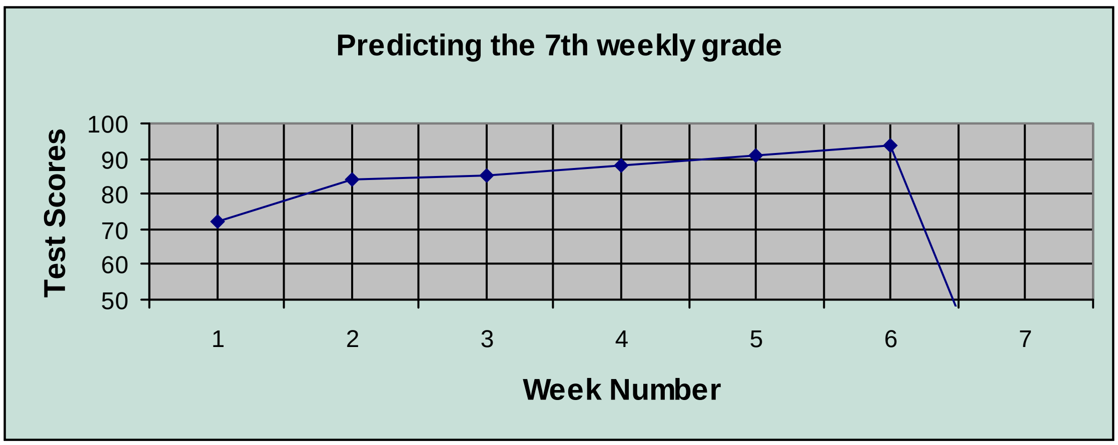


Look at the trend you see emerging from the past 6 weeks.

Let's assume this trend continues into the 7th week. What score do you expect to see on the 7th weekly test [Something a little higher than the last test, which was a 94]?

How does it compare to the simple average? [It is higher than the average.]

Do you think the simple average will be a good predictor of what to expect next week? [No] Why? [It will be too low based on the trend we are seeing.]



SIMPLE MOVING AVERAGE ("SMA")

WEEKLY TEST SCORES

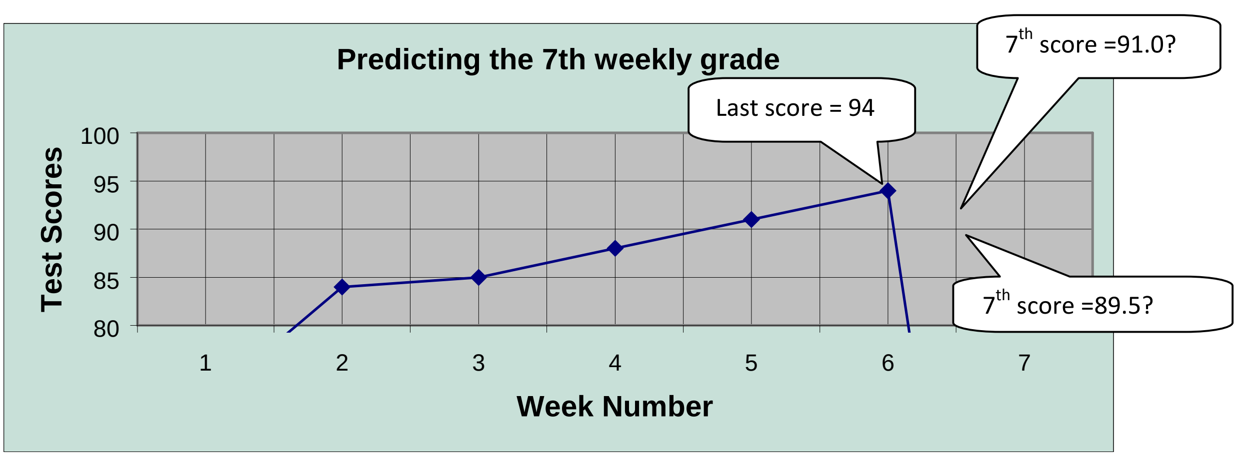
Each week that goes by means that our test scores have gotten better.

Instead of averaging the entire period to include the "ancient history" of six weeks ago, maybe we should consider the more recent scores because they seem to have more in common with where we are today instead of how we were six weeks ago.

If we just count the last 2 scores, we may not have enough for a fair sampling of test scores. Averaging three will be better. If we average the last four, are we going too far back? There is no way to be certain whether three or four are better. We will try them both.

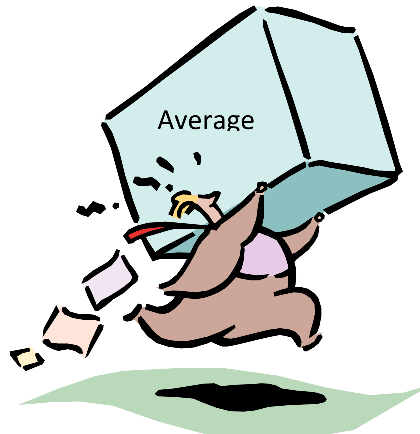
Our last four scores from the most recent have been 94, 91, 88, and 85. The average of the last 3 is **91.0**. The average of the last 4 is **89.5.**

Since our last score was **94** and the trend shows that we are improving steadily, has the moving average score helped our prediction for next week's score? [yes] Why? [Intuitively we expect the moving average reflecting the upward rend to be closer to the actual test score.]



WEIGHTED MOVING AVERAGE ("WMA")

We will leave the prediction about the 7th test grade alone for a few minutes and recall another aspect of grade school, the dreaded "SEMESTER PROJECT".



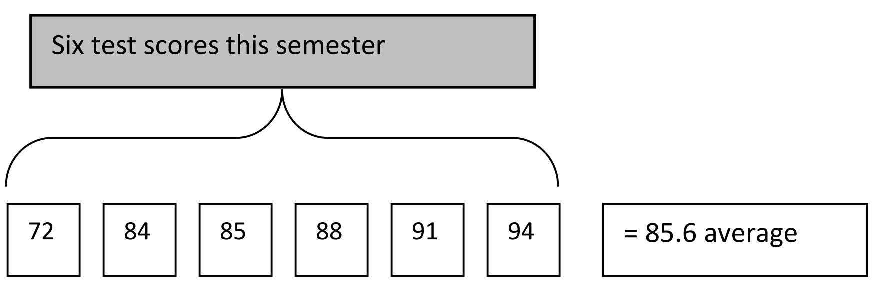
The teacher would always say something like, "The semester project is very important and your score on will be **weighted 4 times as much** (or some amount that she decided) in relation to your test grades".

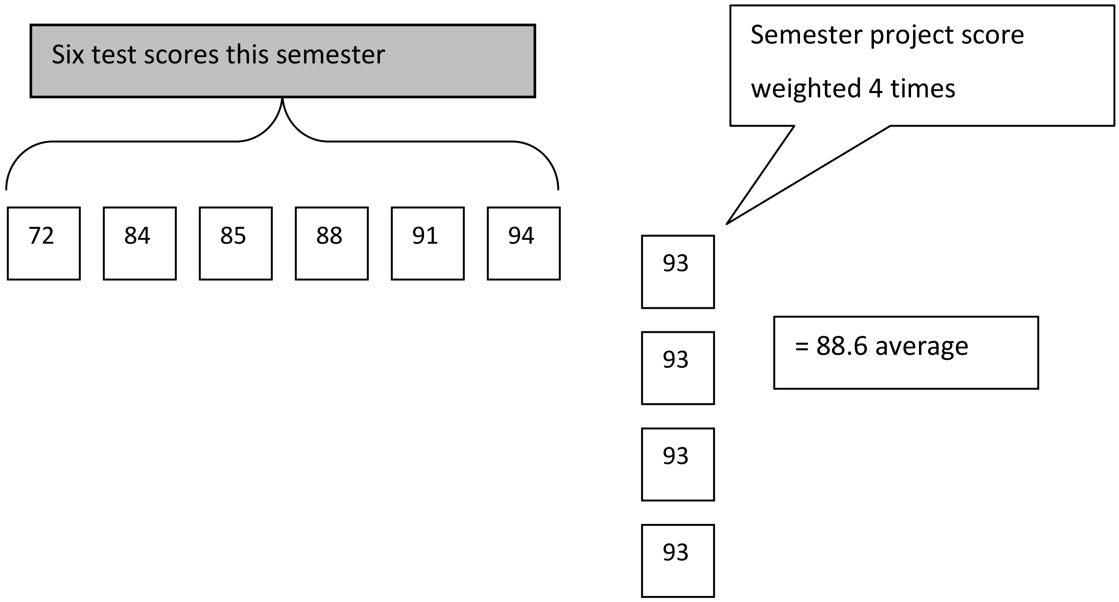
This means that if you received a **93** on the semester project, she would count it as four 93's when she figured your semester grade.

Suppose your test grades were the six we used back on the "simple average" topic on page 50 and we had an average of 86. Now she adds 93, 93, 93, and 93 to that (the actual score of 93 you received repeated four times to give it a **weight of 4**) which brings your **semester score total to 886.** (72, 84, 85, 88, 91 and 94+93+93+93+93 = 886)

Now when you divide the semester total score of 886 by 10 scores (the six test scores plus the project score repeated four times), your semester average will be **88.6**.

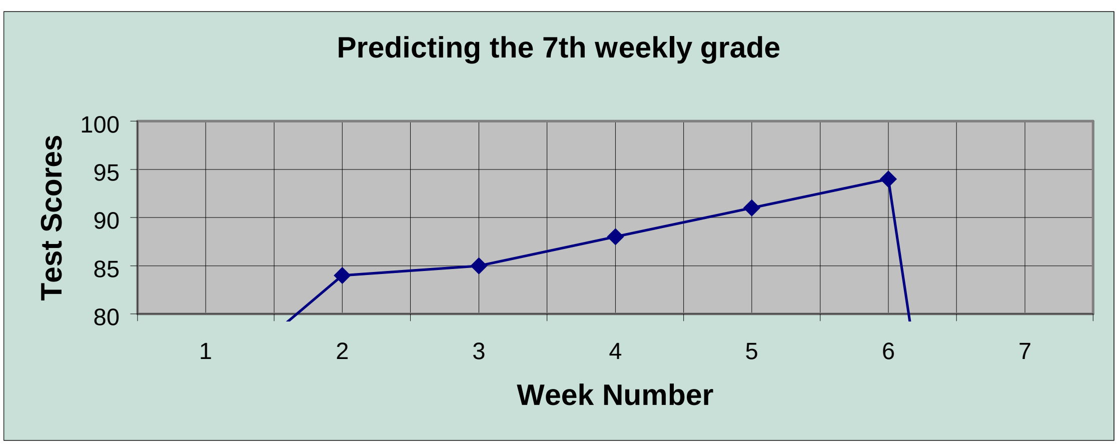
Compare this to your semester average of six tests alone that was **85.6**





You can see how the **WEIGHTED** score pulled the average higher from **85.6** to **88.6**

We will use this same "weighted" concept that pulled our semester average higher in predicting what our next test score will be.



We see that our weekly test scores have been improving steadily. So, if we want to add a weighted number into our calculation for the future, we would be smart to use the latest number ("94"). We can add it into our calculation as many times as we want.

There is no "best number" of times you should add a number for proper weighting.

The shaded scores are the first six tests.

Look at this model to see what we mean.

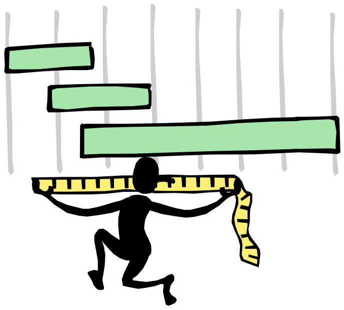
Average	Extra 94's	1	2	3	4	5	6	7	8	9	10	11	12
85.67	0	72	84	85	88	91	94						
93.55	104	72	84	85	88	91	94	94	94	94	94	94	94
92.33	24	72	84	85	88	91	94	94	94	94	94	94	94
89.83	6	72	84	85	88	91	94	94	94	94	94	94	94

This is how the prediction for the next test score changed as we added different weights of 94's to the calculation.

We added this amount of extra 94's to our calculations.

You can see that the more times we include another "94" to add weight to the calculation, the average increases slightly. You will have to decide through experience how many times you want to add a "weight" to your calculations.

Our weighted prediction for our next test score ranges from 85.67 – 93.55.



CHANGE MEASUREMENT ANALYSIS (CMA)

Another method we can consider for use in predicting what our next grade will be is *Change Measurement Analysis.*

This is used if we are confident that a trend that we've seen in the recent past will continue into the next month.

Let's look back at our grades to see how this works.

Test #	1	2	3	4	5	6
Score	72	84	85	88	91	94
Change from prior		12	1	3	3	3

Average change = 4.4

We added the 5 change amounts and found their average to be 4.4. We had 6 test scores but only divided by 5. Why?

(We divided by 5 because there were 5 changes between the 6 scores.)

If our grades have changed ***an average of 4.4 points better*** on each test, we can add that average change to our last test score and predict the <u>next</u> test score. We add **4.4** to the last score of **94** and get a prediction of **98.4**. (We round that down to 98.)

STOP AND REVIEW BEFORE GOING AHEAD

Take a few minutes to discuss the value of each forecasting method thinking about when it is best used and when it is not useful.

Forecasting Method	Useful for this..	Not useful for this..
Simple Average		
Simple Moving Average		
Weighted Moving Average		
Change Measurement Analysis		

PREDICTING SEASONAL TRENDS

We look at predicting seasonal trends in a similar way that we look at predicting our next grade on a test. We will use the holiday shopping season as an example.

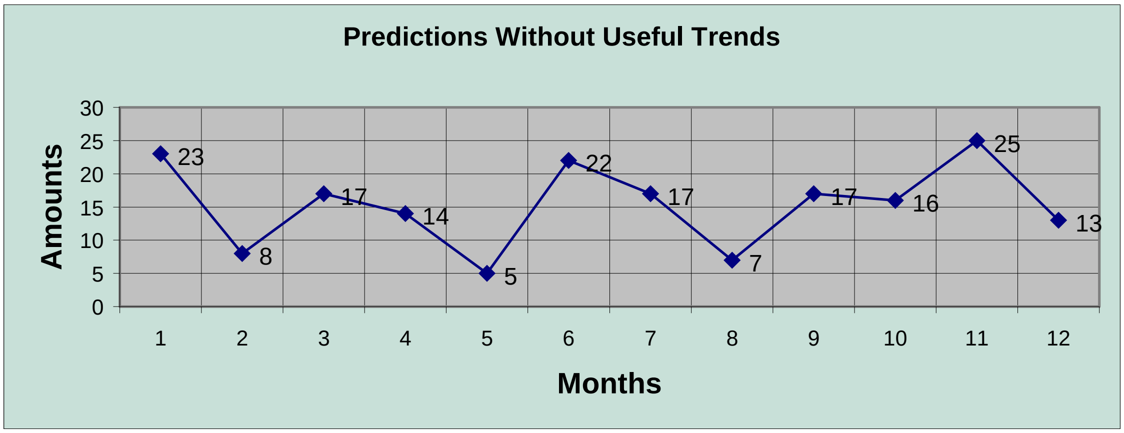
Instead of looking at the previous months of this year to predict what kind of a holiday season we can expect, we will look at the ***previous holiday seasons*** over the past few years to make a prediction.

There are conditions outside of our control, of course, such as the economy in general, the weather, and possible shortages of a particular item that we must always consider in addition to the pure math data of past seasons.

The point we want to make here is that we compare similar data when making a prediction of a future measurable event. That is why we compare similar **previous holiday seasons** instead of **previous months** on this year's calendar.

MAKING PREDICTIONS WITHOUT USEFUL TREND DATA

Sometimes we have to make a prediction when there is no discernable pattern to the past.



What prediction would you make for the 13th month from this chart? [None. It is too random!]

Practical Problem Solving

It is time to review what we have covered so far and see if we can apply it to the real world where you work. We will combine several topics that we have covered.

The ACME tool company makes a wide variety of farm equipment. Here are the tasks and lengths of time associated with making a new design called *The Field Master*. Their company currently works an 8-hour day. This is the initial sequence of tasks needed to produce one Field Master.

Use the work sheets on the next page to help lay out your ideas.

Task	Sequence Requirement	Task Time/min
A	1st task	10
B		4
C		6
D		24
E	after D	6
F		8
G		5
H	last task	16

If this sequence arrangement were installed as shown and called "an assembly line", how many Field Masters could be produced in an 8-hour day? **2.5 (see next page)**

What is the **cycle time** of each assembly line using this arrangement? **192 minutes**

What is the efficiency of this assembly line? **41.1%**

If each task were done at a separate workstation, how many workstations would we need for this assembly line? **8 because there are 8 distinct tasks as it is set up like this.**

If we hired one new employee for each workstation, how many would we need to hire using this assembly line? **8 new employees**

How would you rearrange it to increase the efficiency to over 80%? **(Next page)**

If you achieved efficiency greater than 80%, what is the least number of assembly lines you would need to produce 20 Field Masters per day?

Call this the ORIGINAL ASSEMBLY LINE

Task	Sequence Requirement	Task time in minutes	Longest Task	Wait Time
A	1st task	10	24	14
B		4	24	20
C		6	24	18
D		24	24	0
E	after D	6	24	18
F		8	24	16
G		5	24	19
H	last task	16	24	8
		79		**113**

Actual work time = **79** minutes   Total wait time = **113** minutes

Product cycle time (actual work + wait time) = **192** minutes

Efficiency = 41.1% [79/192 = .411]

(480 MIN/DAY)/192 MIN/CYCLE = 2.5 PRODUCTS/DAY

Use these forms to try different arrangement ideas.

Task	Sequence Requirement	Task time in minutes	Longest Task	Wait Time
A	1st task	10	24	14
D		24	24	0
BCEF	"E" after "D"	24	24	0
G		5	24	19
H	Last task	16	24	8
		79	**120**	**41**

Assembly Line Proposal "A"

Actual work time = **79** minutes

Total wait time = **41** minutes

Product cycle time = **120** minutes

Efficiency = **65.8%**

(480 min/day)/120 min/cycle = **4 products/day**

Task	Sequence Requirement	Task time in minutes	Longest Task	Wait Time
A	1st task	10	24	14
D		24	24	0
BCEF	"E" after "D"	24	24	0
GH	Last task	21	24	3
		79	**96**	**17**
We are still doing "H" last. We are doing it at the same work station we do task "G".				

Line Proposal "B"

Actual work time = **79** minutes

Total wait time = **17** minutes

Product cycle time = **96** minutes

Efficiency = **82.2%**

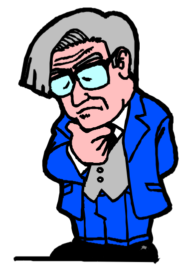
480/96 = **5 units/day**

Assembly line "B" can produce 480 min/96 min cycle time = 5 Field Masters/day.

We would need 4 assembly lines like "B" to produce 20 Field Masters/day.

LESSONS FROM THE PAST

There is another opportunity available to improve the accuracy of our predictions **if we have kept accurate data from the past.**



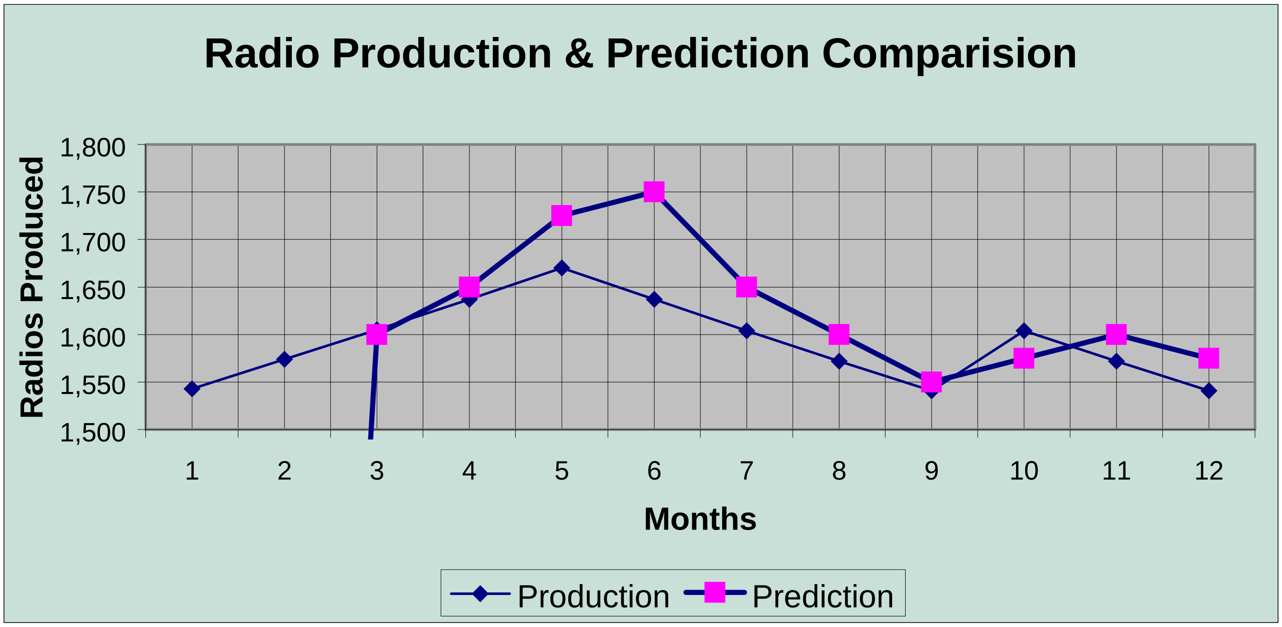
We can apply our new prediction skills to past records, make hypothetical predictions, and see how close our prediction would have come to the actual event.

Let's go back and look at the Big Sound Radio Company and apply this concept. Here are their monthly production numbers and the "predictions" you made as you practiced your new skills.

Month	Actual Production	Predicted Amount	Prediction Error
1	1,543	0	N/A
2	1,574	0	N/A
3	1,605	1,600	-5
4	1,637	1,650	13
5	1,670	1,725	55
6	1,637	1,750	113
7	1,604	1,650	46
8	1,572	1,600	28
9	1,541	1,550	9
0	1,604	1,575	-29
11	1,572	1,600	28
12	1,541	1,575	34

You did not make predictions for the first 2 months because you did not feel there was enough data.

These are the results of your predictions.



We must examine our predictions looking to see how far off (high or low) we were. The amount we are off is called the "**DEVIATION.**" If we do not consider how much high or low we were, we are considering only the **ABSOLUTE** deviation; the distance away from the actual amount.

We added this column to calculate the **ABSOLUTE DEVIATION.**

Month	Actual Production	Predicted Amount	Prediction Error	Absolute Deviation
1	1,543	0	N/A	N/A
2	1,574	0	N/A	N/A
3	1,605	1,600	-5	5
4	1,637	1,650	13	13
5	1,670	1,725	55	55
6	1,637	1,750	113	113
7	1,604	1,650	46	46
8	1,572	1,600	28	28
9	1,541	1,550	9	9
0	1,604	1,575	-29	29
11	1,572	1,600	28	28
12	1,541	1,575	34	34

Notice the absolute deviation numbers are the same as the **"prediction error"** but without the "+" or "-"signs.

We must calculate to find our "***average absolute deviation".*** We do that by adding all of the absolute deviation amounts (we get a sum of 360) and dividing by the number of amounts we have (10). This gives us an **"average absolute deviation" of 36**. [This is also called the ***"Mean Absolute Deviation or MAD."***]

This means we were wrong by an average of 36 every time we made a prediction. This only tells us part of what we need to know. The rest of the question is, "Were we 36 too high or 36 too low?" Now we will answer the rest of the question and factor in whether we were too high or low.

First, we add the prediction errors AND INCLUDE THEIR SIGNS of "+" or "-".
This gives us the sum of "292". Then we divide that by 10 to get an average, we get 29.2 (which we rounded to 29). <u>This number, +29, is very important.</u>

Month	Actual Production	Predicted Amount	Prediction Error	Absolute Deviation
1	1,543	0	N/A	N/A
2	1,574	0	N/A	N/A
3	1,605	1,600	-5	5
4	1,637	1,650	13	13
5	1,670	1,725	55	55
6	1,637	1,750	113	113
7	1,604	1,650	46	46
8	1,572	1,600	28	28
9	1,541	1,550	9	9
0	1,604	1,575	-29	29
11	1,572	1,600	28	28
12	1,541	1,575	34	34
			292	360
			29	36

Details about this table:

- We did not have enough data for the first two months to make predictions.
- **"360"** is the <u>sum</u> of the 10 absolute deviations.
- **"36"** is the <u>average</u> of the 10 absolute deviations
- We interpret that positive aspect of the "29" and the average deviation (36) to mean, *"I averaged 36 TOO HIGH (if it were a negative aspect for '29', it would be TOO LOW) in my predictions for the month."*

The direction high or low is called "bias."
A **negative** bias means the prediction is <u>too low</u> while a **positive** bias means it is <u>too high</u>.
The ***positive aspect*** of the 29 tells us that we were consistently TOO HIGH in our predictions.
It does NOT MEAN we were too high by 29 – only that we were too high. The "36" is HOW MUCH we were too high

Review these terms and describe a situation where you would use them.

- ✓ **Simple Average** [Finding the average of all sales prices of homes in a geographic area]
- ✓ **Simple Moving Average** [Going back in three year increments to see if housing sales have increased over a period of time in a geographic area.]
- ✓ **Weighted Moving Average** [Giving more weight to most recent sales to predict near future sales prices]
- ✓ **Change Measurement Analysis (**If we can measure a steady change in sales prices, we can add that change to the current year's average and get a good prediction for next year.)
- ✓ **Using MAD and bias** (MAD tells us the magnitude of error – bias tells us the direction high or low)
- ✓ **Nominal Group Method** (Get most ideas from a group of people in a short time)
- ✓ Which of these measuring methods are most responsive for making predictions when the past has been steadily increasing or decreasing? **(Change measurement analysis)**
- ✓ When the past has not been a steady trend either up or down? **(None is good for random events.)**