The Lean Process: *A DIY Approach*

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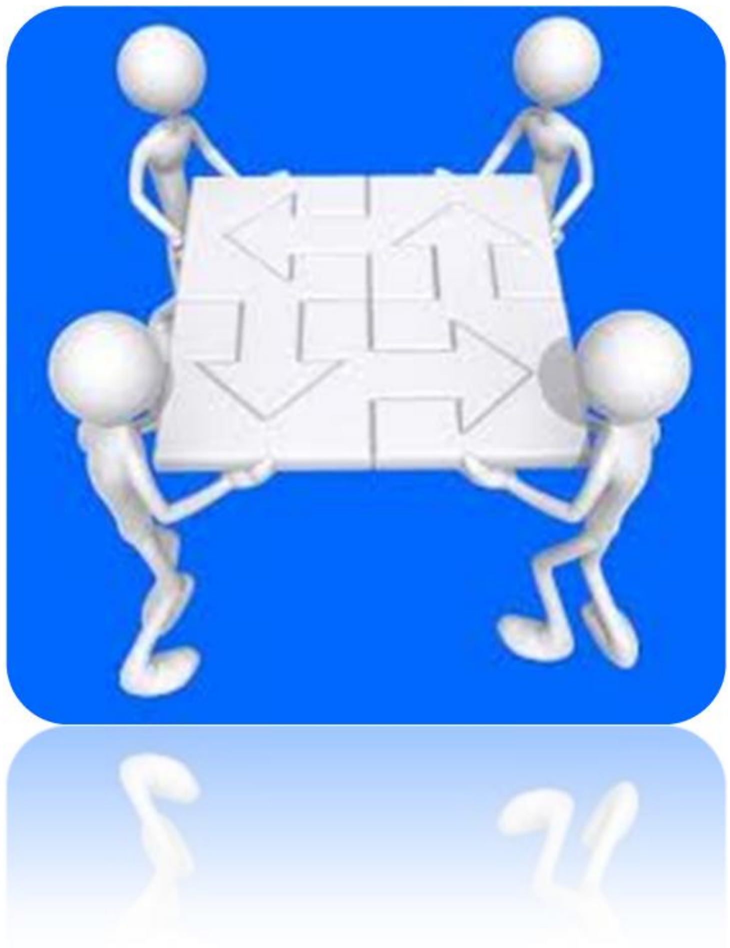
THE LEAN PROCESS:

A DIY APPROACH



By

Richard Grimes

OVERVIEW

Much has been written about the LEAN **manufacturing (lean enterprise** or **lean production)** practice that *"considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination."*[1]

First let me assure you, THIS IS NOT A REHASH OF THAT! There are many volumes available to present that topic from every possible angle telling readers the WHAT and WHY of LEAN practices. Unfortunately, there are not as many telling you HOW.

This course is an attempt to fill that gap in a non-technical, basic examination of several of the concepts within LEAN from a practical application standpoint asking the question, *"How do I translate that flowery rhetoric into real-time use in my situation?"*

We answer that question in analyzing such favorite LEAN-Speak terms as:

- **Make processes more efficient** –
  "*How do we do that? How can we measure the efficiency of a process? Unless we can measure that efficiency, how can we tell if we're improving anything?" This course will show you HOW.*
- **Increasing productivity** –
  "Can we tell the difference between "busy" and "productive"? If we aren't sure of the difference, are we being as efficient as we can be?" This course will show you HOW.
- **Eliminate non value-added work such as waiting for parts, sorting, reviewing, etc.** –
  Is there a simple way to understand supply-chain management? This course will show you HOW.
- **Eliminate unbalanced production workloads** –
  How do we determine whether a production line is balanced? What can we do about it? This course will show you HOW.

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[1] http://en.wikipedia.org/wiki/Lean_manufacturing

- **Reduce your unleveled scheduling** –

  How can we forecast more accurately so we can reduce the highs and lows in production? This course will show you HOW.

This course will provide a practical understanding with easy-to-apply examples of these broad subjects:

- **MEASURING INDIVIDUAL PERFORMANCE AND PRODUCTIVITY**

  How do we know if we're getting the most out of our workforce?

- **CAPACITY PLANNING**

  How much can we produce?

- **STRATEGIC MAINTENANCE MANAGEMENT**

  How do we keep the means of production available?

- **SUPPLY CHAIN MANAGEMENT**

  What is involved in keeping raw materials flowing in to maximize production?

- **DATA ANALYSIS AND FORECASTING**

  What are the most appropriate methods of forecasting based on historic data analysis?

I hope it is a useful resource for you long after you have passed the associated quiz and earned your professional development credits.

If you have suggestions on how we can make it better, please contact me through this website.

Dick Grimes

Birmingham, AL

LEARNING OUTCOMES

Participants in this self-study course will learn to:

1. Compare and contrast productivity with just being busy.
2. Clarify their expectations with elements of quality, quantity, and time.
3. Explain why much workplace stress stems from poorly defined expectations.
4. Reduce much of their workplace stress by asking leaders for clarification of expectations.
5. Explain what SMART goals are and why they are important
6. Write their own measurable performance goals and help others with theirs.
7. Identify the critical elements necessary for productivity.
8. Define and construct "feedback loops" for their work setting.
9. Contrast the advantage of sharing information with employees instead of hoarding it to make them seem indispensable to the department.
10. Analyze floor plans for optimal work flow
11. Analyze work flows to determine their current efficiency
12. Explain and apply the principles of 'line balancing'
13. Determine work process flow adequacy
14. Revise workflows to improve efficiency
15. Explain the concept of 'flow time'
16. Create optimal production cycle timing
17. Apply three capacity planning strategies effectively.
18. Apply the skills learned to practice exercises within the course
19. Learn how to integrate your maintenance program into the business plans of the company
20. Be able to identify the four broad generational stages of the evolution of maintenance
21. Know how to develop the internal talent necessary to maintain the equipment and machinery of your business
22. Be able to identify several major changes in the external business environment that present an increasing challenge to maintenance professionals today
23. Be able to identify four reasons why people are one of the major changes in the business environment

24. Be able to identify two reasons why processes are one of the major changes in the business environment
25. Be able to identify three reasons why plants are one of the major changes in the business environment
26. Be able to list four reasons for the “WHAT” of strategic maintenance management (SMM)
27. Be able to list six reasons for the “WHY” of strategic maintenance management.
28. Be able to list four reasons for the “HOW” of strategic maintenance management
29. Be able to ask several relevant questions about talent *developmen*t issues
30. Be able to ask several relevant questions about talent *deployment* issues
31. Learn to analyze the cost/risk relationship graph beyond the generic responses
32. Identify at least 12 miscellaneous planning issues to consider regarding SMM
33. Construct a three step model for building a strategic maintenance plan
34. Describe the general flow of a supply chain and list the typical components within it.
35. Explain how the supply chains of manufacturers and service providers differ and are alike
36. Define correctly and use appropriately the various terms associated with supply chain management
37. Learn to use key performance indicators
38. Identify typical uncertainties in a supply chain and suggest ways to protect against them

INTENDED AUDIENCE

We assume the audience for this course to be a competent operations manager or someone similar with the influence and authority to implemental the techniques and practices that we describe here. We further assume they do not have a background in Industrial Engineering or broad experience in the Quality Movement.

This individual needs to understand the concepts presented here sufficiently enough to be able to converse with experts so they can translate the lofty pronouncements of the executive leadership into measurable, profitable results.

There will be some math later in the course. Naturally, math is nothing new to engineers but there is a chance that the reader hasn't used it in the manner we present.

While we do not claim that you will be successful using these techniques, we do know that all of them have been used effectively in operational settings and will work if given an honest effort to implement them. The extent of their success depends on the skills of the implementer and the support received from upper management.

PART 1 - WHAT IS PERFORMANCE AND PRODUCTIVITY?

One day Alice came to a fork in the road and saw a Cheshire cat in a tree. *"Which road do I take?*" she asked. *"Where do you want to go?"* was his response. *"I don't know",* Alice answered. *"Then*", said the cat, *"it doesn't matter. When you don't know where you are going, any road will take you there."* (Lewis Carroll, *Through the Looking Glass or the Adventures of Alice in Wonderland)*

The Cheshire cat's response is a model for much of the difficulty with defining performance in the workplace today as employees hear phrases like these:

- "Make it look very professional"
- "I need you to do a great job!"
- "Make sure they get their money's worth."
- "You need to do more to embrace the culture"
- "I will need that report in a timely manner."

Think about this…

What vague directions do you hear daily?

How do you know when you have met their expectations?

How do those vague directions make you feel?

By the time you finish this course, you will be able to define your performance expectations very clearly, have no doubt in your mind (or the other person's either) if they have met your expectations, feel very confident that you will get exactly what you are expecting, and have taken a major step in creating the LEAN process culture that you want.

THE ELEMENTS OF PERFORMANCE & PRODUCTIVITY

Nearly every article written about performance always includes the concept of SMART goals (From Paul J. Meyer's *"Attitude Is Everything")* According to Meyer's viewpoint, goals should be **S**pecific, **M**easurable, **A**ttainable, **R**ealistic, and **T**angible.

While that certainly encompasses the overall concept of performance and gives people another acronym to use even when they are not sure what it all means, it leaves out a critical component: *how do we measure subjective items or activities such as:*

- Team work
- Communications skills
- Customer service
- The best cake in a baking contest
- The best picture in a photography contest

In this course, we will not mention performance without associating it with <u>productivity</u> because productivity is why employers pay people for work. They do not pay for just doing things ("performance") but for doing things *with a specific outcome in mind; i.e., PRODUCTIVITY*. This goes back to the Cheshire cat's comment to Alice: *when you do not know where you are going (predefined productive outcomes), any road will take you there.* The more those employees wander aimlessly trying to figure out what the boss wants, the greater their inefficiency and related expenses. These are certainly not activities for which you can bill a client. And it is certainly not a LEAN way of doing things.

We will provide a more practical, LEAN oriented definition of performance than just telling you to set SMART goals. We will show you how to create your own measurement systems. Then, after we introduce the elements of performance and productivity, we will give you examples of how to create a measurement system in your workplace.

Will they be foolproof and fit every situation? No, not perfect but if you understand the 'why' of what we present, you will be able to select the best 'how' to create a useful means to measure performance until someone comes along with a better one.

THE CRITICAL TRIO

Just as there are three critical elements necessary for fire (fuel, heat, and air), there are three critical elements necessary for LEAN **productivity** (which is much different from just "being busy'): **quality, quantity, and time.**

Occasionally in this course we will abbreviate them into QQT.

Productivity means people clearly understand how error-free it must be (quality), how many you require (quantity), and by when (time.) An additional benefit for the leader who defines expectations using QQT standards is that it becomes extremely difficult for an employee to explain their failure to perform by claiming, "I didn't understand what you wanted."

Think about this…

How many of your current performance expectations can you redefine using the quality, quantity, and time components?

Could you comfortably whether you have been busy or productive today?

If you could not, are you putting yourself into some measure of career risk?

Would you want to have your job defined more clearly with elements of QQT?

It's Showtime

Another aspect of performance is allowing the employee to work alone to master the skill. You must also be willing to let them fail as part of the learning process. (NOTE: "Letting them fail," means you still provide a safety net so they do not harm the organization, someone else, or themselves. Still, many people learn best from a trial-and-error approach. If you do not believe this, what is the first thing most people do when they see a "Caution: Wet Paint' sign?)

Think about this…

Does your work situation allow you the chance to succeed BIG and fail within certain safety nets so that you can learn from your mistakes?

What kind of "safety nets" do you have in place for your employees so they can learn through small failures?

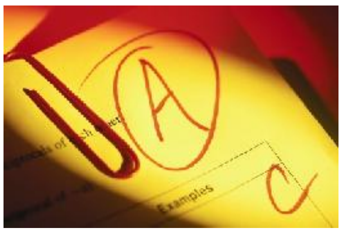
How does your boss react when you make a mistake? Is their reaction one that allows you to learn from it or are you deathly afraid to make a mistake?

If you are afraid to fail, how does that fear impact your productivity? If you were not so afraid of your boss' wrath (or someone else's in authority), would you be able to work much faster (and probably just as accurately?)

Many times, we learn more from our failures than from our initial successes!

PERFORMANCE FEEDBACK LOOPS

People must be to tell how they are doing without having to wait to be told (especially from the boss.) There must be a feedback loop in the work process that allows the employee to self-monitor their progress.



Think back to when you were in school. Did you have to wait until the report cards came out before you knew how you did that semester or were there ways for you to keep track?

The grades you got back on tests, reports, and homework plus staying out of trouble and making sure you were not excessively late or absent created a “feedback loop” that let you know how you were doing without having to ask the teacher every day.

In addition, the teacher gave you the system for grading at the beginning of the school year. The system may include how many days you be could absent without hurting your grade; the progressive scoring range such as <65 = F; 65-70 = D; 71-80 = C; 81 – 90 = B; >90 = A; a term paper weighted to count as three grades; the midterm test counts half of the final grade; etc.

With that feedback loop, you could track your own progress and had an answer every time your parents would ask, “How are you doing in school?”

Think about this…

What kind of performance feedback loops do you have in your job?

If there are none, how would you create some if it were your decision to make?

What advantage is there for you to share your ideas about performance feedback loops with your supervisor?

NEED HELP?

The next component of performance is being available when your employees need help or guidance. Even something as simple as this can go wrong if not handled with some forethought.

The ultimate goal of developing your employees should include that they can work alone without supervision and be productive. That said, the next question is, "How do we get them to that point?"

The first thing would be an effective orientation and training plan for the department that develops new people into productive employees as quickly as possible. (We can show you how to do that if you want to contact us through this website.)

The next thing would be to choose from two basic methods that the leader could use to provide help or guidance when needed.

RELUCTANT HELP – INFORMATION HOARDING

With one method, the department leaders are reluctant to share information because to them, knowledge is power, and allowing others to become as smart as they are means they are no longer special.

As juvenile as it sounds, many people still act that way. However, if they are the keepers of the knowledge, it becomes difficult to get away from work without having people keep contacting you for information. Of course, to them, that just reinforces their image of self-importance.

"That place can't get along without me!" is a favorite saying as they answer another call from work. What they fail to consider is, once others learn the secrets – as they always do – they will remember that lack of cooperation and the self-serving one will gradually become isolated from the work group.

This can be a problem for the knowledge-hoarding leader because the employees are always more intimately involved with the workflow than is the leader. Employees frequently know when things are not running properly or when there are opportunities to improve the workflow and *they alone determine whether to alert the leader.*

If the leader willingly shared information and helped the employee develop skills and knowledge, there is a strong probability they will alert the leader of the pending problem or opportunity for improvement.

If the leader hoarded knowledge and made the employees always come to him or her thus stunting the employee's development, there is a high probability the employees will not alert the leader and the disaster, when it happens, will be a great source of entertainment for the employees.

Remember: it's the EMPLOYEE'S CHOICE about how much they will tell you about a situation. Treating them decently can only influence them to tell you.

HELP FROM SELF-DISCOVERY

The other method of helping is to make available as many learning resources as possible that allow the employees to find their own answers. *This leads to their self-discovery and self-development.*

Also, if you are the only person with the expert knowledge about that position, you can never be promoted out of it! You are tying yourself to that job forever!

However simple this may sound, there are three ways to do this.

1. One is to say, "Look it up! I had to when I was in your situation" and offer no real help to the employees.

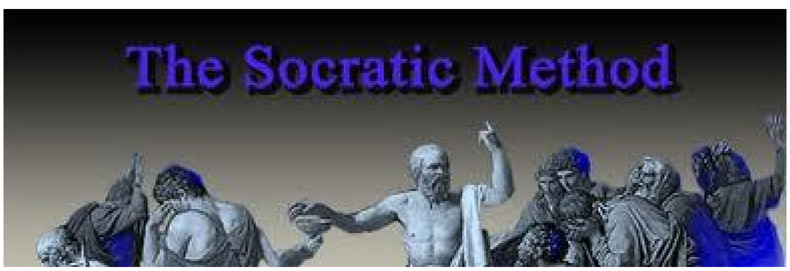
2. Another is to say, “My door is always open. Just call me when you need help!” While this is a little better than the first approach, it may cause a dependency on the leader for employees too lazy to do a little research.

3. The last method is the best. Here, the leader says, *“Call me if you can’t find the solution for yourself.”* He or she has clearly defined their expectation that the employee will make an effort on their own first as a means of self-development.

   And, even when an employee comes to them, their first question is something like, *“Before I tell you the answer, where did you look for yourself?”*

If the employee made no effort on their own, the leader tells them to do a little investigation first. However, if the employee made a bona fide attempt and failed, the leader may point them to a better information source or tell them the answer. Either way, it will not take long for employees to realize the leader will be available for them but expects them to attempt to find their own solutions first.

Please burn this next section about the Socratic Method into your memory chip!



If time allows, use the Socratic Method of learning with your employees.

In ancient Athens, the philosopher Socrates taught students by asking question after question, seeking to expose contradictions in their thoughts and ideas to then guide them to arrive at a solid, tenable conclusion. The principle underlying the Socratic Method is that students learn through the use of critical thinking, reasoning, and logic, finding holes in their own theories and then patching them up. Try playing the Devil’s Advocate and take an opposing viewpoint and encourage them to defend theirs as you help them understand the “why” behind many policies that define “what” in every organization.

IF YOU WILL HELP THEM UNDERSTAND THE “WHY” OF SOMETHING, THEY CAN USUALLY FIGURE OUT THE “HOW” FOR THEMSELVES!

ESTABLISHING SMART GOALS

Now we will start using some of the performance and productivity concepts we mentioned earlier in the establishment of meaningful Specific, Measurable, Attainable, Realistic, and Tangible goals.

Specific means using as many of these six "W's" as you can. Who (is involved?). What (do I want to accomplish?) Where (Identify a location); When (Establish a time limit); Which (Identify requirements and constraints); Why (Specific reasons, purpose or benefits.)

Measurable can take many forms but the essential information you must know is, "How will I know I am making progress?" and "How will I know when I have finished?" The essential elements for this are quality, quantity, and time (QQT).

This is why announcing a goal such as, *"My goal is to improve the relationship between our departments"* is a waste of time unless you have measurables that will tell you:

- The extent of the current relationship
- The minimum acceptable level for the 'improved' relationship
- How we will know if it is getting better, worse, or not changing
- The actual goal to achieve or do we just keep working at it? (This is Alice's problem when she talks to the Cheshire cat. When you do not know where you are going, any road will take you there.)

Attainable – The goals must be realistic enough that you can actually attain them. Setting a goal to lose 50 pounds before your high school reunion next month is not attainable *because it is not realistic* outside of possible extreme surgery.

"Attainable" means there are no laws of science (such as losing 50 pounds in 30 days) or society (we can drive across the city in 20 minutes if we take a shortcut down the airport's main runway) preventing it from happening. The fact that it has never happened to you but has happened to other people means it can be done but only you can determine if it can be done BY YOU! (For example, not everyone has won a marathon race but some people have. If you are physically able to compete in a marathon, it may take a lot of practice and will power but it is attainable by you.)

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. (This is very much like attainable.)

Tangible - They must involve his/her *doing something* that they can observe and measure. A goal that calls for *"Understanding how a travel expense voucher flows through the Accounting Department"* is useless because you cannot measure ***UNDERSTANDING*** in a meaningful way.

It only becomes useful if he/she must ***do something*** that demonstrates his/her understanding such as, "*explain in writing* the complete workflow of a request for travel reimbursement from the time Accounting receives it until they deposit the money into your account."

We will use the three elements of quality, quantity, and time as the basic essentials for a measurable goal and to define productivity. This is a key element of the LEAN process.

The other parts of the SMART goal are important, too, but QQT are the most critical.

PRACTICE ACTIVITY

Describe an activity associated with your job that has all of the elements of a SMART goal and then break down each element afterwards.

The specific components are

The measurable (QQT) components are

The attainable components are

The realistic components are

The tangible components are

We asked you to describe some vaguely defined activities at your work earlier. What parts of SMART goals are missing?

How does **this clear definition** (above) of what your leader expects affect your personal satisfaction and your work performance?

How does your work performance and personal satisfaction regarding this **clearly defined task** compare with the **vague task** you identified earlier?

How can you use this comparison *between vague and more specific tasks* to talk with your supervisor? (Help him or her see the difference between them, how it affects your performance, and ask if they can be more specific about the vague goals.)

How can you use this same concept of comparing specific and vague goals with your employees? (It may give you some insight why they are not working to your expectations.)

Why would you want to do this? (You are ultimately responsible for their productivity. Anything you can do to clarify expectations for them can only improve their productivity and make you look very good to your boss.)

Work Stress or Work Tension?

Think about how frustrating it is when someone expects you to do something for him or her but have difficulty defining exactly what they want. The examples we used earlier are heard from too many workplace supervisors and managers:

- *"Make it look very professional"*
- *"I know you will do a great job!"*
- *"You need to embrace the culture"*
- *"Make sure they get their money's worth."*
- *"I will need that report in a timely manner."*

We believe that people inherently want to do the right thing. However, because of their supervisor's inability to articulate specific expectations in terms of QQT or some other objective manner, they endure unnecessary stress trying to guess what is expected. Additionally, they stress after they turn it in because they still are not sure that is what the boss wanted and they continue to fret about it.

On the other hand, we can deal with work tension more easily because, even though we may have a large workload, *we know the expectations and are confident we can do the job*! When it is over, we put it out of our mind and relax in the knowledge we did it right.

Although this is a simplification, it describes the basic model.

Work stress occurs when you are not sure of the expectations and your anxiety grows as you try to guess right and never know if you are doing the right things. A way to reduce some work stress is to get as much clarification as possible about your boss' expectations.

Work tension means you are sure of the expectations, may have a lot to do and will have to move fast to get it all done. There is no doubt in your mind what the boss wants: the problem is getting it all done by the time he wants it.

However, when it is over, you can forget it because you always knew that you were doing the right things.

PART 2 - SYSTEMATIC PERFORMANCE ANALYSIS

Before getting into this analysis tool, we must first have a universal understanding of what we mean by "problem behavior" that may be impacting our desire for a more LEAN process and then determine whether we should do anything about it.

The easiest, most universally relevant question to ask when trying to determine if we have problem behavior in the work place is, **"DOES THAT BEHAVIOR IMPACT THEIR WORK OR SOMEONE ELSE'S?"**

If the answer is "yes," then go after it. If the answer is, "No" or "Not sure," then take some time to think about it some more. *If the behavior just irritates you but does not affect your work, it may cause more trouble dealing with it than any gains from ignoring it.*

For example, suppose you are a manager with an employee who you think could be a lot more productive but, for some reason you cannot identify, just isn't reaching his potential.

This flowchart will prove to you that 90% of the reasons for employee performance problems have their roots in systems controlled by management. Work your way through these ten steps and you will see what we mean.

Once again, you cannot begin to coach for a **change in behavior** without first addressing the **CAUSE OF THE PROBLEM**. Otherwise, the problem will never be resolved!

REMEMBER, YOU MUST *DO SOMETHING DIFFERENTLY* IF YOU WANT A DIFFERENT OUTCOME!

PERFORMANCE PROBLEM FLOWCHART

This flowchart will prove to you that 90% of the reasons for employee performance problems have their roots in systems controlled by management. Work your way through these ten steps and you will see what we mean.

Before you begin

Ask yourself, "Is this issue worth pursuing?"

Question: How do you know if it is worth pursuing?"

(If it interferes with work, it is worth pursuing! If it is only a nuisance or aggravation, but does not interfere with work, it may be best to leave it alone.)

If so, go to STEP #1. If not, you are done! Remember, you can stop anytime the problem is ***"sufficiently solved."***

(This means it is not worth the time, effort, or expense to "fix it better".)

STEP #1

Ask yourself, "Are my expectations clear?"

#1 Question: What do you ask your employee here?

(I want to make sure I did a good job of explaining. Please tell me what you think I expect you to do.)

If your expectations are clear, go on to the next step. If not, what should you do?

STEP #2

Ask yourself, "Are the resources adequate?"

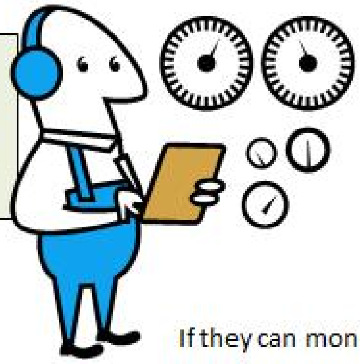
#2 Question: What do you ask your employee here?

(Do you have everything you need to do what I expect?)

If they have everything, go on to the next step. If not, what should you do?

STEP #3

Ask yourself, "Do they get fast and frequent feedback on their performance?"



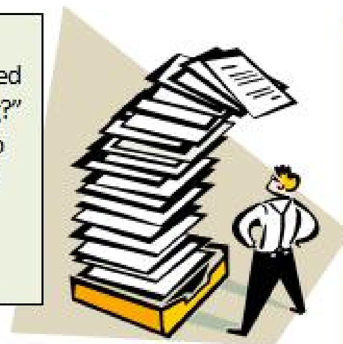
#3 Question: What do you ask your employee here?

(How do you know how you are doing?)

If they can monitor their progress, go on to the next step. If not, what should you do?

STEP #4

Ask yourself, "Does the desired performance seem punishing?" (Hint: What do you usually do if they finish early and **others have not finished yet?)**



#4 Question: What do you ask your employee (or yourself about the situation) here?

(If their "reward" for finishing early is you give them the work the slower people have not finished, you will soon have no one finishing early.

You must praise the ones who finish early, let them know you documented their file that they finished ahead of the others, and ask if they will help the slower ones.

This way they do not feel that the slackers are getting away with anything)

If you are inadvertently punishing their behavior, what should you do? If not, go on to the next step.

STEP #5

Ask yourself, "Is poor performance rewarded somehow?" (Hint: What do you usually do if **they have not finished yet** but others have?)

#5 Question:

What do you ask your employee (or yourself about the situation) here?

(This is the opposite of above. If they are behind, let them know you documented their file that they were behind and you asked a faster worker to help pick up their slack.

This way, they realize they are not getting away with anything.)

If you are inadvertently rewarding poor performance, what should you do? If not, go on to the next step.

STEP #6

Ask yourself, "Is there any penalty for not doing it right?"

#6 Question: What do you ask your employee (or yourself about the situation) here?

("Is there any penalty for not doing it right?" If there were no penalty, why would they stop doing it?)

If there is a penalty, go on to the next step.

If not, what should you do?

STEP #7

Ask yourself, "Is their non-performance a genuine skill deficiency?"

#7 Question:
What do you ask your employee (or yourself about the situation) here?

(Can they not do it or can they do it but just do not want to?)

If it is a genuine skills deficiency, go on to the next step. If not sure, what should you do?

#7A Question:

Have they ever done this in the past?

(If so, give them practice to refresh their skills) If not, continue to the next step.

STEP #8

Ask yourself, "Can the task be made easier?"

#8 Question:
What do you ask your employee here?

(Can you think of any easier way you can do this?)

If it can, do it. If not, go to the next step.

STEP #9
Ask yourself, "Are there any other obstacles?"

If there are, what can you do?

If there are not, go to the next step.

#9 Question:
What do you ask your employee here?

("Can you think of anything keeping you from doing this?")

STEP #10

Ask yourself, "Does the person have the potential to change?"

Question: What do you ask your employee here?

(Do you have any plans to change your behavior?)

If they have the potential and desire to change, go to the next step.

If they do not, **REPLACE THEM!**

Train them to the desired skill level!

Have you noticed that every step, except #10, is a factor controlled by management?

This means there is a 90% probability that an employee's performance problem is caused by something controlled by management!

SUMMARY OF THIS SECTION

The student should understand these concepts of LEAN performance and productivity at this point.

- ✓ Productivity only occurs when the elements of *quality, quantity, and time* are present. If any of these are missing, the person has simply been 'busy' and not really accomplished anything.

- ✓ SMART goals are better than no goals but not as good as goals including quality, quantity, and time.

- ✓ Staring a project or a journey as Alice in Wonderland without a clear destination (outcome) in mind will result in a lot of wasted effort, possible stress, and may be career damaging if you do it too often.

- ✓ You must allow people to fail (gently) if they are going to learn. The trail-and-error process is a primary learning method for many people. **Experience only comes from making mistakes while making mistakes only comes from lack of experience.**

- ✓ Feedback loops are essential in a work process if we want people to become accountable for their performance. If there is no way for someone to track their work progress, they will not be able to self-correct when going wrong or continue as they are when going right without having the boss tell them.

- ✓ **Work stres**s comes when people's anxiety builds as they try to meet vague expectations and there is no outlet after they finish because they are still worrying whether it was the right thing. This is very draining emotionally and can become unhealthy.

- ✓ **Work tension** means we have a heavy workload but know how the expectations and can relax afterward. This is very draining physically but is a healthy way to exercise our abilities.

PART 3 - CONCEPTS OF CAPACITY

Capacity is about an organization's *capability of producing something*. Planning for this capacity typically happens at a variety of levels and detail. This part of this course will focus on the basics essential to a fundamental understanding of the process.

An organization's capacity is *pulled* by customer demand (if they didn't want it, why would you make it?) and *pushed* by the receipt of raw materials from suppliers. In a perfect world, the demand would be constant, the supplies on time and in the exact quantities and quality we need, while our machines would hum along at peak efficiency.

[*Remember, also, that we are not just talking about the industrial world here: "production" also applies to assembling complex documents such as all the paperwork associated with buying a home, or serving customers at the drive up window of a fast food outlet*.]

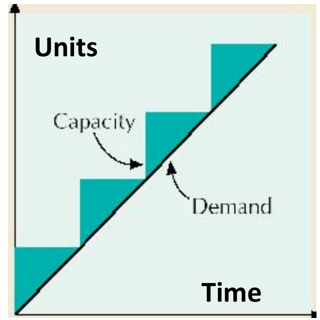
Taking this a step farther, our customers would pay early and we would pay our providers (suppliers) at the last possible minute before incurring penalties so we can hold on to the cash as long as possible and maximize our cash flow.

Unfortunately, this is not a perfect world and many factors can impact the ability of our assembly lines to hum along at peak efficiency. Companies who enjoy greater success in producing, selling, and delivering products focus on the demand side of the equation. *In other words, the more they can understand their customers' needs and meet them, the greater their success*. This is in contrast to companies who focus primarily on their suppliers by fighting hard for the best prices, quantities, qualities, and delivery dates.

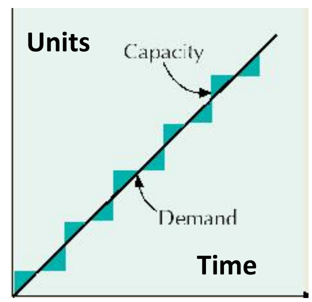
Although it is certainly important to fight for the best prices, etc. from your supplier, it is only through a strong relationship with their customers that a producer can make sure they buy the right kinds of raw materials in the qualities and quantities they need to meet demand. It is surprising but true that many manufacturers have a lot of money tied up in inventory that is either obsolete or just not part of what customers are demanding currently. They focus on what they have to sell instead of what their customers want to buy.

We will begin our learning by looking at three strategies to plan capacity: *lead, average, and lagging.*

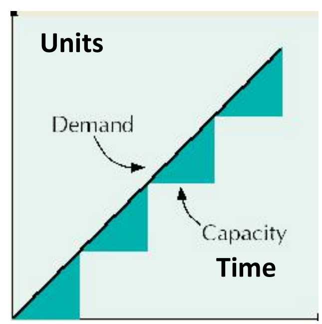
1. **Lead capacity strategy** – capacity is expanded in *anticipation* of a growth in demand. This anticipation may result from a marketing plan to lure customers away from another or by entering a market by offering special pricing or quantities. It also helps companies plan for anticipated surges in demand or to provide high levels of customer service during specific periods.



2. **Average capacity strategy** – we expand capacity to coincide with an *average of what we expect* knowing there will be times when we cannot meet all the demand as well as time when we have too much capacity for a lowered demand. We expect that about 50% of the time, capacity will lead demand and lag behind it at about 50%, too.



3. **Lagging capacity strategy** – capacity expands *after* an increase has been documented. Although customer service suffers initially, it assumes they will be back because there are few (if any) other places where they can obtain this product after our capacity has increased.



Once a capacity strategy is identified, then the extent of the increase is based upon:

- The volume and certainty of anticipated demand
- Strategic objectives in terms of customer service, anticipated growth, and anticipated competition
- The cost of anticipated expansion and operation to meet the company's strategy

We will address the issues of anticipating demand and production planning later in this course.

How would these various strategies be used in higher education?

Suppose that a state is experiencing a large increase in population which means there will be a demand for higher education in just over a decade. This is how the three different strategies would be applied:

Think about…

- An *established* university that is guaranteed applicants even in lean years may follow a **lag strategy**
- A *new university* may use a **lead strategy** to capture applicants who cannot get into the established university
- A community college may use the **average strategy** because there is little risk when considering its mission to admit all eligible applicants.

LAYING OUT THE FACILITY

The art (or science depending on how you look at it) of laying out a facility has changed over the years because of changes in:

1. Our concepts of how to produce (do we keep extensive inventory on hand because we are supplier driven or small amounts -"just-in-time" - because we are pulled by customer needs);
2. What to produce (markets have changed in demand and location)
3. The constant evolution of technology plus a shrinking, ageing workforce can change our long-term strategy.

We will cover many of these LEAN processing topics in this course:

- Minimize material-handling costs
- Utilize space and labor efficiently
- Eliminate bottlenecks
- Facilitate communication and interaction between all involved
- Reduce manufacturing cycle time and customer service time
- Eliminate wasted or redundant movement
- Increase capacity (produce more, not just do more)
- Facilitate entry, exit, and placement of material, products, and people
- Incorporate safety and security measures
- Promote product and service quality
- Encourage proper maintenance activities
- Provide a visual control of activities and flexibility to adapt to changing conditions

Types of Layouts

We will look at three basic types of layouts. Please remember that capacity planning is not confined to just "making things*", it is also relevant to customer service businesses and retail outlets where customers serve themselves.* The three most common examples are:

1. **Process (aka 'functional') layouts** - group similar activities together according to the process or function they perform

2. **Product layouts -** arrange activities in line according to the sequence of operations for a particular product or service

3. **Fixed-position layouts -** are used for projects in which the product cannot be moved – the workers come to it.

Process (or functional) Layouts

This layout groups similar functions together. It may be thousands of different types of items in a do-it-yourself 'big box' store, types of clothing in a retail store that makes it easy for clerks or customers to find what they need by visiting different departments or a machine shop may group saws in one place, drills in another, and sanders in a third.

This layout is characteristic of intermittent operations where a wide variety of customers with wide-ranging needs are served. In a process layout, like a machine shop or automotive repair center, the equipment is general purpose and the workers are skilled at operating their machines in their departments or areas.

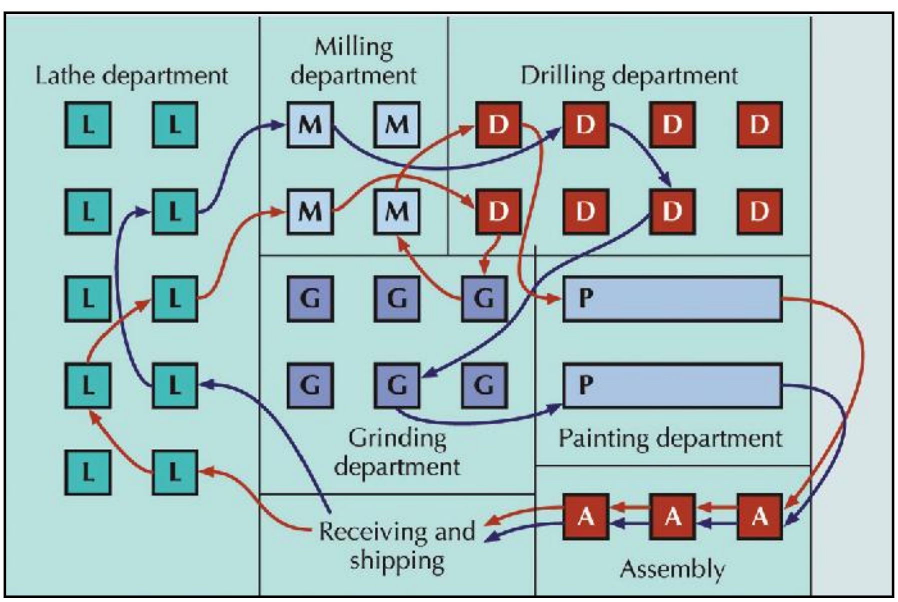
The advantage of this is flexibility and can meet customers' needs easily and quickly but, since work doesn't flow smoothly through it and may 'backup' from downstream stations, or cross the flow of other work, this is also a disadvantage.

Table 1 - Process Layout Summary

Characteristics	Application to a Process Layout
Description	Functional grouping of activities
Type of Process	Intermittent, job shop, batch production, mainly fabrication
Product	Varied, made to order
Demand	Fluctuating
Volume	Low
Equipment	General Purpose
Workers	Varied skills - some potential for cross-functional working
Inventory	High in-process, low finished goods
Storage Space	Large
Materials Handling	Variable path (forklift)
Aisles	Wide
Scheduling	Dynamic – varies with the demand
Layout Decision	Machine location
Goal	Minimize material handling cost
Advantage	Flexibility

Process Layout for a Retail Business

Process Layout for a Manufacturing Business



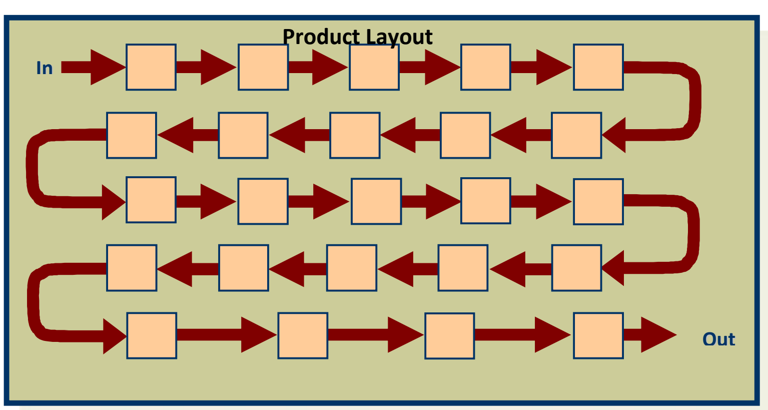
PRODUCT LAYOUTS

Product layouts are better known as *assembly lines.* Henry Ford taught this to American industry when he demonstrated that a line of sequential events with each sub-assembly having its own line was a secret to mass production. (This assumes, of course, that materials flowed into the plant at about the same speed finished cars rolled out the other end.) The flow of work is orderly and efficient moving from one workstation to the next where the technicians wait to perform their specialty – whether welding the car frame or tightening a lug nut on a wheel.

Since the market for these products is very specific, dependable, and stable, it makes economic sense to purchase large, immovable machines performing limited functions. The product made is a standardized one (not like a craftsman's single piece) and the volume is high.

Table 2 Product Layout

Characteristics	Application to a Product Layout
Description	Sequential arrangement of activities
Type of Process	Continuous, mass production, mainly assembly
Product	Standardized – made to stock
Demand	Stable
Volume	High
Equipment	Special Purpose
Workers	Limited skills - no cross functional work potential
Inventory	Low in-process, high finished goods
Storage Space	Small
Materials Handling	Fixed path (conveyor)
Aisles	Narrow
Scheduling	Stable - Varies with balancing and demand
Layout Decision	Line balancing
Goal	Equalize work at each station
Advantage	Efficiency



Fixed Position Layouts

This layout is the only one suitable for its products that cannot be moved until nearly completed. They are too large, bulky, or fragile to be moved such as houses, ships, or airplanes. The highly skilled workers – such as carpenters, plumbers, electricians, and painters – come to the layout. Their specialized equipment, such as cranes, scaffolding, generators, or air compressors for painting, is rented for the project.

Designing Process Layouts

There is one primary consideration when designing a process layout: MINIMIZE MOVEMENT AND/OR MATERIALS HANDLING COSTS. Following that rule, work stations with the greatest interaction between each other should be as close as possible while those having the least amount of contact with the others should be placed at the fringes of the work area unless some safety, construction, or cost consideration must take precedence.

There are two commonly used methods of approaching the layout design:

- **Block diagramming** – use to minimize nonadjacent workloads or when quantitative data is available
- **Relationship diagramming** - based on location preference between areas or when quantitative data is not available

Block Diagramming

We use historical data or talk with experienced employees to estimate the presumed movement between two work stations. We will express our finding in terms of "loads" and distance to move that load. The content and weight of the load depends on the business. It may be palletized for moving with a forklift like lumber that a cabinet maker would use, in baskets of sub-documents that an employee would carry for a document processing business, or parts of a meal that an employee of a fast-food restaurant would assemble and hand to the customer on a tray.

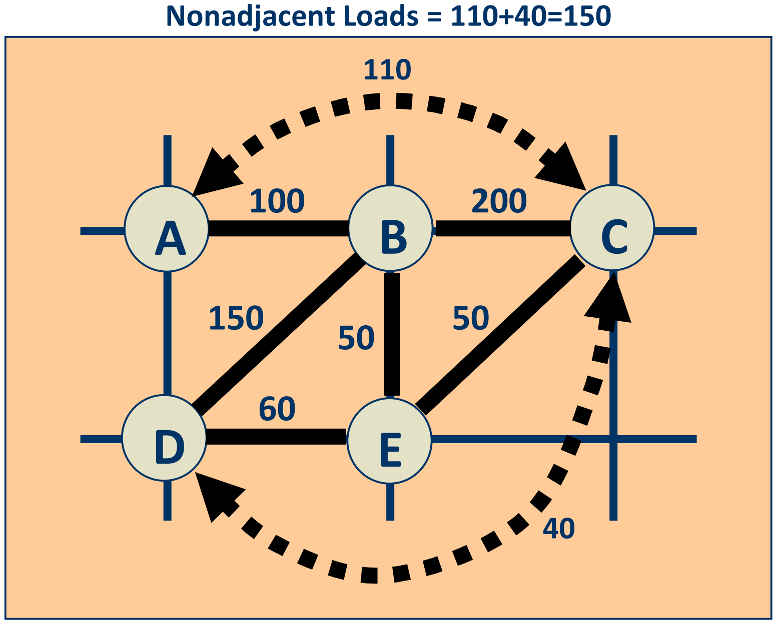
Begin developing the block diagram by listing all the work stations involved in the process. We will list them here as A, B, C, D, and E. Then list the possible combinations with the typical daily load movement between them. (A-B reads as "going from A to B.")

Stations	Loads	Stations	Loads	Stations	Loads	Stations	Loads	Stations	Loads
A-B	100	B-A	0	C-A	0	D-A	0	E-A	0
A-C	110	B-C	200	C-B	0	D-B	0	E-B	0
A-D	0	B-D	150	C-D	40	D-C	0	E-C	0
A-E	0	B-E	50	C-E	50	D-E	60	E-D	0

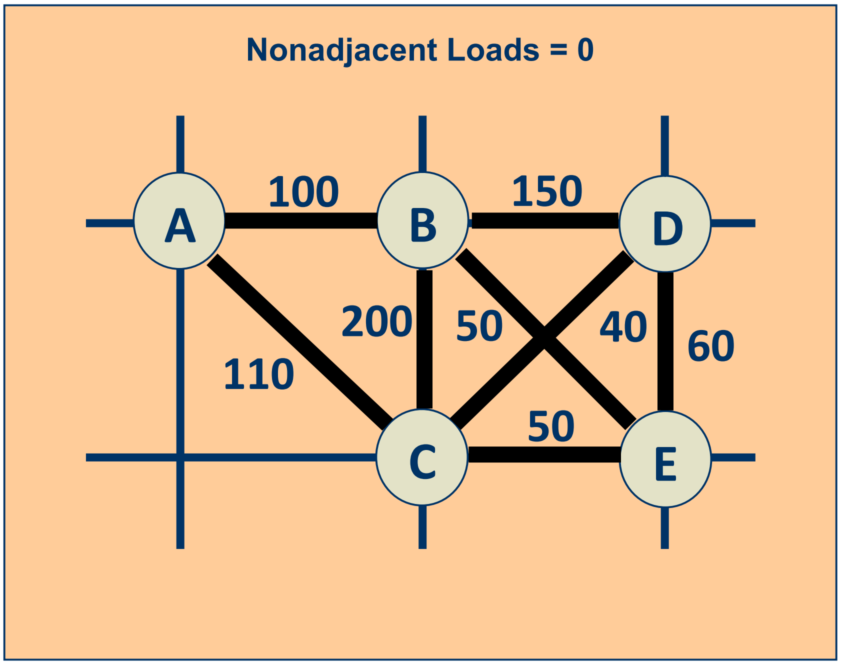
Obviously, there will be places that receive work but do not send it back into the system such as workstation "E" in our example which, by simply looking at the activity, indicates it's the end of the production line. Materials from here do not come back into the layout but must go "outside the system", i.e., out of the factory to the consumer.

Although this table is accurate regarding the data, it doesn't tell us much about the potential layout. But, if we construct a simple grid to understand the flow better, it all becomes more visible. Especially the 150 loads moving between non-adjacent locations (dotted lines).

Nonadjacent Loads = 110+40=150

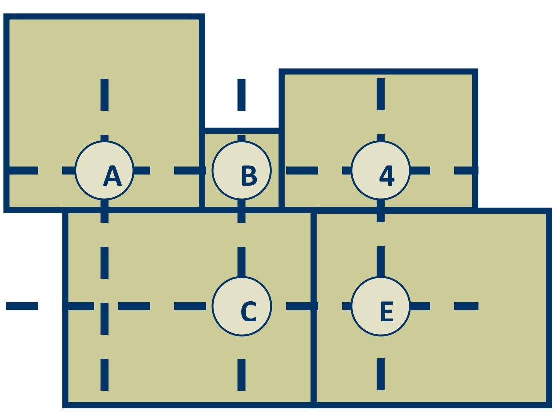


A little change in the work locations of the future facility can greatly improve the workflow like this. The same amount of loads move but there is no long trips around work stations as in the first diagram.

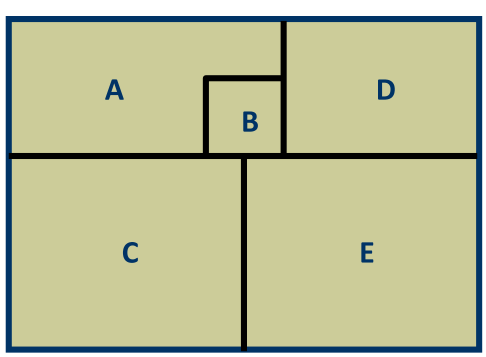


Now that you have a better positioning of the work stations by eliminating all of the nonadjacent workloads, you can use that layout as a basic for the building plans. Many vendors provide templates for the space required for their equipment installation and maintenance and will help you begin to sketch the layout. Since this is not a design course, we won't go into great detail. Suffice it to say the diagram above can easily become these block diagrams.

(a) Initial block diagram



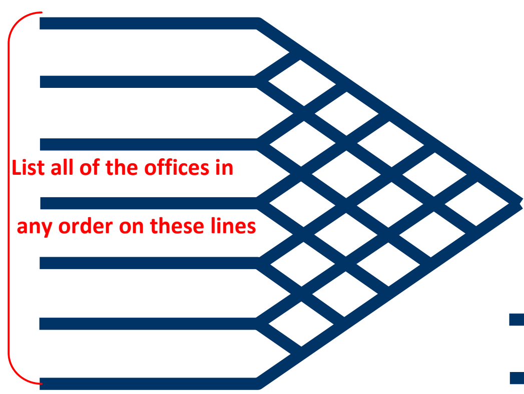
(b) Final block diagram



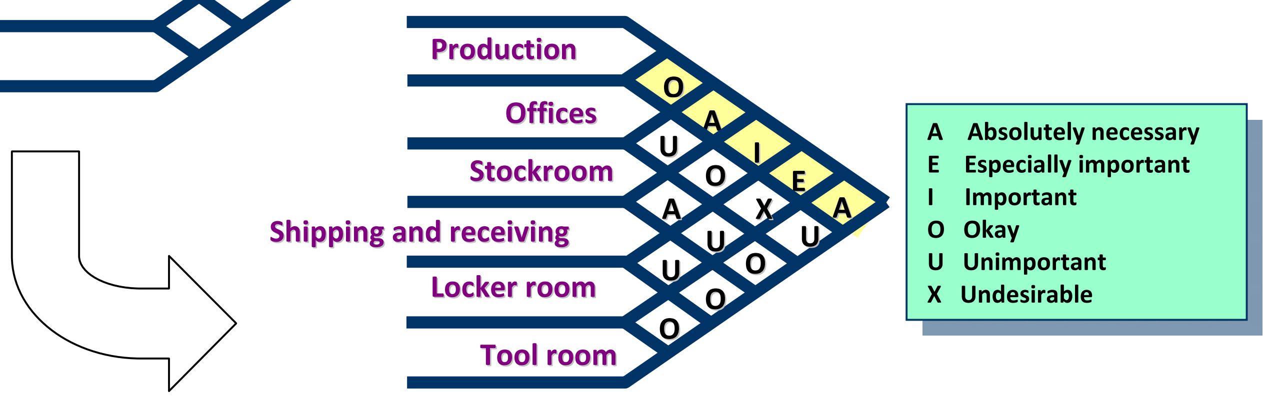
Relationship Diagramming

If quantitative data is not available or moving large amount of material is not relevant to the organization's function, a relationship diagram is very useful when managers want to plan the layout of their department. (This planning tool, a *Muther's Grid*, was devised by Richard Muther, an Industrial Engineer, in 1956 and has grown in use well beyond the scope of this course.)

Like all good tools in engineering, it is based upon a simple concept that can be applied universally. The preference information for the location of offices is based on the familiar five vowels used in English: A, E, I, O, and U with the letter X added. The letters help us remember the preference code used in the grid. "A" means "**A**bsolutely necessary", "E" is "**E**specially important", "I" means simply "**I**mportant", "O" is "**O**kay", "U" is "**U**nimportant", and "X" is "**U**ndesirable." As you can see, they descend in logical order from absolutely necessary to undesirable.

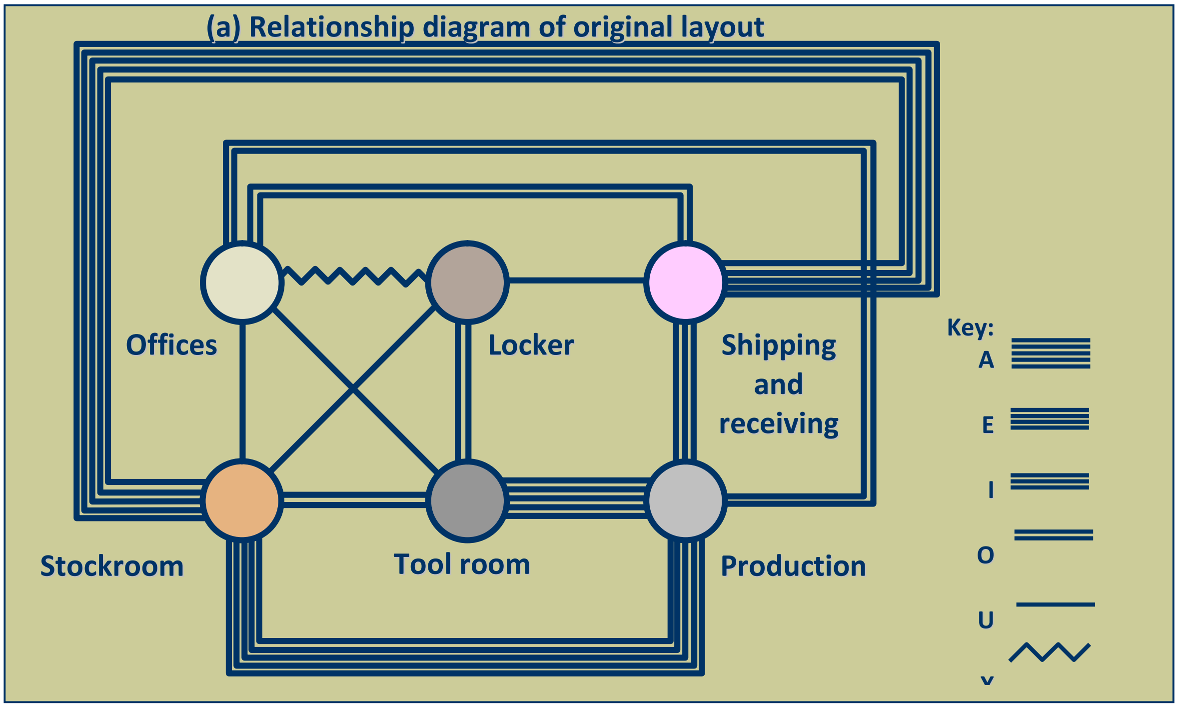


Come into the grid like a highway mileage chart along the colored row comparing the top of the list with each office below in order. For example, what about putting offices next to the production area, and we say, "OK" by putting an O there.

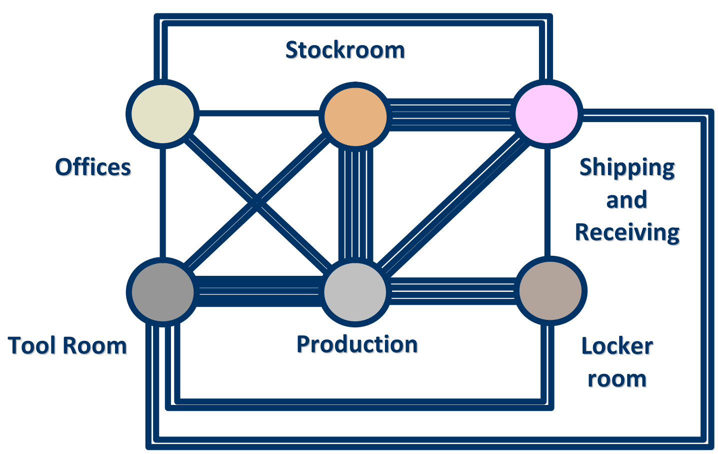


This final look at the grid tells us the department manager says (among other things), "It's <u>OK</u> (O) if offices are next to production, <u>absolutely necessary</u> (A) that the stockroom be next to production, important (I) that shipping and receiving be next to production but that the offices MUST NOT (X) be next to the locker room."

Once you have decided on the preference for the placement of the offices using a Muther's Grid, you can represent the importance of your choices of A, E, I, O, U, or X using a series of lines like this:



Clearly, we see in this diagram those three stations with great importance for each other, the stockroom, production, and shipping and receiving, are too far apart for maximum efficiency. Also, the locker room should not be next to the offices. So, if we rearrange the offices based on the Muther Grid showing our preferences, we will get a traffic pattern like this.



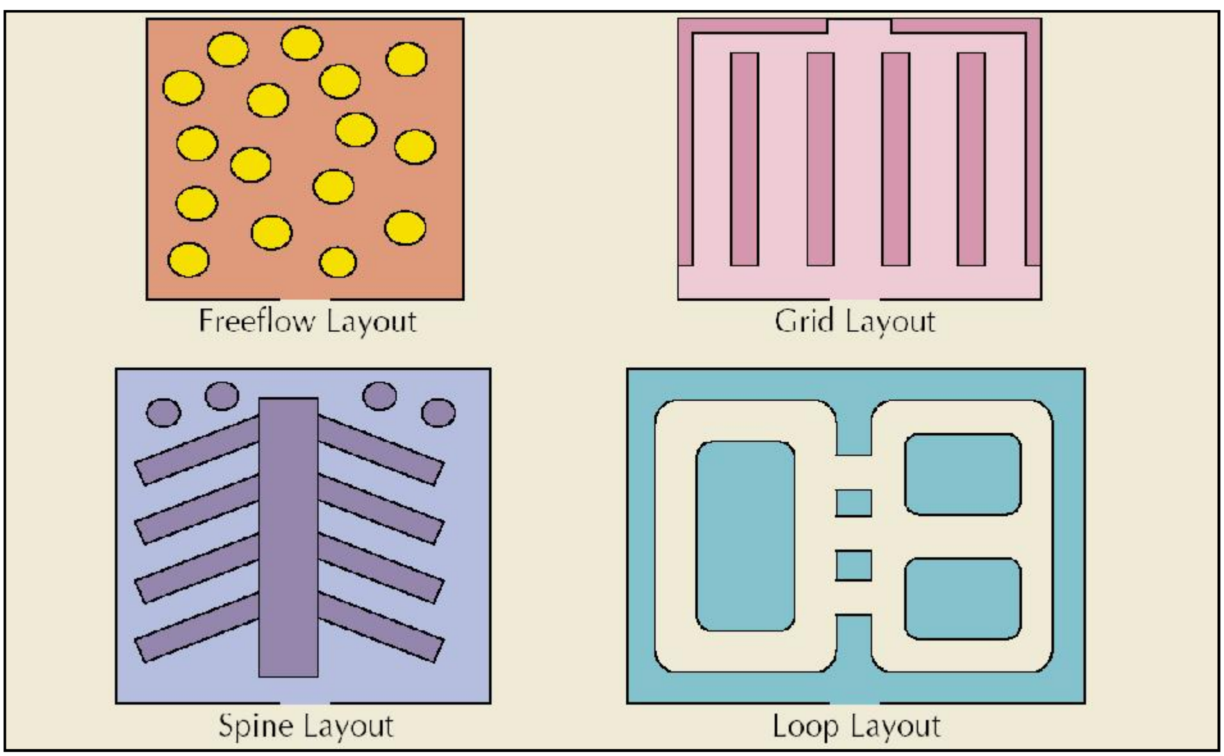
Designing Service Layouts

Service layouts frequently follow production layouts from the perspective of smooth flows of traffic but in retail outlets, the businesses' objectives will influence parts of the layout.

For example, a grocery store will arrange its shelves with milk at one end of the store with bread at the other to lead customers along a path of attractive displays, much lighting, and sale items as they fill their shopping carts. Retail clothing outlets encourage shoppers to browse around randomly spending as much time as possible at every counter.

Some typical layouts:

- **Free flow** - encourages browsing, increases impulse purchasing, are flexible and visually appealing
- **Grid** - encourages customer familiarity, are low cost, easy to clean and secure, and good for repeat customers
- **Spine** and **Loop** - both increase customer sightlines and exposure to products, while encouraging customer to circulate through the entire store



DESIGNING PRODUCT LAYOUTS

The product layout is the basic assembly line of sequential tasks that Henry Ford immortalized when he created the American auto industry. Although a very straightforward concept, there are some considerations necessary to optimize the potential speed and efficiency of the line. These 'optimization' topics are what we will consider next.

Some terms that we will use are

- **Precedence requirements** - tasks that must be completed before doing the next one such as testing the components inside a radio before sealing the outer shell.

- **Precedence diagram** – a drawing showing the assembly line with work stations arranged so as to honor the precedence requirements

- **Work station** – any place along the line where work is done on the product

- **Line balancing** – the process of equalizing the amount of work at each work station so the line keeps moving and no back-ups occur

- **Cycle time** – the maximum amount of time a part in the assembly process <u>can spend</u> at any single workstation in order to meet production requirements in a balanced line. We emphasize "can spend" because we want to meet some production criteria. Do not confuse this with "does spend" which is the amount of time a part may spend at a station if the line is not balanced.

- **Flow time** – the amount of time it takes a product to emerge from the end of the production line when measured from when it entered the line. This includes all time spent waiting at any workstation.

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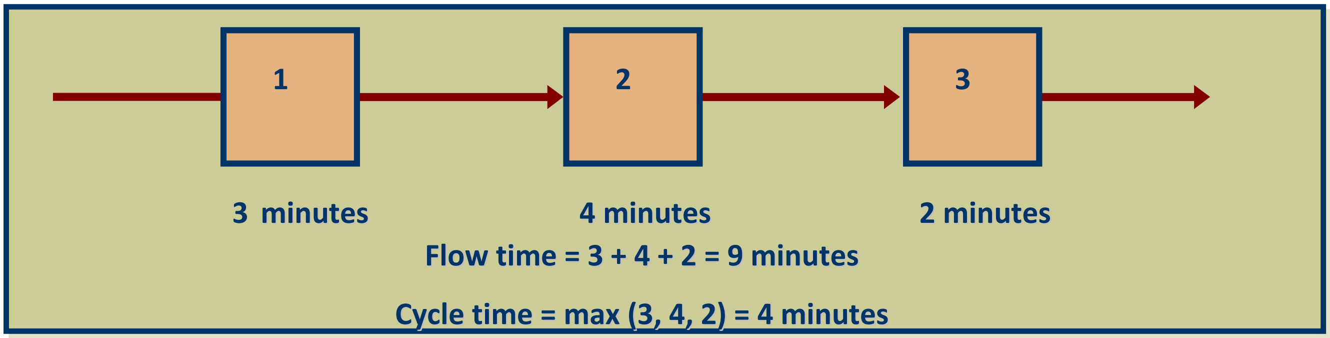
- **Line efficiency** – is the ratio of the time spent doing work to the overall flow time of an assembly line. The overall flow time may include some idle time at one workstation while work at another takes a little longer for completion. For example, if the flow time for a product is 200 seconds which includes 40 seconds of idle time at one workstation while work is being done at another, the amount of time the machines were working was 200 – 40 = 160 seconds. Then 160/200 = 80% efficient.



Think about…

Let's talk about **cycle time** and see how the term, "the maximum time that can be spent at a work station" applies in a production setting.

Suppose a company wants to produce 100 radios in an eight hour day (or work shift.) The first thing we must do is break the hours into minutes to get the smallest practical time unit available. Therefore, an eight hour day (or shift) is also equal to 8 hours x 60 minutes in an hour = 480 minutes. So we now know the company wants to produce 100 radios within 480 minutes.

Our formula for cycle time is C_t = production time available/desired units of output or 480/100 = 4.8 minutes. This means the longest time a radio can spend at any workstation is 4.8 minutes.

It does not matter how many work stations you have in the process because this assumes the radios are working their way along the assembly line continuously. What it DOES TELL YOU is the longest it can sit *at any one station is 4.8 minutes* if you expect to produce 100 radios in 480 minutes.

Next, we will look at **line balancing** which is fundamentally a trial and error process.

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 huge seller.

Based on the drawings we have seen, it looks like there are eight steps in the production process with an estimated time (in seconds) of 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 volt 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, send to shipping department, and get ready for the next one. (This must be done last.)	8

This is what we must determine: (come back and answer these as we move through the lesson.)

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

- 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 line balancing** 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 and placing in a shipping box must come last.)

- Steps 2 & 3 can be reversed if neither must come before the other and there isn't some other reason why we can't such as having the AM & FM receivers in the cabinet would make it hard to install the speakers. We will have to talk to the workers who actually do this to find the answer. (Talking to the people doing the work is a simple concept many managers do not understand.)

- 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 with all workstations filled and taking into account delays while longer processes are completed.

Work Station #	Process	Task Time	Longest time for any task	Idle time waiting for next work station
1	Receive the new radio shell & clean it. (This must be done first.)	12	**120**	108 (We work for 12 seconds and wait for another 108 until station 3 completes it work of 120 seconds.)
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 Flow Time**	**663**

This is an important consideration 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.**

More Questions

1. 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 "flow" in the assembly of one radio. (297 seconds of work and 663 seconds of idle time = 960.) Since our answer for flow 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**.

2. 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 flow 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 within a flow by the length of the work flow. **This is 297 ÷ 960 = 30.9% efficient.**

3. What is the **best line balancing** we can achieve on 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.

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		
4	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, grouped three steps together for completion (117 seconds) as station #3 while waiting for step #2, and three steps at station #4 for 48 seconds. This means we can save money on purchasing workstations and hiring workers for each station.

Work flow 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.

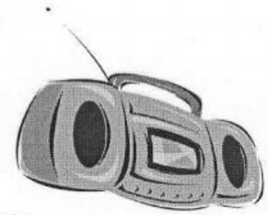
If it now takes 480 seconds to build a radio and we have 28,800 seconds on the shift, we can build 28,800 ÷ 480 = **60 radios per shift**.

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 #		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.

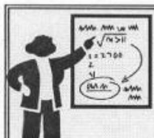
Given information

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

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

30.9% Line Efficiency

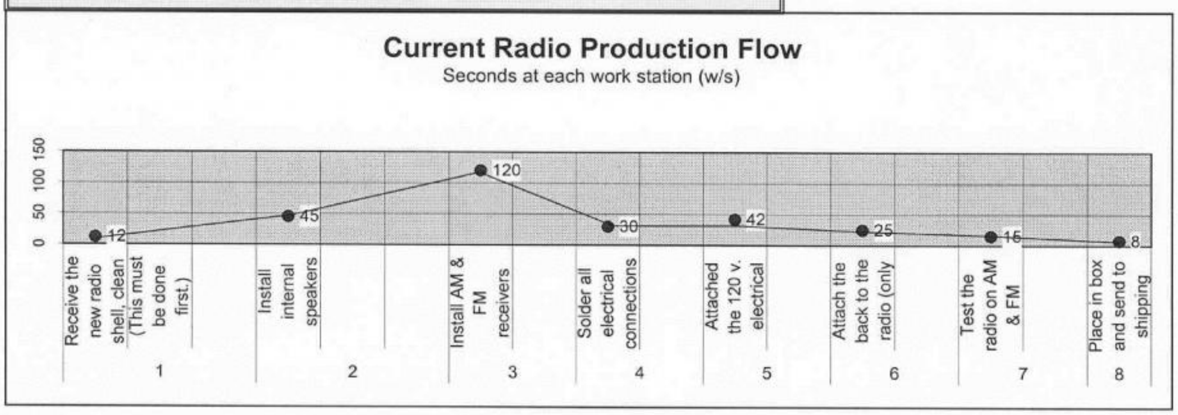
$$\text{Radios produced/shift} = \frac{28{,}800 \text{ seconds in a shift}}{960 \text{ seconds to produce each radio}} = 30 \text{ radios/shift}$$



Check your calculations!!

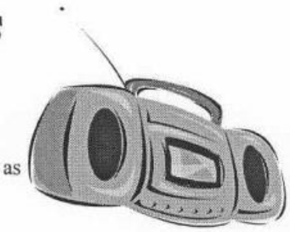
TOTAL CYCLE TIME SHOULD EQUAL WORK TIME + WAITING TIME.

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

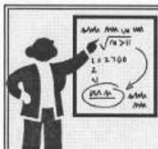
Work Station #	Task		Time to do the task and move it to the next w/s	Longest time any one task	Idle time waiting for the longest task to end.
1	Receive the new radio shell, clean it, place on conveyor belt. (This must be done first.)		12	120	108 seconds waiting after the production line is "full"
2	Install 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	45			
	Solder all electrical connections - melt weld all plastic connections	30			
	Attached the 120 v. electrical cord to the radio	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)	25			
	Test the radio on AM & FM receivers.	15			
	Place in box and send to shipping dept. And ready for next.	8			
	(This must be done last.)		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**

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

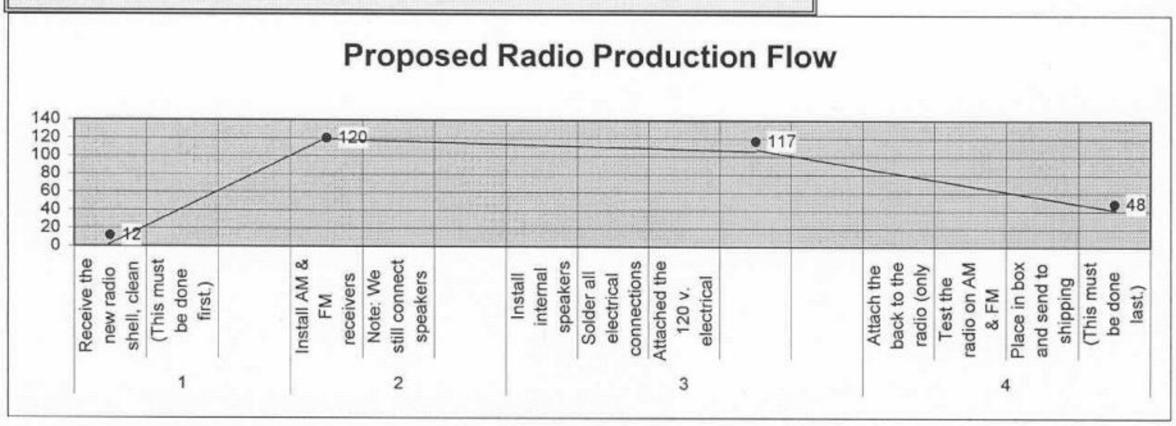
$$\text{Radios produced/shift} = \frac{28{,}800 \text{ seconds in a shift}}{480 \text{ seconds to produce each radio}} = \mathbf{60} \text{ radios/shift}$$



Check your calculations!!

TOTAL CYCLE TIME SHOULD EQUAL WORK TIME + WAITING TIME.

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

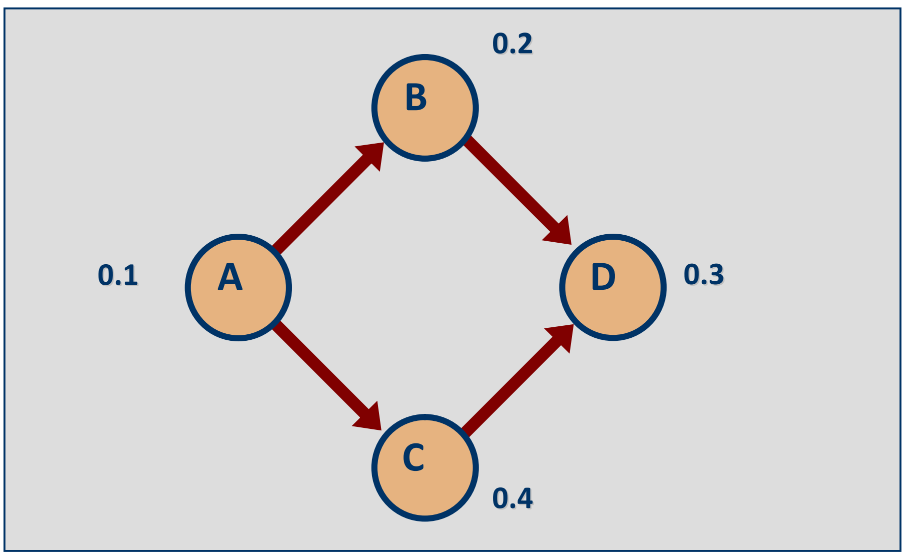


DESIGNING WITH PRECEDENCE CONSIDERATIONS

Here is another way of line balancing that considers the precedence requirements as we package food. We will use the information in the boxes below.

1. Draw and label a precedence diagram
2. Calculate desired cycle time required for line (the most that can be spent at any one station and still give us the daily production we need)
3. Calculate theoretical minimum number of workstations (we will do this next)
4. Group elements into workstations, recognizing cycle time and precedence constraints
5. Calculate the efficiency of line
6. Determine if theoretical minimum number of workstations or an acceptable efficiency level has been reached. If not, go back to step 4.

	WORK ELEMENT	PRECEDENCE	TIME (MIN)
A	Press out sheet of fruit	—	0.1
B	Cut into strips	A	0.2
C	Outline fun shapes	A	0.4
D	Roll up and package	B, C	0.3



How many workstations will we need to have for this example?

	WORK ELEMENT	PRECEDENCE	TIME (MIN)
A	Press out sheet of fruit	—	0.1
B	Cut into strips	A	0.2
C	Outline fun shapes	A	0.4
D	Roll up and package	B, C	0.3

This assumes a 40 hour production week and a desire to produce 6,000 units per week. First, we convert 40 hours into minutes by multiplying 40 hours x 60 minutes/hour to get 2,400 production minutes per week.

If we want to produce 6,000 units during these 2,400 minutes, we see we have only .4 minutes available to produce one item (2,400/6,000 = .4)

Our chart above shows the maximum cycle time is .4 minutes at step C and the flow time is 1.0 minutes (.1 at A; .2 at B, .4 at C, and .3 at D = 1.0 minute.)

$$\textit{Cycle Time} = \frac{\text{40 hours x 60 minutes / hour}}{\text{6,000 units}} = \frac{\text{2,400 minutes}}{\text{6,000 units}} = \text{0.4 minute/unit}$$

Number of workstations required is =

$$\frac{0.1 + 0.2 + 0.3 + 0.4}{0.4} = \frac{1.0}{0.4} = 2.5 \rightarrow \text{3 workstations}$$

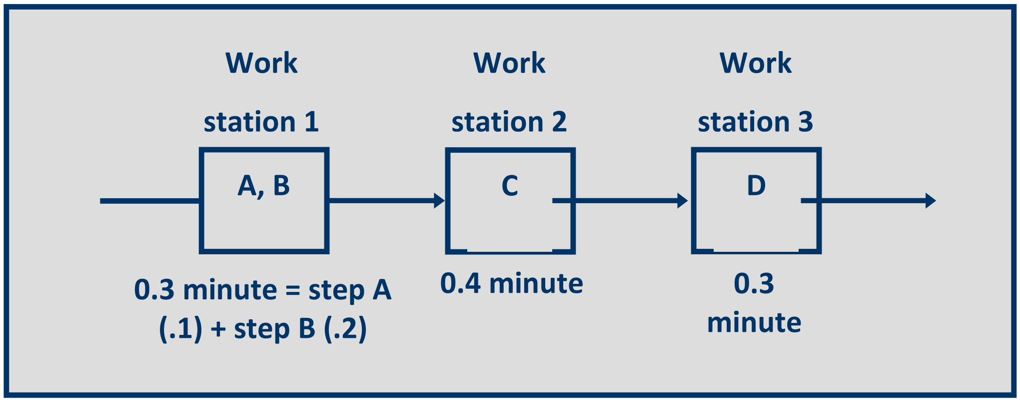
(We cannot have less than a whole workstation)

Here is the line balancing calculation for this process:

***Cycle Time* = 0.4**

***Number of workstations needed* = 2.5**

(i.e., 3 stations since we can't have less than a whole one.)



$$E = \frac{0.1 + 0.2 + 0.3 + 0.4}{3 \times (0.4)} = \frac{1.0}{1.2} = 0.833 = 83.3\%$$

3 workstations x the longest time at any one station (the cycle time of .4)

Total working time

Flow time = working time + idle time

Here is another practice opportunity for streamlining an office workflow.

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/seconds**

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.

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.				

Although the comments made may not all lead to a change (would clerks REALLY be authorized to approve expenses up to a limit?), they do indicate some potential opportunities for process improvement. And, when you think about it, that is what this part of the course is all about...streamlining the workflow to increase your production capacity.

PART 4 - LEAN STRATEGIC MAINTENANCE MANAGEMENT

If a business wants to pursue the LEAN process regarding production, there must be as much strategic planning in the maintenance of the equipment upon which it relies as there is in any other part of the business plan. Obviously, efforts taken and costs involved to maintain their machinery or equipment have a direct impact on everything that affects the overall health and welfare of any manufacturing or other capital-intensive industry.

Unfortunately, many organizations see equipment maintenance as an expense instead of an investment. They take a "least-we-can-do-to-get-by approach" of doing just enough to keep things running or assume a much worse "band aid" mentality of temporary repairs to keep things going with some wire and duct tape. These "just-get-by" quick fixes are always temporary and may fail before correction.

"Working from can to can't" is a common refrain among operating engineers and maintenance technicians when employers reduce workforce-staffing levels to rein in costs farther. Unfortunately, this leaves the remaining staff to deal with an increasing workload.

Morale and productivity continue to decline, as those still on the job cannot conduct preventive maintenance and must enter a reflexive mode of running from one problem to the next as the downward maintenance spiral and workforce morale deepens.

The "WHAT" of Strategic Maintenance Management

Strategic (business) planning is the *process of determining a company's long-term goals and then identifying the best approach for achieving those goals.*[1]

Strategic maintenance management (SMM) is latest generation of the age-old need of maintaining your equipment or machinery. (A few years ago, around the turn of the century, the term was *Enterprise Asset Management* – EAM.) This new name for an existing process appears to fit a trend of "when something doesn't work, rename it, and try it again." [2]

Basically, the concept of strategic maintenance management is the *integration of your maintenance program into the business plans of the company for the least amount of production disruption for customers while maintaining the equipment*.

Success in a market requires an ability to orchestrate many business functions simultaneously. Companies must integrate the functions of financing, marketing, supply chain management, data collection, workforce training and development, new hire recruiting, and retention programs to keep production humming along at optimal capacity. SMM means that those who maintain the physical means of production must have a seat at the business-planning table because the company cannot sell what the machinery cannot produce.

When the industrial age began, it was enough for the machinery maintainers to make sure it stayed sharp, they kept it well oiled, and tightened all the nuts and bolts when they were loose enough to notice. They knew that good maintenance paid off and the reliability of their equipment improved while their cost of owning it declined.

We consider the cost of ownership as part of the cost of production. (Other costs include raw materials, fixed costs of the facility, wages, insurance, distribution, marketing, product development, etc.)

For example, if a machine cost $1000 and made 1000 products, the ownership cost of each product is $1.00. However, if it produces 10,000 products, the ownership cost of each drops to $0.10 per unit.

The Evolution of Maintenance Management

This is a broad review of the evolution of maintenance management. (These are time estimates given only to identify broad changes.)

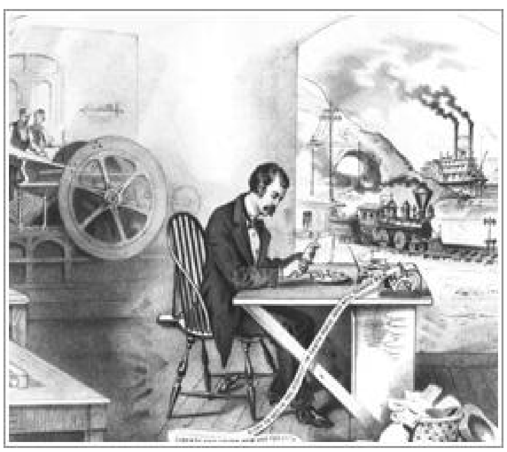
	1st generation < 1940-1960	2nd generation 1960-1985	3rd generation 1985-2000	4th generation >2000
Intentions	Downtime was a fact of life	Greater plant capability, definite equipment life, lower unit costs	Greater plant reliability, longer equipment life, improved work efficiency, higher safety standards, environmental damage control, sustainable higher product quality	Greater on-demand reliability, longer equipment life, greater efficiency, control complexity and quality, near zero waste, zero tolerance on safety and environmental issues, greater costs controls and business flexibility
Methods	Fix it when it breaks, run it until it stops	Scheduled maintenance, development of systems to control work, big (and slow) computers, introduction of cycle time strategy	Plants and equipment designed for reliability and ease of maintenance, greater skills at failure analysis, improved system controls, HAZWOP reviews, improved computers, condition-based strategies	Advances in plant and equipment design for "maintainability" by lesser skilled technicians, improved supply chain management skills further reduces maintenance downtime and costs, shorter equipment life cycles, more integration into the business strategy, greater reliance on computers

THE FIRST GENERATION

The need to protect and maintain your property is as old as human history. Ancient farmers cleared stumps and stones out of their fields to get a better crop while the hunter checked his bow and sharpened his arrows.

Over time, the need to maintain those assets and tools became more narrowly focused and trades such as blacksmithing emerged. The industrial revolution made our tools more mechanized and increased the specialization of the trades. Maintenance trades emerged to keep the equipment running or repairing it when it broke down. Some particularly gifted "mechanics" occasionally made improvements in the machinery.

This was effectively the start of the first generation of maintenance, where owners ran their equipment until it failed and downtime was a fact of life. Since the equipment frequently had to withstand harsh use, it was built solidly (even overbuilt in some cases). This made breakdown maintenance the most cost effective maintenance practice.



In the early eighteenth century, there was a scarcity of trained artisans, and the low level of education meant that there was no real way of supporting or spreading any improvements in performing maintenance.

People could easily understand why equipment needed fixing when it was broken. But it was difficult for them to comprehend any other form of maintenance, hence the old adage of "Why fix it when it isn't broken?"

The Second Generation

Eventually, Man's inventive mind introduced newer design technologies. The equipment and processes started to become bigger, faster, more specialized, and in many cases, better. The newer designs included equipment with a finite life, and identified key components as replacement or consumable.

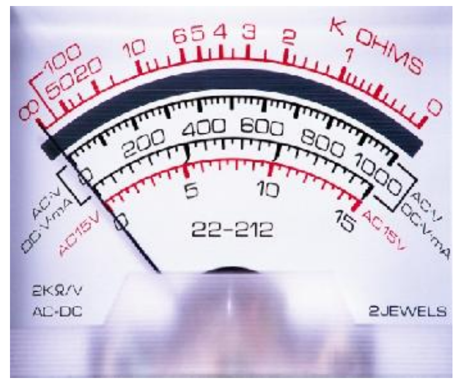
Maintenance specialists and artisans immediately felt the impact of this and introduced the concept of planned shutdown periods to replace these consumable parts. Although these planned shutdowns did not eliminate breakdowns, they were able to reduce the number and frequency of them by replacing key components. This was the introduction of the second generation of maintenance, and the beginning of maintenance schedules.

Gradually, this evolved as mechanics and engineers identified wearing parts that deteriorated in proportion to the usage of the equipment, and cycle-based maintenance emerged. These planned outages and component replacement activities also drove a higher expectation and skill level into the maintenance environment, and the development of formal trade training became the norm throughout the industrial world.

The Third Generation

Over time, these planned outages became an unwanted focus of attention as their costs spiraled outside of the budgets. Owners began asking financial questions about what parts actually needed replacement and the frequencies of these shutdowns / turnarounds. They stretched maintenance intervals forcing the maintenance crew to reuse or repair the wearing parts during these turnarounds. This “bare bones” approach introduced a new level of risk and increased the potential for breakdowns and safety hazards.

The unintended consequences of this minimalist approach drove maintenance engineers into finding innovative ways of identifying failures before they had actually caused any downtime. This allowed them the chance to plan for the event and replace the components when it suited the operational teams best. Soon, the wisdom of condition monitoring as the solution to all maintenance problems became the rage and a wide range of gauges and specialties emerged.



- **Vibration Analysis** uses probes to convert vibration into electronic signals.
- **Wear Particle Analysis** helps engineers understand the nature of contaminants in oil. This became the discipline of Tribology where practitioners study the effects of friction on moving machine parts and of methods, as lubrication, of minimizing them.[3]
- **Thermography** which started as trying to identify abnormal heat generating sources with temperature probes has evolved to infrared temperature sensors that finally drove the cost of infrared cameras down low enough to be a cost effective technology.
- **Non-Destructive testing** allows the analysis of machinery and equipment without invasive procedures. Common NDT methods include ultrasonic, magnetic-particle, liquid penetrant, radiographic, and eddy-current testing. It is a commonly used tool in forensic engineering, mechanical engineering, electrical engineering, civil engineering, systems engineering, aeronautical engineering, medicine, and art.[4]

Inevitably, this greater ability to monitor the equipment requires a greater level of specialization, skills, and knowledge. Unfortunately, the same market economy that drives the innovation demonstrated by these techniques can create and market them faster than it can develop the experts to use it and interpret the findings. As a result of too much technology and too few skilled users, it is easy to bring down a production line when overzealous analysts cannot interpret the results accurately, and raise the alarm bells too soon (or not all).

In reality, these three generations of maintenance need to co-exist in a well-balanced, well-planned maintenance plan, where we define the first generation as a Run-to-Failure (RTF) strategy, the second generation as a defined time or cycle-based strategy, and the third generation as a condition-based strategy.

For example

:

- Lighting in an office is usually managed via the first generation or a RTF strategy. If a light burns out, we replace it.

- Lighting in a production environment where light levels are very important, could be subject to the second generation maintenance or a time based replacement strategy (batch replacement) based on calculations of diminishing light levels due to the age of the bulbs

- Lighting in a highly complex environment could be subject to a third generation maintenance environment or condition based maintenance strategy, which would trigger the standby lighting to be brought on line and a maintenance request to replace the failed bulb.

All three of these generations of maintenance or maintenance strategies should be applied in all maintenance environments based on the criticality of the equipment being maintained, at any point in time.

The Fourth Generation

A fourth generation is evolving as several major changes in the external business environment present an increasing challenge to maintenance professionals today. These external factors include:

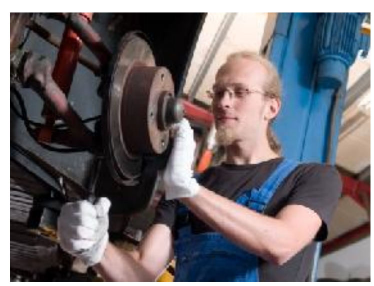
People

- More and more of the baby-boom generation are retiring. This is draining a wealth of experience from the maintenance environment and leaving a potential skills shortage that can only be made up by new emphasis on employer training and development.

- Although an increasing number of two-year technical schools have emerged in the United States, an employer may still need some kind of internal "apprenticeship" program to tailor the general skills taught in the technical school to the specific needs of the employer.

- The younger generation are also less inclined to get their hands dirty, preferring to apply their skills in managerial roles[5] when everyone is titled an engineer (i.e., heavy equipment operators being called "operating engineers"[6]) whether they have an engineering degree or not.

- Due to affluence and changing technology, we have lost the skills-development breeding ground of former generations. For example, very few growing up in the 1950s and 60s could afford to pay someone to service and tune their cars, so they bought a Chilton manual[7] and learned to do it themselves. (In all fairness, today's cars are much more complicated to repair[8] but oil changes are not too complex.)



  This hands-on learning fostered a number of generations of engineers and artisans who were driven by the desire to try and understand how things worked, and tried to get them to work better.

Process

- Information technology has developed in leaps and bounds over the last few years, so much so that many of the older generation of maintenance engineers would never have seen or worked on computers in their youth, but cannot do without them in their work life now.

- The internet has become a way of life for many people in the western world, with information almost freely available. Twenty-five years ago, we may have had an encyclopedia in our homes, and when we needed to do research, we would go to the library to find the information we needed. Today we can go online and find a wealth of information at our fingertips through a search on the internet.

Not only has the information become freely available, our means of accessing this information has also become portable. We can access information from virtually anywhere in the developed nations on our mobile phones.

Plant

- Due to the advances in materials technology and our understanding of fundamental design parameters, we have been able to develop equipment that is smaller and lighter with higher throughput and performance characteristics. This means that in many cases, the equipment is running closer to the edge of its ability. This places a higher demand on artisans to work to closer tolerances, as well as understanding the impact of not working to the correct tolerances in terms of performance and cost.

- Modern equipment designs such as industrial robots have integrated IT components, adding complexity, but also resulting in huge advances in control. This has added a whole new maintenance skill set to industry within the space of 15-20 years - the IT Technician who is responsible for keeping IT systems and networks running.

- The equipment we use and how its integration has also become more intelligent, with error logs and operational information almost being universally available. In most instances, this is more data than we use yet it provides a vast wealth of information we can use to understand and trend the performance of the system as well as providing statistical information about the system failures.

THE "WHY" OF LEAN SMM

If you have read carefully the pages preceding this chapter, the LEAN "why" of SMM should be fairly clear and will not require much additional explanation. Essentially, business owners choose to maintain their equipment for at least three broad reasons:

1. As a means to grow their share of the market for their products or services;

2. As a means to maintain their share of the market while they adjust their plans to do something else;

3. As a means to not self-inflict economic, legal, and/or safety damage by being a cause of events like these while trying to maintain or grow their share of the market:

a) The August 14, 2003 **power blackout** in the NE US and Canada[9] In fact, the first recommendation made in the power blackout report was *make reliability standards mandatory and enforceable with penalties for non-compliance.*

b) **Various utility power failures** - *Additional causes of failures were primarily man made outages that show up in the form of vehicle and construction accidents with power poles and power lines, maintenance from utilities, (emphasis by the author) and the occasional human error.*[10]

c) **Technical failures** were the biggest cause of air disasters in 2003 (a 2004 report)[11]

d) **Upper Big Branch Coal Mine** explosion, April 4, 2010 when 29 died[12]

e) The **BP oil well disaster** in the Gulf of Mexico, April 2010[13]

LEAN SMM gives a company the best chance of achieving its business goals while attending to the necessary functions of equipment maintenance. The need for it will continue to increase for these reasons:

- System owners are requiring higher on-demand reliability and performance from their equipment, in the sense that 100% availability with zero demand is a waste of energy and something for which you cannot bill customers.

- Equipment and component development is taking place at a faster pace and this pace will continue to increase, which will lead to component obsolescence occurring faster than ever before. We need to learn how to balance this against the expectation that systems have longer productive lives.

- Efficiency demands are increasing in terms of both system performance and in spares stock holding to reduce costs and remain competitive in the market.

- With the reduction in the cost of IT and control systems, equipment and system complexity is increasing and building in more functionality. The level of expertise required to maintain systems increases and diverges further as this control complexity increases.

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- The elimination of waste of all kinds is a huge driver in the current LEAN business environment. This includes waste in terms of:
    - **Personnel** – are all utilized fully?
    - **Processes** – are all clearly defined and focused?
    - **Equipment/systems** – are all performing at an optimal rate?

- The overall drive to improve safety has been increasing steadily over the last 15 years, and with recent changes in legislation, this will become even more important to senior executives. The overall driver will be a zero tolerance on meeting all safety requirements.

- Concern for the environment has and will become far more stringent over the next few years.

- We have seen a huge drive to ensure tighter quality control on products, and we will see this drive continue.

- Cost control has and always will be a serious driver in business, and we will see even tighter costs controls being applied to the maintenance environment as we try to prolong equipment life and reduce operating costs through efficiency improvements.

- Businesses have learned to their detriment that they need to remain flexible, and business models and environments will continue to change rapidly. Maintenance teams need to be increasingly flexible with their maintenance plans in order to respond to the changing needs of the business

The practice of maintenance has gained enough status to form a professional organization, Association for Maintenance Professionals complete with its own website, forums, and blogs.

THE "HOW" OF LEAN SMM

Once they are convinced of the value of strategic initiatives, many companies rush to develop and implement their plans of "World Class" or "Best Practices" strategies. Unfortunately, the results often fall far short of expectations. When they analyze their failures carefully, the root cause usually is due some very common issues.

Here is what we suggest. Before ordering their "World Class – Best Practices" hats, T-shirts, and memorabilia for the inevitable cheer-leading launch of their maintenance initiatives, we urge potential maintenance managers to look back to the definition of strategic maintenance planning, "…the *process of determining a company's long-term goals and then identifying the best approach for achieving those goals."*

If the practitioners of maintenance management want to be considered "strategic" and an integral part of the business, they must take care to align the objectives of their maintenance practices with those of the business. Failing to do that risks their being lumped in with the machinery and equipment they maintain as necessary business costs that should be reduced at every opportunity – including workforce layoffs!

Here are some issues for initial strategic planning consideration with emphasis on the LEAN, customer-driven approach:

1. **How closely do your maintenance management objectives align with shareholder, stakeholder, and customer expectations?**
    a. If business expectations are for a particular level of production, can the existing maintenance plan support them or do we have to develop a new one?
    b. What is the capacity level at which the machinery must operate and for how long to meet those expectations?
    c. Can the equipment even perform to those levels? How do you know?
    d. Does this greater performance requirement increase the risk to the operators and maintenance technicians?
    e. Do you have the spare parts available to do it?

f. Do you have the skilled technicians available to maintain the equipment at these higher levels? Have you developed any "bench strength" within your maintenance ranks in case your primaries are out?

2. **How well do your (or will your if planning for a new business initiative) maintenance objectives meet customer expectations?**

Customer expectations vary with the industry. Transit customers want a smooth, clean, and reliable ride. They will not care how often you change the oil or brakes on any given bus as long as there is a bus at the corner when the schedule promises there will be one.

Unnecessary oil changes and brake replacements will drive up operating costs without improving customer satisfaction. The maintenance objective is to find the optimal combination of maintenance schedule (without getting into repair or replacement) and customer satisfaction that will generate the greatest profit with the lowest costs.

3. **Where do the business needs of other functions within the company – human resources, sales and marketing, financial, procurement, etc. - intersect with the maintenance objectives?**

a. **Human Resources** – Do you have the available (in-house or 3rd party contract) maintenance talent needed to meet corporate objectives? Can they recruit the talent that you need for maintenance? Do they have strong relationships with technical schools and professional associations? Do they have workforce development and training initiatives that will help develop the talent internally? (We will discuss this in greater depth later.) Do they have the policies and initiatives to retain the critical talent?

b. **Sales and Marketing** – Can your equipment and machinery support the kinds of commitments sales and marketing are making to customers?

c. **Financial** – Can they raise more capital or increase credit based on the condition of the equipment and machinery? Can any gains be realized in reduced insurance premiums based on the maintenance objectives and practices?

d. **Procurement** – Can you get the best quality parts (or raw materials) at competitive prices on a reliable basis to minimize impact on production? Do you have a sufficient supply of on-hand parts? Do you have enough confidence in their supply-chain management skills to reduce your in-house inventories and stocking costs?

e. What is our realistic **self-assessment** of our ability to meet the desired business objectives?

When assessing the ability of the existing equipment and/or machinery to meet the desired business outcomes, there are only two choices:

- We can meet them with our existing capacity (Note: "Capacity" includes the total organizational capabilities of the equipment and its operators and maintainers, the materials suppliers, the product marketers, etc.)
- We cannot meet them with our existing capacity

If we decide that we <u>can meet</u> the new business objectives, these options are available:

- **Administrative, operational, or procedural changes in the existing maintenance practices** – Small "fine tuning" adjustments using any lessons learned from the past that can help to optimize productivity.

- **Workforce configuration** – Can we make any changes in the training programs or skill level requirements to maximize productivity in the next year?

- **Renewal and replacement policies** – Should we evaluate the existing renewal and replacement policies for potential cost reductions or production impact?

If we decide that we <u>cannot meet</u> the new business objectives, these options are available:

- **Change expectations** – can we adjust the expectations or productivity or risk management?

- **Redesign** – can we redesign the workflow, the work floor, or anything impacting production to help us meet the new objectives?

- **Acquisition** – Can we acquire additional resources through either purchase or contract to help us meet these new objectives?

***Please note a word of caution here**. There is more to determining whether the business can meet the desired objectives than by simply comparing them to past productivities. Just because the machinery, equipment, and staff met the desired goals last year doesn't mean they can do it next year.*

The business environment may not be the same when you consider:

- ✓ ***Regulatory issues** – Have they changed or expected to change soon enough that may impact our plans?*
- ✓ ***Political or economic issues** – Recently (2012) many businesses have been hesitant to make long-term plans for the future based on uncertainty in the political and economic climate.*
- ✓ ***Reliable performance data** – Are we are confident that we have a grasp on the condition of our equipment and/or machinery to forecast capabilities confidently?*
- ✓ ***Past history** – Do we have a reliable history of our performance ("lessons learned") so we can avoid a repeat of past problems?*
- ✓ ***Contractual agreements** – Will our existing contracts with vendors (and possibly labor) allow us to meet these new business objectives? Do our vendors have any potential issues that may keep them from supplying us?*
- ✓ ***Maintenance management practices** – Are we are comfortable with our abilities to manage and maintain our assets? This means the human (the maintenance "bench strength") and knowledge capital as well as machinery and equipment.*

Skills and Talent Development Issues

The availability of highly skilled and experienced technicians available to any single employer is on a downward trend as we identified earlier. This is due to retirement, competitors lure them away, and poorly planned and executed efforts to attract, develop, and retain skilled replacements.

Some questions that employers should ask themselves about skills and talent development in their LEAN SMM planning are:

- What is the maintenance skill level for each machine or piece of equipment required to deliver the performance the business demands?
    - Is there preferred or requisite previous experience associated with the positions?
    - Do we have a means to develop those skills levels?

- Do we have a plan to locate, recruit, retain, and develop future technicians?
    - Do we have a benefits package that would help us retain this (and all other companywide) talent?

Unfortunately, many employers rely on fewer skilled technicians to do more work or attempt to train others to help them. The problem with this is that skilled technicians *are not skilled trainers* and the novice rarely gains much useful knowledge in this attempt.

Some questions that employers should ask themselves about skills and talent deployment in their SMM planning are:

- How many people are required (as opposed to assigned) to maintain the equipment or machinery for the site?
- How much reactive work should there be - and how much planned work?
    - How do we know?
- Where is the best place to locate the response teams, and what do they do when not responding to system malfunctions?
    - How do we know that is the best?
    - Where should they not be located?
    - What should (can) they not be doing when not responding?

- Who should be responsible for the general equipment cleanliness?
    - Why are they the best choice?
    - What is the optimal plan for that work?

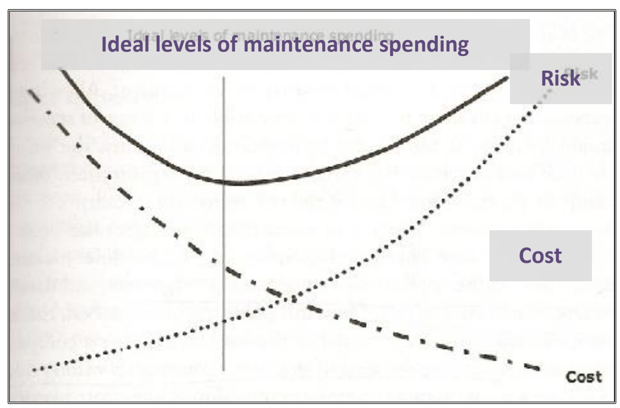
- Which teams provide the best response times?
    - Why are they better?
    - Can we duplicate the reason to other teams?

- Which teams complete the most planned maintenance activities?
    - Why do they complete more?
    - Can we duplicate the reason to other teams?

Reliable Measurement Issues

A simplistic view of maintenance management would be to envision an automobile's dashboard with its various gauges for fuel availability, electrical charge, engine temperature, engine speed, vehicle speed, and oil pressure that gives the driver a remote, yet real-time status report on the vehicle. Although it tells the driver what is happening, it does not provide a cost/risk analysis of each piece of data.

For example, what is the cost/risk of running out of gas? Is it different for on a city street than it would be on the open prairie? What is the cost/risk of running your engine without sufficient oil pressure? While it is nice to know how much fuel or oil pressure we have, that knowledge is only part of the value of the data. Sometimes we forget the message behind the familiar gauges we see every day.



The traditional graph of the cost/risk relationship discussion almost always simplifies the greater issues beneath the surface and we fail to assess it critically for our situation.

Look at these pairs requiring maintenance. It becomes evident there is much more to this discussion than a simple inverse relationship:

- Contrast a *soft drink bottling plant* with a *nuclear power plant* (both are "plants" but are the potential risks the same if you manipulate the cost or maintenance frequency variables?)

- Contrast a *bank's check processing* center with a *pharmaceutical processing center* (similar names – processing centers – but different potential risks if something stops or goes wrong)

- Contrast a collection of machinery called a *diesel locomotive* with a collection called a *nuclear-powered submarine* (If the collection of machinery called a locomotive is not well maintained, it stops. What happens if a submarine's crew does not maintain the machinery and it stops?)

These paired examples should make the point that there is not always a direct link between the cost of maintenance and its associated risk level. Do not let the graph mislead you.

Miscellaneous Issues

Some additional LEAN SMM planning questions and issues for consideration are these:

- Which issues regarding any aspect of your maintenance are on-going and which are new?
- What is the impact of on-going issues on your maintenance planning (financial, scheduling, production, supply chain ripples, etc.)?
- What SHOULD we measure to support our strategic planning as opposed to what we CAN measure? In other words, do we start with identifying the information we need to know and then ask, "How can we get this" or do we start with the information easily available and ask, "What can we do with this"?
- Can we measure and predict how the system copes with changing live production volumes (as opposed to test volumes)?
- Can we identify existing and potential load balancing issues
- What measurables should we use to determine equipment performance over time to understand and predict potential downtime?
- Do we understand the relationship between error reports and the actual cause of the problems? Are there any common causes or trends that we should investigate?
- How can we determine the worst performing equipment? Why is it performing at undesirable levels? Has it always or just recently? If always, why do we still have it?
- Do we have a business-wide understanding of what "optimized production" means? Do we have measurables as part of that definition? What measurements will help us determine the effectiveness of the maintenance in optimizing production performance? What are the various components of "optimized production performance" for our operations?
- How do we identify when it is best to perform maintenance on the system? Can we develop prioritized maintenance schedules within various scenarios dealing with unexpected supply chain problems, power outages, labor disputes, etc.?
- Have we established a baseline of system performance prior to performing the maintenance or enhancement so we can monitor the effectiveness of the maintenance or enhancement post-implementation

- Do we have a strategy for component replacement? Do we have a means of determining whether we should refurbish or replace a component? What criteria do we use for determination?
- How do we identify potential equipment breakdowns in advance of system breakdown?
- Is our maintenance regime optimally effective and are we working on the right equipment? How do we determine “optimally effective”
- When there are problems in specific areas, can we determine whether it is an adjustment issue or is it a flow saturation issue? How do we know? Are these problems predictable?
- Has the improvement had a negative ripple effect to another piece of equipment further down the line?

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A MODEL FOR LEAN SMM

Here is a sample plan that will illustrate some of the considerations involved with developing a LEAN strategic maintenance program if you do not have one. Sometimes, the most daunting question is, "There is so much here. Where do I start?"

If you are a novice to this topic, this model will give you enough of an understanding about the process to discuss it intelligently with senior management or any consultants the company may bring in.

We will use a hypothetical situation of developing the maintenance requirements for a baggage handling system in a new airport terminal.

Step 1 - Identify all Assets

Assets are assets, what can be difficult about identifying them? Well that depends entirely on how extensively you want to define one. Take a baggage conveyor for example - do we take the asset structure down to component level, such as the drive motor, or do we leave the asset at conveyor level and take a motor as a component? Either approach will work but you cannot have it both ways. The importance here is not how you identify the assets but that you are consistent throughout your system.

Ultimately, asset identification becomes a fine balance between the identification of local classes (similar equipment) and discrete equipment (one of a kind, dedicated equipment.) This may sound simple, but there is an art to doing it in a way that helps to simplify the development of your overall maintenance strategy. (We will try to clarify what local classes mean in Phase 2.)

Step 2 – Identify their Criticality

Once you have identified all of the discrete assets in your system, you will need to define how critical they are to the performance of your business. A practical way of doing this (using our airport model) is to take a process layout of the system, and mark off large areas such as "Check-In area A" or "Bag delivery area B," which has a measurable impact on your production or business.

Next, apply a series of business-related questions with five possible realistic answers to each one such as:

1. What would happen to our business if "Check-In area A" was out of operation for 24 hours (or the time needed to repair it)?
    a. Production loss of over $1Million
    b. Production loss of over $500k
    c. Production loss of over $X (some number of your choice)
    d. <u>Significant</u> production loss that we could supplement somewhere else (must get agreement with all stakeholders of the criteria for "significant")
    e. <u>Minor</u> production losses that we could supplement somewhere else (get a similar definition for 'minor")

2. How would our customers react to the identified section being out of operation for 24 hours (or the time needed to repair it)?
    a. Losses in sales in excess of $1Million
    b. Losses in sales in excess of $500k
    c. Losses in sales in excess of $X (some number of your choice)
    d. <u>Significant</u> losses in sales that we could supplement somewhere else
    e. <u>Minor</u> losses in sales that we could supplement somewhere else

Be sure to apply these questions to the various aspects of your business, such as environmental impact, media coverage, customer perception, reputation, supply chain, and any other issues that have a direct impact on them and their ability to function and operate.

The questions and their relevance might change over time as the business and its environment changes. Once the business criticality for an area has been determined, you will need to consider the failures that could take place on the equipment in that area, and the frequency at which these failures might occur.

These should not be operational issues (such as bag jams, power outages, or understaffing), but rather equipment failure issues (labeled A-C in the table sample) that would require component replacement or adjustment, such as motor failure or belt adjustment. At this stage, you should ignore the length of time it takes to repair the failure – just focus on the frequency and business risk of it happening.

Plot these two factors, **business risk** and **failure frequency**, in a table using a numerical score (we suggest 1-5) where 1 is the lowest and 5 is the highest. This will help you allocate your maintenance resources and convey to all not intimately familiar with your world of machinery and equipment (such as finance, sales, and marketing – all of the other groups within your organization with whom you have to compete for resources) the rationale behind your maintenance strategy. Repeat this analysis for all of the areas you have defined on your process layout.

Failure Issue	Business Risk	Failure Freq
Issue A (Primary conveyor belt motor failure)	4	1
Issue B (All belt tension)	3	3
Issue C	1	4

Two items you will need to be aware of when performing this activity:

- You should seriously consider any business risks that include a health and safety question in relation to people performing maintenance on the equipment. While the resulting injury could be extremely serious, an owner can readdress the risk assessments and resulting method statements or redesign the maintenance process (if possible) without increasing the business risk.

If the business risk is too high, then you might consider doubling up on the equipment to reduce it. (But remember, twice the equipment also increases an injury risk when maintaining it.)

- All of the equipment and process routes in an area do not necessarily fall into the same criticality as the main routes for the area. You will need to identify the main process routes, secondary and tertiary process routes through the

Reality Check
The preparation and presentation of your strategic maintenance plan is also a political tool to help you compete with any flashier, higher profile parts of your organization when competing for budget monies or face-time with the boss.

area and assign lower priorities based on their potential impact on the area.

This process should be kept as simple and flexible as possible, and ensure all decisions are well documented to eliminate the possibility of misinterpretation or to support any decisions made. (The CYA – cover your *assets* – concept applies here, too) Remember that the business need and market forces will change over time and this criticality review will need to be re-evaluated fairly frequently (usually annually or in major shifts of the economy) to ensure you are still applying the correct strategies. Changes to your environment could quite possibly change the maintenance plan you have adopted for the equipment on site over time.

When looking through all of the equipment on your site, you may notice that there are several pieces of equipment that are very similar. The probability is high that the maintenance strategy applied to them can be the same, while making allowances for various criticality levels.

An easy way to identify these equipment groups is by giving them a Local Class designation. Develop the maintenance strategies for each of these local classes while defining different frequencies (and strategies if necessary) for all five critical levels at the same time.

Based on your list of local classes, you will need to:

1. Draw up a list of every maintenance activity that you will possibly perform on this equipment/local class, including:

    a. **Component replacements** where you need to consider the level at which you want to carry out your maintenance. For example, if a bearing on a motor failed at a site in a large city, the replacement unit cost less than $50 and it was easy to get, you might choose to replace it instead of repairing it. But the same situation in a more remote location where replacement may cost the same but not be as readily accessible may mean you choose to repair it.

    b. **Component adjustments** cover activities such as belt tensioning, oil replacement, parts realignment, or defragmenting hard drives on system controllers.

c. **Cleaning activities** are all that cover the equipment and the immediate surroundings. Although cleaning could fall to a lower skill level, it should never be ignored from the maintenance plan as it forms part of a holistic approach to maintenance. Simple cleaning in some systems can reduce downtime by reducing dirt in the system and identify potential problems if your staff will just observe their surroundings instead of blindly focusing on the equipment they clean.

d. **Conduct inspections** including visual inspections, stoppage inspections, and regulatory inspections.

e. **Make condition-based inspections** such as vibration, thermography, and ultrasound. If there is no in-house expertise to perform these activities, you could contract them out to specialist companies to perform the work.

2. Estimate the following:

   a. How long each of the identified tasks will take to complete (Mean Time to Repair [MTTR]), and how many people will be needed to complete the work.

   b. Predict the Mean Time between Failures (MTBF) for replacements and adjustments. To define the MTBF, you might want to look at the design or predicted life of a component that you intend to replace or adjust.

   c. Decide if the work will require the equipment to be isolated in order to complete the work.

   d. Define one of the following strategies for each of the criticalities you are using

      i. **Time based** where you define a set frequency to perform the maintenance activity. Unless the equipment vendor can provide recommended time intervals, you may have to rely on thermal inspection (thermography) or vibration inspection (vibration monitoring) and excellent record keeping to build your database for maintenance frequency.

ii. **Operational based** which sets out the flow or operations required between maintenance activities (hours of running, units produced, etc.)

iii. **Condition Based** using an inspection or other strategy which will identify the onset of failure and allow for reaction time to address the failure.

iv. **Run to fail** which allows the component to fail before replacement or adjustment. (Changing burned out lights or fuses)

e. As part of the creation of the maintenance strategies, you can also develop safe working practice method statements and generic risk assessments for all of the maintenance tasks that you have identified. These method statements and risk assessments are an ideal way of helping to develop a training plan for new employees.

Step 3 – Construct the Maintenance Plan

You can develop steps 1 and 2 simultaneously but need to finish them before starting step 3. By now, you will know:

- All of the equipment you plan to maintain
- How critical it is to your business
- What maintenance you will perform
- The strategies you will use to maintain it

We now need to construct a maintenance plan for each piece of equipment. Taken together, these equipment maintenance plans become your strategic maintenance management system. You can combine them into large binders, online files on your internal system (if you have one), or your Computerized Maintenance Management System (CMMS) if your company is that advanced.

In a spirit of complete disclosure, this task can become very daunting! Do not quit now! If you calculate the number of equipment units you have needing maintenance and the number of maintenance activities per unit, you will have created a very intimidating mountain of PM tasks.

(This can also be to your advantage if you consider the documentation you put together to get this result. **Imagine dropping several huge binders of supporting documentation on the table in front of you during budget meetings to justify your requests when you are competing with other groups in your company for funding.** The sheer size and volume of your "props" should sway the decisions in your favor. If a picture can speak a thousand words, imagine what 20 pounds of documents in a budget meeting can do for you!)

In order to develop a manageable maintenance plan, you will need to identify and group these PM tasks together, based on frequency, strategy, skill and on a physical grouping of equipment to restrict the impact on the system during an inspection when you must turn it off. We suggest you consider one person for a maximum of 4 hours per maintenance route. This will minimize the impact on the system if you have to shut it down and increase the likelihood of task completion during a shift.

At this point, there are a few key items to consider:

- Your maintenance plan needs to be flexible:
  - It should allow you to review and enhance the strategy, adding/modifying/deleting tasks or check list items.
  - It should allow you to review criticality (impacting on the frequency and strategy applied)
- Every time these change, you must consider the ripple effect upstream and downstream in the maintenance routes and update any associated checklists.
- Reassess any changes in risk

As additional benefits, the development of a strategic maintenance management process can also help to:

- determine and justify the manpower needed to support and maintain the system

- anticipate the equipment spares consumption for the future
- create the training material used to train the technicians on the maintenance of the equipment

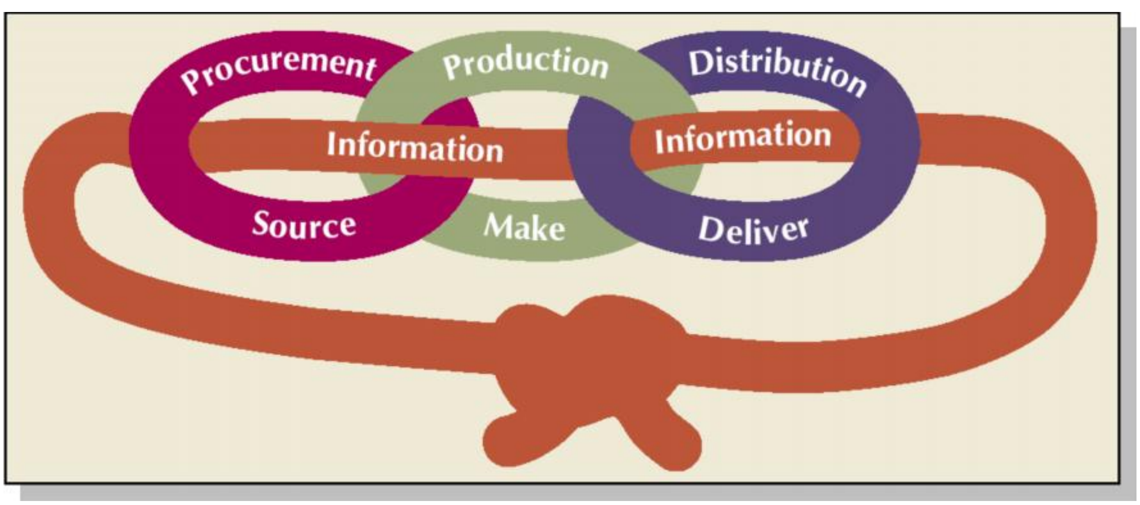
PART 5 - UNDERSTANDING LEAN SUPPLY CHAIN MANAGEMENT FUNDAMENTALS

The supply chain of a business includes all of the facilities, functions, and activities involving the flow and transformation of goods and services from raw materials to final customer, as well as the associated information flows. It is an integrated group of processes to “source,” “make,” and “deliver” products.

There are basically two different business models with supply chains: *manufacturers of finished goods* with very distinct flows of materials from suppliers and out to consumers (see the diagram in this section) and *service companies* whose supply chains are not so easily described because they do not focus on the flow of physical goods but rather on human resources and support services. They are often more compact and less extended than their manufacturing counterparts.

The key to success of supply chain management whether it is manufacturing or service is DATA. There are three critical elements of using that data that determines the success of a business. It must:

1. Collect it from their customers to learn what they want, how they want it, and when it must be there (the *demand* or *pull* side of the equation)
2. Interpret it carefully to improve:
    a. Their production, purchasing, and staffing forecasting
    b. Inventory management (enough of the right inventory to meet customer demand but not tie up too much capital in it)
    c. Planning for growth
3. Share it with suppliers to make sure their flow of needed materials stays reliable.



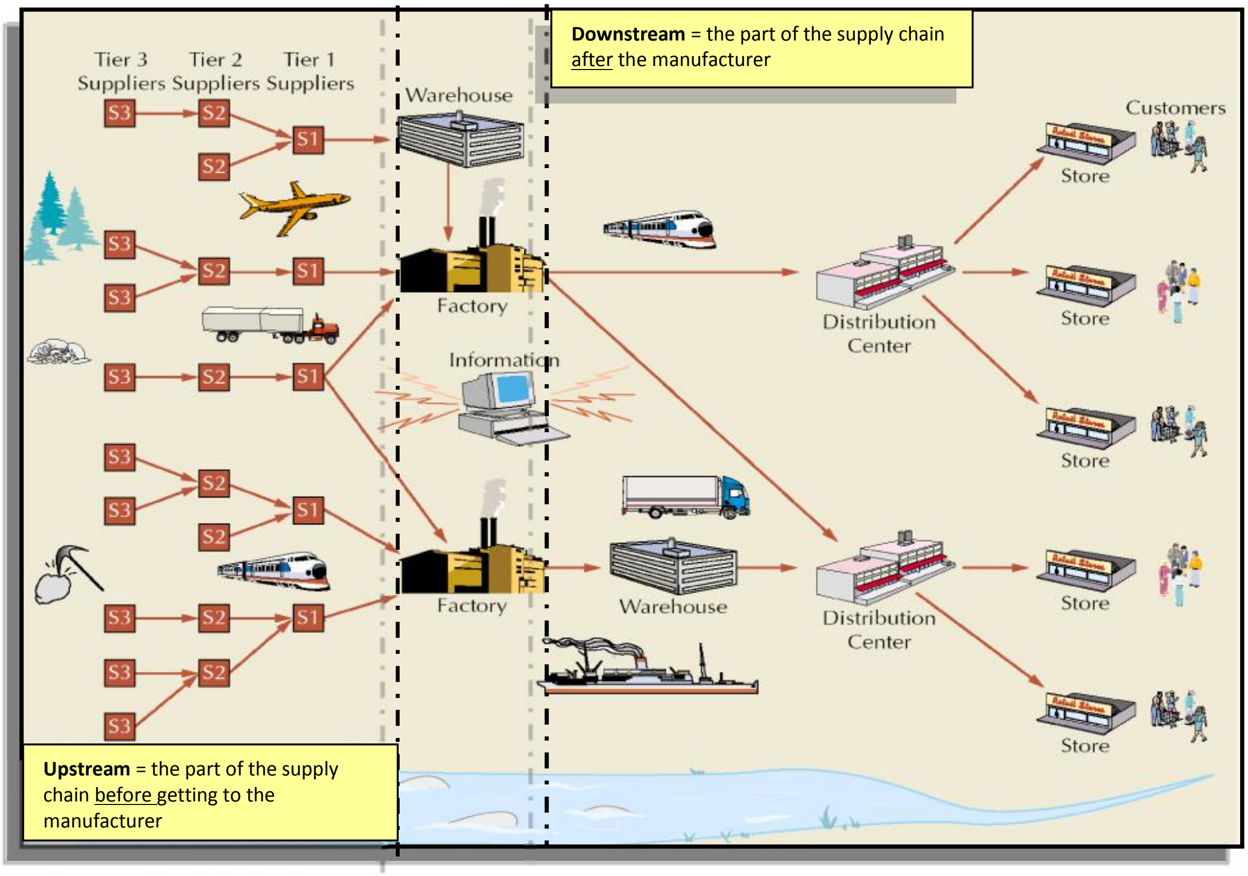
The picture below tells us a lot about the supply chain concept.

Suppliers:

- **Tiers** - First tier suppliers provide materials that are ready for the manufacturer without additional processing. Second tier means it needs one more step of preparation before going to the manufacturer and so forth for additional tiers.

- **Information –** this is the heart of an effective supply chain as data is exchanged as close to real time as possible between suppliers, the manufacturer, distribution centers, and end-user access at stores.

- **Distribution Centers & Outlets to customers** – the customer end also provides the "demand" which helps the factory forecast future needs so they can contact their various tiers of suppliers to begin the cycle.



Service Providers

Although we will spend most of this course talking about the supply chain and how it relates to manufacturing, it is important to apply the same model to service providers such as a dentist, a lawn service business, or a community services agency.

A dentist must purchase equipment (and have it serviced as necessary) and supplies such as drugs used in their office procedures and that bag of goodies they always give you after cleaning your teeth with the new toothbrush, dental floss, and maybe a travel-sized tube of toothpaste inside. They are very focused on the human resources aspect of their business because it's their employees who clean the teeth or assist in the more serious dental procedures that interact with their patients and determine, to a large extent, whether the patients stay with them or look for another provider.

The lawn service provider must have sufficient equipment and tools from a supplier plus enough employees to make their business successful. They may not interact with customers as much as a dentist's employees do but customer satisfaction and reliability is still an important element of their job.

The community service provider must also obtain materials (depending on the nature of their services) from suppliers and, using the skills of their employees, apply those materials appropriately in their service to their customers. Any disruption in the flow of their supplies can mean a breakdown of service.

Various "Chain" Terms

The word "chain" has been used in a wide range of references dealing with manufacturing or services and has become fairly universal. This is a breakdown of their current usage for familiarization:

- **Value chain -** every step from raw materials to the eventual end-user where its "value" increases steadily as a result of something being done to it.

For example, a cabinet manufacturer uses oak as a primary ingredient of his product. Going to the source of that material, we see the logger who cuts down the tree and sends it to a saw mill. (He “manufactures” a tree ready for the saw mill.) This adds value to the wood because it is no longer in the forest but getting closer to becoming a cabinet.

The saw mill “manufactures” additional value by cutting the raw tree trunk into boards and pressing the scrap into a thin veneer for cabinet facing. This wood is shipped to the cabinet maker.

The cabinet maker manufactures additional value by transforming the finished oak lumber into the cabinets which are sent to the retail outlet for the builder/consumer.

The builder adds value to the cabinets by installing them in the new home he is building and staining them to complement the colors in the house.

- **Supply chain** – the sum of all activities that get raw materials and subassemblies into manufacturing operation. The ultimate goal is the same as that of a value chain but it does not emphasize the increasing value of the item at each stop in its trip to the manufacturer: this focuses more on the flow of the materials into and out of the manufacturer.

- **Demand chain** – This focuses on the end-users seeking to know more about what their customers want (their “demand” from the manufacturer) in terms of quality, quantity, and delivery time of particular items. The more data they can collect from the demand side means they can improve their forecasting projections. This is a critical component of the LEAN processing model.

Better forecasting means being more specific in buying raw materials (thus wasting less) from suppliers and, thus, carry a lower inventory of raw materials in the factory. As the quantity of the data exchange between end-users, manufacturers, and suppliers increases and the quality improves, the greater the opportunities for just-in-time supply delivery. (We will talk more about this later.)

Supply Chain Management (SCM)

Traditionally, each segment of the supply chain – upstream or downstream – tended to focus on its own part of the process. The manufacturer's Accounts Payable (AP) department focused upstream on taking as long as possible to pay suppliers without incurring late charges while Accounts Receivable (AR) spent their time looking downstream to getting paid from consumers as quickly as possible.

Inventories commonly bulged with materials that were no longer needed or were in greater quantities than simply having "safety stock" (an emergency amount of inventory in case we were caught short for some reason) on hand. The costs of carrying that inventory were either not considered or deemed too difficult to calculate accurately. [We will discuss this at greater extent later in this course, also.]

However, the evolution of technology from telephones, to faxes, to real-time data via the internet has radically changed the way successful manufacturers view the management of their supply chain. Not only does *supply chain data* flow via the internet but *financial data* also moves to and from suppliers, customers, and the bankers who finance it all. **In today's world, a successful manufacturer must take a holistic view of the whole supply chain as well as rethink the relationship they must have with their vendors. This is the foundation for a successful LEAN model.**

Uncertainties in the Supply Chain

In an ideal world:

1. A manufacturer would know exactly what the customer wants, when they expect it and the extent of the quality and quantity demanded
2. The suppliers would always deliver on time and provide the quality and quantity of exactly what we wanted
3. Our customers would always pay on time (or earlier)
4. We would pay our suppliers at the last possible moment before incurring finance charges (and they would be happy to get it)
5. The employees and equipment would always work to maximum productivity
6. We would grow at a steady and predictable rate and our investors would love us.

Obviously, we don't live in an ideal world but it does help us identify some of the obstacles and opportunities keeping us from it. Let's look at these 'ideal world' components and talk about what we can do about them in the real world.

The ideal world: *A manufacturer would know exactly what the customer wants, when they expect it and the extent of the quality and quantity demanded.*

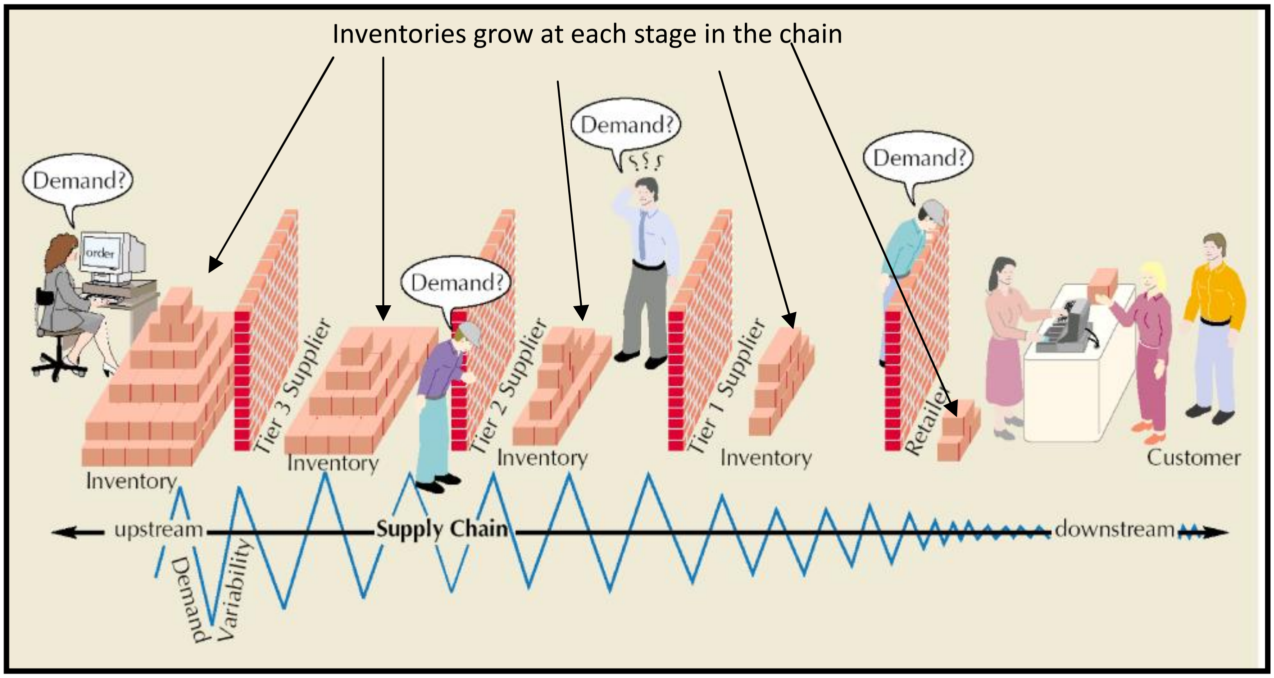
The real world: The goal of SCM is to develop an ability to respond to uncertainty in either the upstream or downstream sides of the equation without creating costly excess inventory. [Some excess inventory is necessary as insurance against supply chain uncertainty. The key is to determine just how much we need without being excessive.]

Typical factors that contribute to uncertainty in the supply chain include:

- inaccurate demand forecasting
- long variable lead times
- late deliveries
- incomplete shipments
- product changes
- batch ordering
- price fluctuations and discounts
- inflated orders

One aspect of life in the real world of SCM is the ***Bullwhip Effect*** – what happens when slight demand variability is magnified as information moves back upstream in the data flow from the consumers.

Suppose each participant in the supply chain experiences low confidence in their forecasting abilities based on inaccurate demand data from the ultimate consumer. Suddenly, each begins to look more to their own security when placing orders and hold a little inventory as insurance against this uncertainty. As inventories grow, downstream customer service suffers because the needed goods are being stored, not shipped. Production and delivery schedules are missed while associated costs increase.



One way to reduce the impact of this bullwhip effect is the concept of "risk pooling": a strategy of spreading the risk among many to reduce the impact on the individuals.

Here are four aspects of that risk pooling strategy:

1. Establish distribution centers between manufacturer and end-seller where inventory can be stored for quicker delivery to stores than waiting for the factory to send it.

2. Reduce the range of parts and variability within components needed for a product which reduces the chances to get a forecast wrong. Also, fewer forecasts can mean fewer errors.

3. Multiple suppliers for a manufacturer can create a flexible capacity situation reducing uncertainty if you don't have to rely on one source: i.e., "don't put all your eggs in one basket."

4. Likewise, the customer can reduce their risks by working with multiple manufacturers of similar products.

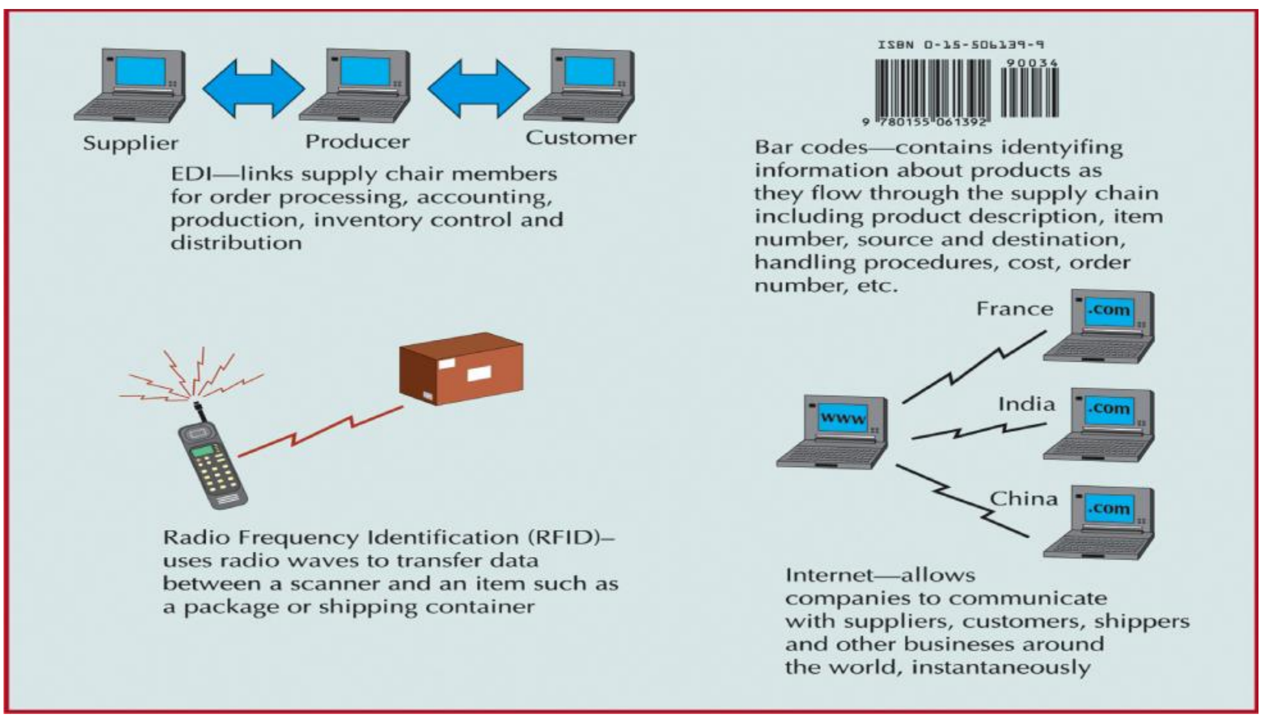
THE IMPACT OF TECHNOLOGY

By now, it should be apparent that maximizing communication between all chain members using all of the available tools of technology is the key to successful management of the supply chain. The closer that real-time information is traded between end-users, manufacturers, and their suppliers, the better the supply chain management resulting in, as a minimum:

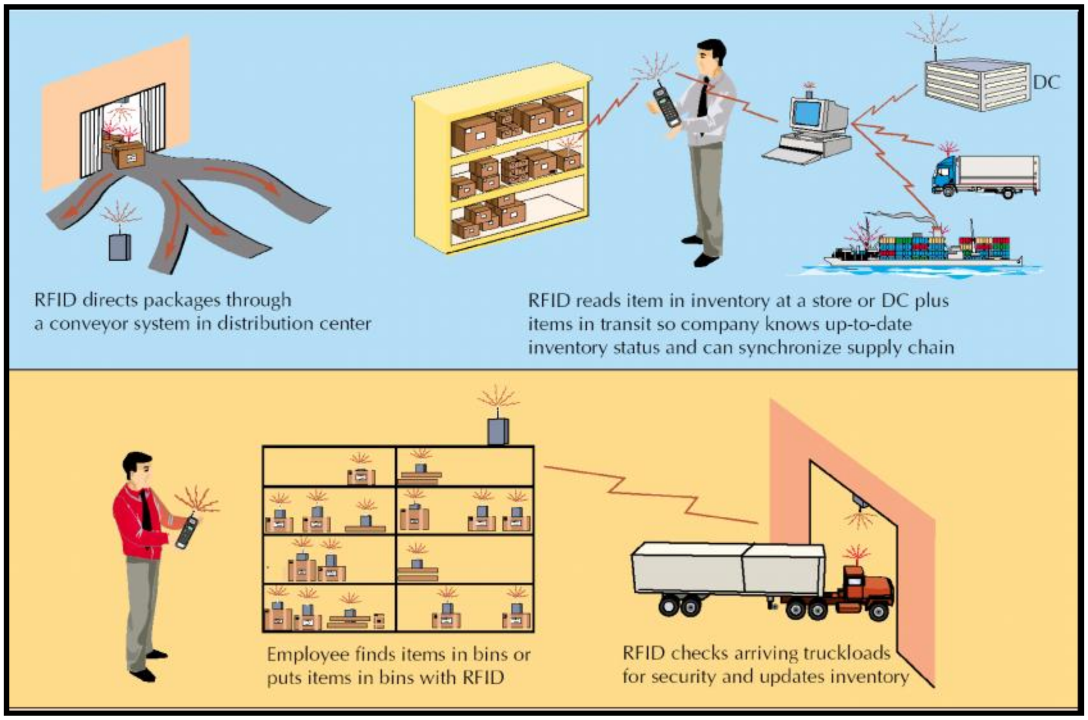
- Increased customer service leading to increased demand of the products
- Increased sales for producers and suppliers of raw materials to the producers
- Reduced inventory costs for all.

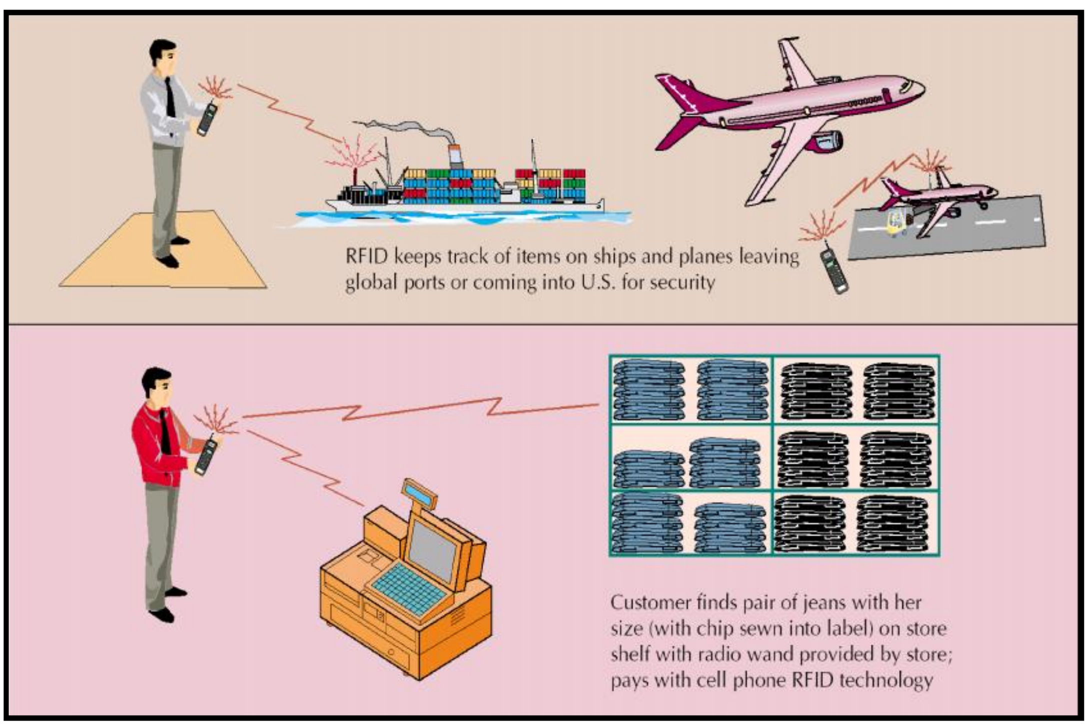
Technology tools and strategies in use today include:

- E-business - replacement of physical business processes with electronic ones
- Electronic data interchange (EDI) is a computer-to-computer exchange of business documents
- Bar code and point-of-sale (POS) data creates an instantaneous computer record of a sale
- Internet allows companies to communicate with suppliers, customers, shippers and other businesses around the world instantaneously
- Build-to-order (BTO) direct-sell-to-customers model via the Internet with extensive communication with suppliers and customer



➢ <u>Radio frequency identification</u> (RFID) technology can send product data from an item to a reader via radio waves speeding production, transportation, or inventory maintenance.





Communicating Along the Supply Chain

The ideal world:

- *The suppliers would always deliver on time and provide the quality and quantity of exactly what we wanted*
- *We would pay our suppliers at the last possible moment before incurring finance charges (and they would be happy to get it).*

The real world – Suppliers must look out for themselves first because if they aren't fiscally healthy, they aren't much good to their customers. Having said that, there are great opportunities for manufacturers and their suppliers to work together closely for their mutual benefits <u>if they can develop a foundation of trust between them.</u>

By now, it should be evident that communications – human and machine - along the supply chain are essential for the success of the chain. This includes:

- The use of technology "talking" with each other at each stage of the process
- The ability of the humans along the supply chain to trust each sufficiently so when their technology communicates, it exchanges useful information.

As trust develops and communication improves, increased sharing of reliable information among supply chain members can have these beneficial outcomes:

- Reduced bullwhip effect
- Early problem detection
- Faster response
- Additional building of mutual trust and confidence - "Trust is historic"

Once we see that we need each other to maximize our potential for success, we can collaborate in planning, forecasting, replenishment, and design which will:

- Reduced bullwhip effect (once again)
- Lower costs because of less guesswork and improved forecasting (material, logistics, operating, etc.)
- Higher capacity utilization for all (fewer machines idle, less unused storage space)

- Improved customer service levels which keeps demand high

Additionally, we can work together to coordinated workflow, production and operations, as well as procurement. The results of these efforts can increase:

- Production efficiencies for all involved
- Faster response to demands
- Improved service through the chain
- Quicker to market

Finally, as trust among quasi-partners grows, they can adopt new business models and technologies for:

- Penetration of new markets
- Creation of new products
- Improved efficiency
- Mass customization which will open new markets

SCM Performance Measurements

So far we have talked about what the supply chain is, the importance of communications between participants along it, and now we'll look at applying metrics as a way of monitoring our management of it.

We will look at measurements from two distinct perspectives:

- **Internal focused** – how well do we manage what we can control of the supply chain
- **Customer focused**; i.e., the DEMAND side of the chain

INTERNAL FOCUSED

Some metrics for the supply chain costs only come from the actual numbers of a real company. We will identify them and tell you what to look for. The metrics for supply chain asset management are universally used and we will include the formulas for practice calculation.

Supply chain costs include:

- **Supply chain management costs** – the direct and indirect cost to plan, source, and deliver products and services
- **The cost of goods sold** – the direct costs of material and labor to produce a product or service
- **Value-added productivity** – (gross revenue – direct material cost) / # of employees
- **Warranty / returns processing costs** – direct and indirect costs associated with returns including defective, planned maintenance, and excess inventory.

Supply chain asset management includes:

- **Average aggregate value of inventory** = <u>This is the total value AT COST of all items held in inventory including raw materials, work-in-progress (WIP), and any finished goods.</u> [We use 'at cost' as a method of consistency because the sales price of the finished goods can vary widely across a wide range of discounts that can be given to bulk buyers.]

We calculate it by summing all inventory items and multiplying that by the average number of units on hand at any one time multiplied by the unit value.

The Benster Vacuum Cleaner Company wanted to do these calculations.

Last year, the cost of goods sold was $142.5 million. It has this average value of production materials, work-in-progress, and finished goods inventory:

- Production materials $3,045,138*
- WIP 9,573,055*
- Finished goods inventory 7,004,733*

Total avg. aggregate value of inventory $19,622,926

*the numbers are the average numbers of units on hand in each category multiplied by the unit value.

- **Number of times the inventory turns over** = Cost of goods sold / aggregate value of the inventory. The more you sell inventory, the more revenue you generate so you can pay employees, stock holders, investors and buy more inventory so you can sell more and so on. The more the inventory turns means the more money is churning through your business. Higher numbers are better.

Inventory turns = $142.5 million / $19,622,926 = **7.26**

- **The days or weeks of inventory supply you have –** The amount of inventory you have on hand at any given time = average aggregate value of inventory / (annual cost of goods sold / 365 days or 52 weeks)

If you run out of inventory before the next shipment arrives, you aren't generating a cash flow. At the other extreme, if you have too much inventory, you have excessive capital tied up in it that you can't use for anything else. The key here is to have enough plus a "safety surplus" to keep the money flowing but not too much that limits your available capital.

Days of supply = $19,622,926/($142.5 million/365) = **50.3**

Weeks of supply = $19,622,926/($142.5 million/52) = **7.2**

- **The Cash-to-cash cycle (C2C) of your money** - Measures the number of days between the initial cash outflow as accounts payable (AP) when you pay your suppliers to the subsequent cash inflow as accounts receivable (AR) when you collect the money from customers. This is *measured in days, not dollars,* and helps people with financial backgrounds like accountants, bankers, some shareholders, or potential investors get a snapshot of how the company is managing its cash.

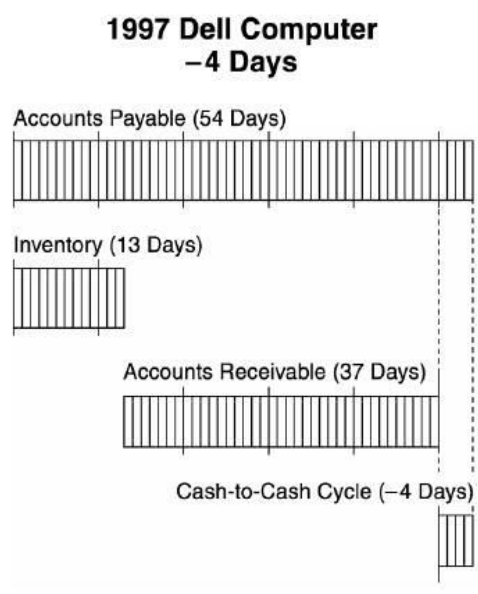
Inventory days of supply + AR – AP = **C2C**

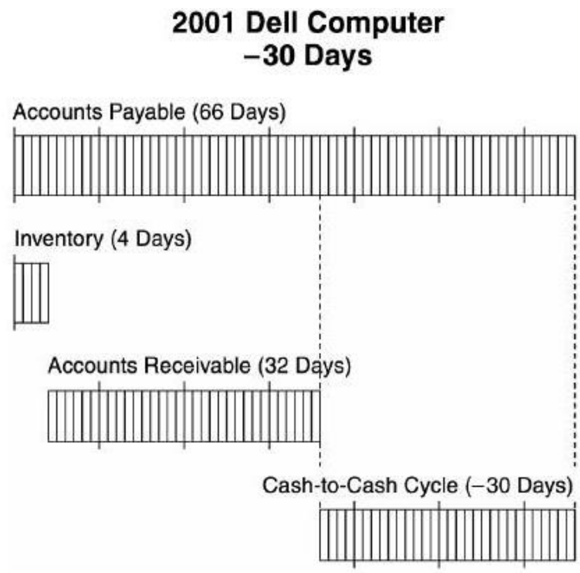
Expressing your company's SCM as C2C also helps with negotiating terms for AP with suppliers and AR with customers without divulging actual dollar amounts and balancing supply chain transactions to obtain overall efficiencies.

Here is a diagram of how Dell computers used the concept initially to become such a power in the made-to-order manufacturing business.[14]

This tells us that in 1997, Dell:

- Took an average of 54 days to pay suppliers without incurring late charges
- They had 13 days' inventory on hand
- They took an average of 37 days to get paid by customers
- Their C2C was -4 days meaning they were using other people's money for an average of 4 days per cycle.





They worked hard to improve their data communications with customers and suppliers. This meant improved forecasting which lead to more precise inventory needs and delivery dates.

This allowed their on-hand inventory to shrink tying up less money there and making more available to grow the business.

They gradually increased the time until they paid bills while speeding collections – primarily through credit card payments via secure websites.

Their C2C grew to -30 days meaning they were using other people's money more than seven times as long as they were just four years earlier. Another way of looking at it is they are *making money off the money* for 30 days before having to pay it out!

A review of 12 years of data from the Research Insight of more than 22,000 public companies indicated a direct correlation between shorter cash-to-cash cycles and higher profitability for 75% of industries[15]

DEMAND FOCUSED

These metrics are critical when looking toward the customer. Remember, nothing good ever comes from unhappy customers!

Your supply chain reliability is based upon these three elements:

- **Delivery performance** – the percentage of orders delivered IN FULL and ON TIME to the customers
- **Fill rate** – the percentage of orders shipped within 24 hours of receiving the order
- **Perfect order fulfillment** – the percentage of orders delivered on time, in full, perfectly matched with the order with no errors.

NOTE: All three assume there are no damages to the product and no returns.

Supply chain responsiveness is based on the order fulfillment lead time. That is, the number of days between receipt of the customer's order and product delivery.

Supply chain flexibility is about:

- **Supply chain response time** – this is the number of days needed for your supply chain to respond to an unplanned significant change in demand without a cost penalty. A "significant change in demand" means suddenly the customer wants more or less than you expected and there are no surcharges from your suppliers or late charges by the customer for delivery problems caused by the bullwhip effect.
- **Production flexibility** – the number of days needed to achieve an unplanned 20% change in orders without a cost penalty.

PART 6 - LEAN PRODUCTIVITY MANAGEMENT FUNDAMENTALS

This part of the course presents 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.

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 overtime 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.

<table>
<tr><td>1</td><td>Equipment</td><td>AL Machine</td><td>AL Machine OT</td></tr>
<tr><td>2</td><td>Hourly production capacity</td><td>1,500</td><td>1,500</td></tr>
<tr><td>3</td><td>Hrs. per production period</td><td>8.00</td><td>9.25</td></tr>
<tr><td>4 (rows 2x3)</td><td>Production/ machine /period</td><td>12,000</td><td>13,875</td></tr>
<tr><td>5</td><td>Annual prod periods/ machine</td><td>250</td><td>250</td></tr>
<tr><td>6 (rows 4x5)</td><td>Annual production/ machine</td><td>3,000,000</td><td>3,468,750</td></tr>
<tr><td>7</td><td>Hourly cost/ machine</td><td colspan="2" rowspan="2">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.</td></tr>
<tr><td>8 (rows 3x5x7)</td><td>Annual cost/ machine</td></tr>
<tr><td>9</td><td>Number of these machines</td><td>4</td><td>4</td></tr>
<tr><td>10 (rows 8x9)</td><td>Total annual machine cost</td><td>N/A</td><td>N/A</td></tr>
<tr><td>11 (rows 6x9)</td><td>Total annual production</td><td>12,000,000</td><td>13,875,000</td></tr>
<tr><td>12 (row 10/11)</td><td>Current cost / product</td><td>N/A</td><td>N/A</td></tr>
</table>

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.)

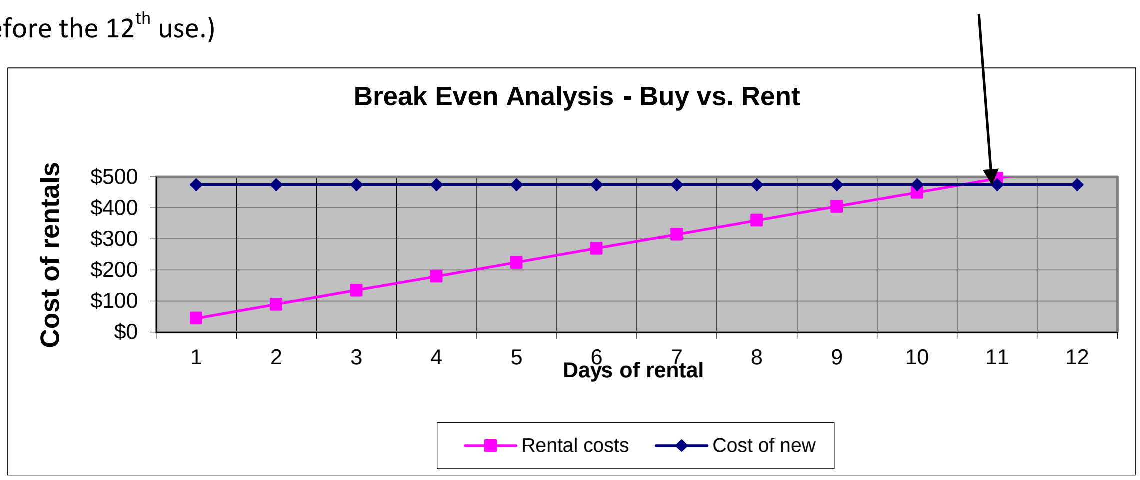


Figure 1

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 2

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					

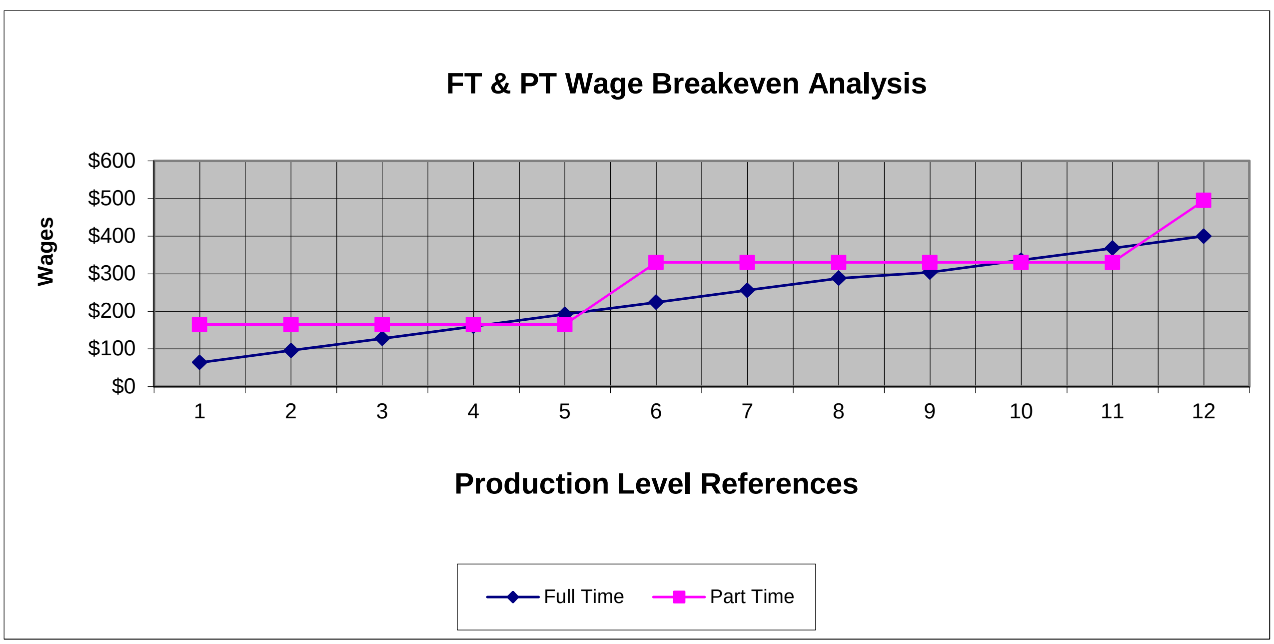
Answers are on the following page.

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

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



Answers to the practice problem

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.

Data Sheet for use with Problems Above				
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.

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

1 2

1 2
3 3

1 2 3
4 4 4

1 2 3 4
5 5 5 5

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!

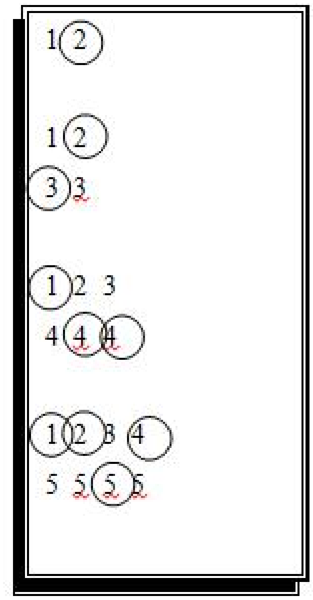
It would be very confusing for people to consider all five choices at once and expect them to select a priority order. We can make it easier for them by asking them to select a preference from between two choices at a time. That is what we have done with the layout above. If you look carefully at the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

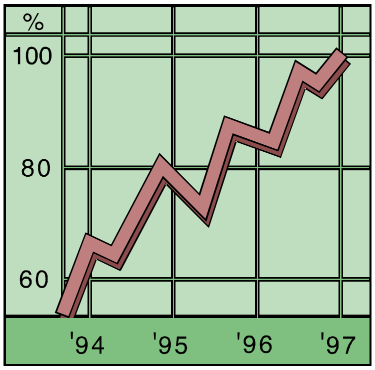
3 = 1

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.

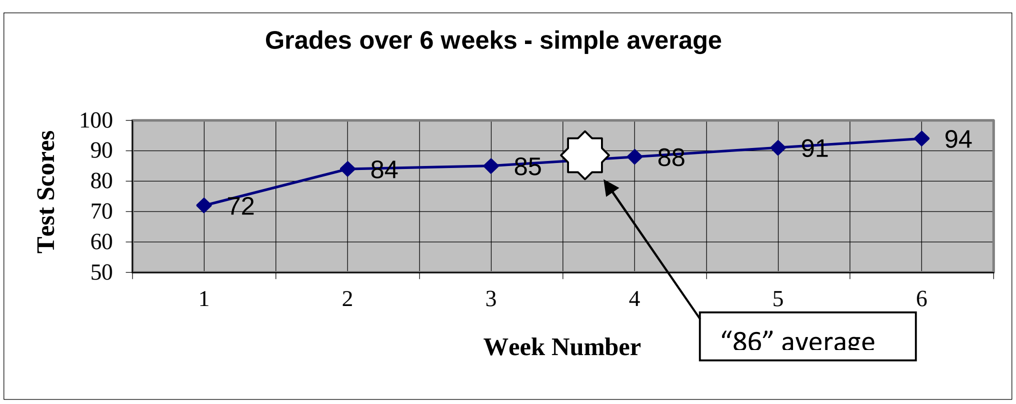
Simple Average ("SA")

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

Although the report card was given to us at some point 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]**

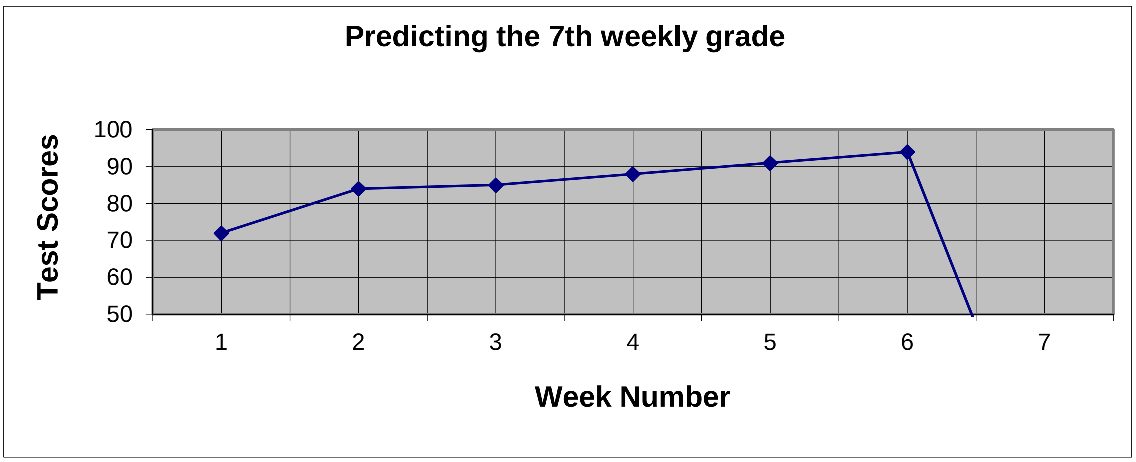


Look at the trend you see emerging from the past 6 weeks.

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")

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

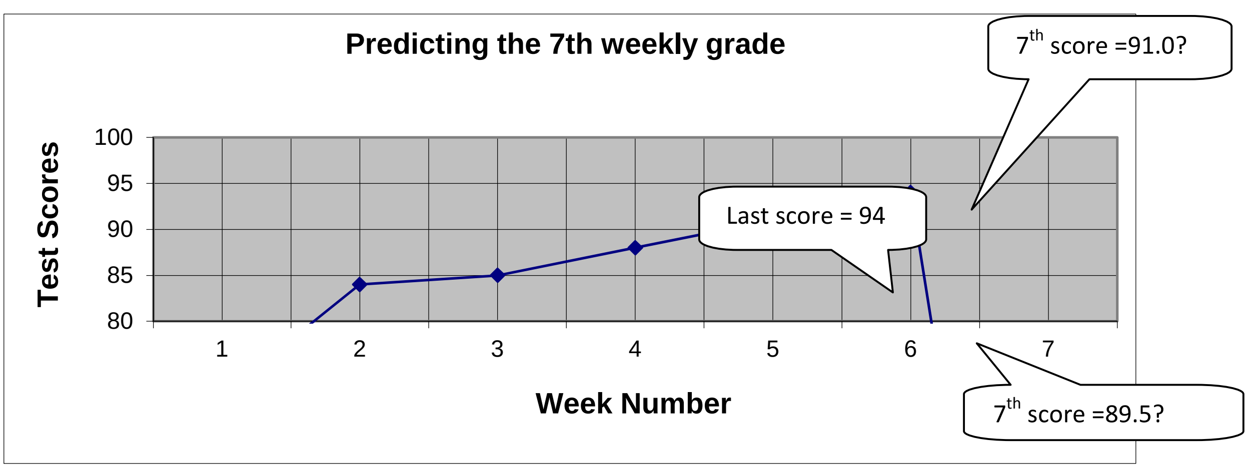
WEEKLY TEST SCORES

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.

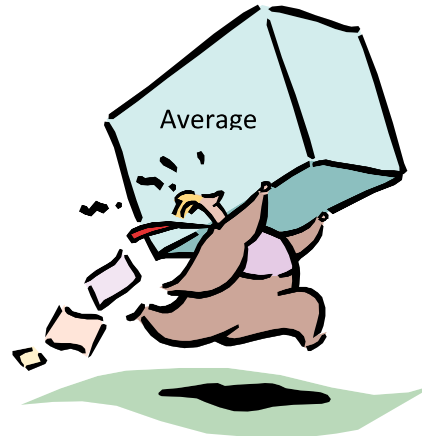
If we just count the last 2 scores, we may not have enough for a fair sampling of test scores. Averaging three will be better. If we average the last four, are we going too far back? There is no way to be certain whether three or four are better. We will try them both.

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 trend to be closer to the actual test score.]



WEIGHTED MOVING AVERAGE ("WMA")

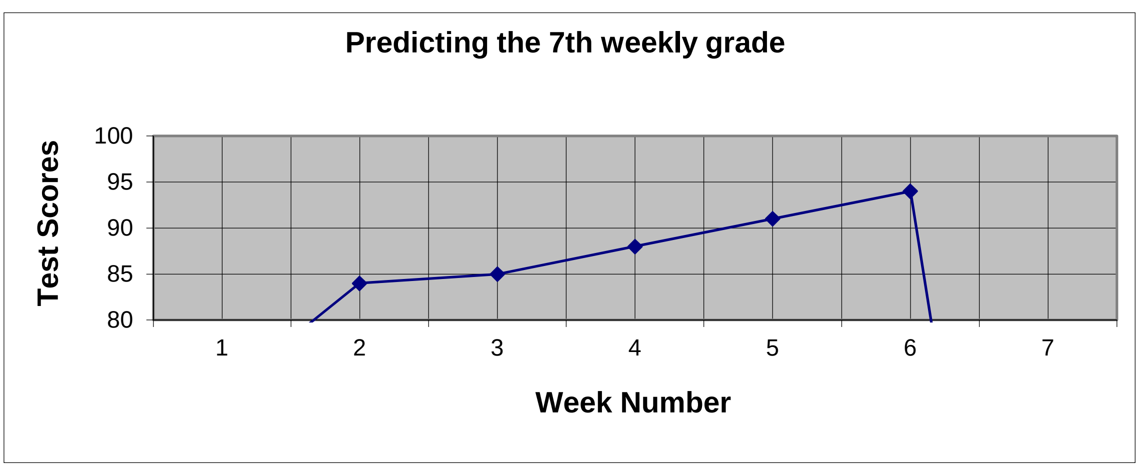


We will leave the prediction about the 7th test grade alone for a few minutes and recall another aspect of grade school, the dreaded "SEMESTER PROJECT".

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 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

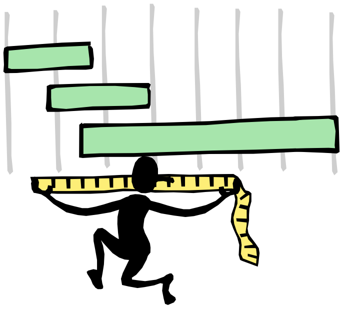
This is how the prediction for the <u>next test score</u> changed as we added different weights of 94's to the calculation.

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

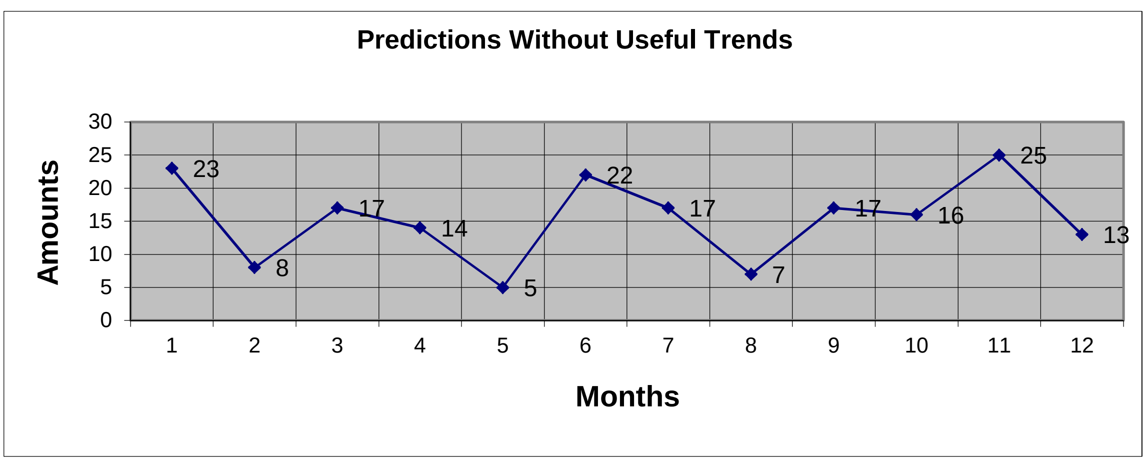
We look at predicting seasonal trends in a similar way that we look at predicting our next grade on a test. We will use the holiday shopping season as an example.

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 discernible 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** **It is 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]

Products/day = (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%**

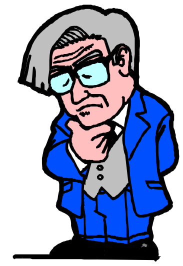
480/96 = **5 units/day**

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.**



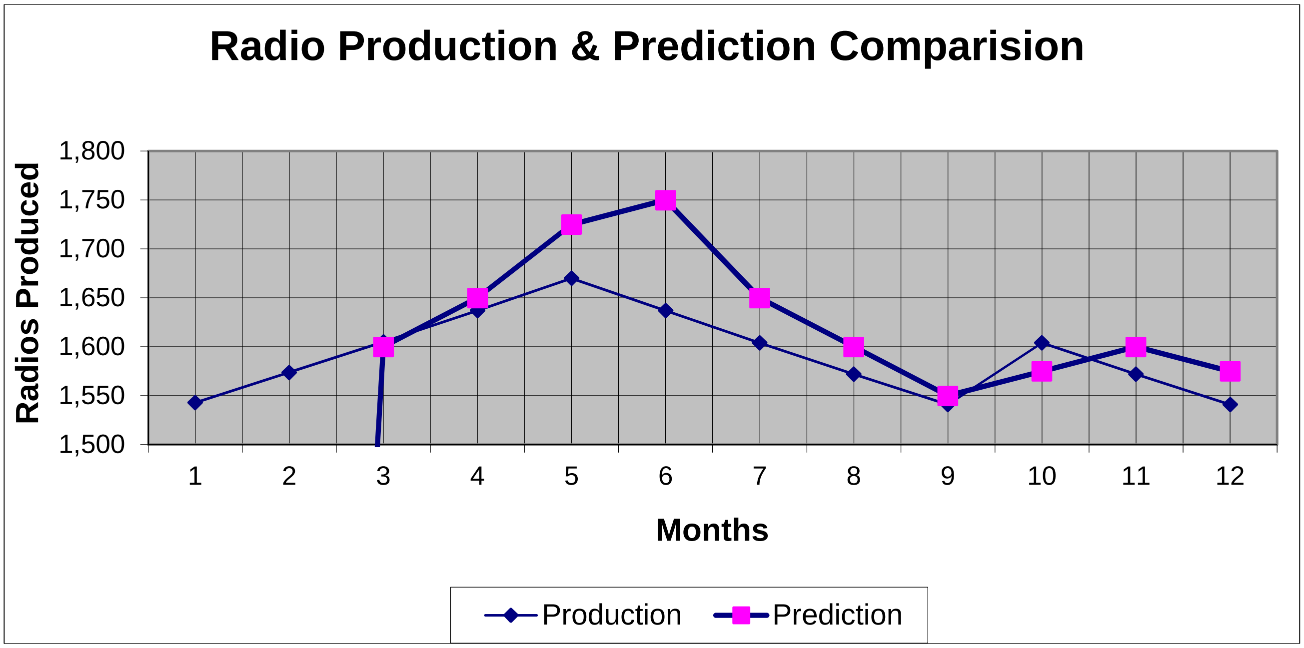
We can apply our new prediction skills to past records, make hypothetical predictions, and see how close our prediction would have come to the actual event.

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.


Radio Production & Prediction Comparision
Radios Produced
1,800
1,750
1,700
1,650
1,600
1,550
1,500
1
2
3
4
5
6
7
8
9
10
11
12
Months
Production
Prediction

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). This number, +29, is very important.

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 sum of the 10 absolute deviations.
- **“36”** is the average 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 too low while a **positive** bias means it is too high.

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 <u>steadily</u> increasing or decreasing? **(Change measurement analysis)**
- ✓ When the past has <u>not been a steady trend</u> either up or down? **(None is good for random events.)**

[1] http://ask.reference.com/related/Strategic+Planning?qsrc=2892&l=dir&o=10601

[2] http://terrywireman.com/why_strategic_maintenance_initia.htm

[3] http://dictionary.reference.com/browse/tribology

[4] http://en.wikipedia.org/wiki/Nondestructive_testing

[5] http://www.humanresourcesmagazine.com.au/articles/FB/0C0516FB.asp

[6] http://www.iuoe.org/

[7] http://www.chiltondiy.com/default.aspx

[8] http://motortorque.askaprice.com/news/auto-0905/growth-in-diy-repairs-39could-be-dangerous39.asp

[9] http://www.iwar.org.uk/cip/resources/blackout-03/

[10] http://www.dieselserviceandsupply.com/Causes_of_Power_Failures.aspx?adsource=PowerUpdate

[11] http://www.allbusiness.com/operations/shipping-air-freight/733444-1.html

[12] http://www.usmra.com/saxsewell/Upper_Big_Branch.htm

[13] http://www.washingtonpost.com/wp-dyn/content/article/2010/06/21/AR2010062103007.html

[14] Hutchinson, Paul D.; Farris, M. Theodore II; Anders, Susan B. Cash-to-Cash Analysis and Management. *The CPA Journal*; Aug 2007; 77, 8. 42.

[15] Ibid.