OPERATIONS MANAGEMENT
MGMT 401
FALL 2016
DR. GUPTA

DISCUSSION NOTES

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(other times available by appointment)

(Surest way to reach me is to use "Email to Dr. Gupta" button on our Blackboard site)

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UNIVERSITY OF LOUISVILLE.

COLLEGE OF BUSINESS

Operations Management
MGMT 401-01
Fall 2016

I. Professor / Instructor	
Instructor	Dr. Mahesh Gupta
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Office hours	M,W12:00-12:45 AM & 2:15-3:00 PM (others by appointment)

II. Course Information	
Class time/Rm.	401-01-4162: Mon & Wed 1:00-2:15 AM Rm. 211 College of Business
Textbooks 	**H**eizer, Render & Munson, *Principles of Operations Management*, Pearson (10th ed.). ISBN: 9780134467283 (Hardcopy and eText) & 9780134184111(eText only) **E**li Goldratt, *THE GOAL* – A Process of Ongoing Improvement, North River Press (any edition), Inc. (available on CD as well)
Course description	This course covers the general functions of operations management as applied to the transformation process. It presents operations management concepts and analytical methods of handling problems in manufacturing and service operations. You should not take the matter of prerequisites lightly. This course builds on the qualitative concepts, quantitative, and statistical skills learned in the courses below.
Prerequisites	ACCT 201, ACCT 202, ECON 201, ECON 202, MGMT 201, MGMT 301, CIS 300. Note: You must withdraw immediately if you have not already taken any of these prerequisites.
Learning objectives	Upon completion of this course the student should be able to: LO1: Explain the strategic role of operations management and its competitive advantage, LO2: Explain, describe and apply, as appropriate, concepts of process design such as project management, process design, & facility layout, LO3: Explain, describe and apply, as appropriate, concepts of quality management and process improvement, LO4: Explain, describe and apply, as appropriate, concepts of capacity planning and scheduling such as forecasting, facility location, and aggregate planning, and LO5: Explain, describe and apply, as appropriate, concepts of inventory management such as material requirement planning, just-in-time/lean systems, and drum-buffer-rope system.

Central Question	The central question addressed in this core course is: **How to design and operate a manufacturing or service organizational system to create value**?
Fundamental & Powerful Concepts	The underlying fundamental and powerful (F&P) concepts include (i) Quality management and control, (ii) Process design and analysis, (iii) Capacity management and analysis, (iv) Inventory management and control. The disciplinary point of view is efficiency and effectiveness
Teaching / Learning Pedagogy	It is my belief that **the most** fundamental and powerful concepts of operations management is the management of Dependent Events and Statistical Fluctuations (DE/SF) in a system and maximizing the flow of products/services through the system. The central question and F&P concepts will be pursued through an integration of theory and practice. This is intended to be a fun-filled class with serious learning objectives. For that reason, the class will be informal and interactive with substantial amount of lecture (with the help of power point slides). The course activities will also include experiential exercises, case analyses, quantitative problem solving, videos, and classroom discussions. Remember, the purpose of the lecture in this class is not to reiterate what is in the textbook. The purpose is to summarize the key issues, provide perspectives on what you have read, and to facilitate intensive discussions. It is absolutely expected that you will have read the required readings and come prepared to make meaningful contribution in the discussions. Having read all the required readings is very important in this course because weekly pop-quizzes, practice problems, formal assignments, and class contribution comprise a significant percentage of your final grade (collectively 15%). In fact, if you cannot attend class regularly for some reason, you are HIGHLY ADVISED to drop this class because you may not do well.
Drop Date	See: http://louisville.edu/calendars/academic/undergrad-grad.html
Expectations of outside time req.	This course requires a substantial amount of time to be devoted outside the class. To be successful you should allow about 6.0-8.0 hours per week (a typical student) i.e., about 2.5 hr. outside class for every hour in class.

III. Evaluation

Grading scale	A+ = 98 to 100 B+ = 88 to 89 C+ = 78 to 79 D+ = 68 to 69 Below 60 = F	A = 93 to 97 B = 83 to 87 C = 73 to 77 D = 63 to 67	A- = 90 to 92 B - = 80 to 82 C - = 70 to 72 D- = 60 to 62
Grading scheme	**Grading component**	**Grading percentage**	
	Term Tests (2 @20%)	40%	
	Final Exam	35% (20% +15%)	Cumulative
	Class Contribution	15%	
	YouTube Project	10%	

IV. Additional Work Details	
Term Tests	Each "*test*" will consist of three types of questions: (i) multiple-choice, (ii) short answer, and (iii) quantitative problems with equal percent coverage. **Note**: **T**here are no make-up tests per se. If a conflict arises within 48 hours of the scheduled test, it is your responsibility to notify me. If you fail to do so and do not show up for the test, your test grade is 0.
Participation and class contribution	Attendance (on time) and participation in class and on blackboard is encouraged and should help you to do well in exams. Assignments are there to help you to do well in the quantitative portion of the term tests. Don't turn in loose sheets, or worse, 'dog-eared' sheets. The assignments should be prepared in a professional manner (i.e., on time, on one side of page only, and stapled) and failing to do so will hurt your grade. I will develop an overall impression of your performance in class and on Blackboard (Bb). This impression is based on (i) the assignments submitted, and (see (http://wps.prenhall.com/bp_heizer_opsmgmt_10/147/37737/9660836.cw/-/t/index.html) pop quizzes, (ii) the questions you ask in class, (iii) more than one unexcused absence will reduce or eliminate significant class participation points. I will have pop quizzes and call on you randomly asking question. NOTE: YOUR CELL PHONE SHOULD BE OFF & IN YOUR BACKPACK.
YouTube Presentation	You are required to make a Power Point Presentation via Tegrity for an assigned topic. Step-by-step guidelines will be posted on the Blackboard. You must (i) prepare 1st draft on the due date, submit a hardcopy of your transcription of abou 300-350 words for my feedback, and post a revised copy on Blackboard, (ii) prepare 2-4 ppt. slides of the main points (make use figures or tables), and (iii) prepare a Tegrity Recording (approx. 4-5 minutes long).

V. Student Responsibilities / College and University Issues	
UofL & COB Student conduct and responsibilities	This course will abide by UofL and COB student conduct and responsibilities: http://louisville.edu/dos/students/policies-procedures/student-handbook.html#codeofstudentconduct and http://business.louisville.edu/students/college-of-business-academic-dishonesty-policy
UofL Title IX Clery Act Notification	Sexual misconduct (including sexual harassment, sexual assault, & any other non-consensual behavior of a sexual nature) and sex discrimination violate UofL policies. Student experiencing such behavior may obtain **confidential support** from the PEACC Program (852-2663), Counseling Center (852-6585), and Campus Health Services (852-6479). To report sexual misconduct or sex discrimination, contact the Dean of Students (852-5787) or UofL Police (852-6111). Disclosure to **UofL faculty or instructors** of sexual misconduct, domestic violence, dating violence, or sex discrimination occurring on campus, in a UofL-sponsored program, or involving a campus visitor or UofL student or employee (whether current or former) is **not confidential** under Title IX. Fa culty and instructors must forward such reports, including names & circumstances, to the UofL's Title IX officer. For more information, see (http://louisville.edu/hr/employeerelations/sexual-misconduct-brochure).
Religious holiday conflict policy	http://louisville.edu/diversity/resources/work-restricted-holy-day-policies-calendar.html
Equal access policy	http://louisville.edu/disability/policies-procedures
Classroom policy	Eating food is not permitted in this class.

V1. Tentative Schedule (Subject to change)

DATE	READING MATERIAL (Chapter/Topic)
Aug. 22nd Monday	**Textbook: Chapter 1 and Discussion Notes - Operations and Service** **Novel: The Goal (pp. 1-112) and Discussion Notes on TOC** 1. Discuss the history and significance of Operations Management (OM). 2. Discuss OM as a system, a functional area, and a decision-making framework. 3. Define service and discuss major differences between service and manufacturing. **Assignment # 1 (sent to you via email): Due on the 1st day of the class.**
Aug. 24th Wednesday	**Textbook: Chapter 1 and Discussion Notes – Productivity Measures** 4. Discuss types of productivity ratios and significance of productivity indices.
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.** **Assignment # 2 (posted on Blackboard): Due Date to be announced.**
Aug, 29th Monday	**Textbook: Chapter 2 and Discussion notes - Operations Strategy** 5. Discuss generic business strategies (BS) - Cost Leadership and Differentiation. 6. Discuss the performance criteria or measures or objectives (D, E, F, Q) of OM. 7. Discuss briefly each of the 10 decisions that operations managers make. 8. Discuss Operations Strategy (OS) and its relationship with Business Strategies. 9. Discuss the product life cycle stages and its relationship with BS and OS.
Aug. 31st Wednesday	**Textbook: Chapter 3 and Discussion Notes – Project Management** 10. Discuss the definition of Project and Project Management. 11. Project Planning and Work Breakdown Structure, Activity-on-Network Diagram
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
Sept. 5th Monday	**LABOR DAY HOLIDAY**
Sept. 7th Wednesday	Project Scheduling and Control Method: PERT and CPM **Assignment #3 (posted on Blackboard): Due Date to be announced**
Sept. 12th Monday	**Novel: REVISIT *The Goal* (pp. 1-112) and Discussion Notes on TOC** 12. What is the Theory of Theory of Constraints (3Ms of TOC)? 13. What is THE GOAL of a for-profit organization? (ensure to include the discussion on the difference between the goal and necessary conditions.
Sept. 14th Wednesday & **Sept. 19th Monday**	**Novel: REVISIT *The Goal* (pp. 1-112) and Discussion Notes on TOC** 14. Discuss TOC performance measures: Throughput, Inventory, operating expenses (T,I,OE) ensure to address unconventional nature of these measures. 15. Discuss the relationship between TOC measures and traditional financial measures: Net Profit (NP), Return-on-Investment (ROI), Cash Flow (CF). **Assignment # 4 (posted on Blackboard): Due Date to be announced**
Sept. 21st Wednesday	**Textbook: Chapter 4 and Discussion Notes - Forecasting** What is forecasting and what is its strategic importance? Discuss various types of forecasting including Naïve Approach, Moving Averages and Exponential Smoothing (with trend adjustments)
Sept. 26th Monday	**TERM TEST I (Only Scientific Calculator allowed)**
Sept. 28th Wednesday	**Textbook: Chapter 6 and Discussion Notes - Total Quality Management** 16. Discuss the definition of TQM from operations viewpoint. 17. Discuss the distinguishing characteristics of Quality as provided by gurus such as Deming, Juran, Feigenbaum, Ishikawa and Crosby (at least three) 18. Discuss important tools of TQM (at least three) with an example.
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
	MID-TERM BREAK October 3-4 2016

Oct. 5th Wednesday	**Textbook: Chapter 6 *Supplement*: Statistical Process Control & Discussion Notes**
&	19. Discuss types of variations (Natural and assignable causes) and
Oct. 10th Monday	Types of Control Charts (Variables and Attributes)
	20. Discuss the concept of Process Capability (ensure to discuss Cp and Cpk indices).
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
	• Assignment #5 (posted on Blackboard): Due on the day of Term Test II
Oct. 12th Wednesday	**Novel: THE GOAL (pp. 113-148) and Discussion Notes on TOC**
	21. Discuss the concepts of dependent events (DE) and statistical fluctuations (SF) using The Boy Scout and Dice Game examples from THE GOAL.
	22. Discuss steps the Boy Scout took to get to the campsite (Five Focusing Steps).
Oct. 17th Monday	**Textbook: Chapter 7 & Discussion Notes - Process Strategy/Capacity Planning**
	23. Discuss types of process strategy (Process Focus and Product Focus) and their relationship with business strategies (in exam, I will ask for one only).
	24. Discuss the definition of Facility strategy as it relates to various business strategies.
	25. Discuss various definitions of Capacity and their relevance from TOC perspective.
Oct. 19th Wednesday	**Textbook: Chapter 8 and Discussion Notes – Location Strategies**
	• Review and do yourself examples 1 to 3 and solved problems at the end of chapter.
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
	• Assignment #6 (posted on Blackboard): Due on the day of Term Test II
October 24th Monday	**LAST DAY TO WITHDRAW**
Oct. 24th Monday	**Textbook: Chapter 9 and Discussion Notes - Layout of World-Class Operations**
&	26. Discuss the objectives, advantages, and disadvantages of (i) product-oriented
Oct. 26th Wednesday	and (ii) process-oriented layout strategies (in exam, I will ask for one only).
	27. Discuss the concept of Focused factory and focused work center.
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
	• Assignment #7 (posted on Blackboard): Due on the day of Term Test II
Oct. 31st Monday	**Novel: THE GOAL (pp. 149-212) and Discussion Notes on TOC**
&	28. Discuss bottleneck/non-bottleneck concepts (ensure to discuss Capacity definitions).
Nov. 2nd Wednesday	29. Clearly state and Discuss Five Focusing Steps of TOC as used by Alex in his plant by giving specific examples for each of the focusing steps.
	Catch up and Review
November 7th Monday	**TERM TEST II (Only Scientific Calculator allowed)**
Nov. 9th Wednesday	**Textbook: Chapter 13 and Discussion Notes - Aggregate Planning**
	30. Discuss the concept of Aggregate Planning and its main characteristics.
	31. Discuss two extreme Aggregate Planning strategies and their relationship to BS.
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
	• Assignment #8 (posted on Blackboard): Due Date to be announced
Nov. 14th Monday	**Textbook: Ch. 12 – Inventory Management & Enterprise Resource Planning**
	Inventory Management of Independent Demand: Basic EOQ and Reorder Points
	32. Discuss the relationship among various components of manufacturing module of
Nov. 16th Wednesday	ERP: aggregate planning, master production schedule and material requirements planning; resource requirements planning, rough-cut capacity planning, capacity requirements planning.
	33. Discuss the main concepts of ERP. What are its various merits and demerits?
	34. How do MRP I, closed loop MRP, MRP II, and ERP differ from each other.

Nov. 21st Monday	**Textbook Chapter 14 and Discussion Notes: Material Requirements Planning**
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
	• Assignment #9 (posted on Blackboard): Due Date to be announced
Nov. 23rd-27th	**THANKSGIVING BREAK**
Nov. 28th Monday	**The Goal (pg. 213-270) –Inventory Management/Operations Planning**
	35. Discuss the "lead time" concept and its relationship with WIP Inventory.
	36. Discuss the TOC approach to manage inventory – implementing Drum-Buffer-Rope system and reducing the batch sizes.
Nov. 30th Wednesday	**Chapter 12 - *Supplement 12* Just-in-time Systems/Lean Manufacturing Systems**
	37. Discuss the JIT philosophy and its fundamental concepts e.g., waste and variability reduction, and pull system.
	38. Discuss JIT applications in dealing with suppliers, layout, inventory, etc.
Self-Assessment:	Visit course website take self-study quizzes & practice problems**.**
December 5th Monday	39. Compare and contrast JIT, MRP and TOC philosophies (at least four)
	40. Discuss the strategic (D,E,F,Q) importance of managing/reducing inventories.

Saturday 10th	**FINAL TEST**	**8:00am – 10:30pm (Combined Section Exam in Auditorium)**

Tegrity-based YouTube Project Guidelines

For an assigned essay question:

(i) Prepare a transcription of about 300-350 words primarily following discussion notes, class lectures, textbook and Internet for a specific Question assigned to you from **Detailed Schedule** (to be announced in the class); Bring rough draft on the day your question is being discussed in the class as per detailed schedule, make modifications based on the lecture and class discussion and then, must email me the first draft within 24 hours. Based on my feedback, revise the draft and post a copy on Discussion Board within 24 hours.

(ii) Prepare 3-4 ppt. slides of the main points (you are encouraged to include figures or tables);

(iii) Prepare a Tegrity Recording (4-5 minutes long)

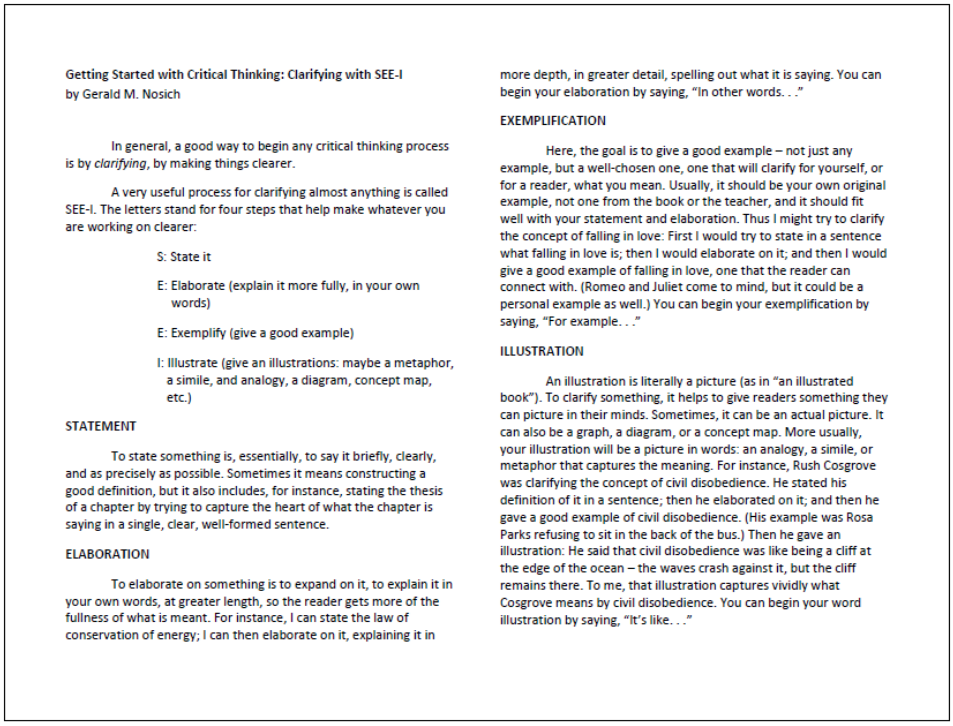
Step-by-step Guidelines for Tegrity Recording

Follow the following instructions step by step:

1. Open your PowerPoint
2. Minimize your power point to the bottom of your screen
3. Click on Tegrity classes in your course
4. Click on Student Classes
5. Click on record a class (the first time you click this it will download the Tegrity Recorder on to your computer)
6. Click on your power point again to bring it up behind your Tegrity screen
7. Click on slide show for your PowerPoint and then click on full screen
8. Your PowerPoint will be behind your Tegrity Recording screen
9. Fill in the title of your presentation under Title on your Tegrity screen
10. Under the test audio, make sure you set the audio bar to the recommended audio where the arrow is pointed (This is the default setting)
11. When you are ready to begin recording click OK
12. Tegrity will begin recording
13. Once you have finished recording, click on the stop button on the lower right hand side of your screen and click on the third button which is your stop button
14. Tegrity will ask you if you want to end the recording, click yes
15. Your screen will say Tegrity recording completed. Recording will be uploaded later
16. Walk away from your computer for at least one hour
17. Go back to your Tegrity Recording button
18. Click on Student classes

Your recording will be there

What is SEE-I?



Getting Started with Critical Thinking: Clarifying with SEE-I
by Gerald M. Nosich

In general, a good way to begin any critical thinking process is by *clarifying*, by making things clearer.

A very useful process for clarifying almost anything is called SEE-I. The letters stand for four steps that help make whatever you are working on clearer:

S: State it

E: Elaborate (explain it more fully, in your own words)

E: Exemplify (give a good example)

I: Illustrate (give an illustrations: maybe a metaphor, a simile, and analogy, a diagram, concept map, etc.)

STATEMENT

To state something is, essentially, to say it briefly, clearly, and as precisely as possible. Sometimes it means constructing a good definition, but it also includes, for instance, stating the thesis of a chapter by trying to capture the heart of what the chapter is saying in a single, clear, well-formed sentence.

ELABORATION

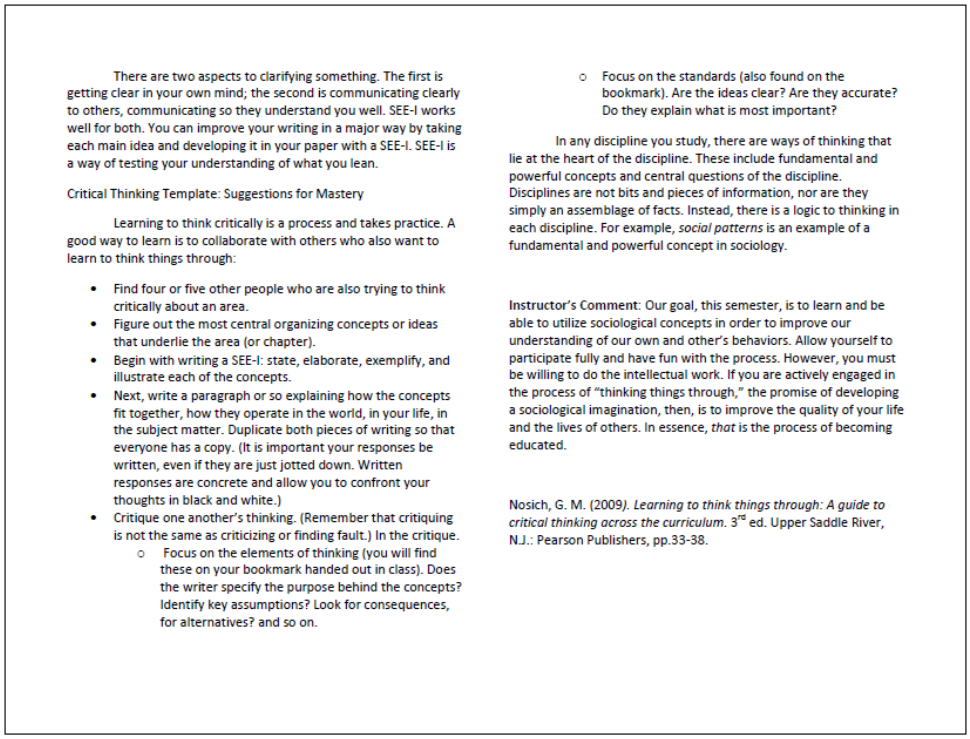
To elaborate on something is to expand on it, to explain it in your own words, at greater length, so the reader gets more of the fullness of what is meant. For instance, I can state the law of conservation of energy; I can then elaborate on it, explaining it in more depth, in greater detail, spelling out what it is saying. You can begin your elaboration by saying, "In other words. . ."

EXEMPLIFICATION

Here, the goal is to give a good example – not just any example, but a well-chosen one, one that will clarify for yourself, or for a reader, what you mean. Usually, it should be your own original example, not one from the book or the teacher, and it should fit well with your statement and elaboration. Thus I might try to clarify the concept of falling in love: First I would try to state in a sentence what falling in love is; then I would elaborate on it; and then I would give a good example of falling in love, one that the reader can connect with. (Romeo and Juliet come to mind, but it could be a personal example as well.) You can begin your exemplification by saying, "For example. . ."

ILLUSTRATION

An illustration is literally a picture (as in "an illustrated book"). To clarify something, it helps to give readers something they can picture in their minds. Sometimes, it can be an actual picture. It can also be a graph, a diagram, or a concept map. More usually, your illustration will be a picture in words: an analogy, a simile, or metaphor that captures the meaning. For instance, Rush Cosgrove was clarifying the concept of civil disobedience. He stated his definition of it in a sentence; then he elaborated on it; and then he gave a good example of civil disobedience. (His example was Rosa Parks refusing to sit in the back of the bus.) Then he gave an illustration: He said that civil disobedience was like being a cliff at the edge of the ocean – the waves crash against it, but the cliff remains there. To me, that illustration captures vividly what Cosgrove means by civil disobedience. You can begin your word illustration by saying, "It's like. . ."



There are two aspects to clarifying something. The first is getting clear in your own mind; the second is communicating clearly to others, communicating so they understand you well. SEE-I works well for both. You can improve your writing in a major way by taking each main idea and developing it in your paper with a SEE-I. SEE-I is a way of testing your understanding of what you lean.

Critical Thinking Template: Suggestions for Mastery

Learning to think critically is a process and takes practice. A good way to learn is to collaborate with others who also want to learn to think things through:

- Find four or five other people who are also trying to think critically about an area.
- Figure out the most central organizing concepts or ideas that underlie the area (or chapter).
- Begin with writing a SEE-I: state, elaborate, exemplify, and illustrate each of the concepts.
- Next, write a paragraph or so explaining how the concepts fit together, how they operate in the world, in your life, in the subject matter. Duplicate both pieces of writing so that everyone has a copy. (It is important your responses be written, even if they are just jotted down. Written responses are concrete and allow you to confront your thoughts in black and white.)
- Critique one another's thinking. (Remember that critiquing is not the same as criticizing or finding fault.) In the critique.
  - Focus on the elements of thinking (you will find these on your bookmark handed out in class). Does the writer specify the purpose behind the concepts? Identify key assumptions? Look for consequences, for alternatives? and so on.
  - Focus on the standards (also found on the bookmark). Are the ideas clear? Are they accurate? Do they explain what is most important?

In any discipline you study, there are ways of thinking that lie at the heart of the discipline. These include fundamental and powerful concepts and central questions of the discipline. Disciplines are not bits and pieces of information, nor are they simply an assemblage of facts. Instead, there is a logic to thinking in each discipline. For example, *social patterns* is an example of a fundamental and powerful concept in sociology.

Instructor's Comment: Our goal, this semester, is to learn and be able to utilize sociological concepts in order to improve our understanding of our own and other's behaviors. Allow yourself to participate fully and have fun with the process. However, you must be willing to do the intellectual work. If you are actively engaged in the process of "thinking things through," the promise of developing a sociological imagination, then, is to improve the quality of your life and the lives of others. In essence, *that* is the process of becoming educated.

Nosich, G. M. (2009*). Learning to think things through: A guide to critical thinking across the curriculum.* 3rd ed. Upper Saddle River, N.J.: Pearson Publishers, pp.33-38.

Original source: https://sharepoint.louisville.edu/sites/sphis/acprogs/ph101/pubs/SEE-I%20Process.pdf
For an instructional youtube: http://people.eku.edu/jonesp/Critical%20Thinking%20Guide%20Using%20the%20%20SEE-I%20Method/index.html

Rubric for Assessing SEE-Is

Component	Excellent 100-90 Points	Good 89.9-80 Points	Fair 79.9-70 Points	Poor 69.9-50 Point
State	The definition or thesis is stated in a single clear, precise, well-formulated sentence	The definition or thesis is either not completely clear or not stated concisely	The definition or thesis is vaguely stated or omits key elements	The definition or thesis is substan-tially incorrect
Elaborate	All significant aspects of the concept or thesis are clearly explained	The explanation is not quite clear, missing minor elements, or contains slight inaccuracies	The explanation is vague, missing key elements, or contains some inaccuracies	The explanation is substantially incorrect
Exemplify	The example is original and is rich enough to capture all important aspects of the concept or thesis	The example is either not original or does not capture all significant aspects of the concept or thesis	The example does not capture significant aspects of the concept or thesis or is incorrect in some ways	The example does not relate to the concept or thesis
Illustrate	The illustration is original, captures all important aspects of the concept or thesis, and provides a vivid mental image	The example is either not original, does not capture all significant aspects of the concept or thesis, or does not provide a vivid mental image	The example does not capture significant aspects of the concept or thesis, or does not provide a mental image	The illustration doesn't appear to relate to the concept or thesis

Note: Visit Blackboard for a sample excellent example of SEE-I

A tentative outline:

SEE-I for _____

"Understanding the concept of xxxx"

1. **STATE** the concept or idea in a single sentence or two. (Clearly and succinctly state the concept).

2. **ELABORTE** on the concept in your own words. Explain it at greater length in a paragraph or two. Clarify the concept in your own words. "In other words,. . ."

3. **EXEMPLIFY** the concept by giving concrete examples (and counter examples) of the concept. Specify the concept by giving specific examples. "For example, . . ."

4. **ILLUSTRATE** the concept with a real-world example and preferably with picture. Draw something, find an existing picture, or create a picture with words, such as with a metaphor or analogy. "It's like ..."

Analyzing the Logic of an Assignment (Article or Essay): Guidelines

To help you be prepared to be called on, you should type an analysis/critique for each article addressing the "*eight elements of reasoning*" (see below to the best of your ability). Evidence provided by *www.criticalthinking.org* suggests that it is desirable to use this basic structures of thinking to analyze assignments, articles, essays, and chapters. This analysis will deepen your insight into the author's reasoning.

The heading for the assignment should include your name, ID, due date and section (MGMT 401__) in the top left corner of the page followed by a word count. The name of the article should be centered a line below this information (see below).

Name: _____ Student ID. _____MGMT 401 Section: ____Date: _____ Word count: _____
Assignment Title and #:_____

One important way to understand an assignment, essay, article or chapter is through the analysis of the parts of the author's reasoning using the "*eight elements of a thought*". Once you have carefully read the article, I suggest you to copy the following template and try filling in the blanks by providing details.
Here is a template to follow:

1) The main **purpose** of this article is _____. (Here you are trying to state, as accurately as possible, the author's intent in writing the article. What was the author trying to accomplish?)
2) The key **question** that the author is addressing is _____. (Your goal is to figure out the key question that was in the mind of the author when he/she wrote the article. What was the key question addressed in the article?)
3) The most important **information** in this article is _____. (You want to identify the key information the author used, or presupposed, in the article to support his/her main arguments. Here you are looking for facts, experiences, and/or data the author is using to support his/her conclusions.)
4) The main inferences in this article are _____ _____. (You want to identify the most important conclusions the author comes to and presents in the article.)
5) The key **concept**(s) we need to understand in this article is (are) _____. By these concepts the author means _____. (To identify these ideas, ask yourself: What are the most important ideas that you would have to know to understand the author's line of reasoning? Then briefly elaborate what the author means by these ideas.)
6) The main **assumption**(s) underlying the author's thinking is (are) _____. (Ask yourself: What is the author taking for granted [that might me questioned]? The assumptions are generalizations that the author does not think he/she has to defend in the context of writing the article, and they are usually unstated. This is where the author's thinking logically begins.)

7a) If we accept this line of reasoning (completely or partially), the **implications** are _____. (What consequences are likely to follow if people take the author's line of reasoning seriously? Here you are to pursue the logical implications of the author's position. You should include implications that the author states, and also those that the author does not state.)

7b) If we fail to accept this line of reasoning, the **implications** are _____. (What consequences are likely to follow if people ignore the author's reasoning?)

8) The main **point(s) of view** presented in this article is (are) _____. (The main question you are tying to answer here is: What is the author looking at, and how is he/she seeing it? For example, in this mini-guide we are looking at "analysis" and seeing it "as requiring one to understand" and routinely apply the elements of reasoning when thinking through problems, issues, subjects, etc.)

These are the eight basic structures that define all reasoning and are also called essential elements of a thought. If you truly understand these structures as they interrelate in an article, essay or chapter, you should be able to role-play the thinking of the author. (**Note**: Each of these eight elements can further be evaluated by employing **intellectual standards**: *clarity, accuracy, precision, relevance, depth, breadth, logic, significance and fairness* by posing few simple questions as suggested on the next page.)

Please single space your assignment and try to make them no more than two pages. 800-1000 words should be adequate. Less than 800 words is probably not enough to adequately address the issues. Note: You are encouraged to submit a duplex page (or you must staple the pages together – no paperclips or fold by hand!!)

Grading Rubric: Analyzing the Logic of an Assignment, Article or Essay

	Achieved the goal (100-90 pts.)	**Some weakness (89.9 - 80 pts.)**	**Significant errors (79.9 - 70 pts.)**	**Did not achieve the goal (69.9-0 pts.)**
Purpose	Author's purpose was clearly and accurately stated	Author's purpose was stated but with some lack of clarity	Author's purpose was stated but was either not clear or not accurate	Author's purpose was not stated correctly or was missing
Key Question	The key question was accurate and well formulated	The key question was slightly misstated	The key question was not clearly stated	The key question was not stated correctly or was missing
Information	List, or statements of facts, experiences, and/or data were correctly identified and stated	List, or statements of facts, experiences, and/or data was missing one significant item	List, or statements of facts, experiences, and/or data were not complete or incorrect in part	List, or statements of facts, experiences, and/or data were incorrect or significantly incomplete
Concepts	The most important ideas that need to be understood are clearly and accurately stated	The most important ideas that need to be understood were not succinctly stated	The most important ideas that need to be understood are either not clearly or are only partially identified	The most important ideas that need to be understood are incorrectly stated or are missing
Assumptions	The statement(s) of the author's assumptions is (are) accurately and clearly stated	The statement(s) of the author's assumptions is (are) slightly misstated or missing a significant assumption	The statement(s) of the author's assumptions is (are) either only partially complete or not clearly stated	The statement(s) of the author's assumptions is (are) not correctly stated or missing
Points of view	The point(s) of view in the article is (are) correct and are clearly stated. The source(s) is (are) identified	The point(s) of view in the article is (are) slightly misstated or missing a source	The point(s) of view in the article is (are) only partially identified or not clearly stated	The point(s) of view in the article is (are) incorrectly identified or missing
Conclusions or Inferences	Key conclusions are correctly identified and stated	Key conclusions were not succinctly stated	Key conclusions are identified only in part and/or not clearly stated	Key conclusions are incorrect or missing
Implications or consequences	Both the positive and negative consequences of following the author's line of reasoning are clearly stated	Both the positive and negative consequences of following the author's line of reasoning are stated but the reasoning is faulty	Both the positive and negative consequences of following the author's line of reasoning are not clearly stated	Both the positive and negative consequences of following the author's line of reasoning are missing or incorrect.
Use of proper grammar, punctuation , and spelling	Grammar and punctuation were correctly used. No misspelled words	More than one grammar or punctuation error, no misspelled words	Several errors in grammar and punctuation and/or a misspelled word	Significant errors in grammar and/or punctuation and/or more than one misspelled word

Managing a Business - An Excel-Based Dice Game

Notes: You must turn in this assignment with your answers attached. You must also attach (i) completed Survey Form and Excel based Scenario Output page (See Blackboard) where you have recorded your results from various scenarios. THANK YOU.

Purpose: The purpose of this fun and interactive assignment is to sharpen your understanding of core Operations Management and Theory of Constraints concepts using an Excel-based variant of *The Dice Game* which Alex played with the boy scouts in Chapter 13 of *The Goal*.

Story Line: A very close friend of yours, Mr. Herbie, had a great idea and developed a very successful product while pursuing his undergraduate degree in engineering school. Following an advice from engineering school, Herbie decided to open a company, The XYZ Company and made an investment of $50,000 in a production system consisting of 5 processes. His initial thinking was that he will run a single shift operation – 5 days per week, 4 weeks a month i.e., 20 days per month. Each process will have mean daily production capacity of 3.5 units, and the production system should be able to produce 70 units per month (a very definite market demand estimate). Herbie expected mean daily production of 3.5 units to vary $\pm$ 2.5 units i.e., ranging between 6 and 1 (similar to the fair roll of a dice) due to various sources of variation e.g., machine break down, bad quality raw material, and worker morale. Because of interdependencies among processes and variation, he expected work-in-progress (WIP) to form in front of each process. (**Note**: Thus, *Mean*, *Variation* and *WIP* levels at each process can be manipulated to represent various states of the production system)

Product Flow: At the 1st process, assume that The XYZ Company has big supply of high quality raw material from our vendor on consignment basis i.e., it belongs to the vendor until the first process uses it. Thus, each process rolls a fair dice on each day which implies that the process has capability to produce that many units (higher number, say 6, represents a productive day and lower number 1 representing a bad day). It also implies that the process tries to produce that many units on that day provided it has work-in-progress (WIP) in its queue from the upstream process. The number of units processed will be the minimum of the WIP available at beginning of that day and roll of a die. The number of units in the queue of a process on any day will be equal to the units shipped from upstream on that day plus ending WIP from previous day i.e., the number of units in the queue minus the number of units produced from previous day. (**Note**: Units processed at the last process is assumed to be sold, i.e., no finished goods inventory exists).

Performance Measures: How do we know that Herbie understands the goal of the company and he is making right business decisions? Of course, Herbie can look at typical *local efficiencies* of each process and use *bottom line measures* e.g., Net Profit (NP) and Return-on-Investment (ROI). Additionally, he might also want to determine the impact of his various decisions on the company's future profitability by using measures e.g., Customer Service level and Lead Time and company's operational performance e.g., Productivity and Inventory Turns. Of course, Herbie can also calculate and use TOC measures, Throughput (T), Inventory (I) and Operating Expenses (OE) to evaluate the impact of his decisions on the goal of the company. (Note: Local efficiency of a specific process is calculated by dividing *Actual Units Produced by Standard Production Units* where the standard is set at Mean Production Rate i.e., 3.5 units per day).

Excel-based Dice Game: In order to use the Excel base-model effectively to run various scenarios, let us explain the model by dividing it into various Panels (You are advised to download and open the Excel Model at this point). **Notice that each time you click F9 key on your computer, the results are renewed as a new run. You will use this key, each time you make any changes to the input variables in order to see the updated results.**

Panel A is a simple flow chart showing how raw material moves from one process to the next till it is turned into a finished product. The purpose of this flow chart is to be able to create an image of this simple 5 process assembly line and be able to generalize the results to more complex production environments such as Job Shops and large flow shops.

Panel B consists of input variables – Starting WIP, Daily Mean Production Rate, and Maximum Variation around mean - which user can change to represent various scenarios. In the Base Model (see Exhibit I), (i) starting WIP in front of each process is set at zero except for 1st process where we assume unlimited supply of raw material, (ii) Mean daily production capacity is set at 3.5 units, and (iii) Maximum variation around mean is 2.5 units (imitating a roll of dice ranging between 6 and 1). The user is expected to input these variables in this panel to represent various scenarios.

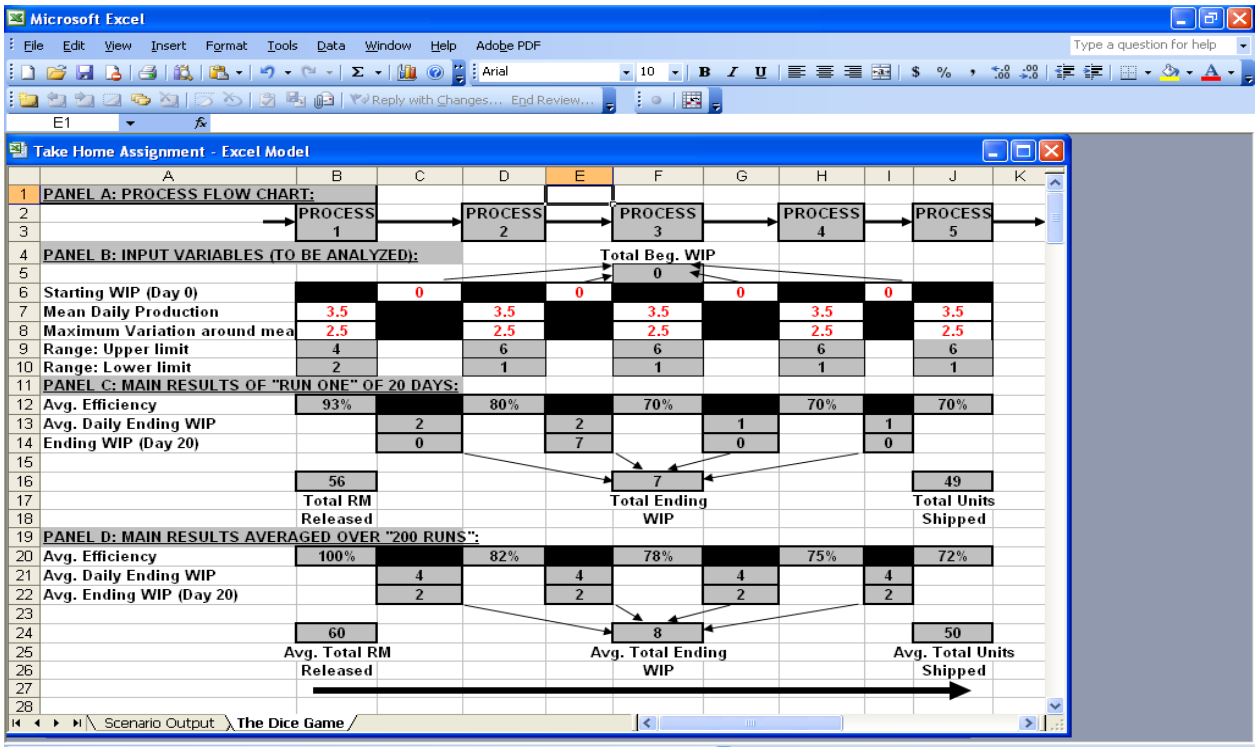
Panel C shows some main results visually e.g., (i) Average Efficiency of each process and Average Daily Ending WIP in front of each process over one month, and (ii) Total Raw Material released in the production system, Ending WIP at each process at the end of 1 month, and Total Units shipped in 1 month. We point out that these results are for one random run representing a single game played for 20 days and a click of F9 (recalculation) key changes these results. More detailed performance measures for the company as a whole are calculated and shown in Panel E.

Panel D shows visually the results similar to Panel C but averaged over 200 runs. These results are simulated by using Excel's "Data Table" function (see Panel F). We notice that with each hit of F9 (recalculation) key, results in Panel C varies significantly where as the results in Panel D do not vary much because these results are averaged over 200 replications. Therefore, these steady state results should be looked and analyzed when we want analyze the impact of a specific scenario where user might change some input variables (see Panel B).

Panel E provides another set of input variables (e.g., assumed monthly demand, days in a month, selling price, raw material cost, period expenses, and investment. Although these input variables can also be varied to create additional scenarios, in this case study we assume these variables are given and fixed. Next, this panel shows the system performance for 1 Run and Average over 200 Runs at the end of one month in terms of *TOC measures* T, I, OE, *bottom line measures* e.g., Net Profit, ROI, *Operational measures* i.e., Productivity and Inventory turns, and *competitive measures* e.g., Lead Time and customer service level. Finally, this panel also shows well known formulas to compute these measures.

Panels F exhibits detailed results of a complete run showing (for each day of the month) the units released in the system, queue length, actual roll of the dice, and units processed at each process respectively. Thus, day by day account of events is recorded for the complete month.

Panel G shows the simulated results for some of the main performance measures and averaged over 200 runs using "Data Table" function. Some of these main measures (e.g., Ending WIP and Total Units shipped) are further used to calculate other performance measures over 200 runs shown in Panel E.



Microsoft Excel

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Take Home Assignment - Excel Model

	A	B	C	D	E	F	G	H	I	J	K
1	PANEL A: PROCESS FLOW CHART:										
2		PROCESS 1		PROCESS 2		PROCESS 3		PROCESS 4		PROCESS 5	
3											
4	PANEL B: INPUT VARIABLES (TO BE ANALYZED):					Total Beg. WIP					
5						0					
6	Starting WIP (Day 0)		0		0		0		0		
7	Mean Daily Production	3.5		3.5		3.5		3.5		3.5	
8	Maximum Variation around mea	2.5		2.5		2.5		2.5		2.5	
9	Range: Upper limit	4		6		6		6		6	
10	Range: Lower limit	2		1		1		1		1	
11	PANEL C: MAIN RESULTS OF "RUN ONE" OF 20 DAYS:										
12	Avg. Efficiency	93%		80%		70%		70%		70%	
13	Avg. Daily Ending WIP		2		2		1		1		
14	Ending WIP (Day 20)		0		7		0		0		
15											
16		56				7				49	
17		Total RM				Total Ending				Total Units	
18		Released				WIP				Shipped	
19	PANEL D: MAIN RESULTS AVERAGED OVER "200 RUNS":										
20	Avg. Efficiency	100%		82%		78%		75%		72%	
21	Avg. Daily Ending WIP		4		4		4		4		
22	Avg. Ending WIP (Day 20)		2		2		2		2		
23											
24		60				8				50	
25		Avg. Total RM				Avg. Total Ending				Avg. Total Units	
26		Released				WIP				Shipped	
27											
28											

Scenario Output | The Dice Game

Draw AutoShapes

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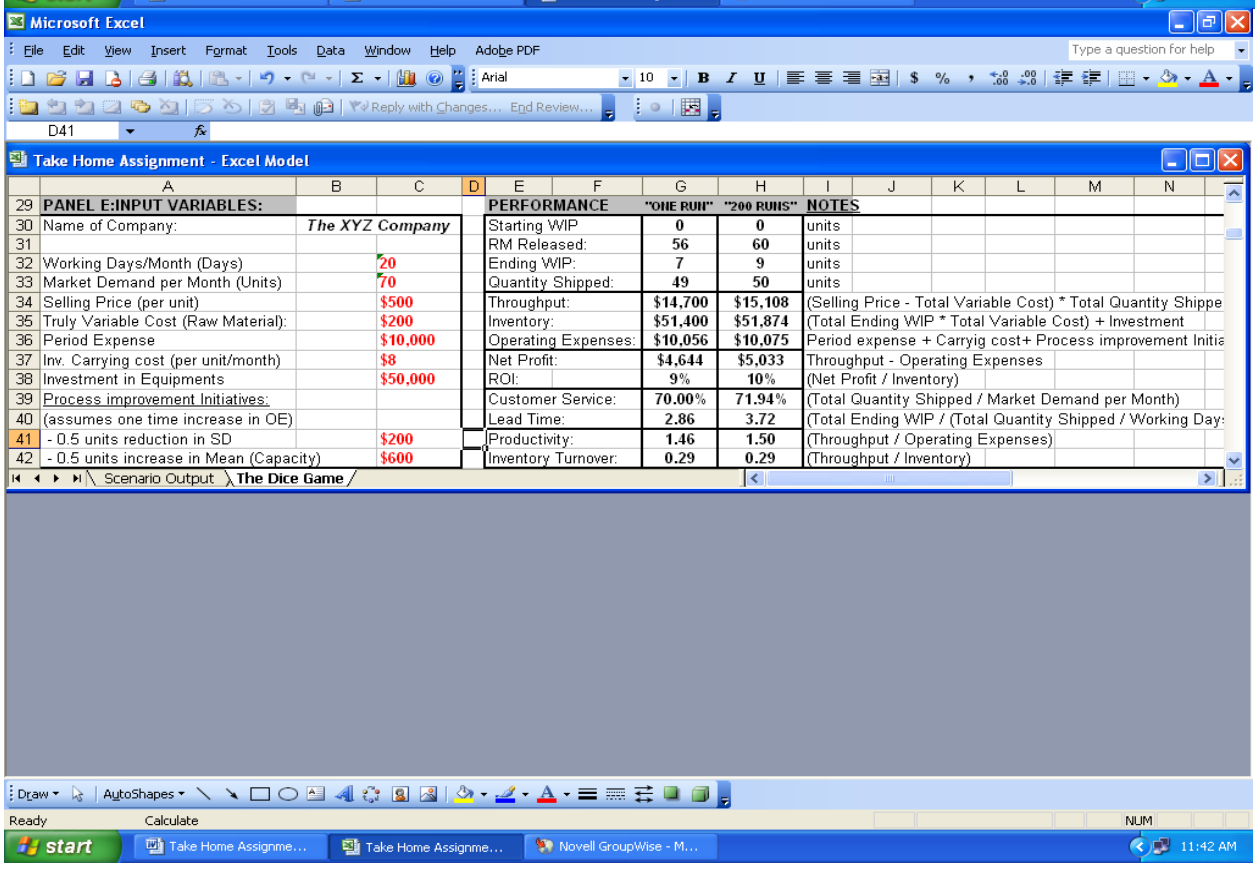

Microsoft Excel

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Take Home Assignment - Excel Model

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
29	PANEL E:INPUT VARIABLES:				PERFORMANCE		"ONE RUN"	"200 RUNS"	NOTES					
30	Name of Company:	The XYZ Company			Starting WIP		0	0	units					
31					RM Released:		56	60	units					
32	Working Days/Month (Days)		20		Ending WIP:		7	9	units					
33	Market Demand per Month (Units)		70		Quantity Shipped:		49	50	units					
34	Selling Price (per unit)		$500		Throughput:		$14,700	$15,108	(Selling Price - Total Variable Cost) * Total Quantity Shippe					
35	Truly Variable Cost (Raw Material):		$200		Inventory:		$51,400	$51,874	(Total Ending WIP * Total Variable Cost) + Investment					
36	Period Expense		$10,000		Operating Expenses:		$10,056	$10,075	Period expense + Carryig cost+ Process improvement Initia					
37	Inv. Carrying cost (per unit/month)		$8		Net Profit:		$4,644	$5,033	Throughput - Operating Expenses					
38	Investment in Equipments		$50,000		ROI:		9%	10%	(Net Profit / Inventory)					
39	Process improvement Initiatives:				Customer Service:		70.00%	71.94%	(Total Quantity Shipped / Market Demand per Month)					
40	(assumes one time increase in OE)				Lead Time:		2.86	3.72	(Total Ending WIP / (Total Quantity Shipped / Working Day:					
41	- 0.5 units reduction in SD		$200		Productivity:		1.46	1.50	(Throughput / Operating Expenses)					
42	- 0.5 units increase in Mean (Capacity)		$600		Inventory Turnover:		0.29	0.29	(Throughput / Inventory)					

Scenario Output | The Dice Game

Draw AutoShapes

Ready Calculate NUM

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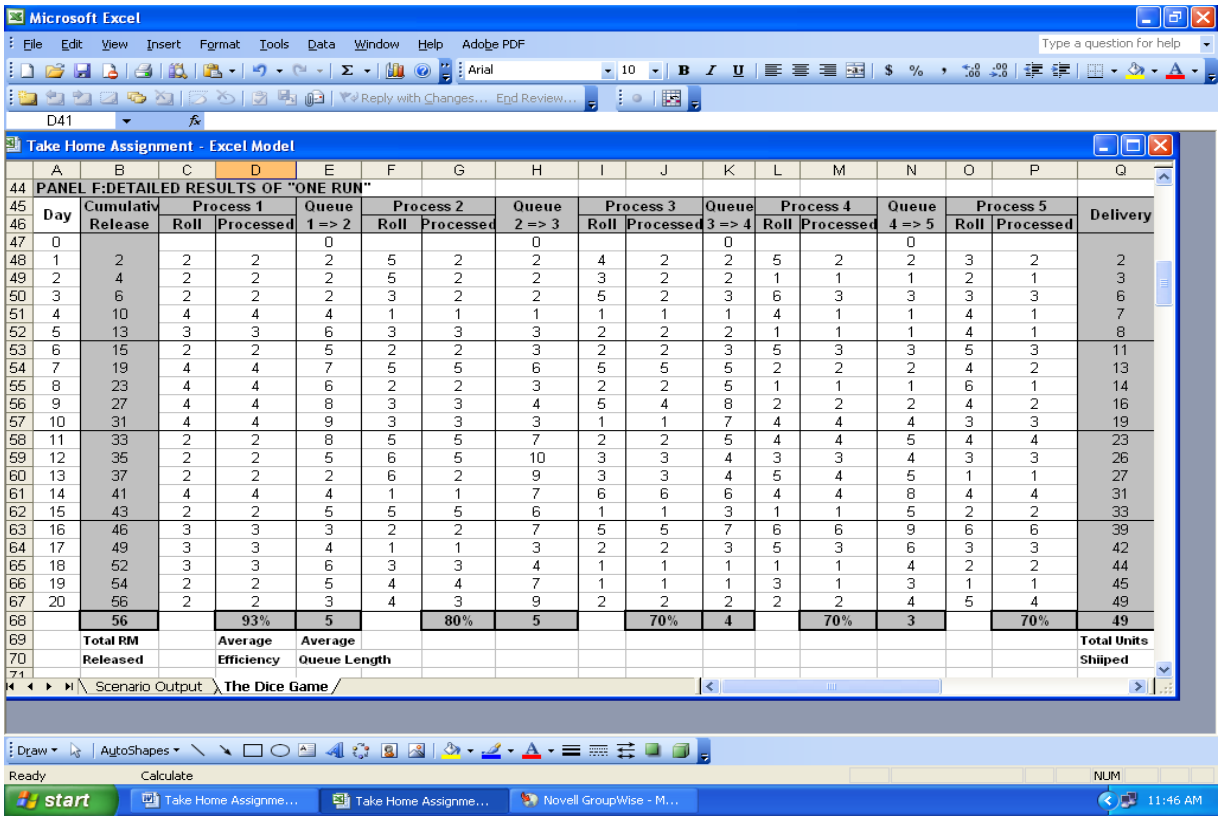


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
44	PANEL F:DETAILED RESULTS OF "ONE RUN"																
45	Day	Cumulativ	Process 1		Queue	Process 2		Queue	Process 3		Queue	Process 4		Queue	Process 5		Delivery
46		Release	Roll	Processed	1 => 2	Roll	Processed	2 => 3	Roll	Processed	3 => 4	Roll	Processed	4 => 5	Roll	Processed	
47	0				0			0			0			0			
48	1	2	2	2	2	5	2	2	4	2	2	5	2	2	3	2	2
49	2	4	2	2	2	5	2	2	3	2	2	1	1	1	2	1	3
50	3	6	2	2	2	3	2	2	5	2	3	6	3	3	3	3	6
51	4	10	4	4	4	1	1	1	1	1	1	4	1	1	4	1	7
52	5	13	3	3	6	3	3	3	2	2	2	1	1	1	4	1	8
53	6	15	2	2	5	2	2	3	2	2	3	5	3	3	5	3	11
54	7	19	4	4	7	5	5	6	5	5	5	2	2	2	4	2	13
55	8	23	4	4	6	2	2	3	2	2	5	1	1	1	6	1	14
56	9	27	4	4	8	3	3	4	5	4	8	2	2	2	4	2	16
57	10	31	4	4	9	3	3	3	1	1	7	4	4	4	3	3	19
58	11	33	2	2	8	5	5	7	2	2	5	4	4	5	4	4	23
59	12	35	2	2	5	6	5	10	3	3	4	3	3	4	3	3	26
60	13	37	2	2	2	6	2	9	3	3	4	5	4	5	1	1	27
61	14	41	4	4	4	1	1	7	6	6	6	4	4	8	4	4	31
62	15	43	2	2	5	5	5	6	1	1	3	1	1	5	2	2	33
63	16	46	3	3	3	2	2	7	5	5	7	6	6	9	6	6	39
64	17	49	3	3	4	1	1	3	2	2	3	5	3	6	3	3	42
65	18	52	3	3	6	3	3	4	1	1	1	1	1	4	2	2	44
66	19	54	2	2	5	4	4	7	1	1	1	3	1	3	1	1	45
67	20	56	2	2	3	4	3	9	2	2	2	2	2	4	5	4	49
68		56		93%	5		80%	5		70%	4		70%	3		70%	49
69		Total RM		Average	Average												Total Units
70		Released		Efficiency	Queue Length												Shiiped

OPERATIONS AND PRODUCTIVITY (Chapter 1)

OPERATIONS MANAGEMENT

Generally speaking, Operations Management is a continual process of effectively using management functions to integrate resources efficiently in order to achieve operations goals (i.e., DEFQ : Dependability, Efficiency, Flexibility and Quality).

Broadly speaking, Operations Management can be defined in three ways:

- as a business function - an active one
- as a transformation system – converting inputs into outputs and improving the system
- as a decision-making framework – make important operational decisions (10 OM decisions)

Examples

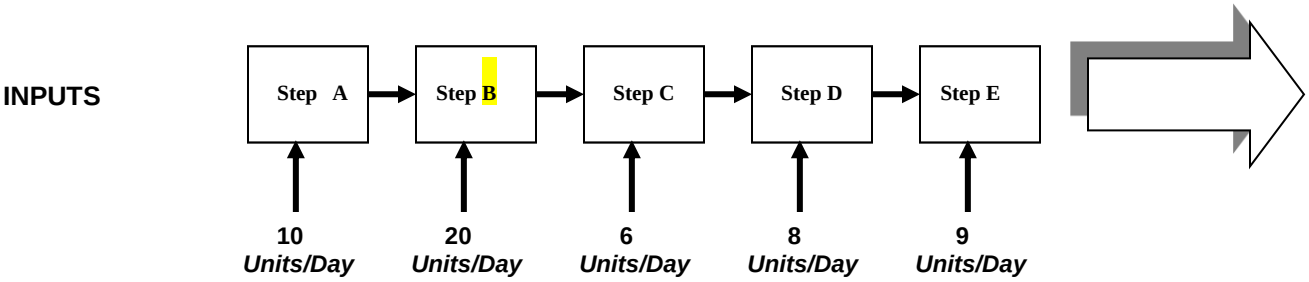


Figure 1: A Generic Example: Line Flow Processes

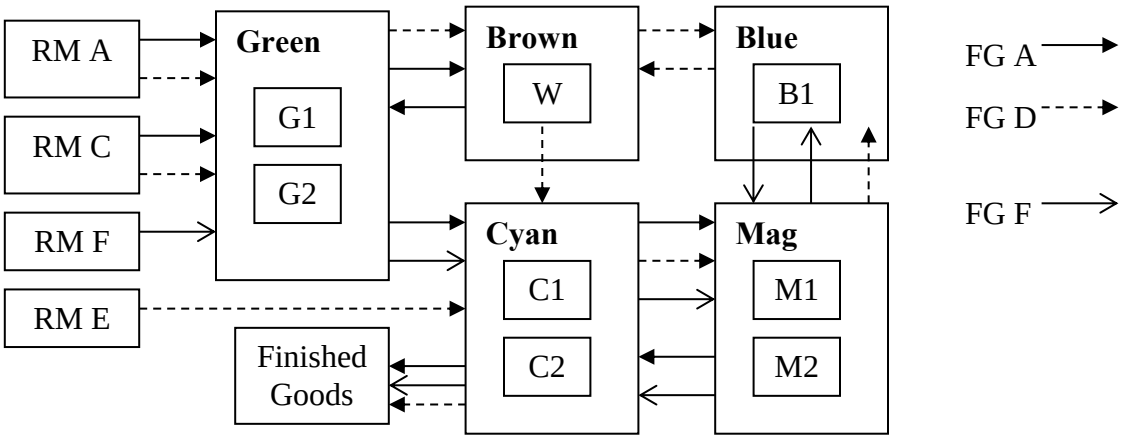


Figure 2: A Generic Example: Batch Flow Processes

What is so unique about service operations management?

"Service is something which is produced and consumed simultaneously"

- The customer is brought into direct contact with operation
- A service can't be produced in one place and shipped to another
- Intangibility, (ii) Multi-locations, (iii) Demand variability, (iv) Perishability

PRODUCTIVITY MEASURES

- **Productivity Ratio: O**utput/**I**nput **or** Units produced / Input used
- **Total Factory Productivity (TFP):**

$$\frac{\text{Total Output}}{\text{(Labor + Capital +Material + Other)}}$$

- **Partial Productivity Measures** e.g., Labor Productivity, Material Productivity

Labor Productivity (LP):

Total Output / Labor

Productivity Index: (%age increase or decrease compare to base year)

$$\frac{\text{Productivity Ratio, a specified period}}{\text{Productivity Ratio, base period}} \times 100$$

EXAMPLE:

Years	**'08**	**'09**	**'10**	**'11**
Total Output ($ '000)	377	415	290	478
Input ($ '000):				
Capital	36	40	41	44
Material	138	141	103	172
Labor	99	103	79	130
Other	99	103	79	130
Total Input	372	385	304	448

1. Total factor productivity ratios:
2. Labor productivity ratios:
3. Material productivity ratios:
4. Capital productivity ratios:

5. Labor productivity Indices:
   (Assume Base Year = '08)

6. Total factor Productivity Indices:
   (Assume Base Year = '08)

OPERATIONS STRATEGY (Chapter 2)

A well-managed business has a mission statement, a general business strategy, functional strategies to cover major business activities, objectives to guide the firm.

CORPORATE STRATEGY (CS)

"Setting corporate strategy is the process of determining the organization's mission of monitoring and adjusting to changes in the environment, and of identifying organization's distinctive competencies".

THE GENERIC BUSINESS STRATEGIES (SBU)

The essence of business-level strategic planning is to take offensive or defensive actions to create a defendable or advantageous position within an industry in order to successfully cope with the competitive forces and thereby realize a superior return on investment for the company. Obviously, a company might pursue many different strategies. However, at the broadest level two basic types of strategies, called **generic strategies**, enable a company to outperform its industry competitors: cost leadership and differentiation

COST LEADERSHIP

The first strategy is achieving cost leadership within the industry. Important components of this strategy include aggressively constructing efficient-scale facilities; emphasizing operating efficiency; vigorously controlling and reducing costs and overhead, particularly in such areas as research and development, services, sales force, and advertising; and avoiding marginal customer accounts.
Under this strategy, company managers devote a great deal of attention to reducing costs, although they do not ignore quality, service and other areas.

DIFFERENTIATION

The second generic strategy, differentiation, is for the company to differentiate its product or service by creating a product or service that is recognized industrywide as unique and able to command a premium price because of the uniqueness of its attribute(s).
Company managers devote much attention to product differentiation, although they do not ignore cost reduction. The approach the company might choose for differentiating its products from those of competitors may include one or more of the following: quality, brand image, innovative technology, superior customer service and rapid delivery.

Porter also defines a third generic strategy, called **focus**, which means finding a niche within an industry. However, the basic types of competitive advantage are low cost and differentiation, regardless of whether a company's scope of competitive activity is narrow or broad.

BUSINESS STRATEGY ALTERNATIVES

- Product imitator: Operations must focus on keeping costs low.
- Product innovator: Operations must maintain flexibility in processes, labor and suppliers.

FUNCTIONAL STRATEGIES

Functional strategies are developed to support the established business strategy in each functional area:

- Marketing
- Human resources
- Operations
- Finance

OPERATIONS STRATEGY (OS)

In general, "Operations strategy specifies how operations can achieve the organization's overall goals, within the framework of corporate strategy."

→ determine operational shortcomings

→ overcome any shortcomings or change OS

else, alert top management to revise CS

Operations Strategy is a strategy for the operations function that is linked to the business strategy and other functional strategies, leading to a consistent pattern of decision making and competitive advantage (in terms of D,E,F,Q) for the firm. (Schoreder, 2000)

Operations strategy is a functional strategy that should follow a consistent set of operational measures (DEFQ) and result in a consistent set of operational decisions.

TEN OM DECISIONS:

1. Product
2. Quality
3. Process
4. Location
5. Layout
6. Human resource
7. Supply chain
8. Inventory
9. Scheduling
10. Maintenance

PERFORMANCE CRITERIA (or MEASURES) FOR OM DECISIONS

1. **Dependability (**e.g., • delivery promises • price promises)
2. **Efficiency** (e.g., • cost efficiency • capital efficiency)
3. **Flexibility** (e.g., • product flexibility • volume flexibility)
4. **Quality** (e.g., • product quality • service quality)

PERFORMANCE CRITERIA (or MEASURES) FOR OM DECISIONS

For your manufacturing plant, how important is the ability to (rated on a 7-point scale with 1 = Not Important, 4 = Very Important, and 7 = Absolutely Critical):

Competitive Priorities	Not Important						Absolutely Critical
Cost Efficiency							
• Reduce inventory	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Increase capacity utilization	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Reduce product costs	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Increase labor productivity	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Quality							
• Provide high-performance products	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Offer consistent, reliable quality	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Improve conformance to design specifications	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Delivery/Dependability	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Provide fast deliveries	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Meet delivery promises	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Reduce production lead time							
Flexibility							
• Make rapid design changes	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Adjust capacity quickly	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Make rapid volume changes	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Offer a large number of product features	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Offer a large degree of product variety	**1**	**2**	**3**	**4**	**5**	**6**	**7**
• Adjust product mix	**1**	**2**	**3**	**4**	**5**	**6**	**7**

PROJECT MANAGEMENT (Chapter 3)

What is a Project? What are its characteristics? A project is a series of tasks (jobs) performed sequentially or in parallel aimed to achieve an important goal, and that require a significant amount of resources and time.

- Single unit, Unique with definite starting and ending points
- Many related activities
- General purpose equipment
- High labor skills
- Difficult production planning and inventory control

Some examples: Construction of a building, implementing an ERP system, writing a term paper

What is project management? A systematized phased approach to defining, organizing, planning, scheduling, and controlling large projects.

Project Planning is (i) establishing objectives, (ii) defining project, (iii) creating work breakdown structure, (iv) determining resources, and (v) forming organization

A project can be organized in different ways (based on who is managing the project):

- Project-based organizations
- Functional-based organizations
- Matrix Organization

Work breakdown structure is a statement of all the work that has to be completed:

- Project
  - Major tasks in the project
    - Subtasks in the major tasks
      - Activities in tasks – the smallest unit of work effort consuming both time and resources that can be planned and controlled.

Project Scheduling is specified by the start and finish times for each activity

1. Sequencing activities
2. Identifying precedence relationships
3. Determining activity times & costs
4. Estimating material & worker requirements
5. Determining paths and critical paths

Project scheduling techniques *include (i) Gantt chart, (ii) Critical Path Method (CPM), (iii) Program Evaluation & Review Technique (PERT)*

Six Steps common to PERT and CPM

1 Define the project and all of its significant tasks and/or activities
2 Develop relationships among the activities. (Decide which activities must precede and which must follow others)
3 Draw the network connecting all of the activities
4 Assign time and cost estimates to each activity
5 Compute the longest time path through the network. This is called the critical path
6 Use the network to help plan, schedule, monitor, and control the project

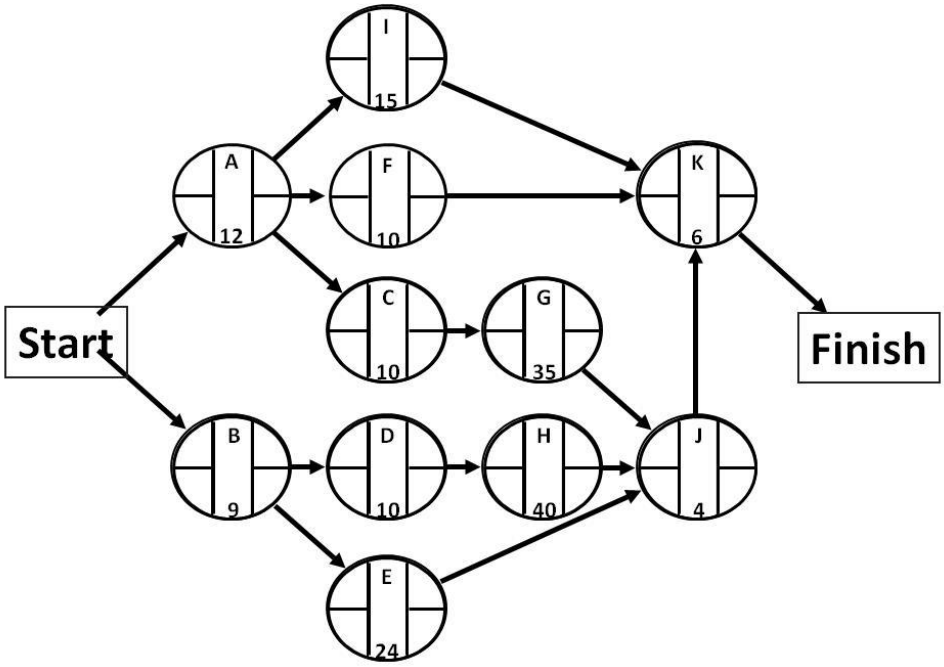
Questions addressed by PERT and CPM

1. When will the entire project be completed?
2. What is a project path and a critical path?
3. What are the critical activities – the one which will delay the project completion?
4. Which are the noncritical activities?
5. At any particular date, is the project on schedule, ahead of schedule, or behind schedule?
6. On any given date, is the money spent equal to, less than, or greater than the budgeted amount?
7. Are there enough resources available to finish the project on time?
8. If the project must be finished in less than the scheduled amount of time, what is the way to accomplish this at least cost?

EXAMPLE: St. John's Hospital Project

Activity	Immediate Predecessors	Activity Times (wks)	Responsibility
ST. JOHN'S HOSPITAL PROJECT			Kramer
START		0	
ORGANIZING and SITE PREPARATION			Stewart
A. Select administrative staff	Start	12	Johnson
B. Select site and survey	Start	9	Taylor
C. Select medical equipment	A	10	Adams
D. Prepare final construction plans	B	10	Taylor
E. Bring utilities to site	B	24	Burton
F. Interview applicants for nursing and support staff	A	10	Johnson
PHYSICAL FACILITIES and INFRASTRUCTURE			Walker
G. Purchase and deliver equipment	C	35	Sampson
H. Construct hospital	D	40	Casey
I. Develop information system	A	15	Murphy
J. Install medical equipment	E, G, H	4	Pike
K. Train nurses and support staff	F, I, J	6	Ashton
FINISH	K	0	

1. Develop Activity-On-Node (AON) Network



2. **Develop a schedule:** Perform Critical Path Analysis (Find Earliest & Latest Start, Earliest & Latest Finish, Slack)

3. **Analyzing Cost-Time Trade-offs –** Total project costs are the sum of direct cost, indirect costs and penalty costs. Project crashing is about shortening or expediting some activities to reduce overall project completion time.

DIRECT COST AND TIME DATA FOR THE ST. JOHN'S HOSPITAL PROJECT

Activity	Normal Time (NT) (weeks)	Normal Cost (NC)($)	Crash Time (CT)(weeks)	Crash Cost (CC)($)	Maximum Time Reduction (week)	Cost of Crashing per Week ($)
A	12	$12,000	11	$13,000	1	1,000
B	9	50,000	7	64,000	2	7,000
C	10	4,000	5	7,000	5	600
D	10	16,000	8	20,000	2	2,000
E	24	120,000	14	200,000	10	8,000
F	10	10,000	6	16,000	4	1,500
G	35	500,000	25	530,000	10	3,000
H	40	1,200,000	35	1,260,000	5	12,000
I	15	40,000	10	52,500	5	2,500
J	4	10,000	1	13,000	3	1,000
K	6	30,000	5	34,000	1	4,000
	Totals	$1,992,000		$2,209,500		

Also assume that indirect costs are $8,000/wk and the Regional Hospital Board imposes on St. John's a penalty cost of $20,000/wk after week 65 if the hospital is not fully operational.
What is the Total Project cost and How to determine a minimum-cost schedule?

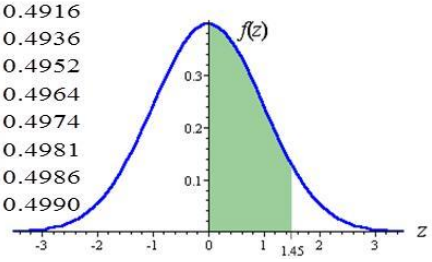
4. **What is the expected project completion time and what is the probability of completing a project by a given date using the Normal Distribution Appendix? (Formula for t_e and σ^2 see pg. 66)**

	Time Estimates (week)			Activity Statistics	
Activity	Optimistic (a)	Most Likely (m)	Pessimistic (b)	Expected Time (t_e)	Variance (σ^2)
A	11	12	13		
B	7	8	15		
C	5	10	15	10	2.78
D	8	9	16	10	1.78
E	14	25	30	24	7.11
F	6	9	18	10	4.00
G	25	36	41	35	7.11
H	35	40	45	40	2.78
I	10	13	28	15	9.00
J	1	2	15	4	5.44
K	5	6	7	6	0.11

$t_e = (a+4m+b)/6$; $\sigma^2 = [(b-a)/6]^2$

Calculate the probability that St. John's Hospital will become operational in 72 weeks using the critical path.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3304	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990



Forecasting (Chapter 4)

- Forecasting demand for operations output
  - Forecasting: what we think demand will be
  - Planning: what we think demand should be
  - Demand: may differ from sales
- Forecasts are necessary for operations decision areas: process design, capacity planning, scheduling, inventory management

Forecasting Time Horizons

- Short-range forecast: Up to 1 year, generally less than 3 months
  - Purchasing, job scheduling, workforce levels, job assignments, inventory Mgmt
- Medium-range forecast: 3 months to 3 years
  - Sales and production planning (Aggregate Planning), budgeting
- Long-range forecast: 3^{+} years
  - New product planning, Process design, Capacity planning, Facility location,

Forecasting Approaches: Qualitative Methods (see Table below)

- Used when situation is vague and little data exist
- New products; New technology
- Involves intuition, experience e.g., forecasting sales on internet
- Methods: Delphi technique; Market surveys; Life-cycles analogy; Informed judgment

Forecasting Approaches: Quantitative Methods (see Table below)

- Used when situation is 'stable' and historical data exist
- Existing products; Current technology
- Involves mathematical techniques e.g., forecasting sales of LCD televisions
- Major Methods: Time-Series Forecasting; Moving avg.; Exponential smoothing; Causal Models

Use of Forecasting: Operations Decisions

	Time Horizon	Accuracy Required	Number of Forecasts	Management Level	Forecasting Method
Process design	Long	Medium	Single or few	Top	Qualitative or causal
Capacity planning, facilities	Long	Medium	Single or few	Top	Qualitative and causal
Aggregate planning	Medium	High	Few	Middle	Causal and time series
Scheduling	Short	Highest	Many	Lower	Time series
Inventory management	Short	Highest	Many	Lower	Time series

Components of Demand

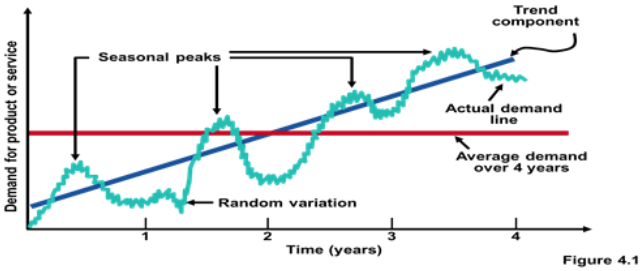


Figure 4.1

Moving Average Example

Month	Actual Shed Sales	3-Month Moving Average
January	10	
February	12	
March	13	
April	16	(10 + 12 + 13)/3 = 11 $^{2}/_{3}$
May	19	(12 + 13 + 16)/3 = 13 $^{2}/_{3}$
June	23	(13 + 16 + 19)/3 = 16
July	26	

Weig

Weights Applied	Period
3	Last month
2	Two months ago
1	Three months ago
6	Sum of weights

Month	Actual Shed Sales	3-Month Weighted Moving Average
January	10	
February	12	
March	13	
April	16	[(3 x 13) + (2 x 12) + (10)]/6 = 12 $^{1}/_{6}$
May	19	[(3 x 16) + (2 x 13) + (12)]/6 = 14 $^{1}/_{3}$
June	23	[(3 x 19) + (2 x 16) + (13)]/6 = 17
July	26	[(3 x 23) + (2 x 19) + (16)]/6 = 20 $^{1}/_{2}$

Exponential Smoothing

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$$

New forecast = Last period's forecast
+ α (Last period's actual demand
– Last period's forecast)

Predicted demand = 142 Ford Mustangs
Actual demand = 153
Smoothing constant α = .20

New forecast = 142 + .2(153 – 142)
= 142 + 2.2
= 144.2 ≈ 144 cars

Let Actual demand = 150, what will be the new forecast for the next period?

Choosing α

The objective is to obtain the most accurate forecast no matter the technique

We generally do this by selecting the model that gives us the lowest forecast error

Forecast error = Actual demand - Forecast value
= $A_t - F_t$

4 - 37

Common Measures of Error

Mean Absolute Deviation (MAD)

$$MAD = \frac{\sum |\text{Actual} - \text{Forecast}|}{n}$$

Mean Squared Error (MSE)

$$MSE = \frac{\sum (\text{Forecast Errors})^2}{n}$$

4 - 38

Comparison of Forecast Error

Quarter	Actual Tonnage Unloaded	Rounded Forecast with α = .10	Absolute Deviation for α = .10	Rounded Forecast with α = .50	Absolute Deviation for α = .50
1	180	175	5.00	175	5.00
2	168	175.5	7.50	177.50	9.50
3	159	174.75	15.75	172.75	13.75
4	175	173.18	1.82	165.88	9.12
5	190	173.36	16.64	170.44	19.56
6	205	175.02	29.98	180.22	24.78
7	180	178.02	1.98	192.61	12.61
8	182	178.22	3.78	186.30	4.30
			82.45		98.62
		MAD	10.31		12.33
		MSE	190.82		195.24
		MAPE	5.59%		6.76%

MSE for α

4 - 45

Collaborative Planning, Forecasting, and Replenishment (CPFR)

- Aim is to achieve more accurate forecasts
- Share information in the supply chain with customers and suppliers
- Compare forecasts
  - If discrepancy, look for reason
  - Agree on consensus forecast
- Works best in B2B with few customers (e.g., a small number of large retailers)

11-10

4 - 10

TOTAL QUALITY MANAGEMENT (Chapter 6)

CONCEPTS

In general, quality is the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs.

What is the right quality for a producer? ➔ its relationship with Business Strategy?

Consumer Definitions

- "Value": How well the product or service serves its intended purpose at a price they were willing to pay.
- "Fitness for use": How well the product performs with respect to customer

Producer Definitions

- "Conformance to Specifications": Quality is associated with designing and producing a product to meet customer needs and expectations.

- *"TQM is a continuous proactive effort to determine customer expectations and meet the specifications."*
- *"TQM is about continuous improvement of a stable process"*

Various Quality perspectives within the framework of Continues Improvement Process

Customer → Marketing → Design/Engineering → Manufacturing → Distribution

1. Transcendent product-based quality

2. User-based quality

3. Value based quality

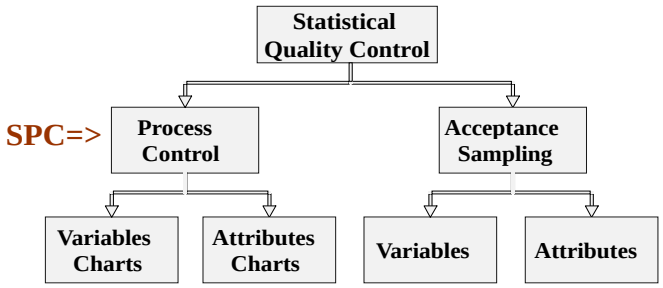
4. Manufacturing-based quality

Major Contributors towards QUALITY MOVEMENT (Historical Perspective)

Taylor – Inspected quality
Deming- Process quality control
Juran – Quality management
Feigenbum – Total quality management
Ishikawa – Preventive quality
Taguchi – Design quality
Crosby – Quality costs
Kearns – competitive quality i.e., benchmarking
Mazda – Innovative quality
Motorola, G.E. – Six sigma

Costs Of Quality : Control Costs i) Prevention Costs; and ii) Appraisal Costs
Failure Costs iii) Internal Failure Costs; and iv) External Failure Costs

STATISTICAL QUALITY CONTROL (Chapter 6 Supplement)



Three Basic Applications of SPC:
1. To establish a state of statistical control,
2. To monitor a process and signal when the process goes out of control
3. To determine process capability

- The purpose of **acceptance sampling** is to determine the disposition of goods or services i.e. accept, reject or screen. The focus being on the product after it has been produced.
- The purpose of **statistical process control** (SPC) is to apply statistical techniques to control a process. The focus being on the process and the product as it is being produced.

1. PROCESS CONTROL – Variables :

(i) Characteristics that you measure, e.g., weight, length; (ii) May be in whole or in fractional numbers, (iii) Continuous random variables

R chart -> measures variability in the process

The control limits are as:

$$CL = \bar{R}; \qquad UCL = D_4\bar{R}; \qquad LCL = D_3\bar{R}$$

X chart -> measures variability in the mean

The control limits are as:

$$CL = \bar{\bar{X}}; \qquad UCL = \bar{\bar{X}} + A_2\bar{R} \qquad LCL = \bar{\bar{X}} - A_2\bar{R}$$

PROCESS CONTROL – Attributes

(i) Characteristics that you count or use to categorize; (ii) Two types of attributes data: Classify products as either 'good' or 'bad'; (iii) Count # of defects; (iv) Categorical or discrete random variables

p chart -> measures percent defects

The control limits are as:

$$CL = \bar{p}; \quad UCL = \bar{p} + 3\sqrt{\bar{p}(1-\bar{p})/n} \qquad LCL = \bar{p} - 3\sqrt{\bar{p}(1-\bar{p})/n}$$

2. CONTINUOUS PROCESS IMPROVEMENT

PROCESS CAPABILITY INDICIES (see Textbook): c_p and c_{pk}

Note Sample Size,n, = 7

Number of Samples, N, = 25

Day	Sample Number	Shaft Diameter 1	2	3	4	5	6	7	Sample Mean	Sample Range
1	1	0.628	0.630	0.637	0.615	0.625	0.625	0.631		
	2	0.616	0.626	0.622	0.630	0.626	0.630	0.616		
	3	0.626	0.605	0.624	0.623	0.634	0.621	0.622		
	4	0.617	0.629	0.632	0.626	0.615	0.623	0.614	0.6223	0.018
	5	0.623	0.621	0.632	0.626	0.618	0.625	0.628	0.6247	0.014
2	1	0.627	0.635	0.636	0.614	0.621	0.619	0.615	0.6239	0.022
	2	0.630	0.611	0.616	0.628	0.627	0.618	0.612	0.6203	0.019
	3	0.610	0.635	0.629	0.622	0.616	0.617	0.607	0.6194	0.028
	4	0.621	0.630	0.631	0.625	0.623	0.615	0.622	0.6239	0.016
	5	0.611	0.615	0.625	0.639	0.623	0.613	0.617	0.6204	0.028
3	1	0.627	0.627	0.624	0.623	0.638	0.616	0.631	0.6266	0.022
	2	0.623	0.631	0.630	0.616	0.631	0.633	0.625	0.6270	0.017
	3	0.625	0.624	0.636	0.618	0.621	0.619	0.642	0.6264	0.024
	4	0.618	0.634	0.619	0.627	0.623	0.642	0.619	0.6260	0.024
	5	0.620	0.630	0.628	0.621	0.639	0.618	0.631	0.6267	0.021
4	1	0.618	0.616	0.632	0.634	0.617	0.614	0.615	0.6209	0.02
	2	0.614	0.630	0.635	0.623	0.629	0.623	0.626	0.6257	0.021
	3	0.619	0.634	0.626	0.609	0.632	0.631	0.614	0.6236	0.025
	4	0.630	0.616	0.613	0.632	0.623	0.620	0.625	0.6227	0.019
	5	0.623	0.638	0.627	0.624	0.619	0.631	0.611	0.6247	0.027
5	1	0.614	0.633	0.639	0.615	0.624	0.620	0.618	0.6233	0.025
	2	0.622	0.630	0.613	0.626	0.614	0.624	0.629	0.6226	0.017
	3	0.615	0.619	0.625	0.617	0.638	0.620	0.622	0.6223	0.023
	4	0.616	0.629	0.612	0.631	0.631	0.630	0.611	0.6229	0.02
	5	0.629	0.619	0.622	0.613	0.622	0.626	0.638	0.6241	0.025
									0.6237	**0.022**

How to calculate sample Mean and Range?

How to calculate mean of sample Means and Ranges?

$UCL_{\bar{X}} = 0.6237 \quad LCL_{\bar{X}} = 0.6147 \quad UCL_R = 0.0416 \quad LCL_R = 0.0016$

How to calculate UCL and LCL for X and R charts?
Use the given equations and Table from Textbook (also see pp. 31 from your notes)

Figure 18–3 An X Chart from Table 18–1 Data

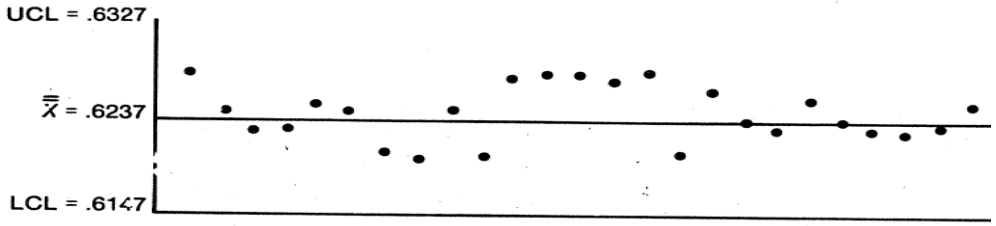
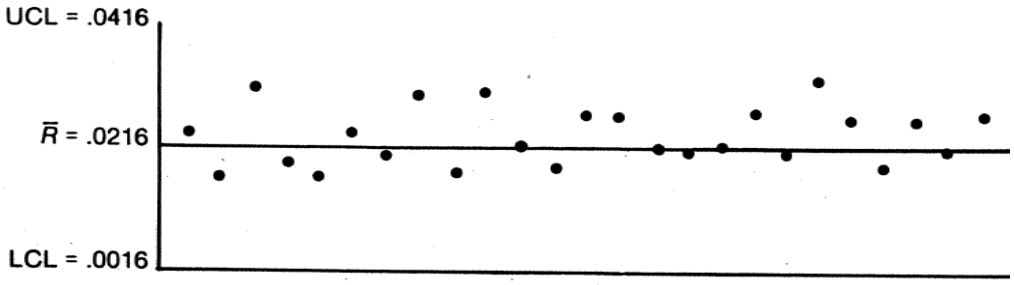


Figure 18–2 An R Chart from Table 18–1 Data



What are VALID control limits?

#	Date	Number of Defectives	Percent Defective (p)
1	August 12	2	
2	August 13	1	
3	August 16	1	
4	August 17	7	0.14
5	August 18	2	0.04
6	August 19	9	0.18
7	August 20	7	0.14
8	August 23	2	0.04
9	August 24	1	0.02
10	August 25	5	0.1
11	August 26	5	0.1
12	August 27	4	0.08
13	August 30	6	0.12
14	August 31	3	0.06
15	September 1	1	0.02
16	September 2	8	0.16
17	September 3	3	0.06
18	September 7	1	0.02
19	September 8	8	0.16
20	September 9	3	0.06
21	September 10	5	0.1
22	September 13	4	0.08
23	September 14	2	0.04
24	September 15	2	0.04
25	September 16	3	0.06

How to calculate value of p-bar?

Sample Size (n) = 50

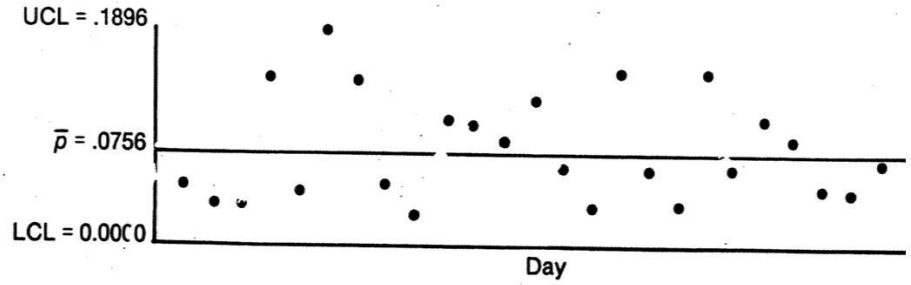
What is N =?

$\bar{p} = 0.0760$ **How to calculate value of p?**

$$UCL_{\bar{p}} = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = .0760 + 3\sqrt{\frac{.0760(1-.0760)}{50}} = 0.1884$$

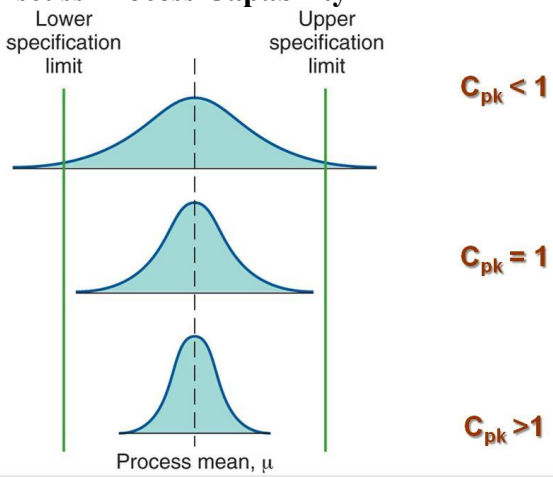
$$LCL_{\bar{p}} = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = .0760 - 3\sqrt{\frac{.0760(1-.0760)}{50}} = -0.0364 = 0$$

Figure 18–4 A p Chart from Table 18–3 Data



What are VALID control limits?

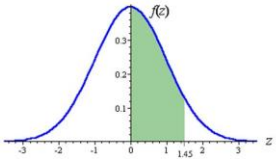
Discuss Process Capability



Natural Variability versus Specifications for Process Capability

c_{pk} = Min {(USL-μ)/3σ), (μ - LSL)/3σ)}

We can tell what %age parts will not meet customer's specifications by using z-Table:
z = (μ - x)/σ where x is either USL or LSL



Population mean, μ , can be estimated by = 0.6237
Population standard deviation, σ , can be estimated by
= 0.0216/2.619 = 0.008

Let us also assume that customer specifications are:

Upper Specification Limit, USL = 0.6300
Lower Specification Limit, LSL = 0.6100

C_{pk} Index:

C_{pk} = Minimum of {(USL - μ)/3σ , (μ − LSL/ 3σ)}
C_{pk} = Minimum of
{(.6300 - .6237)/3 x 0.008 , (.6237 − .6100/ 3 x 0.008) }
Minimum of (.0063 /.024 , .0137/0.024)
Minimum of (.2625, .5708) = 0.2625

%age parts outside the specifications (USL = .6300 and LSL = .6100):

		Appendix A (pp. 519)
Z1 = (.6300 - .6237)/ 0.008 = .0063/ 0.008 = .7875	0.79	0.2852
Z2 = (.6237 - .6100/ 0.008) = .0137/ 0.008 = 1.7125	1.71	0.4564

%age parts outside the specifications = (0.5 - 0.2823) + (0.5 - 0.4564) =
0.2148 + 0.0436
0.2584
26%

Factors for Control Limits

n	A_2	D_3	D_4	d_2
2	1.880	0	3.268	1.128
3	1.023	0	2.574	1.693
4	.729	0	2.282	2.059
5	.577	0	2.115	2.326
6	.483	0	2.004	2.534
7	.419	.076	1.924	2.619

Note: σ = R-bar / d_2

DESIGN OF GOODS AND SERVICES (Chapter 5)
PRODUCT STRATEGY

CONCEPTS

"The whole spectrum of activities leading up to the introduction, revision or dropping of products (goods/services)."

"A continual Process"

PRODUCT LIFE CYCLE consists of five stages.

1. **Product Planning**
   - ideas for new goods/services are generated, screened, and translated
   - Profits -> Negative and Sales -> None
2. **Introduction**
   - operations is still refining production efforts
   - marketing efforts may be modest
   - Profits -> from negative to positive and Sales -> Increasing
3. **Growth**
   - Operations tries to keep up with demand
   - Profits -> increase to peak and Sales -> dramatic growth
4. **Maturity**
   - new competitors create pressures
   - efficiency of operations must be stressed
   - Profits -> begin to decline and Sales -> level off
5. **Decline**
   - demand disappears or a better product enters
   - Profits -> continue to decline and Sales -> decline

ENTRANCE-EXIT STRATEGIES

Strategy	Stage to Enter	Stage to Exit	Implications for OM
1. Enter early & exit late	Intro	Decline	Transition required
2. Enter early & exit early	Intro	Maturity	Low-volume, flexible producer
3. Enter late & exit late	Growth	Decline	High-volume, low-cost producer

Source: Hayes & Wheelwright, "The dynamics of process-product life cycles," HBR, 1979.

SERVICE STRATEGY

WHAT IS SERVICE?

- "Service is something which is produced and consumed simultaneously"
- The customer is brought into direct contact with operation
- A Service can't be produced in one place and shipped to another

FRAMEWORKS FOR SERVICES (Albrecht and Zemke, 1985)

- The Service Triangle assumes that there are four elements which must be considered in producing services: service strategy, people, system, and customer
- Every service is delivered in a Cycle of Service.
- A moment of truth is anytime that the customer comes in contact with the service system during the cycle of service delivery.

A SERVICE MANAGEMENT MODEL

1. **Service Strategy**
   - -defines what business you are in
   - -provides a vision
   - -describes the perception
2. **Service Product Design**
   - -bundled with goods and services
     - The physical items
     - The sensual benefits
     - The psychological benefits
3. **Service Process Design**
   - -degree of customer contact
     - Low contact systems
     - High contact systems
   - -Service process matrix:
     - Degree of labor intensity
     - Degree of interaction and customization
4. **Service Delivery System Design**
   - -consists of five elements
     - i) Technology, ii) Process Flow, iii) Process Type, iv) Location and Size, and v) Work Force
5. **Service Measurement**
   - -documented formal policies and procedures

DIFFERENCES BETWEEN SERVICE & MANUFACTURING ORGANIZATIONS

(I) Multi-locations
(II) Customer interactions
2. Demand variability
3. Perishability
4. Intangibility

PROCESS STRATEGY & CAPACITY PLANNING

CONCEPTS

"Process Design is a continuous selection of process of inputs, operations, work flows, and methods for producing goods and services."

- a long-range planning decision
- a vital link between the various OM decisions
- how to produce

Two Main Strategies:

Process Focus firms generally deal in low-volume customized products and utilize a job shop or batch methodology. The facilities are organized around process; they have a *process focus*, that is the departments carry *title like cutting, sanding, assembly, painting, and packaging and the layout of the process follows this breakdown.* Individual jobs are routed through different departments depending on the operations needed to manufacture the items.

Product Focus firms, by contrast, produces a high-volume standardized products using repetitive or continuous flow processes. The facilities are organized around products. The organization chart and the physical layout reflect the fact that groups of employees and equipment are dedicated to the continuous production of one product. Thus, each department contains the proper tools and equipment arrayed in the proper order to produce the product from beginning to end.

Characteristics	Product Focus	Process Focus
Product		
Order Type	Continuous or large batch	Batch
Flow or product	Sequenced	Jumbled
Product variety	Low	High
Market type	Mass	Custom
Volume	High	Medium to low
Labor		
Skills	Low	High
Task type	Repetitive	Non-routine
Pay	Low	High
Capital		
Investment	High	Medium to low
Inventory	Low	High
Equipment	Special purpose	General purpose
Objectives		
Flexibility	Low	Medium to High
Cost	Low	Medium to High
Quality	Consistent	More variable, meeting specifications
Delivery	High	Medium to low

CAPACITY PLANNING: FACILITY STRATEGY

A facilities strategy (FS) consists of three elements:

1. the amount of capacity
2. the timing of capacity
3. the location of capacity

Strategies for

A. Amount of Capacity Issue

a) Try not to run out
b) Build to average forecast

B. Timing of capacity Issue

a) Preempt the competition
b) Wait and see

C. Location of capacity (See Chapter 8)

a) Close to Market
b) Close to Resources

Issues in Capacity Measurement

1. Capacity should always be measured in units of output per time period.
2. Examples of capacity measures: Barrels of beers per day; Tons of steel per year; customers served per day;
3. Issues in capacity measurement:
   i) An aggregate measure ii) Product-mix effects iii) Operations policies
   iv) Sustained and peak capacity v) Capacity vs. volume

Capacity Definitions

In general, capacity is the highest reasonable output rate that can be achieved with the current product design specifications, product mix, work force, plant, and equipment limitations.

1. "**Design Capacity**" is the *maximum possible output rate* that can possibly be attained under ideal conditions.
2. "**Effective Capacity**" is *the rate of output* that a firm can realistically achieve, given process limitations such as preventive maintenance downtime, setup time, lunch breaks and so on.
3. "**Actual Output/Capacity**" is *the rate of output* actually obtained taking into consideration production losses due to scrap, rework, machine breakdown, fatigue, etc.

Effective Capacity $\leq$ Design Capacity **and** Actual Output $\leq$ Effective Capacity

Modern Capacity Measures:

1. **Throughput capacity**: The amount of a resource's capacity that is needed to directly support the throughput of the plant.
2. **Unused Capacity**: The amount of a resource's capacity that is in excess of the Throughput capacity.
3. **Protective Capacity**: The amount of a resource's capacity that is necessary to maintain the integrity of the schedule by providing recovery capability.
4. **Excess Capacity**: The amount of a resource's capacity that is in excess of the throughput and protective capacities. This capacity can be safely eliminated without effecting the integrity of a plant's schedule.

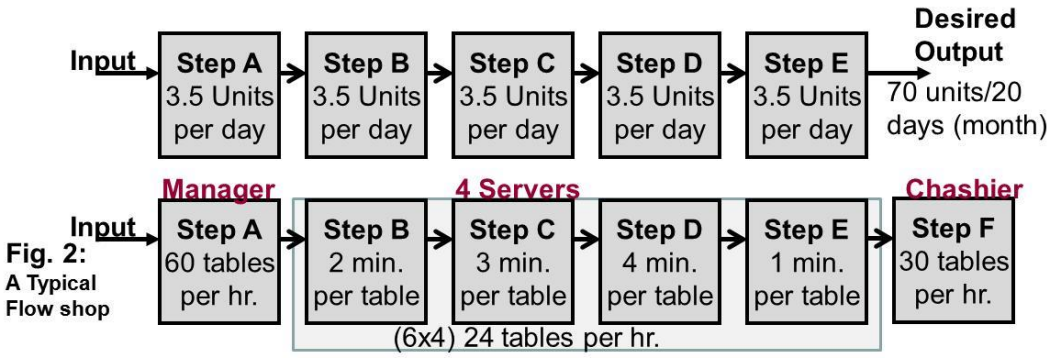


Fig. 2:
A Typical Flow shop

Have you started playing with Excel-based Dice Game (Fig. 1)? What is the
Design Capacity:
Effective Capacity:
Rated Capacity:

In Fig. 2, what is the Effective Capacity fo the system:
Throughput Capacity:
Protective Capacity:
Unused Capacity:
Excess Capacity:

Location Strategy: The Transportation Problem

	Customer (A)	Customer (B)	Customer (C)	Warehouse Supply
Warehouse (D)	5	4	3	100
Warehouse (E)	8	4	3	300
Warehouse (F)	9	7	5	300
Customer Demand	300	200	200	700

What is the solution using Least Cost Method?

What is the total cost of the solution?

LAYOUT STRATEGY (Chapter 9)

CONCEPT

A "planning process" that considers "alternatives" of resource utilization, facility location, and process design, often through the use of "mathematical algorithms", for the "purpose" of greater productivity (defined in terms of quality, cost efficiency, flexibility, or delivery).
It involves decisions about the "physical arrangement" of "economic activity centers" within a facility. The goal is to allow workers and equipment to operate at peak effectiveness and efficiency.

- economic activity center can be anything that consumes space: a machine, a work station, a department, a cafeteria or storage room, etc.
- the term physical arrangement needs answer to the following questions: (i) What centers should the layout include? (ii) How much space and capacity does each center need? (iii) How should each center's space be configured? and (iv) Where should each center be located?

CHOOSING A LAYOUT TYPE

FUNCTIONAL (PROCESS) LAYOUT

Similar equipment processes or similar worker skills are grouped together by departments, (ii) Flows between some departments may be very heavy, while those between others are very light, (iii) Examples of Process Layout: Hospitals, universities, banks, auto repair shops, airlines.

Objective: Minimize the material handling or distance traveled between depts.
Advantages:
(i) System can handle a variety of processing requirements; (ii) System is not vulnerable to equipment failures; (iii) General-purpose equipment is often less costly than special-purpose; (iv) It is possible to use individual incentive systems.
Disadvantages:
(i) In-process inventory costs can be very high; (ii) Routing and scheduling poses continual challenges; (iii) Equipment utilization rates are low: (iv) Material handling is slow and inefficient; (v) Job complexities often reduce the span of supervision; (vi) Higher unit costs; and (vii) Accounting, inventory control, and purchasing are much more involved.

PRODUCT LAYOUT (LINE BALANCING)

The process of assigning work to stations in a line so as to achieve the desired output rate with the smallest number of workstations.
Objectives: A perfectly balanced line (i) will have approximately equal time requirements at each workstation; (ii) Will result in high utilization & low idle time;
Advantages and Disadvantages: See the textbook

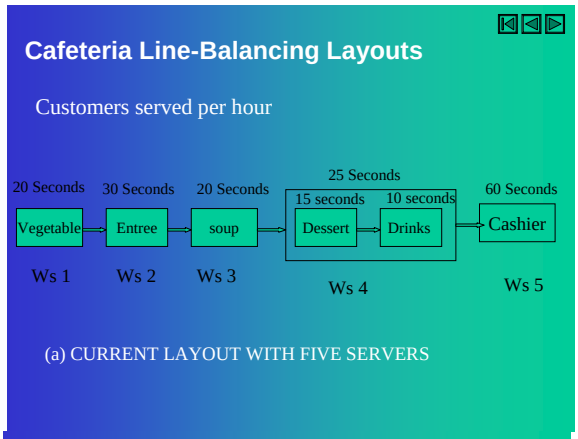
Obstacles: The major obstacle in attaining a perfectly balanced line is the inability to obtain "task bundles" that have same duration. WHY? (i) Not feasible to combine certain activities, (ii) differences among task lengths, (iii) precedence relationship
Steps: (i) Identify "work elements" or "activities"; (ii) Identify "precedence relationships", (iii) Determine "desired output rate", (iv) Determine "cycle time", (v) Calculate "theoretical minimum # of WSs" and (vi) Evaluate three related goals

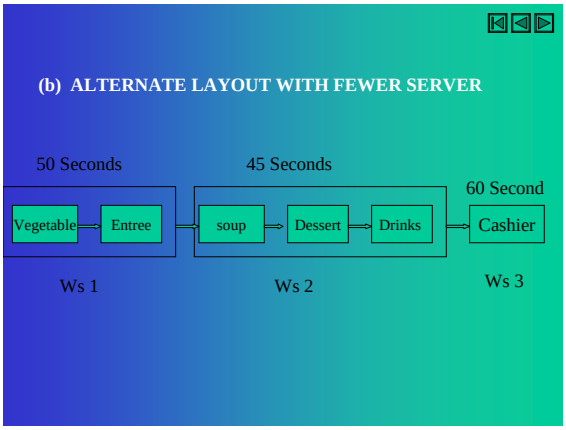
Cycle Time (CT) is the time between completing the two consecutive units. A line's cycle time is determined by the workstation taking the longest time. It also determines the rate of output for the line. Two types: (i) minimum possible cycle time (CT_{min}); (ii) maximum possible cycle time (CT_{max})

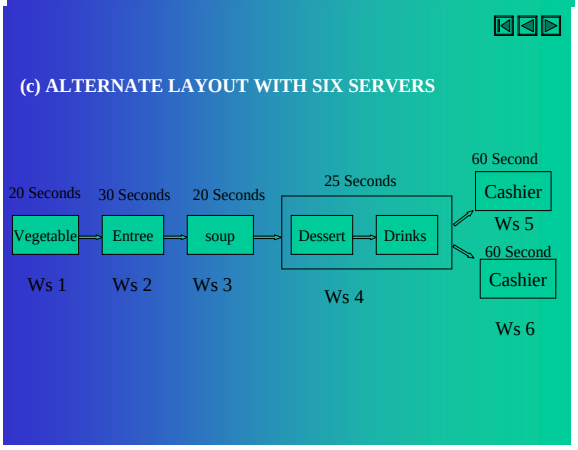
Takt Time is determined by the customer and is the speed at which completed unit must be produced to satisfy market demand

Lead (or Flow) Time (LT) is the total amount of time spent in the system including queue time and set up time.

Output Capacity = Operating Time (OT) / Cycle Time







Theoretical Minimum Number of Stations = Sum of Activity Times/ Cycle Time = $\Sigma A_i/CT$

Three Related Goals:

1. Minimize Idle time per cycle = $(N * CT) - \Sigma A_i$
2. Minimize percentage of Idle time (%) = $\{(N*CT) - \Sigma A_i\}/(N*CT)$
3. Maximize efficiency (%) = (100 - percentage of Idle time)

Where N = Number of Stations; CT = Cycle Time, Ai = Time of i^{th} activity

Product-Oriented Layout Problem: Using Longest Processing Time (LPT) Rule

GIVEN:
1. OPERATING TIME = 480 MINUTES/DAY
2. DESIRED OUTPUT = 80 UNITS/DAY

WHAT IS THE CYCLE TIME?

Job Activites, Times, and Precedence Relationships

Activity *i*	Activity Time A*i* (minutes)	Immediate Predecessors
1	.8	--
2	3.1	--
3	.6	1
4	1.2	1, 2
5	2.0	2
6	2.4	4
7	4.2	2, 4
8	.8	5
9	1.6	6
10	2.2	3, 7, 9
11	1.0	8, 10

Sort activities as per LPT Rule:

How to sort activities?

10	2.2	3, 7, 9
5	2.0	2
9	1.6	6
4	1.2	1, 2
11	1.0	8, 10
1	0.8	-
8	0.8	5
3	0.6	1

AGGREGATE PLANNING

Concept

Aggregate planning is concerned with matching supply and demand of output over the medium time range, up to approximately 12 months into the future.

- The planning is done for a single overall measure of output or, at the most, a few aggregated product categories.

Characteristics

1. A time horizon of 12 months, with updating of the plan on a periodic basis
2. An aggregate level of product demand
3. The possibility of changing both supply and demand variables
4. A variety of management objectives e.g., ...
5. Facilities that are considered fixed

AGGREGATE (CAPACITY)PLANNING

- **Managing Demand**
  Pricing; Advertising and promotion; Backlogging or reservations; and Developing complementary products

- **Managing Supply**
  Hiring and layoff of employees; Using overtime & under time; Using part-time of temporary labor; Carrying inventory; Subcontracting; and Making cooperative arrangements

BASIC STRATEGIES ==> Two extreme strategies

- **Level Strategy** "the rate of regular time output is constant"
  -variations in demand are absorbed by using inventories, overtime, subcontracting etc.
  --unions favor this strategy.

- **Chase Strategy** "work force level is changed to meet the demand"
  -work force observes all changes in demand
  -inventories can be kept very low

- **Choosing a strategy -> A Combination of these two strategies**

- **Characteristics**
  - Level of labor skill required
  - Compensation Rate
  - Labor turnover
  - Hire-fire costs
  - Working Conditions
  - Job Discretion
  - Training required per employee
  - Error Rate
  - Amount of supervision required

AGGREGATE PLANNING STRATEGIES

Beginning Inventory:	50,000 gallons
Production / Worker / Month:	10,000 gallons
Initial Number of Workers:	40 workers
Hiring Costs:	$1000 per worker
Layoff Costs:	$2000 per worker
Unit Costs:	$2 per gallon
Overtime Unit Cost:	$2.15 per gallon
Carrying Costs / Unit / Month:	3% of the unit cost
Desired Ending Inventory:	50,000 gallons

AGGREGATE PLANNING: Strategy

Month:	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
RESOURCES:													
Regular Workers:													
Units Produced:													
Sales Forecast:	**300**	**300**	**350**	**400**	**450**	**500**	**650**	**600**	**475**	**475**	**450**	**450**	**5400**
Ending Inventory:													
COSTS:													
Overtime:													
Hire / Layoff:													
Carrying Costs:													
Total Costs:													

AGGREGATE PLANNING: Strategy

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Regular Workers:													
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Ending Inventory:													
COSTS:													
Overtime:													
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Carrying Costs:													
Total Costs:													

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COSTS:													
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Total Costs:													

AGGREGATE PLANNING: **Strategy**

Month:	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
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Ending Inventory:													
COSTS:													
Overtime:													
Hire / Layoff:													
Carrying Costs:													
Total Costs:													

AGGREGATE PLANNING: **Strategy**

Month:	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
RESOURCES:													
Regular Workers:													
Units Produced:													
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Ending Inventory:													
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Overtime:													
Hire / Layoff:													
Carrying Costs:													
Total Costs:													

ENTER PRISE RESOURCE PLANNING SYSTEM

An Enterprise Resource Planning (ERP) system, a packaged system, is a large, integrated system handling business processes and data storage for a significant number of business units and business functions.

SAP R/3 is a typical and the most popular ERP system - a large transaction-oriented software package and utilizes client/server computer technology. It has four application suits: financial, human resource, manufacturing and logistics, and sales and distribution. Each of these has numerous application modules. For example, Manufacturing application include the following application modules:

PP-BD: Basic data for production
PP-SOP: Sales and operations planning (aggregate planning)
PP-MP: Master planning (Master Production Schedule)
PP-MRP: Material requirement planning
PP-CRP: Capacity requirement planning
PP-SFC: Production orders (Shop floor control - production scheduling)
PP-PC: Product costing
MM : Material Management
QM : Quality Management

Important elements of ERP

1. *Data standards* - the use of common field definitions and codes across different parts of the organization and across the enterprise.
2. *Process standards* -the standardization of business processes across operating units.
3. *Process restrictions* - a firm must fit their processes to one of the options provided by ERP package based on best practices.
4. *Integration*- linking together of the information and processes of distinct subsets of the organization (between functional areas and/or operating units i.e. plants)

Advantages:

1. Provides integration of the supply-chain, production, and administrative process.
2. Creates commonality of databases.
3. Can incorporate improved, reengineered, “best processes.”
4. Increases communications and collaboration among business units and sites.
5. Has a software database that is off-the-shelf coding.
6. May provide a strategic advantage over competitors.

Disadvantages:

1. Is very expensive to purchase, and even more costly to customize.
2. Implementation may require major changes in the company and its processes.
3. Is so complex that many companies cannot adjust to it.
4. Involves an ongoing process for implementation, which may never be completed.
5. Expertise in ERP is limited, with staffing an ongoing problem.

Subsystems of ERP: Aggregate planning, Master production scheduling, Material requirement planning, Resource requirements planning, rough-cut capacity planning, capacity requirements planning

Aggregate Plan

Months	Jan	Feb	Mar	Apr	May	Total
Planned Output	200	300	400	400	350	1650

Master Schedule

Months	Jan	Feb	Mar
Planned Output			
Push	100	100	100
Self-propelling	75	150	200
Riding	25	50	100
Total	200	300	400

Table 1: Aggregate Plan and Disaggregation of Aggregate Plan

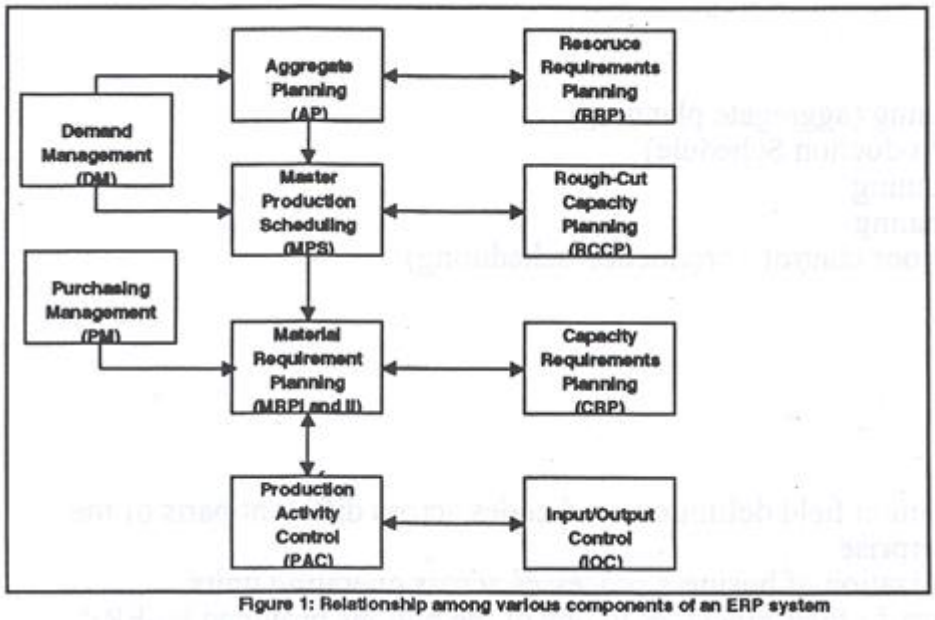


Figure 1: Relationship among various components of an ERP system

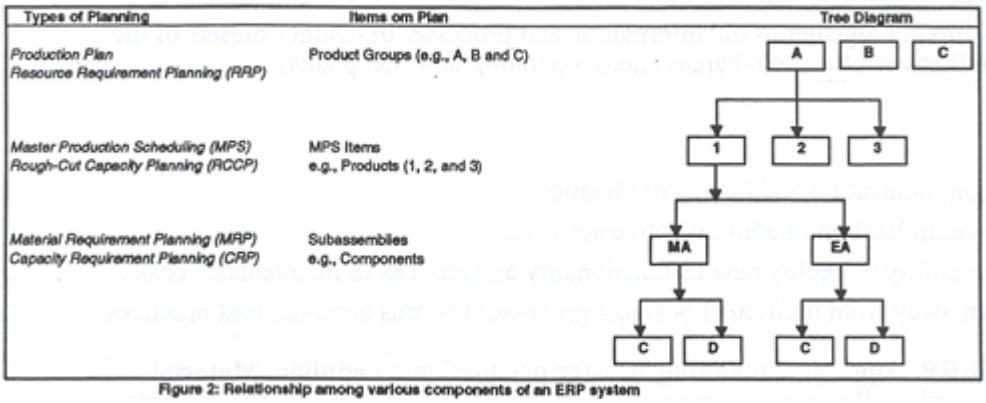
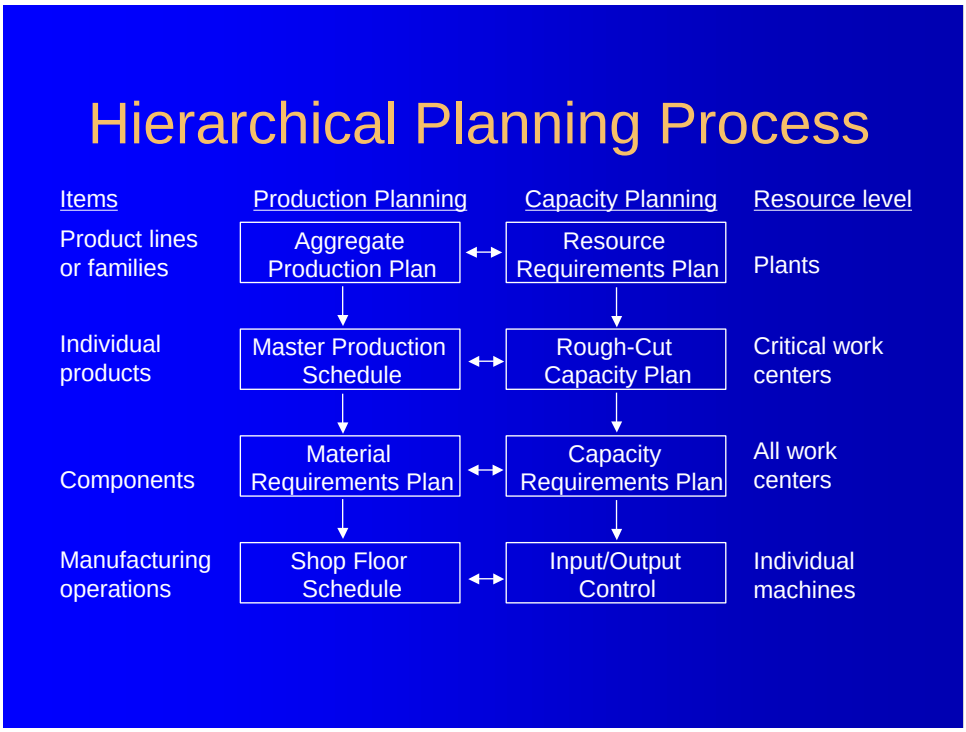


Figure 2: Relationship among various components of an ERP system

Stages	Input	Output
Resource Requirement Planning (RRP)	*Production Plan (product groups) Resource Profiles*	*Resource requirements by months*
Rough-Cut Capacity Planning (RCCP)	*Master Production Schedule Product Load Profile with Lead time offsets*	*Rough-cut capacity requirements by weeks*
Capacity Requirements Planning (CRP)	*Material Requirement Planning Capacity available Inventory status*	*Capacity requirement plans by week or day*

Table 2: Capacity Planning Stages

A key part of the system is shop feedback which is done at on-line terminals.



Capacity Planning - Counterpart of Aggregate Planning

The function of capacity planning is interrelated with that of production planning. It is useful to view the relationship between these two planning functions over a few time ranges: long term to short-term.

Resource requirements planning

The RRP is an Aggregate Capacity Planning which determines the resource requirements in the following manner:

1. Obtain the planned production for each product group by period
2. Determine the resource (work centers) profile for each product group
3. Determine the material profile for each product group
4. Using the planned production, resource profile, and material profile, calculate the resource and material requirements.

Rough-cut capacity planning

Rough-cut capacity planning (RCCP) is an activity that involves an analysis of the master production schedule to determine the implied capacity requirements for critical manufacturing facilities. RCCP

1. Validates the MPS with respect to capacity
2. Serves as the basis for negotiations
3. Indicates the production planning strategy

Capacity requirement planning

The CRP system developed by Honeywell, marketed by Bull Corp. of France, is used to schedule intermittent-process manufacturing facilities. The computerized CRP system performs the following functions:

1. developing a capacity requirement plan,
2. scheduling and dispatching individual orders, and
3. shop floor control reporting

SUPPLY CHAIN MANAGEMENT

Definition of a Supply Chain
The sequence of business processes and information that provides a product or service from suppliers through manufacturing and distribution to the ultimate consumer.

Definition of Supply Chain Management
Planning, designing, and controlling the flow of information and materials along the supply chain in order to meet customer requirements in an efficient and effective manner, now and in the future.

Characterizing the Supply Chain {See Table 11.1 (pp. 435)}
A supply chain must be appropriate to the business strategy of the firm:
Cost Leadership Strategy

- Functional products, such as those sold in retail stores
- Physically Efficient Supply Chains

Differentiation Strategy

- Innovative products
- Market-Responsive Supply Chains

Reasons for Increasing Importance of SCM Concepts

- A great opportunity to reduce the total supply chain cycle time
- Internal chain is improved and it is necessary to reach external links
- Systems thinking suggests that we should optimize the whole supply chain

Phases of Supply Chain Management

- Successful SCM requires a high degree of functional and organizational integration.
- Firms progress through a series of phases:
  Phase 1:Each external & internal entity in the firm controls its own inventories.
  Phase 2: The firm initiate internal integration by combining primarily purchasing, production and distribution into a material management/ logistics management function and seek cooperation with other functional areas to create a strong internal supply chain.
  Phase 3: The internal supply chain is extended to embrace suppliers and customers, thereby linking the internal supply chain to the external supply chain.

Cooperative vs. Non-cooperative SC members

- If the members of the supply chain are cooperating to make more money, then the chain can be managed using DBR (drum/buffer/rope) methodology of TOC

- If the members are non-cooperating, then each member must buffer its own operations by having more than one source of supply and one customer

INVENTORY MANAGEMENT

Definition of Inventory

A stock of materials used to facilitate production or to satisfy customer demands. Inventories include raw materials, work-in-process, subassemblies and finished goods.

Purpose of Inventories: To uncouple the various phases of operations

1. To protect against uncertainties
2. To allow economic production & purchase
3. To cover anticipated changes in demand/supply
4. To provide for transit

INDEPENDENT vs. DEPENDENT DEMAND

"Independent demand" is influenced by market conditions outside the control of operations; it is therefore independent of operations. Finished goods inventories and spare parts usually have independent demand.

When demand for items is derived from plans to make certain products, those items are said to have **"dependent demand"**. Raw materials, subassemblies, and component parts used in producing a finished product have dependent demand.

TOOLS & TECHNIQUES FOR

1. **Independent Demand Management:**
   - Fixed order quantity model (EOQ)
   - Statistical order point methods

2. **Dependent Demand Management**: Material Requirement Planning

COMPARISON OF MRP AND ORDER-POINT SYSTEMS

	MRP	Order Point
1. Demand	Dependent	Independent
2. Order Philosophy	Requirements	Replenishment
3. Forecast	Based on MPS	Based on past Demand
4. Control concept	Control all items	ABC analysis
5. Objectives	Meet manufacturing need	Meet customer needs
6. Lot sizing	Discrete	EOQ
7. Demand Pattern	Lumpy but predictable	Random
8. Types of Inventory	WIP and Raw materials	Finished goods and spare parts

MATERIAL REQUIREMENT PLANNING

Effective management of dependent demand inventory requires that the operations manager know the:

1. Master production schedule (What is to be made and when)
2. Specifications or bill of material (material and parts required to make the product)
3. Inventory availability (what is in stock)
4. Purchase orders outstanding (What is on order)
5. Lead times (how long it takes to get various components

MRP Structure (Examples2 - 6) and Figures (14.4 - 14.7)

TYPES OF MRP SYSTEMS:

1. **MRP I - material requirement planning**: It is an inventory control system which releases manufacturing and purchase orders for the right quantities at the right time to support the master schedule.
2. **Closed Loop MRP:** It is an information system used to plan and control inventories, and capacities in manufacturing companies. It controls both inventories and capacity in an attempt to smooth the workload. How? i.e., using the concepts of overlapping, operations splitting, and lot splitting.
3. **MRP II - Manufacturing Resource Planning**: It is used to plan and control all manufacturing resources: inventory, capacity, cash, personnel, facilities, and capital equipment. It is a manufacturing information system that integrates marketing, finance, and operations.
4. **ERP** – see previous discussion on ERP

MRP Chart							Holding Cost	Set up Cost
	Period							
Production Data	**1**	**2**	**3**	**4**	**5**	**6**		
Gross requirements								
Scheduled receipts								
Projected ending inventory								
Net requirements								
Planned order releases								
Planned order receipts								
Notes:								
Lead time:								
Lot Size Rule:								
BOM Level:								
Quantity on hand:								

MRP Chart						
	Period					
Production Data	**1**	**2**	**3**	**4**	**5**	**6**
Gross requirements						
Scheduled receipts						
Projected ending inventory						
Net requirements						
Planned order releases						
Planned order receipts						
Notes:						
Lead time:						
Lot Size Rule:						
BOM Level:						
Quantity on hand:						

MRP Chart							Holding Cost	Set up Cost
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Planned order receipts								
Notes:								
Lead time:								
Lot Size Rule:								
BOM Level:								
Quantity on hand:								

The TOC Approach to Inventory Management:

DBR Scheduling and Reduce buffer size on non-bottleneck machines

Background

The drum-buffer-rope (DBR) methodology, now being implemented in a large number of manufacturing organizations, enables an improved scheduling and decision-making on the plant floor. Based on the theory of constraints (TOC), drum-buffer-rope places its focus on a system's constraints, their exploitation based on the goal of the organization, and the effects of exploiting these constraints on the non-constraints in the system.

The concept of drum-buffer-rope was developed along with the philosophy of optimized production technology (OPT). Goldratt contends that the focus of optimized production technology is to identify system bottlenecks, with the objective of scheduling efforts on these bottlenecks. OPT philosophy focuses on **5 steps (Five Focusing Steps of TOC)**. The term "bottleneck" is replaced by the broader term "constraint". Constraint is defined as anything that limits the system form achieving higher performance relative to its goal.

Overview of DBR

Drum- A "drum" is the exploitation of the constraint of the system; the constraint dictates the overall pace of the system. The constraint may be a resource, market demand, scarce raw material or management policy. A drum includes a detailed schedule of the constraint in order to ensure it's exploitation.

Buffer-A "buffer" is basically protection time. Buffers are used to protect something from adjacent disruptions. The buffer is expressed in time units, since the parts will reach the protected area before they are scheduled to be processed. Disruptions can stem from things like breakdowns, absenteeism, fluctuations in setup times, unreliable vendors, scrap, or unavailability of certain

resources being used in other jobs. Buffers are planned only in critical areas that need to be protected, such as the drum. There are three types of buffers:

1. Constraint buffer- the purpose of this buffer is to protect the constraints' operations. This buffer should allow for a fairly long, yet realistic lead-time to the constraint.

2. Shipping buffer- The purpose of this buffer is to protect the due dates from disruptions on the way from the constraint buffer to the shipping dock.

3. Assembly buffer- the buffer is used to protect a 'leg" of e process that carries the non-constrained parts. These 'legs" of the operation need buffering, otherwise wise costly constraint parts will have to waft for the non-constraints to reach the assembly.

Rope- A "rope" is the mechanism to force all the parts of the system to work up to the set by the drun3, and no more. This is done by creating a detailed schedule for releasing raw-materials into the shop floor.

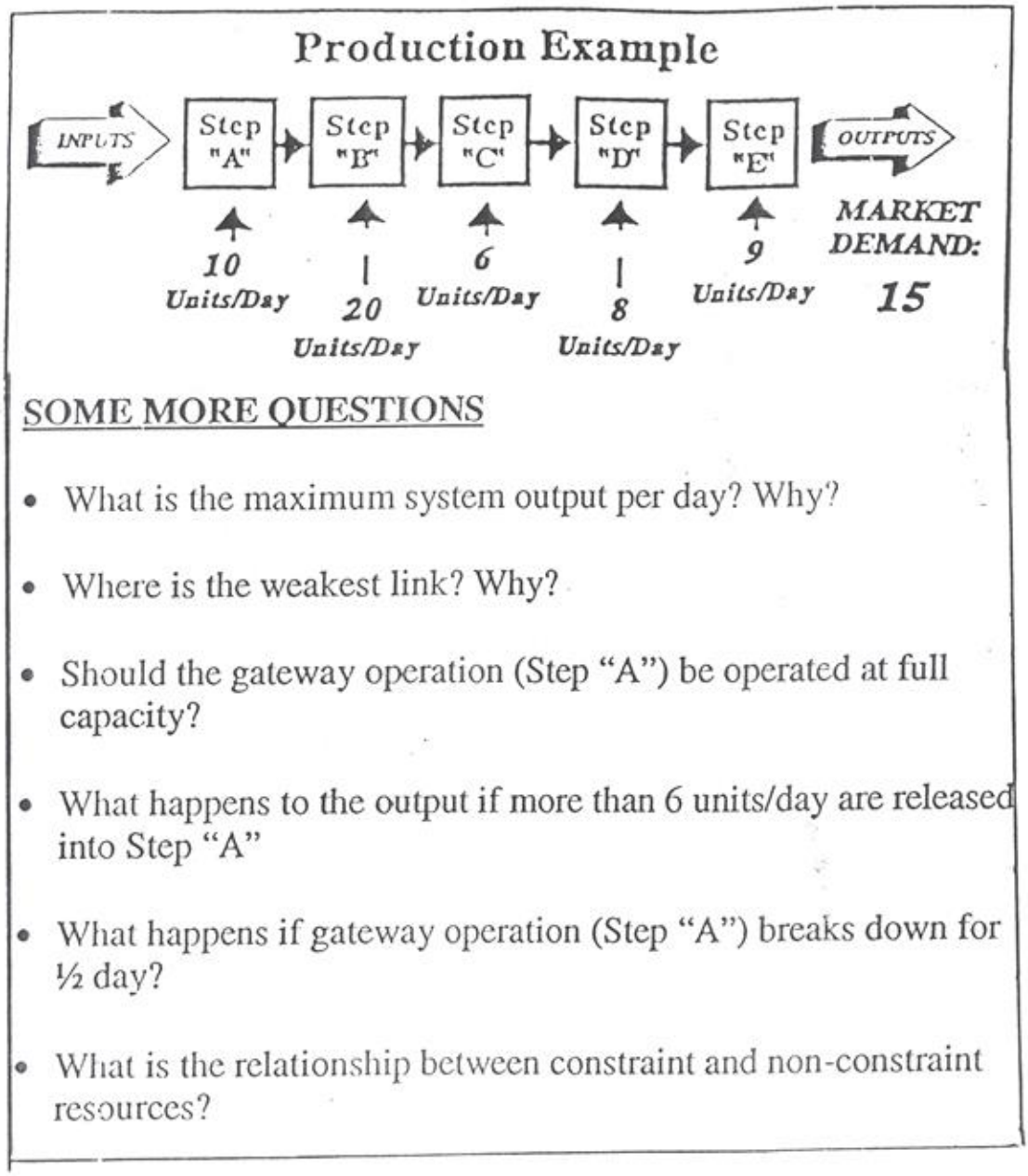
Three steps in developing DBR (To be repeated every time planning process is executed)

Step 1. Schedule the constraints along with the master production schedule (MPS). The MPS is subjected to the capabilities of the system constraints only. Next, exploit the constraints according to the organizational goal.

Step 2. Determine the buffer sizes.

Step 3. Derive the materials release schedule according to steps I and 2.

Source: "Drum-Buffer-Rope Shop Floor Control" by E. Schragenhein and Boaz Ronen, Production and Inventory Management Journal, Third Quarter, 1990, pp. 18-22



LEAD TIME MANAGEMENT

Manufacturing Lead time: The length of time between the release of an order to production and shipment to the final customer or receipt into the finished goods inventory.

Its components (pp. Chapter 28 of The Goal)
It consists of wait time, queue time, setup time and process time.

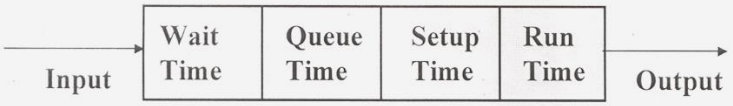
What is the relationship between lead time management and Inventory?

Manufacturing lead time:

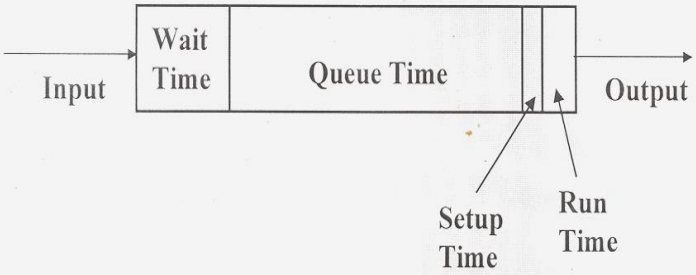
The length of time between the release of an order to production and shipment to the final customer or receipt into finished goods inventory.

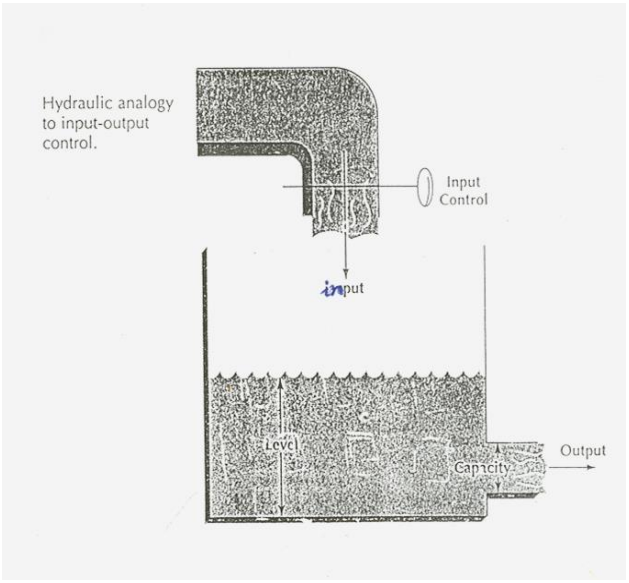
APICS Dictionary, 8th Edition

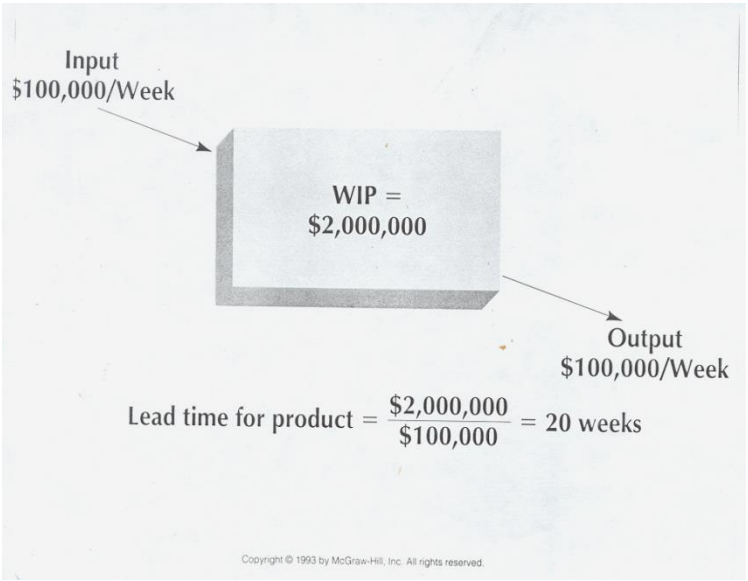
The Components of Lead Time

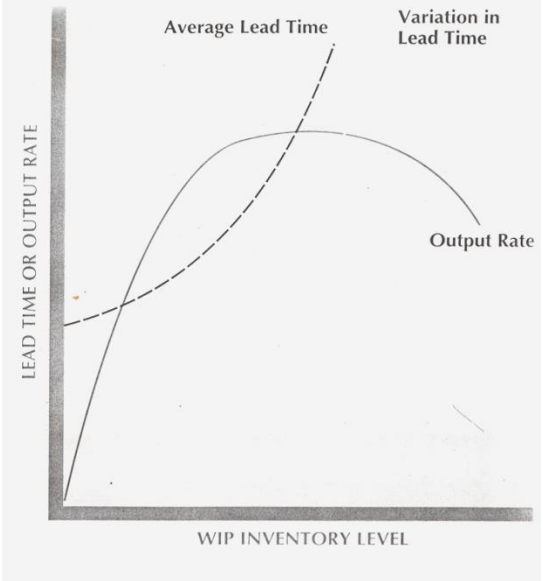


A More Realistic View of Lead Time









Just-In-Time/Lean Systems

The JIT system, developed at the Toyota Motor Company in Japan in the mid-1970s as Toyota Production System (**TPS**), has been implemented at many of the best US corporations.

The major application to date of JIT has been in repetitive industries: auto, electronics, machinery, appliances, motorcycles, and so on. Repetitive manufacturing is the production of standardized discrete products in high volume.

The purpose of JIT is to produce (or deliver) the right items in the quantity needed by subsequent production processes (or customers) at the time needed.

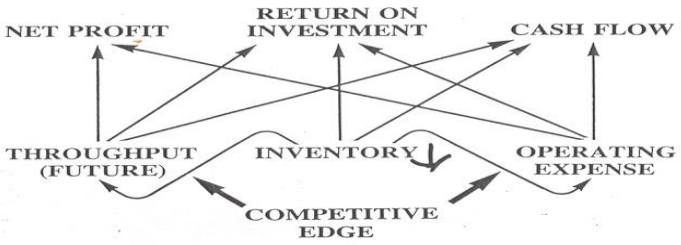
Three fundamental concepts of JIT include:

- eliminating waste, (7 Wastes and 5Ss)
- reducing variability (TQM, SPC, SS, Poke Yoke, Jidoka)
- pulling materials – (Improve Throughput)

Elements of JIT Systems

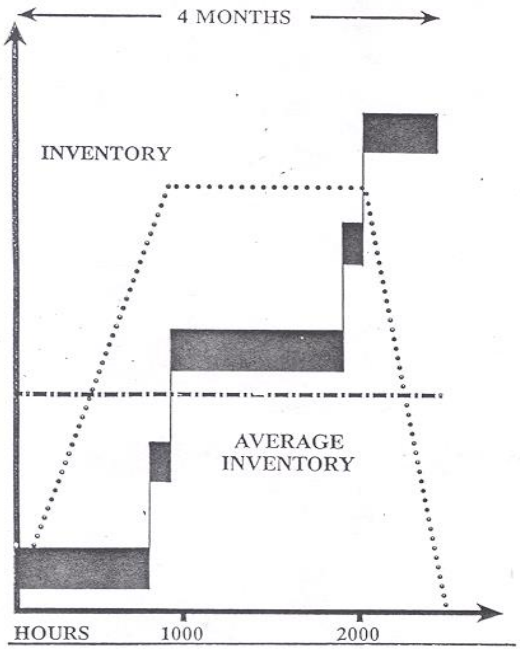
1. A pull system of moving goods
2. A fixed, steady rate of production (Kanban; Takt Time)
3. **Low inventories**
4. Small lot sizes
5. Quick, low cost setups
6. **Cellular layout**
7. **Preventive maintenance** workers
8. **Multi-functional workers**
9. **A cooperative spirit**
10. **High quality levels**
11. **Reliable vendors**
12. Problems solving
13. Continuous improvement

THE COMPETITIVE EDGE IMPACT: OPERATIONAL MEASURES AND THE BOTTOM LINE



A ROLE FOR REDUCED INVENTORY?

HIGH-INVENTORY MANUFACTURING



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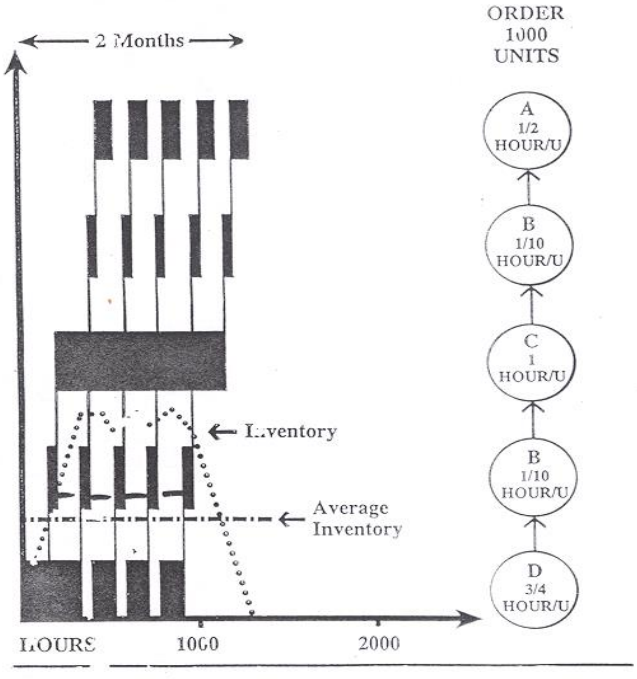
LOW-INVENTORY MANUFACTURING



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COMPARISON OF JIT, MRP AND TOC

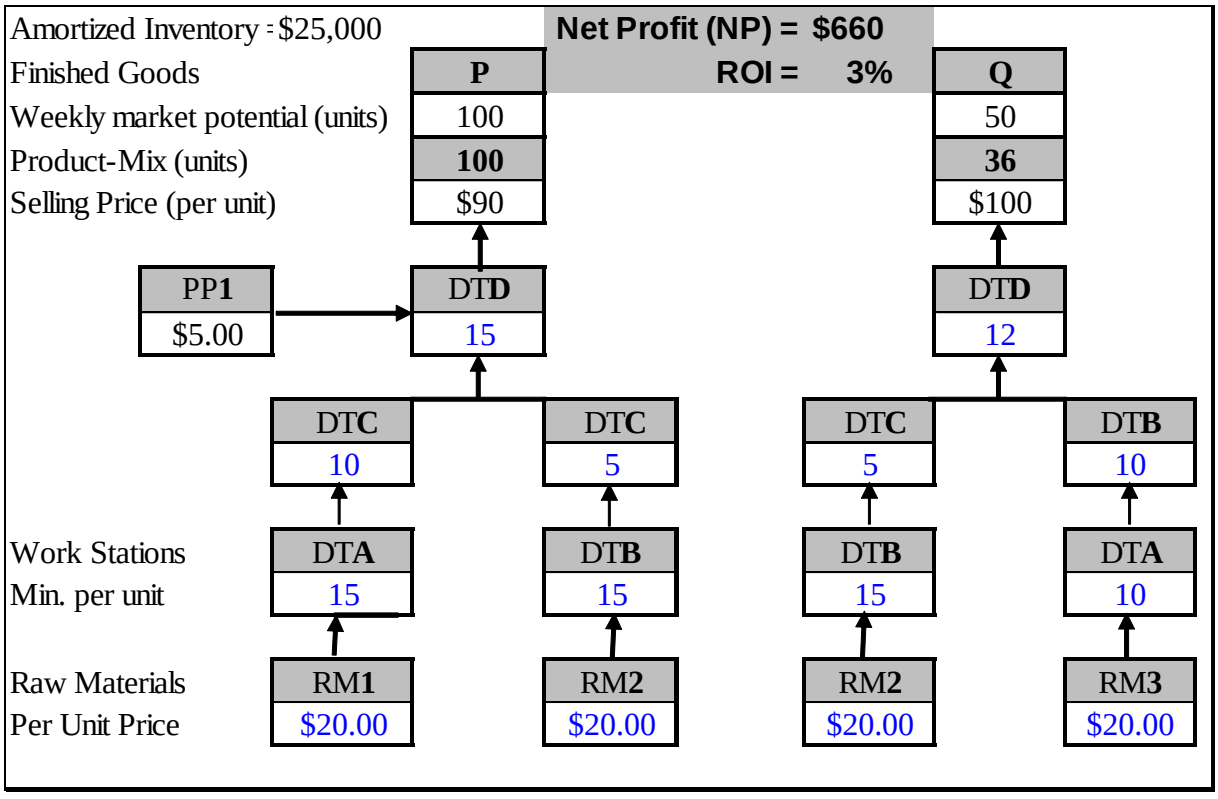
	JIT	MRP	TOC
The Goal (TIOE)	Inventory reduction is #1 goal	OE reduction is #1 goal	???
Business strategy	Cost Leadership	Differentiation	
Mfg. Process	Flow Shop	Job Shop	
Inventory	A liability. Every effort must be extended to do away with it.	An asset. It protects against forecast errors. Some safety stock needed to cover uncertainties.	
Lot sizes	Immediate needs only. Minimum replenishment quantity is desired for both manufactured and purchased parts.	Necessary to scheduling. Select a lot size to balance setup costs against holding costs as a general principle. The lot size should not be too large or too small.	
Setups	Make insignificant. Requires either extremely rapid changeover to minimize the impact on production or the availability of extra machines already set up. Fast changeover permits small lot sizes to be practical and allows a wide variety of parts to be made frequently.	Low priority. Maximum output is the usual goal. Rarely does similar thought and effort go into achieving quick changeover.	
Queues	Eliminate them. When problems occur, identify the causes and correct them. The correction process is aided when queues are small	Necessary investment. Permit succeeding operations to continue in the event of a problem with the feeding operation.	
Vendors	Coworkers, part of the team. Multiple deliveries for all active items are expected daily. The vendor is treated as an an extension of the factory.	Adversaries. Multiple sources are the rule, and it's typical to play them off against one another.	
Quality	Zero defects. If quality is not 100%, production is in jeopardy.	Tolerate some scrap. We usually track what the actual scrap has been and develop formulas for predicting it.	
Equipment Maintenance	Constant and effective. Machine breakdowns must be minimal.	As required. Not critical because we have queues available.	
Lead Times	Keep them short. This simplifies the job of marketing, purchasing and manufacturing as it reduces the need for expediting.	The longer the better. Most supervisors and purchasing agents want more lead time, not less.	
Employees	Management by consensus. Changes are not made until consensus reached whether or not a bit of arm twisting is involved. Vital ingredient of "ownership" is achieved.	Management by edict. New systems are installed in spite of workers, no thanks to the workers. Concentrate then on measurements to determine whether or not They're doing it.	

What is the theory of Theory of Constraints?

- A chain is as strong as its weakest link (See Figures 1 and 2 at Page 18)
- 3Ms of TOC (termed as Throughput Orientation)
    1) Mindset (The Goal and Necessary Conditions, Throughput-world thinking)
    2) Measurements (T, I, OE and its relationship with NP, CF, ROI))
    3) Methodology (Five Focusing Steps, drum-buffer-rope scheduling)
- Higher the degree of Throughput Orientation (TO), Higher will be the business performance of a company

PERFECT PLANT: THE PQ COMPANY
HOW MUCH NET PROFIT PER WEEK CAN BE MADE?

- **Two very good products: P and Q (**with known weekly demands, selling prices, routing and processing times in each department as shown below).
- **Four very different skill sets in four departments: DTA, DTB, DTC, DTD (**in each department there is only one machine i.e., 480x5 = 2,400 minutes of capacity available in each department).
- Weekly Operating Expenses for running this company = $6,000



3Ms OF THEORY OF CONSTRAINTS

MINDSET

One Goal: To make more money now as well as in the future

Two necessary conditions:

1. To provide a secure and satisfying environment for employees now as well in the future.
2. To provide satisfaction to the market now as well as in the future.

< What is the difference between the goal and necessary conditions? >

MEASUREMENTS

Three operational measures:

1. **Throughput (T) -** The rate at which the system generates money through sales.
2. **Inventory (I) -** All the money invested in purchasing things the system intends to sell.
3. **Operating Expenses (OE) -** All the money the system spends in turning **I** to **T**.

< What is so unconventional about these TOC Measures? >

Two performance measures:

1. **Productivity:** T / OE 2. **Turnover:** T/I

Three financial measures:

1. **Net Profit (NP):** T - OE; 2. **Return on Investment (ROI):** NP/I; 3. **Cash Flow (CF)**

METHODOLOGY

Focusing Steps of TOC:

1. IDENTIFY the system's constraint(s).
2. Decide how to EXPLOIT the system's constraint(s).
3. SUBORDINATE everything else to the above decision.
4. ELEVATE the system's constraint(s).
5. If in the previous steps a constraint has been broken, go back to step 1, but DON'T allow INERTIA to cause a system constraint.

TOC Guidelines for managing Bottleneck (Importance of Bottleneck Management)

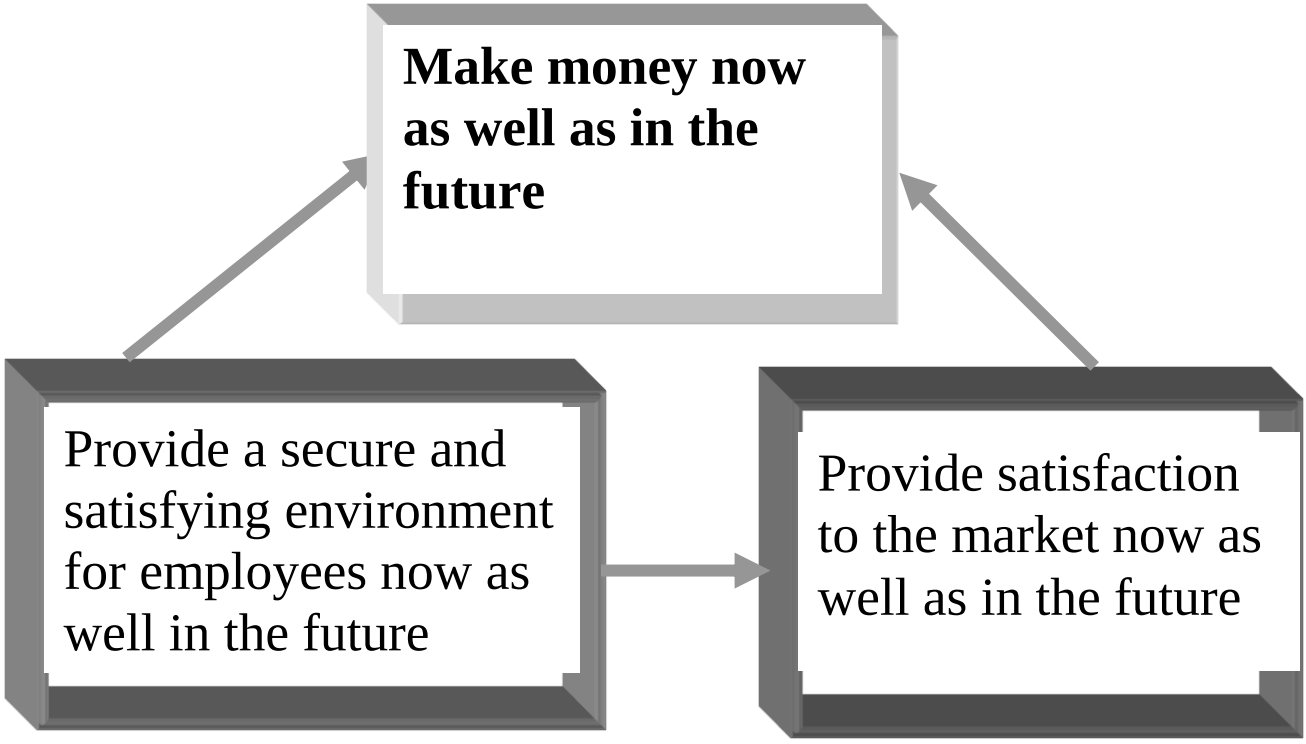
1. *The sum of local optimums is not equal to the optimum of the whole*.
2. *The level of utilization of a non-bottleneck resource is controlled by other constraints within the system*.
3. *Resources must be utilized, not simply activated*. *Utilization* refers to the activation of a resource that contributes positively to the performance (Throughput) and *activation* refers to the employment of a resource to process materials.
4. *The marginal value of time at a bottleneck resource is equal to the throughput rate of the products processed by the bottleneck.* In other words, an hour lost at a bottleneck is an hour lost for the total system.
5. *The marginal value of time at a non-bottleneck resource is negligible*. In other words, an hour saved at a non-bottleneck is a mirage.

TOC-Based Change Management Process: Thinking Processes and the Tools

1. What to change?	Current Reality Tree
2. To what to change to?	Evaporating Clouds, Future Reality Tree
3. How to cause the change?	Prerequisite Tree, Transition Tree

1st M of TOC(MINDSET) - WHAT IS THE GOAL?

- **make money now as well as in the future**
- provide a secure and satisfying environment for employees now as well in the future
- provide satisfaction to the market now as well as in the future



2nd M of TOC (MEASURES)

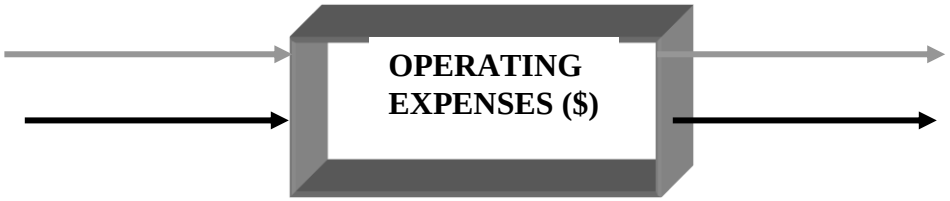
- Throughput (T): the rate at which the system generates money through sales.

➔ ... the money ***coming into*** our organization

➔ Inventory (I): all the money that the system has invested in purchasing things it intends to sell.
... the money ***currently inside*** the system

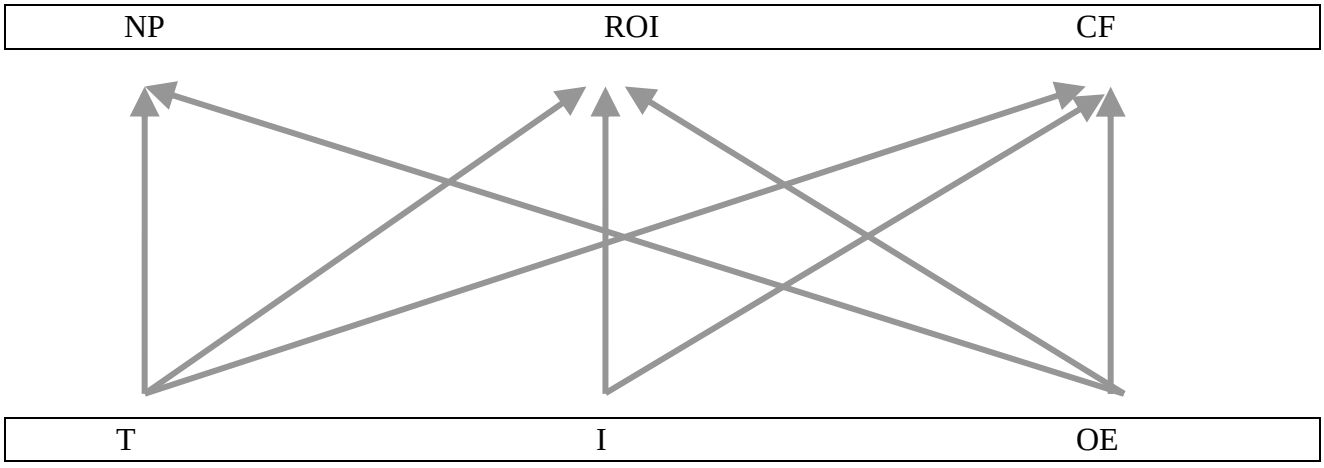
- Operating Expenses (OE): all the money that the system spends in order to turn "I" into "T".

➔ ... the money ***going out*** to make "T" happen



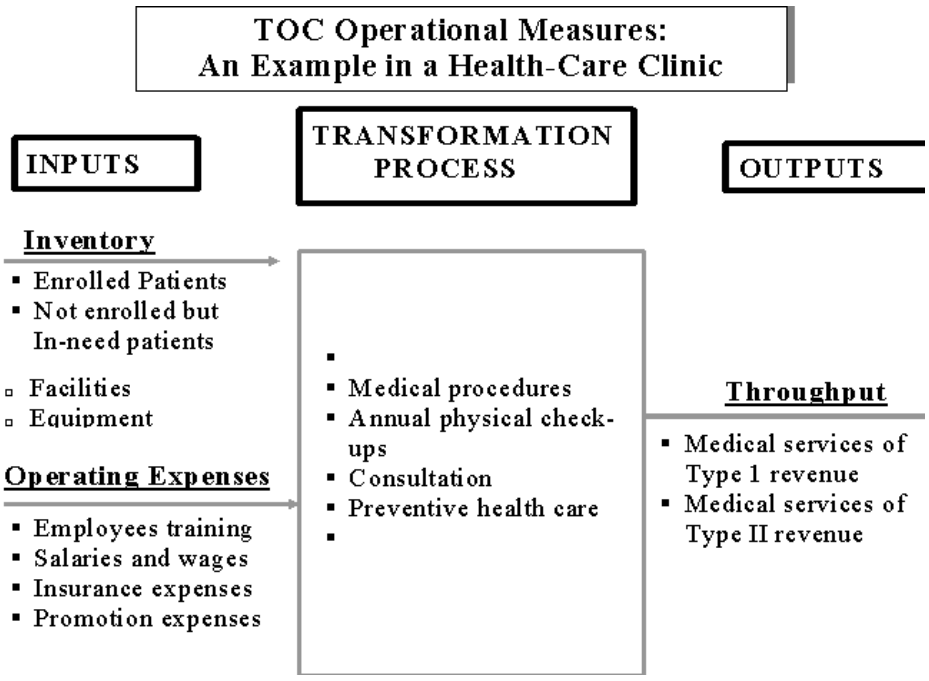
What is unconventional about these measures?

What is their relationship with Financial Measures: Net Profit (NP); Return On Investment (ROI) and Cash Flow (CF)



- Net Profit (NP) = T - OE
- Return On Investment (ROI) = NP/I
- Cash Flow (CF) = Same as Net Profit
- Productivity = T/OE
- Turnover = T/I

(Note: See page 69 of these notes for more details)



The Manual Dice Game

Recall the Dice Game we played in this course. At the end of 10 days (2 weeks) play, (i) How many products did you produce and ship (Throughput)? (ii) How much Total WIP did you observe in the system?
Let Throughput = 24 and WIP = 12, Calculate the following Financial and Operational Measures:

Suppose,

- Selling Price (SP) = $500 per unit
- Raw Material Cost (TVC) = $200 per unit
- Period Expenses (PE) = $2,500 per week
- Inventory (WIP) Carrying Cost (CC) = $80 per unit/month i.e., $20/week (5 days a week)
- Investment in Tools and Machines = $50,000

Using your data for 10 days (i.e., 2 weeks' play), Calculate

1. Total Throughput (Selling Price - Raw Material Cost) =
2. Operating Expenses (Period Expense + WIP Inventory Carrying Cost) =
3. Inventory (Ending WIP x Raw Material Cost) =
4. Total Investment (Equipment + Inventory) =
5. Net Profit (Throughput – Operating Expenses) =
6. Return-on-Investment (Net Profit/Total Investment) =
7. Productivity (Throughput/Operating Expenses) =
8. Inventory Turnover (Quantity shipped/Total Ending WIP) =

Cost World	Throughput World
• Focuses on cost reduction as way to improve profits	• Focuses on increasing throughput as way to improve profits.
• Customers and employees are seen as cost reduction opportunities.	• Recognizes necessary conditions of employee and customer satisfaction.
• Does not recognize system constraints.	• Recognizes system constraints.
• Assumes that local optima result in a global optimum.	• Does not seek local optima.
• Measures impact of actions locally.	• Measures impact of actions globally.
• Assumes making money is same as saving money	• Assumes making money means increasing sales (markets/products)

INCOME STATEMENT: GAAP BASIS

Sales (Revenues)	$500,000	
Less: Cost of Goods Sol (DM +DL+OH)	(120,000)	
Gross Margin		$380,000
Less: Selling and Administrative Expenses		(350,000)
Net Profit Before Taxes		$30,000

INCOME STATEMENT: THROUGHPUT BASIS

Sales (Revenues)	$500,000	
Less: Direct Materials	(50,000)	
Throughput		$450,000
Less: Operating Expense (DL+OH)		(420,000)
Net Profit Before Taxes		$30,000

Note: In GAAP-based Income Statement, Cost of Goods Sold includes Direct Material and Direct Labor and Overhead expenses. In TOC-based Income Statement, Direct Labor and Overhead is considered a part of Operating Expenses

TOC Operational Measures: A Quantitative Example (Revised)

Partial Information from Income Statement:

Gross Sales	$200 million
Cost of Goods Sold (COGS)	
Direct (Raw) Material (DM)	
Direct Labor (DL)	
Overheads (OH)	$180 million
Sales and General Administrative (SGA) Expenses	$2 million

Partial Information from Balance Sheet:

Inventory (Traditional)	
Raw material	
Work-in-Progress	
Finished Goods	$100 million
All Other Assets (Equipment, Land & Building etc.)	$110 million

Other important information needed to calculate TOC measures:

Material Content of COGS	44.44% of COGS
Material content of Traditional Inventory	30% of Inventory

TOC Measures:

Throughput (**T**)	= Gross Sales – Truly Variable Costs
Inventory/Investment (**I**)	= Direct Material portion + Other Assets
Operating Expenses (**OE**)	= DL and OH portion of COGS + SGA
Net Profit (NP)	= T – OE
Return on Investment (ROI)	= NP / I
Cash Flow (CF)	= Same as Net Profit (assumes no change in Inventory)
Productivity Ratio (PR)	= T/OE
Inventory Turnover (IT)	= T/I

Throughput Accounting Based Income Statement

Gross Sales	$200 million
Less: Truly Variable Costs	
Throughput	
Less: Operating Expenses	
Net Profit Before Taxes	

3rd M of TOC (METHODOLOGY)

DEPENDENT EVENTS & STATISTICAL FLUCTUATIONS

The Concept of Dependent Events (DE)

The concept of dependent events suggests that one event must take place before another can begin, - i.e., one process depends on another.

The Concept of Statistical Fluctuations (SF)

Statistical fluctuations are the fluctuations in the output rate of a process (or an event) due to many factors such as unreliable equipment, negligence of an employee, poor quality of raw material, etc.

Let us look at The Boy Scout Hiking Example

Let us play a game … THE PRODUCTION DICE GAME

Each station is capable of producing on average 3.5 unit/day (rolling a fair dice). How many units can be shipped in a month (5 days/wk, 20 days/month)?

BOTTLENECK AND NON-BOTTLENECKS RESOURCES

- A bottleneck is any resource whose capacity is equal to or less than the demand placed upon it.
- A non-bottleneck is any resource whose capacity is greater than the demand placed on it.

Which resource determines the "effective capacity" of the plant?

CONSTRAINTS: PHYSICAL AND NON-PHYSICAL

- A constraint is anything in an organization that limits it from moving toward or achieving its goal.
- There are two basic types of constraints:
  - A physical constraint is something like the physical capacity of a machine, also called Bottleneck
  - A non-physical constraint might be something like demand for a product, a corporate procedure, or an individual's paradigm for looking at the world.

Difference between bottleneck and Non-bottleneck resource management:

1. The sum of local optimums is not equal to the optimum of the whole.
2. The level of **utilization** of a non-bottleneck resource is controlled by other constraints within the system.
3. Resources must be utilized, not simply activated. **Utilization** refers to the activation of a resource that contributes positively to the performance (Throughput) and **activation** refers to the employment of a resource to process materials.
4. The marginal value of time at a bottleneck resource is equal to the throughput rate of the products processed by the bottleneck. In other words, an hour lost at a bottleneck is an hour lost for the total system.
5. The marginal value of time at a non-bottleneck resource is negligible. In other words, an hour saved at a non-bottleneck is a mirage.

Five Steps of Focusing : A Process of Ongoing Improvement

1. IDENTIFY the system's constraint(s).
2. decide how to EXPLOIT the system's constraint(s).
3. SUBORDINATE everything else to the above decision.
4. ELEVATE the system's constraint(s).
5. go back to step 1, but DON'T allow INERTIA to cause a system constraint.

(Note: See page 69 of these notes for more details)

Constraints management: recent advances and practices
By Mahesh Gupta
(Published in *International Journal of Production Research, 2003)*

TOC Measures

1. **Throughput (T)** is defined as "the rate at which the system generates money through sales." More specifically, throughput is the selling price minus totally variable costs (i.e., the money not generated by the system e.g., purchased parts and raw materials).

2. **Inventory (I)** is defined as "all the money invested in purchasing things the system intends to sell." More specifically, inventory is synonymous with Investments such as machines, equipment etc., and finished goods and work-in-process inventory is reported at the raw material costs i.e. the value-added component is not recognized.

3. **Operating Expenses (OE)** is defined as "all the money the system spends in turning inventory into throughput." More specifically, operating expenses include wages, salaries, utility expenses, depreciation etc.

Relationship to standard financial measures

- **Net Profit (NP)** = T - OE
- **Return on Investment (ROI)** = (T - OE)/I

Relationship to standard financial measures

- **Inventory Turns** (IT) = T/I
- **Productivity Ratio** (PR) = T / OE

Table 1: Measures of the Theory of Constraints

1. IDENTIFY the system's constraint(s), whether physical or policy constraint.

2. Decide how to EXPLOIT the system's constraint(s). That is, get the most possible from the limit of the current constraint(s); take actions primarily at the constraint(s); reduce the effects of the current constraint(s); and make everyone aware of the constraint(s) and its effects on the performance of the system. No increase in Operating Expenses or Investment

3. SUBORDINATE everything else to the above decision. That is, avoid keeping non-constraint resources busy doing unneeded work, actions primarily at the non-constraint(s).

4. ELEVATE the system's constraint(s). That is, off-load some demand or expand capability; acquire more capacity of the constraint; Incur operating expenses (Tactical action); or make significant investment (Strategic actions).

5. If in the previous steps a constraint has been broken, go back to step 1, but DON'T allow INERTIA to cause a system constraint

Table 2: Five Focusing Steps of Process Improvement

1. **VAT Analysis**: A constraint management procedure for determining the general flow of parts and products from raw materials to finished products (logical product structure). A V logical structure starts with one or a few raw materials, and the product expands into a number of different products as it flows through its routings. The shape of an A logical structure is dominated by converging points. Many raw materials are fabricated and assembled into a few finished products. A T logical structure consists of numerous similar finished products assembled from common assemblies and sub assemblies. Once the general parts flow is determined, the system control points (gating operations, convergent points, divergent points, constraints, and shipping points) can be identified and managed
2. **Drum-buffer-Rope**: The generalized technique used to manage resources to maximize throughput. The drum is the rate or pace of production set by the system's constraint. The buffers establish the protection against uncertainty so that the system can maximize throughput. The rope is a communication process from the constraint to the gating operation that checks or limits material released into the system to support the constraint. Buffers can be time or material and support throughput and/or due date performance. Buffers can be maintained at the constraint, convergent points (with a constraint part), divergent points, and shipping points.
3. **Buffer Management**: A process in which all expediting in a shop is driven by, what is scheduled to be in the buffers (constraint, shipping, and assembly buffers). By expediting this material into the buffers, the system helps avoid idleness at the constraint and missed customer due dates. In additional, the causes of items missing from the buffer are identified, and the frequency of occurrences is used to prioritize improvement activities.

Table 3: Glossary of TOC based operational Terms (adapted from APICS Dictionary)

Operations Management	**Constraints Management Coverage**		
General Topics	**(100%-A full course)**	**(50%-20%)**	**(20%-5%)**
1. Introduction: Definition/History	Introduction: Definition/History	**	*
2. Business and Operations Strategies	The goal and necessary conditions	**	*
Competitive Priorities: D, E, F, Q	Operational Measures: T, I, OE	***	*
3. Operations Management Decisions:			
Product Strategy (Design and Development)	*It's Not Luck* (Goldratt 1994)	*	
Process Strategy	Dependent Events, V-A-T Analysis,	**	
Total Quality Management	An Ongoing Improvement Process	***	*
Statistical Process Control	Statistical Fluctuations	**	
Facility Strategy (Capacity Management)	Constraints and Non-constraints resources	**	*
Layout Strategy	Product-Process Structure	**	
Supply Chain Management	*Necessary But Not Sufficient* (Goldratt et al. 2000)		*
Aggregate Planning/Master Production Schedule	Drum-Buffer-Rope Schedule	***	*
Inventory Management	Buffer Management, Small Batch Production	***	*
Project Management	*Critical Chain* (Goldratt 1998)	*	

Note: one star indicates limited coverage whereas three stars indicate extensive coverage

Table 4: Constraints Management and its coverage in Operations Management

TOC: A theory in operations management

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(Published in *International Journal of Production and Operations Management, 2004, 2008*)

2.1 Why examine TOC as a theory in operations management?

Goldratt (1990 a, b) has proposed the Theory of Constraints *(TOC)* as a theory of managing manufacturing organizations. Goldratt claims that managing manufacturing organizations has now become a science and TOC research provides scientific knowledge base.

This theory is explained in popular novels, The Goal*,* It's Not Luck *and* Critical Chain*, which have had significant sales around the world and, according to anecdotal evidence, have had significant impact on the financial performance of many companies (Wheatley, 1986; Noreen et al., 1996; McMullen, 1998). These business novels have become popular with CEO's (and business school deans) to shop-floor workers (and professors in accounting and operations) and are becoming required readings in the business world as well as in an increasing number of universities throughout the world. Goldratt and many other scholars have written extensively on the various aspects of TOC in OM related journals, academic as well as practitioner (e.g.,* International Journal of Production Research, International Journal of Production Economics, International Journal of Operations and Production Management*, and* Production and Operations Management*). A number of books have also appeared in the popular press, suggesting that TOC is gaining acceptance and popularity among both academics and practitioners (e.g., Umble and Srikanth, 1990; Stein, 1994 and 1996; Kendall, 1997; Dettmer, 1998; and Cox and Spencer, 1998).*

McMullen, in his recent book entitled *Introduction to the Theory of Constraints (TOC) Management System*, states that Goldratt has invented his own expression of the scientific method, the structured TOC thinking processes (TP) which articulate and refine the scientific method more clearly and fully than other "practicing" scientists. The scientific methods of TOC have provided a theory to communicate and enhance the performance of cross-functional teams in business organizations. However, McMullen (1998) also admits that TOC has not been commented on and judged within the scientific peer review community. To our knowledge, no attempt has been made to judge and evaluate the "theory of constraints" as a theory of Operations Management (McMullen, 1998).

2.2. The basic concepts and principles of TOC

The theory of constraints is an evolving management philosophy that recognizes that every organization is built for a purpose and every action taken by any part of the organization should be judged by its impact on the overall purpose (Goldratt, 1990b). TOC has two broad viewpoints: that of the business system and that of an ongoing improvement process itself. As it applies to the business system, TOC emphasizes the following main points:

What is the system's global goal? One of the main assumptions of TOC theory is that every business has the global goal of *making more money now as well as in the future*. More recently, Goldratt (1992) has verbalized this goal having two necessary conditions (i.e., providing a satisfying environment to employees and, as a result, satisfied customers now as well in the future) (see Figure 1). From the performance measurement viewpoint, this goal of making money is relatively easy to measure (as compared to customer satisfaction and employees' security), and therefore, has been used by Goldratt to develop global operational measures.

How should the performance of a system be measured? Another major assumption of TOC theory is that new operational measures must be defined so that the impact of any subsystem (i.e., any process or activity) and any local decision on the global goal of "making money" can be measured. The measures proposed by Goldratt, Throughput, Inventory, and Operating Expenses, are somewhat unconventional. Figure 2 provides the basic definitions and some explanation of these measures. Figure 3 expresses the relationships among the measures as well as the relationships with the traditional financial measures net profit, return on investment and cash flow. This aspect of TOC has been termed "throughput accounting" and has been discussed

extensively in the accounting literature (see for example, Noreen et al., 1996; Dugdale and Jones, 1996; Corbett, 1999).

How can the system be continuously improved? TOC states that every business system has at least one constraint (or at most very few). A constraint is defined as anything that limits the system from achieving higher performance relative to its goal. Goldratt proposed a five-step focusing process for managing constraints and continuously improving the system by employing logistical tools (e.g., V-A-T analysis, drum-buffer-rope planning and control system, and buffer management). Figure 2 explains these steps with examples. This process is used continuously to increase throughput while simultaneously decreasing inventory and operating expenses. This continuous improvement aspect of TOC impacts such core operations management functions as production planning and scheduling, capacity management, inventory management, and continuous improvement.

From the perspective of an ongoing improvement process, TOC suggests that an organization must ask three fundamental questions to direct its improvement process: (i) *What to change?* That is, how do organizations identify the weakest link, i.e., the constraint(s)?, (ii) *What to change to?* That is, once the weakest link is identified, how should organizations strengthen the weakest link by developing good, practical solutions; and (iii) *How to cause the change?* That is, how should organizations implement the solutions.

Although these three questions are not new, Goldratt and his associates have developed a set of techniques, known as the thinking processes, to address them. Figure 5 provides a brief overview of these tools. The thinking processes can be used as standalone tools or as a set of integrated tools. The foundation of the thinking processes is a set of effect-cause-effect diagramming principles. The advocates of TOC claim that the thinking processes can be used to solve virtually any problem anywhere in an organization (for-profit as well as not-for-profit). Recently, new and successful applications in the areas of distribution, sales/marketing, and project management have been demonstrated (see for example Noreen et al., 1996, and Goldratt, 1992 and 1997).

It is worth noting here that the founders of TOC argue that the logistical methods provide solutions to various operations management related problems. These operations management methods were developed in the late 1980s as an application of the thinking processes to operations management problems. Table 1 provides a glossary of these terms from the Dictionary of the American Production and Inventory Control Society (APICS)(Cox et al., 1995).

2.3. What is the relationship between operations management and constraints management?

In this subsection, we discuss the definition of operations management from the TOC perspective and delineate the laws (or principles) and core concepts of TOC, which suggest that constraints management and operations management are closely related.

In general, operations management is defined as a transformation system that converts inputs (such as energy, material, labor, and capital) into products or services. The transformation system consists of a series of processes (or resources), each performing a unique operation in order to build a product or service. The operations function is responsible for *the management of resources* required to produce a product or service, including people, facilities, inventories, processes, and systems. According to the *APICS Dictionar*y (Cox et al., 1995), "Resource management is the planning, effective scheduling, and control of organization resources to produce a product or service that provides customer satisfaction and supports the organization's competitive edges and ultimately the organization's goals." Various characteristics such as price, quality, flexibility, and dependability serve as competitive edges on which organizations focus their resources for continuous improvement and thereby achieve competitive advantages. Corporate, business unit, and functional strategies are developed and their inter-relationships are established in order to achieve an organization's goals. The strategies are translated into tactical and operational plans which, in turn, form the basis for effective scheduling, execution, and control of organizational resources. A brief review of operations management textbooks reveals that some aspects of TOC related to scheduling of constraint resources have been mentioned, but very little (if any) coverage has been provided to the other dimensions of TOC. This suggests that constraints management has not been widely accepted as a recognized theory in operations management.

According to the APICS Dictionary (Cox et al., 1995), constraints management is defined as "the practice of managing resources and organizations in accordance with theory of constraints principles." The main principles of TOC, outlined in Table 2, provide guidelines for managing operations by focusing on the

constraints. The main components of TOC (reviewed earlier) can be presented as an integrated framework consisting of three dimensions (see Figure 6): (i) throughput-world thinking, (ii) the performance measurement system, and (iii) the operational decision making process. These core dimensions of TOC are related to operations management in a meaningful way, as described below.

Throughput-world thinking: The theory of constraints explicitly recognizes that the primary goal of a business organization is to make more money now and in the future (i.e., increasing sales and introducing new products and services). The two necessary conditions (i.e., provide a satisfying environment to employees and have high customer satisfaction now and in the future) set in the marketplace by competitors are recognized as equally important and suggest a shift from "cost-world thinking" (i.e., reducing costs and saving money) toward the "operations profit-chain". This aspect of TOC provides a common mission to be accomplished by the business unit and all functional areas, including the operations function.

Performance measurement process: The various departments or processes of an organization are viewed as a chain of dependent resource links which are managed as a system. The performance of various processes is measured in terms of unique measures (throughput, inventory and operating expenses) that can be used both locally (i.e., for subparts of the system) as well as globally (for the system as a whole). More importantly, these TOC measures are defined precisely and positively related to standard financial measures (Tables 1) as well as standard operational measures (e.g., work-in-process inventory, cycle time, delivery performance, utilization of constraint resource). This dimension of TOC has important implications for the development of specific operational measures for the use on the shop floor such as inventory turns and productivity ratios.

Operational decision making process: The significance of local decisions made across functional areas (and/or processes) is judged in terms of global measures. The growth of current and future money inflows (i.e., throughput) is preferred over reduction in inventory or operating expenses. A system's performance is determined by a set of constraints that govern the system. According to Umble and Srikanth (1997), any specific area, aspect, or process that limits the business's performance from a customer, competitive, or profit point of view is a constraint. In order to realize its goal, an organization must focus on the most binding constraints, i.e., those that most significantly limit the current performance of the system. A process of continuous improvement, known as *the five focusing steps*, is then employed to identify and manage the system constraint resource(s) in order to achieve the organizational goal (Table 2). The implementation of *the five focusing steps* process involves a number of logistical methodologies (e.g., V-A-T logical structure analysis, drum-duffer-rope, and buffer management, discussed in Table 3) to address production process design and analysis, production planning, scheduling Furthermore, specific competitive edges (such as high quality, high product variety, and short lead-time) which are constraining an organization from achieving its goal can also be identified and practical solutions can be developed to gain competitive advantage (Lockamy and Cox, 1994).

Thus, it appears that the concepts and principles of TOC have been developed and applied to a significant number of important operations management decisions. In the next section, we evaluate the theory of TOC using the scientific theory development and control, and inventory management related problems (Cox and Spencer, 1998). (Table 4)

Improving Operations Strategy: Application of TOC Principles in a Small Business

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ABSTRACT
This paper demonstrates how small business managers can create and sustain competitive advantage by applying basic principles of Theory of Constraints (TOC) using a case study on a small family-owned pizza restaurant. TOC five focusing steps were used to reveal the business constraints and practical recommendations were provided that significantly improved throughput, resource utilization, and customer satisfaction without incurring any significant expenses. TOC performance measures encourage small business managers to find innovative ways of increasing throughput instead of simply cutting costs. Positive outcomes in this study demonstrate how small businesses effectively manage their operations and realize benefits using TOC principles.

INTODUCTION

Operating effectiveness, when based on capabilities embedded in company's people and operating processes, can provide the basis for a sustainable competitive advantage. It is imperative for small businesses to configure and manage their operations to support their business strategies and establish themselves as aggressive competitors (Hayes & Upton, 1998). Small businesses that neglect operations functions risk the danger of not staying ahead of the competition. Companies that adopt operations management philosophies such as total quality management (TQM), just-in-time (JIT), and theory of constraints (TOC) are ahead in the game and are reaping benefits. These concepts advocate for a change in the operations management paradigm through continuous improvement and if used effectively help managers indentify their organizational goals and constraints. That in turn leads to better performance and improved solutions (Motwani et al., 1996). The overall objectives of these philosophies are similar i.e., improving profitability of the business and satisfying customer needs, but their focuses differ tremendously: TQM emphasizes doing the right things the first time; JIT stresses lean manufacturing; and TOC concentrates on the constraints-the weakest link in the chain.

The purpose of this paper is to demonstrate how operations can assist small business managers in creating and sustaining a competitive advantage by applying the basic concepts and principles of TOC using a case study. We analyze operations of a small family owned pizza restaurant (we will call it 'The DT Pizza Company' in order to respect the confidentiality of the real business) and apply TOC-based management philosophy to increase operations effectiveness and efficiency, directly resulting in improved financial successes. The remainder of the paper is organized as follows. Section 2 presents a brief review of the literature on TOC. Section 3 expands on application of the theory of constraints in relation to the DT Pizza Company by discussing the organizational mindset as well as the performance measures beings employed there. Section 4 reports analysis and application of the five focusing steps of TOC employed in this study. Section 5 provides the details of the implementation of recommended solutions at the DT Pizza Company, and finally Section 6 concludes with recommendations for further research and application in business world.

2. LITERATURE REVIEW

Theory of Constraints (TOC), an emerging philosophy, was originally developed by Goldratt (1994) to demonstrate how to effectively manage organizations and is based on two assumptions: (1) systems thinking, and (2) constraint management (Breen, Burton-Houle, & Aron, 2002). The primary focus of TOC is on continuous improvement which in turn results in enhanced

organizational performance. A number of studies have been conducted in the past on application, limitations, and beneficial uses of TOC. Lockamy and Cox (1994) discussed the possibility of using basic concepts of TOC as an aid in successful JIT implementation. Atwater and Chakravorty (1995) demonstrated the value of using TOC to implement TQM based quality improvement projects in a manufacturing company. Dettmer (1997) attempted to explain why TQM efforts fail by using the thinking processes of TOC and provided insights on the effective implementation of TQM programs. Mabin and Balderstone (2000), in their review of over 100 TOC applications, reported that on average, inventories were reduced by 49%, production times measured in terms of lead-times, cycle times or due date performance improved by over 60%, and financial performance also improved by over 60%.

Consequently, a growing number of companies in the U.S. and abroad have begun implementing TOC based operations management philosophy. Both books and academic journals have reported cases in which companies have achieved operational excellence by means of focused process improvement and effective management and scheduling of constraint resources (Cox & Spencer, 1998; Spencer, 2000; Kendall, 1997; Noreen et al., 1996; Womack & Flowers, 1999). Recent research on applications of TOC also indicates similar benefits (Boyd & Gupta, 2004; Mabin & Balderstone, 2003; Pegels & Watrous, 2005; Simatupang et al., 2004; Steele et al., 2005; Umble et al., 2006).

However, applications of TOC in the service sector are comparatively restricted. Only few authors have investigated and provided evidence of improved performance using TOC. Motwani et al. (1996) illustrated how TOC can not only be applied in service organizations like Health Care Clinics but also in case of not-for-profit i.e. Red Cross. The study also revealed that TOC measures (throughput, operating expense, and inventory) can be identified and measured to achieve global organization's goal. Siha (1999) asserted that the recognition of organization constraints play an important role in achieving continuous improvement in service organizations. Techniques like drum-buffer-rope which are predominantly common in manufacturing arena can very well be applied in service sector to exploit system constraints and then subordinate resources to it. Breen et al. (2002) described how TOC provided a logical method of improving performance of health care enterprise. Similarly, Polito et al. (2006) used TOC to improve competitiveness in an airline industry. A study conducted by Gupta and Kline (2008) proposed a framework to improve clinician efficiency and reduce waiting times in case of mental health care agency. Similarly, a recent study by Reid (2008) provided a detailed description on how five focusing steps of TOC can be used to improve the performance of a banking system by drawing the management's attention to system's/subsystem's control point. Even though the above literature clearly shows successful examples of how TOC philosophy can be applied in service sector, its application and beneficial use in small businesses is not well documented and needs to be investigated.

3. THEORY OF CONSTRAINTS: A SMALL BUSINESS APPLICATION

Theory of Constraints seeks to help business owners maintain a proper focus on system constraints. TOC recognizes that system constraints limit the performance of a system and, thus, suggests a unique approach to manage these constraints. TOC-based management philosophy focuses on change at three levels (the 3Ms): ***mindset*** of the organization, ***measures*** that drive the organization, and ***methods*** employed within the organization (Srikanth & Robertson, 1999; Boyd and Gupta, 2003; Gupta and Boyd, 2008).

3.1 Organizational Mindset in the DT Pizza Company

TOC concept of throughput-world thinking (TWT) implies that the goal of a company is to make more money (not to save money or reduce costs). Such an organizational mindset further stipulates that certain necessary conditions should never be violated when making decisions in a company in order to achieve the profit goal. Two such important conditions generally discussed in TOC literature are: (a) provide a satisfying work environment to employees, and (b) provide satisfaction to the market (Dettmer, 1998; Goldratt, 1992). Thus, TOC management philosophy argues that a small business should not let the quality of the product (i.e., customer satisfaction) and working environment (i.e., employees' security) become a constraint towards making more money. The main difference between the goal and necessary conditions is that the goal is something we always want more and more whereas necessary conditions have a threshold value which we should maintain. Goldratt chose the goal of making money because it is relatively easy to quantify as compared to customer and employees satisfactions.

The DT Pizza Company focuses on providing high value to the customers rather than reducing costs. In other words, the prevailing organizational mindset is consistent with throughput-world thinking. Since 1978, the company has aimed to differentiate itself in the food services industry. Consistent with the overall differentiation strategy, the DT Pizza Company's operational mission is to “serve the best tasting pizza in town---anyway you want it”. An interesting aspect of their operations strategy is that the customers can bring their own toppings to create a truly customized pizza and thus, get directly involved with the process. The operational objectives are prioritized to accentuate that operational mission. The operational goals are organized as follows (in order of decreasing priority): 1) quality, 2) flexibility, 3) dependability, and 4) efficiency. The DT Pizza Company achieves quality by integrating informal quality control practices and making each pizza from scratch. Without belaboring the minute details, the owner expects pizzas that are evenly topped, baked without bubbles, and aesthetically pleasing to the eye. To insure flexibility, they forego sales to provide a stellar product (actually a variety of products including various types of sandwiches, salads, soft drinks, and beer, in addition to their main product, a variety of pizzas) to their existing customer base.

3.2 Performance Measures in the DT Pizza Company

Assuming that a firm's goal is to make more money, TOC proposes a performance measurement system consisting of three simple measures: Throughput, Inventory and Operating Expenses. Throughput (T) is "the rate at which the system generates money through sales". It refers to money coming into the business through what is actually sold (i.e., Sales Revenues - Truly Variable Costs e.g., direct materials). If the system produces a product which is not sold, it is not considered throughput. In the DT Pizza Company the main source of generating Throughput is from the sale of 20 different types and 4 different sizes of pizzas (the company also sells sandwiches, salads, soft drinks and beer). More specifically, the throughput per unit of specific pizza is determined by selling price minus truly variable costs (i.e. cheese, flour, yeast, lard, vegetables, and meat). The management stated that 40% of the sales revenue is direct material cost; hence the Throughput is 60% of the sales.

Inventory (I) is "all the money invested in purchasing the things the system intends to sell". It represents the money currently stuck inside the system. It encompasses all assets i.e. properties, furniture, and equipment used in operations in addition to the traditional inventory comprising of raw materials, work-in-process and finished goods. The Inventory at the DT Pizza Company consists of traditional inventories such as daily supply of work in progress and one week’s supply of direct materials as well as other equipment and assets such as an industrial mixer, several pans and bins, four ovens, a dough sheeter, restaurant furniture and fixtures.

Operating Expenses (OE) is "all the money the system spends in turning inventory to throughput". It represents all the money going out of the system which includes selling and

administrative expenses, utilities, rent, supplies, salaries and wages, and other over-heads. The operating expenses at the DT Pizza Company consist of salaries and wages, operational overheads (i.e., waste, depreciation, utilities, and maintenance), administrative expenses, license fees, and rent.

These TOC-based performance measures are: (a) financial in nature [they can be translated in financial measures such as Net Profit (i.e., T-OE), Return on Investment (i.e., (T-OE)/I), and Cash Flow (i.e., T-OE + ΔI)], (b) easy to apply at any level of a company, and (c) global in nature i.e. ensure that local decisions are aligned with the profit goal of the firm (Goldratt, 1990, pp 19-51). Thus, the organizational mindset promotes a managerial decision resulting in a simultaneous increase in throughput, as well as reduction in inventory and operating expenses. Without getting into specific financial information, in the following section, we will show that these TOC based performance measures allow small business managers to analyze various decisions they make on day to day in terms of their impact on T, I, and OE.

3.3 Five-Focusing Step Methodology for Improving DT Pizza Company Operations

TOC stresses that every business system has at least one constraint (or few at maximum), defined as anything that limits a system from achieving higher performance versus its goal. TOC proposed a five focusing step process (Figure 1) for managing constraints and continuously improving the system.

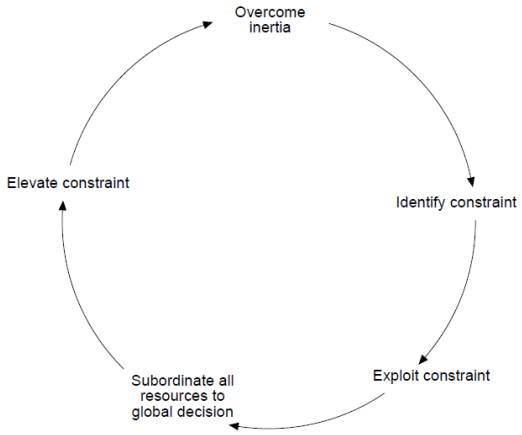

Figure 1: TOC Process of Ongoing Improvement

Source: Adapted from Rahman (1998)

First, IDENTIFY the system's constraint(s). Second, decide how to EXPLOIT the system constraint(s) i.e. get the maximum possible within the limit of the current constraints by increasing throughput without incurring any operating expenses or investing more money. Third, SUBORDINATE everything else to the above decision i.e., avoid keeping non-constraint resources busy doing unneeded work. Forth, ELEVATE the system constraint(s) i.e., if actions taken in the previous two steps fail to break the constraint, off-load some demand or purchase additional capacity for the constraint(s). Finally, if in the previous steps a constraint has been broken, go back to step 1 but DO NOT allow INERTIA to cause a system constraint i.e., revisit all the decision taken in the previous steps and continue the improvement process.

In the DT Pizza Company we analyzed the operations and applied five-focusing steps to manage the system constraint(s) and generate a set of practical common sense recommendations which are discussed in the following sections.

4. ANALYSES AND APPLICATION OF FIVE-FOCUSING STEPS OF TOC

The major challenge for the operations manager/owner at the DT Pizza Company was to create sufficient capacity to "keep up with demand." While the company is generally successful in this regard, peak periods have continually experienced a capacity shortage, which has resulted in unmet demand during this time period. From Sunday through Thursday, demand equates to approximately 60 pizzas daily with capacity ranging anywhere between 24-48 pizzas per hour depending on the size and number of toppings. During peak periods on Friday, Saturday and Sunday evenings, demand jumps to 200 pizzas. According to the business manager/owner, there simply was not sufficient capacity to meet customers' demand during the peak periods. The owner attributed this to an inoperative oven. Based on the following analysis of the production capacities of various processes, however, we derived an alternative conclusion and suggested a number of practical common sense solutions, which can be (and as of now have been) implemented by the company.

4.1 Operations Flow Analysis in the DT Pizza Company

Since the main product and the major source of income for the DT Pizza Company is, as the name suggests, pizza, we selected corresponding product for more thorough analysis. The pizza making procedure consists of three main processes: (i) order taking process, (ii) pizza preparing process, and (iii) pizza baking process (see Figure 2).

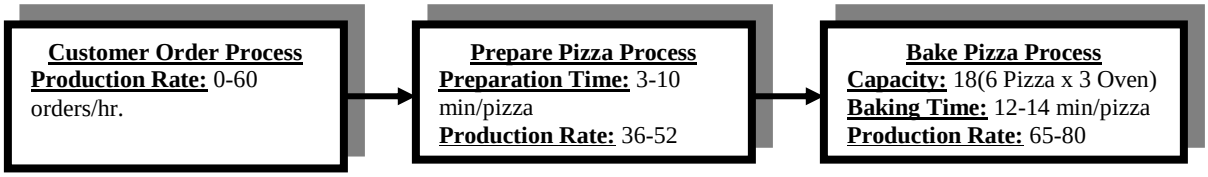

Figure 2: Production Capacity Analysis of the Pizza Making Process

When customers arrive in the evening, orders are placed with a family employee who "calls out" the order to workers responsible for making the pizza. Customers pay for their food when they place the order. The rate at which customer orders are received can vary significantly within any given hour. During peak times the restaurant can receive more than 60 orders, though that is not always the case. Then, the actual pizza preparing process begins. First, the workers sauce the sheeted pizza dough. The sauced pizza is then moved to the next station, where the pizza is topped with custom ingredients. (Note: The pizza preparing process is setup early in the morning with the preparation of large bins containing the sauce and pizza toppings. These bins are refreshed periodically throughout the day). The time to prepare a pizza depends on the size, the number of toppings and the types of toppings. The timings observed were about 3-4 minutes for a small pizza, 4-6 minutes for a family size pizza and 7-10 minutes for a special large pizza. There are four pizza-making stations, and family pizzas are the most popular pizzas ordered. Based on these facts, the estimated rate for the process is 36-52 Pizza/Hr (4 stations * 60/6.6 Average high time - 4 stations * 60/4.6 Average low time).

Next, the pizza is transferred to the oven, where it is monitored regularly during baking until completion. Pizzas are made to order so if there are no orders the oven has idle capacity, and as orders start coming in, the oven starts to get utilized. Unlike the "Prepare Pizza" process the oven used to bake the pizza has a fixed capacity with limited variance, meaning that when there are large numbers of orders, employees are in a hurry to catch up on the orders, but the oven has a finite capacity. There is no way to speed up the baking process, so if the oven is filled to the capacity, there could be times when pizzas are prepared and waiting to go into the oven. There are three ovens with a capacity to place 6 pizzas in each, and the time each pizza is placed in the oven varies between 12-14 minutes. Thus, on average, baking process can produce 65-80 pizzas per hour. Finally, when the pizza is removed from the oven, it is immediately delivered to the customer.

4.2 Identify the System's Constraint

In order to identify the constraint, we observed the process at peak time and also interviewed the management. During our preliminary investigation we identified two primary constraints: the pizza making process and the oven. At peak times customer orders were not the constraint, as there were more orders coming in than the system could process, so the market was not a constraint. The management said that they stop accepting telephonic orders after more than 20 orders are pending. On further investigation of the production rates (as discussed in the previous section and illustrated in Figure 1), we conclude that the pizza preparing process is a bottleneck.

4.3 Decide How to Exploit the System's Constraint(s)

The next step in the ongoing process of improvement is to decide how to exploit the constraint. The company should take actions that ultimately increase the production capacities of the bottleneck process. Any time wasted on this process represents the lost throughput and therefore, profits for the company. In an effort to offer suggestions to exploit the constraint we studied the constraint i.e., pizza preparing process in more detail.

There are a number of activities involved in the preparing pizza process. When a customer order is received, it is written on an order book at the register that is shared by all four pizza-preparing stations. An employee on one of the four available stations starts to work on the order. The first activity is to get the sheeted pizza dough kept in a bin on the side. Once the pizza dough is fetched, it is placed on a wooden board. One wooden board is used to assemble two pizzas and is shared by two people. Pizza sauce is applied on the dough. The second activity involves weighing the cheese kept in the bin. The third activity is to spread the weighed cheese evenly on the sauced pizza dough. Next, desired toppings are checked from the order book at the register and toppings are put on the pizza one at a time. When both pizzas on the wooden board are ready and quality is checked, the board is moved to the baking station to be baked. We further analyzed the time spent on some of these activities and interviewed the owner in order to find methods to exploit the constraint. Our observations are summarized on Table 1. The last (desired) column of the table shows the times that can be attained with minor process adjustments. Based on these observations we are suggesting the following recommendations to exploit the constraint:

Activity	***Minimum (seconds)***	***Typical (seconds)***	***Desired***
Reading the order	30	30	20
Sauce and cheese	30	60	5
Topping the pizza	180	270	180
Refresh bins	10	15	10
*Waste***	10	10	5
Totals	4 min 20 sec	6 min 25 sec	3 min 35 sec*

**The rate of 3 min 35 sec means 67 Pizza/Hr which is slightly more than lower end of the oven capacity.*
*** Time to rework pizza (i.e., wrong topping etc.) and other QC problems*

Table 1: Analysis of the Pizza Preparation Process

The art of topping a pizza improves with experience. While we were observing at the DT Pizza Company, we noticed that the rate and the ease at which the pizza was topped varied from person to person. We also learned that there are several "tricks" that can reduce the time taken to top the pizzas. For example, dipping one's hand in the olive bin prior to adding sausage can significantly reduce the time required for sausage topping. Therefore, we suggest that this knowledge be distributed through some informal training to all employees. We also recommend offering incentives to employees for making good pizzas at the desired rate (i.e., orders are read correctly, and toppings are spread out in a proper sequence evenly and aesthetically without spending extra time).

The processes of recording and reading the order can be improved by making use of order slips with clips, and retaining a carbon copy for records. The clips are used to place the order in front of the worker at the workstation. Hence each pizza station will have its own order in front of it; thus it can save some valuable time in rubber necking and trying to read the order at the register. This will also increase the probability that the orders are prepared correctly and are not misread. This is important, since we learned that it is relatively common for employees to reach for the wrong topping. This mistake is caught only through the management's supervision. In a worse case scenario the mistake is caught only after the wrong topping has been applied to pizza dough. Removing the wrong topping will in that case waste the valuable time of the constraint resource.

The weighing of cheese is an important step as it ensures uniform quality of the pizza. However, it takes valuable time from the constrained resources; hence, other options should be explored. One way to expedite this process is to store the pizza dough with cheese and sauce already applied during the peak time. When the order is received an employee will get this kind of pre-prepared pizza dough from the bin, and since the sauce and cheese is already on it, the employee can start right away to apply toppings. The inventory for this kind of pre-prepared pizza dough could be adjusted to 10 to 15 units based on the experience and wait time. When the inventory drops below that level one employee uses the table where the bin of sheeted pizza dough is stored to prepare more of these pre-prepared dough sheets (during the peak periods when the constraint is in pizza preparing process).

Another way to exploit this process is to use a scoop with the right volume which can reduce the time to weigh cheese. This will further speed up the pizza preparing process. After these steps are integrated, we expect that the time to make a pizza can be reduced from 6 min 25 sec down to 3 min 35 sec. This translates into an approximate 40% increase in production: from 48 pizzas/hour to 67 pizzas/hour. Throughput will increase by almost 11.4% [(60% of (67-48)]). The net profit will also increase by the same percentage. In addition, implementing these suggestions reduces material as well as time waste, which results in a somewhat smaller inventory. Thus, this set of recommendations will increase throughput and reduce inventory and operating expenses simultaneously.

4.4 Subordinate Everything Else to the Above Decisions

After exploiting the constraint, the next step is to subordinate all non-constraint resources to the constraint, which implies that they should be used to enhance the performance of the constraint resource. Based on our observations, we make the following recommendations with respect to off-loading some of the activities of constraint process to non-constraint resources.

While observing the pizza making process, we discovered that at times there is a shortage of processed toppings such as chopped onions and other vegetables in the bins. This results into the constraint resource sitting idle while waiting for the bins to be refilled, especially during the peak time, or wasting the valuable time of the constraint resource. It is possible to refresh the bins, and thereby, maintain an adequate supply of the processed material, so that the bins are not starved for the material. Management should consider the option of pricing pizzas based on the utilization of constrained resource. Some toppings, for example sausage, are considerably slower to apply on a pizza than other toppings (e.g., chopped onions). Since the best possible time utilization of the constraint is crucial for the whole organization, toppings requiring a long time to apply should be priced higher than those requiring less application time. Management should also consider offering "Happy Hour" during the peak time (evenings) and peak load days (Friday, Saturday, and Sunday), thereby dividing the load of the peak hours for a longer period of time. This would reduce the statistical fluctuations and smooth out the flow through the constrained resource.

4.5 Elevate the System's Constraint

Once the steps highlighted in exploitation and subordination have been considered and implemented, the next step is to elevate the constraint of the system, which involves the decision to purchase the constraint resource so that the overall capacity of constraint is elevated to a higher level. Thus, elevation decisions involve some increase in inventory (i.e. investment) and/or operating expenses which is also the main difference between the set of decisions made in step 2 (exploit) and step 4 (elevation). TOC-based management philosophy suggests that management must implement the 2nd and 3rd steps (i.e., exploit and subordinate) so that everyone is aware of the constraint resource, and management has done what it could without incurring any investment and/or operating expenses. Moreover, management should also decide on the strategic location of the constraint. Generally, the constraint should be located on the process, which is the most expensive and may be hard to elevate. For example, in the DT Pizza Company the oven is the most expensive resource and based on our discussions, management wanted to see the constraint moved to the oven. Keeping this in mind, we suggest following three actions to elevate the current constraint:

- Currently in the pizza preparation process, one wooden board is used for two pizzas and in total two wooden boards are being used. Thus, even if one pizza is ready, it has to wait for the other pizza on the board to be ready before it can go into the oven. Based on this observation, we suggested the implementation of separate boards for each pizza to further decrease statistical fluctuations in the process and increase the capacity. This should be a very inexpensive way of increasing throughput.
- Another possibility for elevating the constraint is, for example, the modification of the working stations, so that bigger bins can be used to store the toppings and, thereby reduce the need for frequent refilling.
- The owners should consider adding another bin station to process pizzas. This would involve hiring at least one more employee at the preparing pizza stage, but it would ensure that all the customer orders could be processed during the peak time. Among the three proposed solutions, this is probably the most expensive solution which should be implemented to move the constraint to the next level.

4.6 Go Back to Step 1 and Not Allow Inertia to Cause a System's Constraint

The first part of this step makes the five-focusing steps of TOC, a continuous process. The second part is a reminder that no policy (or solution) is appropriate (or correct) for all time or in every situation. It is important for the business managers to recognize that the previous decisions made have to be refined as the business environment changes. In the DT Pizza Company, once the solutions recommended in the preceding steps are implemented, our current constraint (the pizza preparing process) can increase its capacity up to 85 pizzas/hour, which shows that the oven, due to its limited capacity (i.e., 65-80 pizza/hour), will be the constraint. This means that we need to start our five-focusing steps again. It is important to revisit all the decisions we made in the previous round of improvement process.

5. IMPLEMENTATION OF RECOMMENDED SOLUTIONS

Following completion of TOC-based operations analysis described above, the business owner was briefed on the recommended solutions. His reaction was favorable and many of the recommendations were implemented without any major hurdles as explained below.

The DT Pizza Company manager was in agreement that during peak times, the constraint was in the pizza preparing process and it makes sense to focus improvement efforts to this process. The company now pays close attention to this process during the peak periods. Specifically, the company now ensures that (i) trained personnel are assigned to this process so that toppings are spread out in a proper sequence evenly and aesthetically without spending extra time, (ii) bins with processed toppings are refreshed immediately, (iii) workers use scoop to pour instead of weighing cheese, and (iv) order slips with clips are used at each work station to avoid errors made in reading the order and applying wrong toppings. These changes were implemented without any reservations and the increase in Throughput (and thereby the profitability) was confirmed.

The DT Pizza Company did not implement the following recommendations: (i) storing the pizza dough with the cheese and sauce already applied on it due to the various sizes of the pizza dough they had to store, and (ii) pricing the pizza based on the time consumed by some of the toppings, primarily due to its perceived impact on the operations strategy of the company. The owner wanted to further look into the below listed recommendations: (i) offering "happy hour" during the peak periods, (ii) using two wooden board instead of one to prepare the pizza, (iii) using bigger bins to store the toppings, and (iv) adding fifth workstation to prepare pizza. In principle, the owner agreed that the strategic location of the constraint should be the process involving the most expensive resource i.e. oven and the latter set of recommendations when implemented will ensure that the constraint is strategically located.

6. CONCLUSIONS

One of the main reasons for the failure of small businesses is reported to be poor and inadequate management. This paper demonstrates how the theory of constraints (TOC), an evolving management philosophy, can be used to improve the operations functions, and thereby the financial health of a small family-owned business. Specifically, we reviewed the business and operations strategy of the DT Pizza Company and found that the company had several strengths, including the loyal customer base and concern for the employees' security consistent with the Throughput world thinking mindset. Next, we developed TOC-based performance measures, i.e., throughput, inventory, and operating expenses for the DT Pizza Company to allow the various management decisions to be analyzed in terms of these measures. The major focus of this paper was to analyze the processes to identify the constraint process and explain how five-focusing steps could be applied to generate practical solutions and put the company on a continuous improvement process.

In short, TOC-based management philosophy provides small business owners/managers a simple rule based framework to understand the fundamental issues affecting their operations. Even with our limited exposure to the pizza making process, we were able to zero in onto the problem in no time and provide cost-effective solutions after understanding the processes of the company. It also provided the business under review insight on where to anticipate the next problem and thus continue the ongoing process of improvement.

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