



Manpower and Organization

**AIR FORCE MANAGEMENT ENGINEERING
PROGRAM (MEP) - QUANTIFICATION TOOLS**

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This manual provides tools and information that implements AFI 38-201, *Determining Manpower Requirements*. It may be used to implement and maintain the United States Air Force Management Engineering Program. It explains how to use the different tools available when developing and quantifying an Air Force Manpower Standard (AFMS). It applies to any project officer responsible for the development and quantification of manpower requirements. Maintain and dispose of records created as a result of prescribed processes in accordance with AFMAN 37-139, *Records Disposition Schedule*.

SUMMARY OF REVISIONS

This change incorporates interim change (IC) 2003-1, which operationalizes three new indirect man-hour measurement methods. Paragraphs 13.5 through 13.8.5.2 are all new paragraphs to Chapter 13, *STANDARD INDIRECT ALLOWED MAN-HOURS (SIAM)*. The entire text of the IC is at the last attachment.

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Chapter 1

ANALYSIS TOOLS

Section 1A—Flow Process Charting

1.1. General Concepts.

1.1.1. The flow process charting technique shows a picture of the sequence of all operations, transportation, delays, inspections, and storage of a work procedure. It includes information for analysis such as time needed and distance moved. It is a simple device for visualizing each step of a procedure that is often too long and complicated to be described in words.

1.1.2. Like several other charting techniques, flow process charting can be used in a variety of applications. This guidance aids the study craftsman by noting general applications, advantages, and limitations of this technique.

1.1.2.1. Use flow process charting to study processes involving either personnel or material. Personnel charting shows the process in terms of movements and actions done by work center personnel. The activity shown on such a chart includes all forms of effort, mental and physical. A chart that follows material can show the steps in an office, like processing forms or records as they pass from one worker to another, or any material being processed in a shop, plant, or warehouse.

1.1.2.2. When preparing the flow process chart, it is important to separate the events that occur to the material from the activity of the person. Do not chart both on the same chart.

1.1.2.3. Cost reductions most often happen as a result of simplifying, eliminating, combining or changing the sequence of activities of the operators as they take part in a process. Focus attention on steps done by individuals; however, do not overlook analysis of travel, delays, storage, etc., that affects the overall time.

1.1.2.4. A flow chart shows “hidden” costs, such as excess distances traveled, delays, and temporary storage. Once these costs are found, improvements can be made.

1.1.2.5. A chart shows steps in a process that may be deleted, combined, or changed to improve the sequence and make the procedure more effective.

1.1.2.6. A chart also helps improve the process by showing the steps (operations, inspections, etc.) that need to be given to another person.

1.1.2.7. In general, the flow process chart contains a lot of detail. It is not easily adapted to a complicated process. Use the chart to study individual components of an assembly or one part in an overall process. To avoid suboptimization (simply passing costs to another work center) ensure revisions to a process do not cause an adverse effect on the overall process.

1.1.2.8. The flow process chart gives most of the information needed to identify potential methods improvement, but it does not pictorially show the flow of work. Sometimes, however, such added information is needed to develop a new method. For example, before a transportation step can be shortened, it may be necessary to see where floor space can be changed to reduce distances. Likewise, it helps to visualize work stations, temporary storage points, and the overall layout of the facilities. Thus, the flow process chart is often used with other techniques such as flow or string diagrams.

1.1.3. Paragraphs **1.2. through 1.4.** detail flow process charting and show how to use DD Form 1723, Flow Process Chart.

1.2. Defining an Activity. The basic steps in flow process charting are the same ones that apply to all work simplification. After identifying a process to be analyzed, determine the beginning and ending of the particular process and stick to it. Don't be sidetracked by other processes that may occur at the same time and place. Record all details of the process. Describe each step in the process and classify it as one of five types of activities: operation, transportation, inspection, delay, or storage.

1.3. Flow Process Charting Procedures.

1.3.1. Enter each step in the process on the DD Form 1723. Use this form to record both present and proposed work processes.

1.3.2. The first step in preparing a DD Form 1723 is to complete the data in the upper left corner of the chart. Be specific in identifying the process to be charted, persons or materials being traced through the process, and the place and time the process begins and ends.

1.3.3. Next, list steps in the process in brief narrative form in the column under the heading Details of Present or Proposed Method. Include every detail and verify this information with personnel doing the work. It is important to remember when listing the steps to cover the essential job parts (make ready, do, and put away). Refer to paragraph **1.4.4.** for clarification of these "parts".

1.3.3.1. Make sure details are clear, specific, and listed in the order they occur.

1.3.3.2. Enter distances when transportation steps occur.

1.3.3.3. List quantity and time with operations, inspections, and delays. Use a standard unit of time throughout the chart.

1.3.3.4. If distance, quantity, or time varies in any given step, enter an average figure.

1.3.3.5. Include every specific detail on the chart, or the chart will be of little value. Accurate analysis and good improvements depend on an entire picture of current procedures.

1.3.4. After all steps have been identified and listed, classify each according to the standard symbols in column 12b. Draw a line from each symbol to the next. After giving each step a symbol, enter the total number of steps by each type in the summary box in the upper right corner of the chart.

1.4. Work Flow Analysis. Analyze work flow as follows.

1.4.1. When studying the data on the chart of the present method, ask these questions for each step.

1.4.1.1. Can it be eliminated? Will elimination of this step simply mean another work center must complete the task?

1.4.1.2. Should it be combined with another step? Will this reduce overall cycle time?

1.4.1.3. Should the sequence be changed? How does this change current delays and affect the queues?

1.4.1.4. How can it be simplified? Can technology be inserted to ease the workload?

1.4.2. Use the checklist in **Figure 1.1.** to analyze the present method flow process chart.

Figure 1.1. Flow Process Analysis Checklist.

CHECKLIST FOR ANALYZING A FLOW PROCESS CHART
1. Apply the following questions to each step in the flow process:
1.1. WHY is it necessary? Can the entire process or some of the steps be eliminated?
1.2. WHAT is actually done? Are all steps included? What should be done?
1.3. WHERE should the step be done? Should it be done in another place?
1.4. WHEN should it be done? Is it done in the right sequence? Can it be combined or simplified by moving ahead or back?
1.5. WHO should do it? Is the right person (skill) handling it, or can some other skill do it better?
1.6. HOW is it being done? Can it be done better with different equipment or layout?
2. Apply the following additional questions to the overall work process:
2.1. Have proper administrative controls of the work been set up?
2.2. How often is work checked for accuracy?
2.3. When would an error be caught if present checks were left out? Are there fail-safes that can be put in place to eliminate the need for human detection, harm, or error?
2.4. How serious is the result of errors that are not found?
2.5. Is a sampling check for errors enough?
2.6. What inspections can be merged with operations?
2.7. Can storage locations be moved or cut out?
2.8. Can transportation be shortened or cut out?
2.9. What are the causes of interruptions and exceptions to the work? How can they be cut down or cut out?
2.10. Will a new layout or use of a machine cut out the necessity for moving work?
2.11. Can work be given to a location in a prearranged sequence?
2.12. Are equipment and supplies properly arranged?
2.13. Is there duplication of effort in whole or in part?

1.4.3. Be careful when simplifying, eliminating, combining, or changing steps. Avoid haste when making changes and showing results. Study and analyze the effect of each action. Do not combine operations that require thinking with those of a routine nature. A change in sequence at one point may cause a problem at another. Oversimplification may impair controls. Placing too much responsibility at one point may affect the quality of work. Be thorough in data gathering, accurate in charting, deliberate in analyzing, and thorough in recommending changes.

1.4.4. Every job has three parts: "make ready," "do," and "put away." "Make ready" is the time and activity involved in preparing for a job, such as securing materials, going to the files for papers, or receiving a work request. "Do" is the productive phase of work. "Put away" is the time involved in cleaning up, such as returning papers to file, stacking and packaging finished work, or placing work in distribution. When analyzing the chart, it is helpful to mentally group all steps accordingly. Study "do"

steps first because if they are eliminated or changed, they automatically cut out or change accompanying "make ready" and "put away" steps.

1.4.5. Question each step and make notes on the chart indicating possible improvements. Check types of potential changes in column 12h. Check the form several times because second and third checks may reveal possible improvements previously missed.

1.4.6. After completing the analysis, prepare a new DD Form 1723 to show details of the proposed method. Show improvements in the summary in the upper right-hand corner of the form. Use the proposed process chart to help sell improvements. It may also be used as a permanent record of standard practices for work center personnel to follow.

1.4.7. The addition of a flow diagram chart can support the flow process chart, since flow charts by themselves show little about the physical picture of the work area.

1.4.8. In addition to or in place of DD Form 1723, it is permissible to accomplish flow process charting using available computer software. The same kind of analysis outlined in [Figure 1.1](#) should be applied to the computer-generated flow process chart.

Section 1B—Layout Analysis

1.5. General Concepts.

1.5.1. Layout analysis studies are used to improve production, ease physical exertion, and shorten distances of travel for material and personnel. They concentrate on the physical flow of work. They may lead to substantial improvements and are very useful as an aid to other method improvement techniques. A layout study is defined as a systematic method to analyze procedures and facilities and to develop a plan that gives an optimum workable arrangement of personnel and equipment.

1.5.2. The primary objective of a layout study is to arrange equipment and facilities to achieve material flows at the lowest cost, with the least amount of handling, and in the shortest amount of time. Additional objectives include:

1.5.2.1. Increasing efficiency by getting a straight-line flow of work and minimizing backtracking in work processing.

1.5.2.2. Providing each employee with enough space to work efficiently while, at the same time, minimizing total space. AFOSH/OSHA standards specify minimum work space requirements.

1.5.2.3. Providing the best working conditions in the space available.

1.5.2.4. Allowing expansion, reduction, and rearrangement of space to meet changing needs.

1.5.2.5. Eliminating items of furniture and equipment not needed in the work center operation.

1.5.3. Potential benefits of an effective layout are:

1.5.3.1. Improved production. Streamlining the flow of work increases production and improves quality. Labor costs are correspondingly lowered. Every moment saved in travel and delays aids in increasing the production rate.

1.5.3.2. Increased employee comfort and safety. A more comfortable employee in a safe environment generates higher productivity and takes less time off.

1.5.3.3. Reduced labor turnovers. A more comfortable, attractive office helps recruit better employees and helps keep present employees. Consideration of the individual employee often produces pride and loyalty.

1.5.3.4. Improved supervision. Careful layout planning makes controlling the work flow and inspecting easier for the supervisor.

1.5.3.5. Improved quality. Better layout reduces distractions and worker fatigue, eliminates frustration and undue pressures, and improves the quality of workmanship.

1.5.3.6. Better space utilization. Valuable floor space is used more efficiently through effective planning and layout.

1.5.3.7. Reduced costs. Cost is the most important benefit. Speeding production, controlling waste, and reducing labor expenses all save money.

1.6. Layout Analysis Applicability.

1.6.1. Steps necessary to conduct a layout study will vary with each situation. The techniques presented in this chapter may give more information than necessary for a given study, but all might apply. Flexibility is the key word.

1.6.2. The mere drawing of a proposed layout does not constitute a layout study. A hasty examination of the work center or function may reveal inadequacies in the present layout, but a thorough analysis of procedures and facilities usually reveals underlying causes for problems that create low productivity. Accurate and detailed definition of the problem is essential for problem solution.

1.6.3. Normally, layout studies are originated due to problems caused by one or a combination of these: Ineffectiveness of current layout or work flow; changes in volume of production or services; changes in mission, product, service, or equipment; changes in the number of people in the work center; computerization; poor work environment; frequent accidents; obsolete facilities; or new facilities.

1.6.4. Classify layout analysis studies according to the magnitude of the effort.

1.6.4.1. Minor change to present layout.

1.6.4.2. Major rearrangement of existing layout.

1.6.4.3. Relocating into other existing facilities.

1.7. Familiarization and Data Collection.

1.7.1. Familiarization Phase.

1.7.1.1. Define precise objectives and limits of the study.

1.7.1.2. Check current organization, mission statements, and authorized and assigned manpower.

1.7.1.3. Check current operating directives and previous studies completed within the function.

1.7.1.4. Define individual responsibilities. An effective way to define who is doing what is to have work center personnel prepare activity lists.

1.7.1.5. Define machine and equipment needs.

1.7.1.6. Consider any additional needs such as safety and security. AFI 91-302, *Air Force Occupational and Environmental Safety, Fire Protection, and Health (AFOSH) Standards*, contains guidance and direction for accident prevention. Other 91-series instructions address specific safety environments. The 31-series instructions specify security considerations.

1.7.2. Observation and Data Collection Phase.

1.7.2.1. Document the present layout. A layout of the current arrangement of equipment, furniture, and elements of the physical space (walls, windows, doors, electrical outlets, lights, miscellaneous structural obstructions, etc.) forms a background for comparative purposes during development of improvements. A study of the present layout helps in determining where expansion or change is needed most, sets the relationship between various operations, and aids in identifying the existence of duplicate or overlapping functions. It also serves as a checklist of existing equipment and furniture. Make sure the present layout is a graphic representation of the work center as it exists. Use one of three common methods: scaled drawings, two-dimensional cutout or stick-on templates, or three-dimensional models made to a convenient or standard scale.

1.7.2.2. Prepare the current layout.

1.7.2.2.1. Measure floor space involved. This may be done with a tape measure or by use of blueprints. Be sure to validate any blueprint before use.

1.7.2.2.2. Prepare a sketch of the floor plan, locating doors, windows, posts, fixed and movable partitions, light fixtures, and utility outlets.

1.7.2.2.3. Sketch furniture, equipment, etc., showing types and distances from fixed references.

1.7.2.2.4. Show any peculiar details such as floor drains, electrical outlets, plumbing, etc.

1.7.2.2.5. You may show names of individuals or duty positions relative to furniture and equipment.

1.7.2.3. Analyze results. Select relevant techniques to analyze work flows, personnel movements, and methods and procedures as they relate to the problems under study. How individuals relate to operations must be a governing factor in any layout. Systematic study of operations, processes, and procedures involves individual (or group) activities. Two of the more common techniques used for layout analysis are flow diagrams and string diagrams that are discussed in paragraph 1.8. There are numerous other acceptable layout analysis techniques available that may be better suited. Procedures for using these other techniques are described in various industrial engineering periodicals and books available at your library.

1.8. Two Common Techniques Used for Layout Analysis. Other techniques can be found in the Handbook of Industrial Engineering, 1992 edition, Chapter 67.

1.8.1. Flow Diagrams.

1.8.1.1. Prepare a scaled layout chart of the area under study. Use a standard scale when preparing the chart (for example, 1/4 inch = 1 foot).

1.8.1.2. Record on the layout, as near the point of occurrence as possible, each step in the work process. Use the same symbols as on a flow process chart.

1.8.1.3. Number each symbol in sequence. If the diagram is being used in conjunction with a flow process chart, match each step to the chart.

1.8.1.4. Connect the symbols with a line to show the path traveled by the person or material under observation.

1.8.1.5. When presenting two or more work flows, use a different color for each flow.

1.8.1.6. Study the flow diagram, along with the DD Form 1723, for improvement possibilities. Use the diagram checklist in **Figure 1.2.**

Figure 1.2. Diagram Checklist.

1. Work Flow:
1.1. Does work flow follow a relatively straight line with minimum backtracking and crossover? Where are the bottlenecks?
1.2. Has each step been questioned and analyzed?
1.3. Have other work flows been considered?
1.4. Does furniture and equipment spacing consider at least minimum space requirements per worker as outlined in AFI 32-1024?
1.5. Does layout consider person-person and person-equipment work flow relationships?
1.6. Is there excess furniture or equipment?
1.7. Would movement of furniture or equipment reduce or eliminate the number of moves or distances?
1.8. Does layout recognize nature of work such as privacy or security considerations?
2. Diagram:
2.1. Does diagram portray its story clearly?
2.2. Is diagram too elaborate and/or cluttered?
2.3. Is it easier to understand than a chart or narrative description? Is it more effective?

1.8.2. String Diagrams.

1.8.2.1. Mount a scaled layout chart (e.g., 1/4 inch = 1 foot) on material such as plywood or cork that will hold pins, nails, tacks, etc.

1.8.2.2. Insert pins, etc.; on the layout at each place people or material stop along the path through operations and processes in the work area. Put a pin on each exact location. Additional pins may be placed along the path to show the exact route.

1.8.2.3. Starting with the entry point in the flow, connect the pins with a string by looping each pin, in correct sequence, to the end point of the flow.

1.8.2.4. Label or otherwise identify each step.

1.8.2.5. Use different colors or types of string to represent different workers, products, or materials.

1.8.2.6. String may be measured to get distances, using the same scale as on the layout chart.

1.8.2.7. Analyze the completed diagram for areas needing improvement (and congested masses of string indicating process bottlenecks). Refer to the diagram checklist in [1.2.](#)

1.9. Layout Analysis Development.

1.9.1. Analyze all data collected. This systematic approach is recommended.

1.9.1.1. Determine facility location.

1.9.1.2. Plan overall layout.

1.9.1.3. Plan detailed layouts.

1.9.1.4. Plan processes and machinery around material functions.

1.9.1.5. Plan the layout around processes and machinery.

1.9.2. Consider these needs.

1.9.2.1. Set up space, storage, production, service, safety, people, and type of work.

1.9.2.2. Furnish better working conditions to include lighting; use of colors; ventilation; noise levels; safety; access areas; walls, partitions, and floors; communications; and location of break areas, lavatories, water fountains, and locker rooms, etc.

1.9.2.3. Set up telephone/information system needs including: number and placement of phones and lines, intercom systems, and cabling, etc.

1.9.2.4. Set up a work flow that follows the simplest and shortest path.

1.9.3. Prepare proposed flow process and work distribution charts to optimize work flows and travel. Document the proposal on a revised flow or string diagram.

1.9.4. Check all recommendations, discuss them with work center personnel and the functional supervisor, solicit recommended changes, and delete impractical data from analysis.

1.9.5. Look at the differences between the proposed layout and present layout and evaluate these differences. Does the proposed layout:

1.9.5.1. Produce a better product or increase production?

1.9.5.2. Smooth the flow of work or reduce effort?

1.9.5.3. Minimize material handling?

1.9.5.4. Reduce costs, waste, and scrap?

1.9.5.5. Release floor spaces or reduce wasted space?

1.9.5.6. Decrease maintenance?

1.9.5.7. Eliminate congestion or improve housekeeping?

1.9.5.8. Facilitate scheduling or reduce quality checks?

1.9.5.9. Make supervision easier?

1.9.5.10. Reduce accidents or improve morale?

1.9.5.11. Allow for future expansion?

1.9.6. Finalize proposed layouts, charts, and graphs necessary to present study recommendations. Include a concise implementation plan in enough detail for systematic implementation.

1.10. Implementing the Proposed Plan.

1.10.1. Present all recommendations and the proposed implementation plan to the supervisor, then to other key senior leadership personnel. Recognize that it is the unknown rather than the new that creates apprehension. Sell major ideas of the study in the order of their anticipated acceptability to management. Start off with those of a less controversial nature and follow with those most likely to involve more client hesitance. A close alternative will often be readily accepted, thereby avoiding complete rejection of an idea or proposal.

1.10.2. On acceptance of final implementation plans, make sure all affected personnel are fully informed of the entire plan and their specific responsibilities. Set up a trial period to test new procedures and layout arrangements. Continued contact during the test period is necessary to make sure all work center personnel understand, and to revise any aspects of improvement actions that are contrary to study objectives. Recommendations must be instituted as planned.

Section 1C—Systems and Procedures Analysis

1.11. General Concepts.

1.11.1. Systems and procedures analysis is a specific technique used to solve information and paper flow problems. Systems and procedures are essential parts of the management process. They put managerial decisions into action. They provide for routine handling of recurring situations.

1.11.2. Systems and procedures analysis is well suited for looking at paper flow and clerical activities. This analysis studies the flow of paperwork, the forms used, and where and how work is done.

1.11.3. The following terms are used in systems and procedures analysis:

1.11.3.1. System. A network of related procedures integrated to meet an organization's objectives.

1.11.3.2. Procedures. A sequence of operations set up to get uniform processing by telling what actions are to be taken, who takes them, the sequence to be followed, and the tools to be used.

1.11.3.3. Method. A manual, mechanical, or electronic means for individual operations.

1.12. Preparing a System Diagram. A system diagram is a chart made to aid comprehension of a general activity and its components. It is used for doing relatively coarse analysis of an entire system. There is no specified form; however, the form used should give a framework for the procedures making up a system. The elements in a system diagram should include the system description; procedures action; organizational elements; skills; equipment; information inputs, resources, and outputs; and objectives and goals. Information for doing a system diagram is collected through normal fact-gathering methods. Entries for each of these recommended sections are described below.

1.12.1. System Description. Tell how the system is related to the mission, functional activities, and managerial goals.

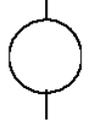
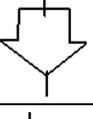
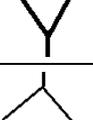
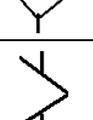
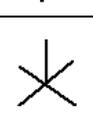
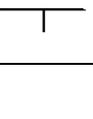
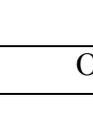
1.12.2. Procedures Action. Summarize what is in each procedure. Use one sentence for each procedure.

- 1.12.3. Organizational Elements. List all the elements responsible for doing the procedures action statement in enough detail for clarity.
- 1.12.4. Skills. List the Air Force specialties needed.
- 1.12.5. Equipment. List the equipment used.
- 1.12.6. Information Inputs. List information entering the system or procedure. The entry identifies the source of the information. There is not always an input to each major action, nor is it necessary to list the output of the preceding step as an input.
- 1.12.7. Information Resources. List data sources such as reports, files, records, guides, and directives. Include in this section information resources added to, or updated as part of, the action.
- 1.12.8. Information Outputs. List all information created or dispatched as a result of the procedure. Identify the format and destination of the outputs if going outside of the procedure. There is not always an output from each major action.
- 1.12.9. Objectives and Goals. Rank, for each procedure, the qualitative aspects of performance and the quantitative measures used.

1.13. Preparing a Procedure Chart.

- 1.13.1. A procedure chart is specifically designed to give, in symbol format, the type of work found in an administrative environment.
- 1.13.2. It follows the flow of information between work stations and shows decisions made and actions taken by individuals in these stations. It also shows interrelationships between two or more forms, forms and material, or forms and workers.
- 1.13.3. A procedure chart gives a quick, accurate, and comprehensive picture of the total activity. It is used to show both existing and proposed procedures. When properly done, a chart is clear and can easily give a complete and correct picture. The objective is to chart normal routine action, recognize possible alternatives, and stay in the main stream of the procedure. If done well, the procedure chart will show the following information about a procedure:
 - 1.13.3.1. The title, number of copies, and source of each document entering the procedure.
 - 1.13.3.2. The method of preparation, organizational element, and person preparing each document originating in the procedure.
 - 1.13.3.3. A symbol, with a short explanation to show each step in the procedure.
 - 1.13.3.4. Processing times and movement distances (optional).
 - 1.13.3.5. Final disposition of each copy of each document involved in the procedure.
- 1.13.4. **Figure 1.3.** shows common chart symbols and their uses.

Figure 1.3. Common Procedure Chart Symbols and Their Use.

FOR PAPERWORK ACTIVITY		
	Origination: When a new document is created.	
	Operation: When some physical operation on the document is performed.	
	Move: When a document changes location or personnel.	
	Delay: When a document is idle.	
	File: When a document is placed in or removed from a formally organized file.	
	Inspection: When a mental verification process is performed.	
	Information Take-Off: When data is moved from one document to another.	
	Destroy: When a document is destroyed.	
	Gap: To omit activity not pertinent to the study.	
	Cross Over: To show that a document has taken a non-intersecting horizontal.	
	Item Change: To show that a document has taken on a different meaning.	
FOR PERSONNEL ACTIVITY		
Operation	Inspection	Move
		

1.13.5. Preparing a procedures chart starts with completing a narrative that describes the work being done in step form, who is doing the work, and where it is being done.

1.13.5.1. Chart preparation begins with entering basic information on the chart such as: Procedure Title, Data, and Analyst.

1.13.5.2. All charting starts in the upper left corner and goes down and across to the right on the chart. The personnel activity flow is always on the left side of the procedure chart. Vertical columns are drawn to keep apart each individual organizational element used on the chart.

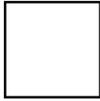
1.13.5.3. There is only one personnel column per chart, but there is a document column for each organizational element on the chart. Explanatory comment generally goes with each symbol.

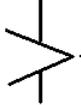
1.13.5.4. Use present tense with personnel symbols (what the person does) and use past tense (what is done to the document) with the document symbols.

1.13.5.5. If pertinent to the study, give the estimated processing time after each document symbol and show the distance moved with each move symbol.

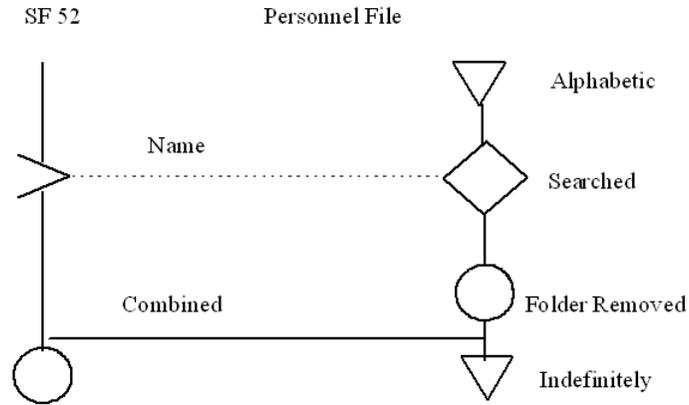
1.13.6. Procedure charts are prepared on a DD Form 2050, **Procedures Chart**. Follow the rules in [Figure 1.4](#) to prepare a procedure chart.

Figure 1.4. How to Prepare a Procedure Chart.

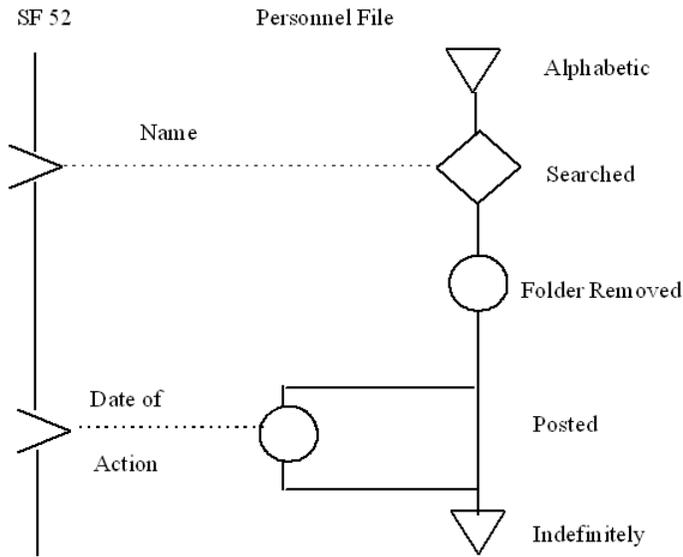
<p>- A document can be introduced into a Procedure Chart in only three ways:</p>	
	<p>Origination</p>
	<p>Gap (from outside the procedure area), or</p>
	<p>File (removed from a formal file).</p>
<p>- When a document is introduced by  origination, provide the following:</p>	
<p>Title (Form Number, if Any)</p>	
	<p>Number of copies - Method of Preparation</p>
<p>(1) For Example:</p>	
<p>Request for Personnel Action (SF 52)</p>	
	<p>3 - copies - typed</p>
<p>- When documents are introduced from outside the procedural area, a  gap symbol is used in this manner.</p>	

<p>Title (Form Number, if Any) - Number of copies</p>	
	<p>Organizational Source</p>
<p>(1) For Example:</p> <p style="text-align: center;">Request for Personnel Action (SF 52) - 3 copies</p>	
	<p>Organizations Division</p>
<p>(2) To introduce existing logs or registers:</p>	
	<p style="text-align: center;">Name and Date</p>
	<p>Request Register on Desk</p>
	<p>Posted</p>
	
<p>- When documents are introduced into the procedure by removal from a formal file, the file symbol is used as follows:</p>	
<p>File Title</p>	
	<p>Method of arrangement</p>
<p>(1) For Example:</p> <p style="text-align: center;">Contract File</p>	
	<p>by contract number</p>

(2) Example of a document being removed from a formal file and not immediately returned but used separately in the procedure:



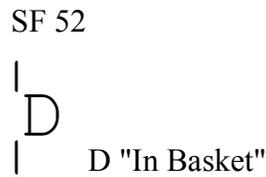
(3) Example of a document being used and immediately returned to the form file:



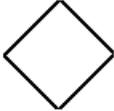
- When action on a document is delayed, the **D** Delay symbol is used in this manner.

D Cause of Delay (except when in "In or Out Baskets" which is awaiting pickup.)

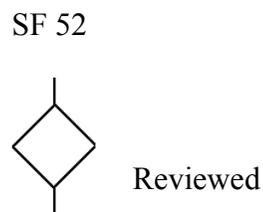
(1) For Example, waiting in an "In Basket";



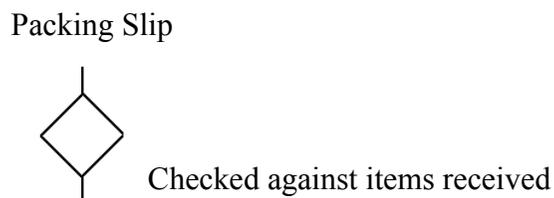
- The  operation symbol is perhaps one of the most used of all. Its use will cover any action that can happen to a document for which there is not some other symbol.

- The  inspection symbol is used to indicate a mental verification process. The following are typical examples.

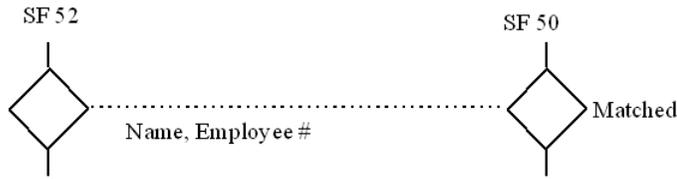
(1) Document checked against a mental standard.



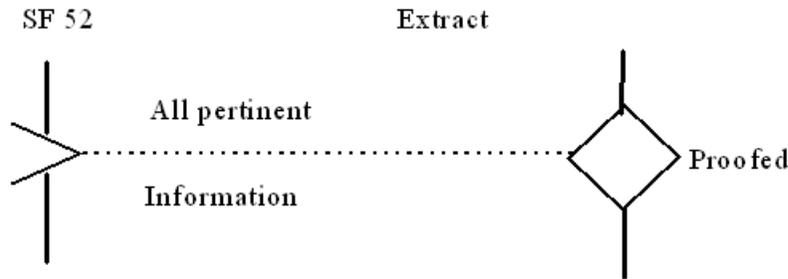
(2) Document checked against materiel received.



(3) Two documents matched by some common factor.

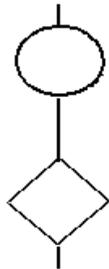


(4) Two documents compared (proofed): One of the documents is the standard, and the other document will be changed if any discrepancy is found.



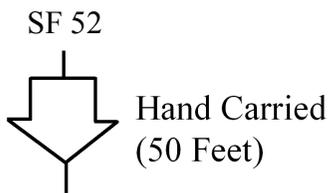
(5) Repetition (verification) of an  operation.

Issue Slip

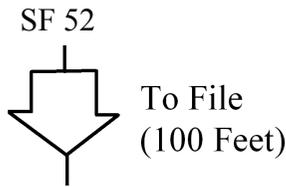


- The  Move symbol is used to show that the document has either changed personnel or physical location. The symbol will explain by noting how the paper moved and, if desired, the distance moved as follows:

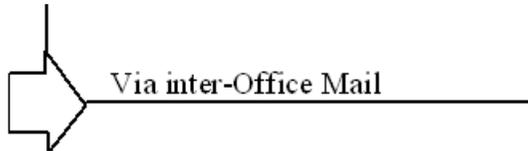
(1) Document moves from one person to another.

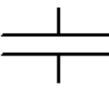


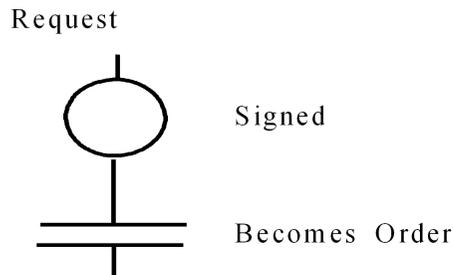
(2) Document moves from one place to another (does not change persons):



(3) Document moves horizontally across the chart to another organizational element:



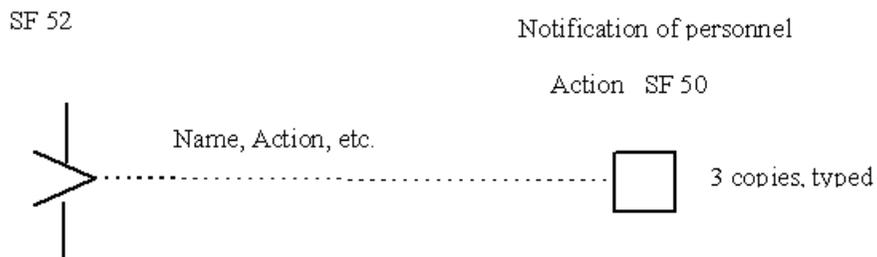
- The  Item Changed symbol is used to indicate that a document has taken on a new significance in the procedure. For Example:



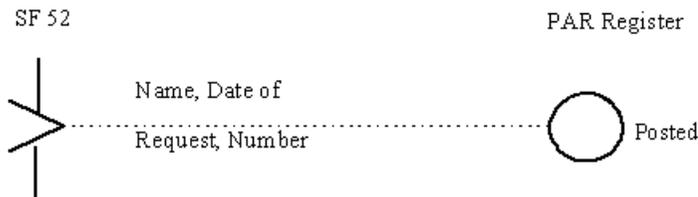
- The  Information Take-Off symbol is used to indicate that information is moving from one document to another for the completion of some action.

Typical examples are:

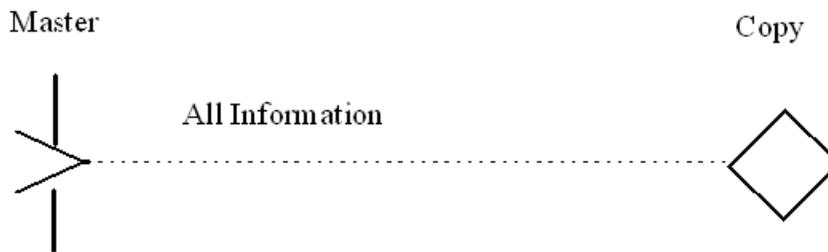
(1) Origination of one document either wholly or partially from another:



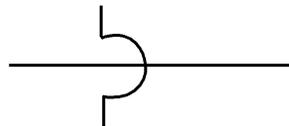
(2) Posting from one document to another:



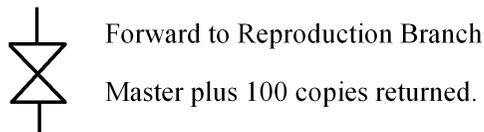
(3) Proofing (reading a source against the extract):



The  Cross Over symbol is used to show that a vertical and a horizontal flow line do not intersect. The half-circle is always on the vertical line as follows:

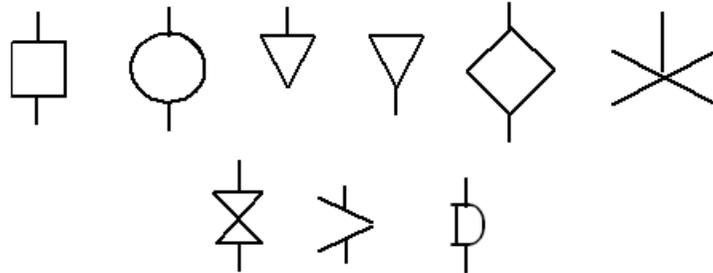


- The  Gap symbol can also be used to show activity that is not pertinent to the study. It should always explain differences in form, number, etc., of documents which enter the uncharted activity and do not return or are altered during that time. For example:



- Flowlines are the connecting links between symbols. The following rules apply in their use:

(1) Solid flowlines go into the top of symbols and out of the bottom as follows:



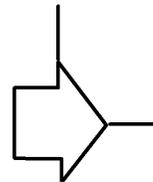
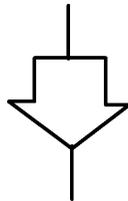
(2) An exception to the above is the
to show horizontal flow as follows:



Move symbol. The flow line can be adjusted

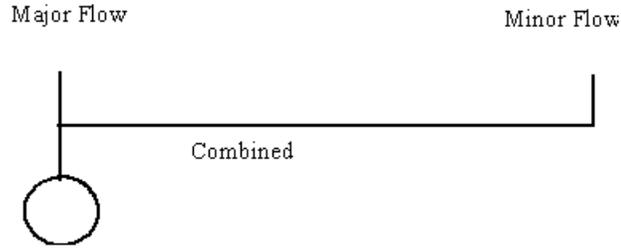
Vertical Flow

Horizontal Flow



(3) No solid flow line can be left dangling. Each must end with a proper terminal symbol or the action is not completely charted.

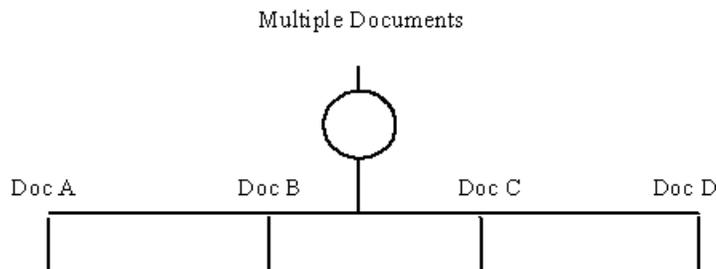
(4) Considerations regarding major flows and minor flows are important during analysis and presentation. This relationship is shown by always having the minor flow document move to join the major flow when they combine. For example:



(5) All symbols fill the space between two guidelines on the chart form except the  Item Change symbol which fills only half. If desired, symbols can be reduced to one half this size.

(6) Each time a new vertical document flow line is begun, the contents of that flow should be listed. For example:

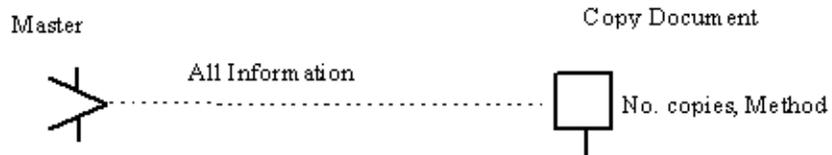
(a) On a  Separation Operation:



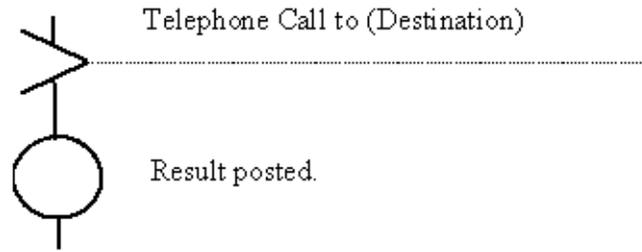
(b) On a horizontal move (from one organization to another):

- Often used combinations:

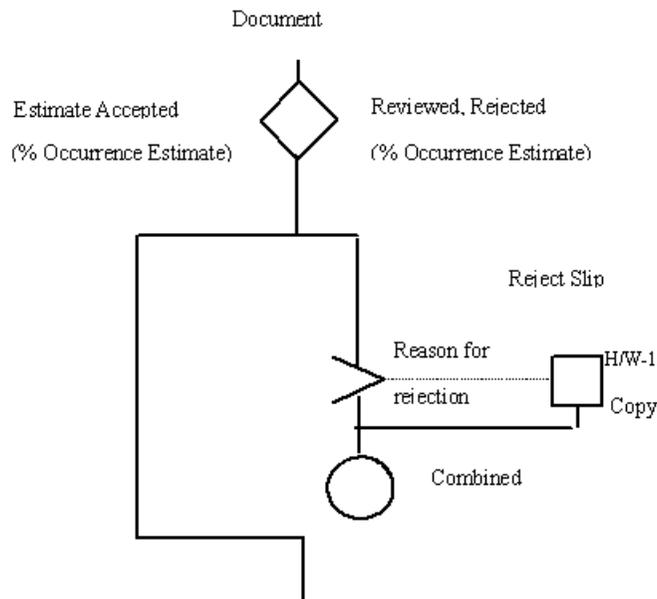
(1) Reproduction of copies from a master document



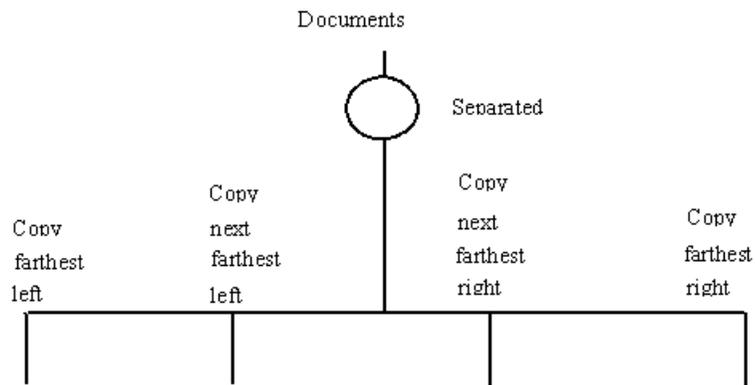
(2) Telephone call. Only flow line which should be left dangling:



(3) Short alternative courses of action:



(4) Distribution of documents:



- All document flow lines must end with one of the three following terminal symbols:

- (1) The  Destroy symbol is used when a document is physically destroyed.
- (2) The  File symbol is used to show the intersection of a document into a formal file.
- (3) The  Gap symbol is used to show a document leaving the procedural area. It may go to a destination either in or outside the organization involved.

Section 1D—Work Distribution Analysis

1.14. General Concepts.

1.14.1. Division of work is a potential area for productivity enhancement and is an aspect of skill determination for manpower standards.

1.14.2. Work distribution analysis is a technique used to evaluate specific steps and find each individual's contribution to work center activity. This technique is useful when the work center consists of several people and skills contributing to the same product or service.

1.14.3. Work distribution analysis looks at work counts and man-hours associated with each responsibility.

1.14.4. This technique is a good tool to check and compare present and proposed procedures during study familiarization and consultant studies.

1.15. How to Prepare a Work Distribution Chart.

1.15.1. Preparing this chart takes three basic steps, and each step must be done accurately and in detail.

1.15.2. First, have each person in the work center complete a DD Form 2030, **Activity/Task List**. Use this form to record each duty activity and type of work done and estimate the average number of hours spent on each.

1.15.2.1. The DD Form 2030 does not merely quote an Air Force Specialty (AFS) or job classification statement. Use the task list to record a complete description of what each worker actually does. Do not include ambiguous phrases like "checking," "administration," or "make contacts."

1.15.2.2. Number tasks by activity (Col. e) to help in developing a work distribution chart. The work unit volume (Col. d) will aid in work distribution analysis.

1.15.3. The second step is to complete a work center DD Form 2030 for the activities. This list records the basic processes that are done by the work center. It includes all the major activities that are done to meet assigned objectives.

1.15.4. The third step is preparing a DD Form 1724, **Work Distribution Chart**. The DD Form 2030 gives the information needed to do the chart.

- 1.15.4.1. First, list the activity of the work center in the left column of the chart, in order of relative importance. Leave space between each line.
- 1.15.4.2. The columns headed "Tasks" are for listing the work done by each person. Complete a column for each person in the work center, listing each of the tasks in summary form. Relate each task to the activity list in the left column. Clearly separate the different tasks, since analysis is impossible if a miscellaneous task is placed on the same line as the major job or operation of the work center.
- 1.15.4.3. For purpose of analysis, list individuals doing the activities in the first column by grade, beginning with the person in charge.
- 1.15.4.4. Record the hours per week spent by each person on each task in the proper column.
- 1.15.4.5. Enter work count data on the chart when relevant. If possible, enter the work count as the number per week to be consistent with hours shown on the DD Form 1724. If a weekly count is not representative, enter the natural frequency of occurrence (e.g., /MO or /YR).
- 1.15.4.6. Sum the hours spent by all workers on each operation and enter the total in the column beside each item in the operation or process list.
- 1.15.4.7. Total the hours for each person.

1.16. Work Distribution Analysis.

- 1.16.1. After completing an initial work distribution chart, do a systematic analysis of the recorded findings. These questions help in examining the detail.
 - 1.16.1.1. Are skills being used properly? Is everyone being used in the best possible manner, or are special skills and abilities being wasted? Persons with higher skills should not do tasks that can be done by lower skill levels.
 - 1.16.1.2. Is work distributed evenly? Measure the relative importance of tasks assigned to persons engaged in similar tasks. For example, two clerks of equal ability and grade normally should be charged with similar volumes of work. Spread the urgent and important tasks as evenly as possible to make certain that all work is done according to schedule.
 - 1.16.1.3. Are tasks spread too thinly? Performances of the same task by many workers may mean duplication of effort. The assignment of a task to one person sets responsibility and enriches the job.
 - 1.16.1.4. Are individuals doing too many unrelated tasks? A large number of tasks in any one column may show that the individual has too many different tasks. Greater efficiency results if workers are assigned related tasks.
 - 1.16.1.5. Are the work center's efforts misdirected? Is the work center spending too much time on relatively unimportant operations or unnecessary work? Instances of misdirected effort are very often found in "miscellaneous" or "administrative" processes.
 - 1.16.1.6. Are there excessive supervision or consultation tasks? Resistance to delegation of authority can restrict creativity and cause unnecessary delays.
 - 1.16.1.7. What activities take the most time? Are they the ones that should take the most time? Normally, the largest total time is spent on what is considered the major activity in the organiza-

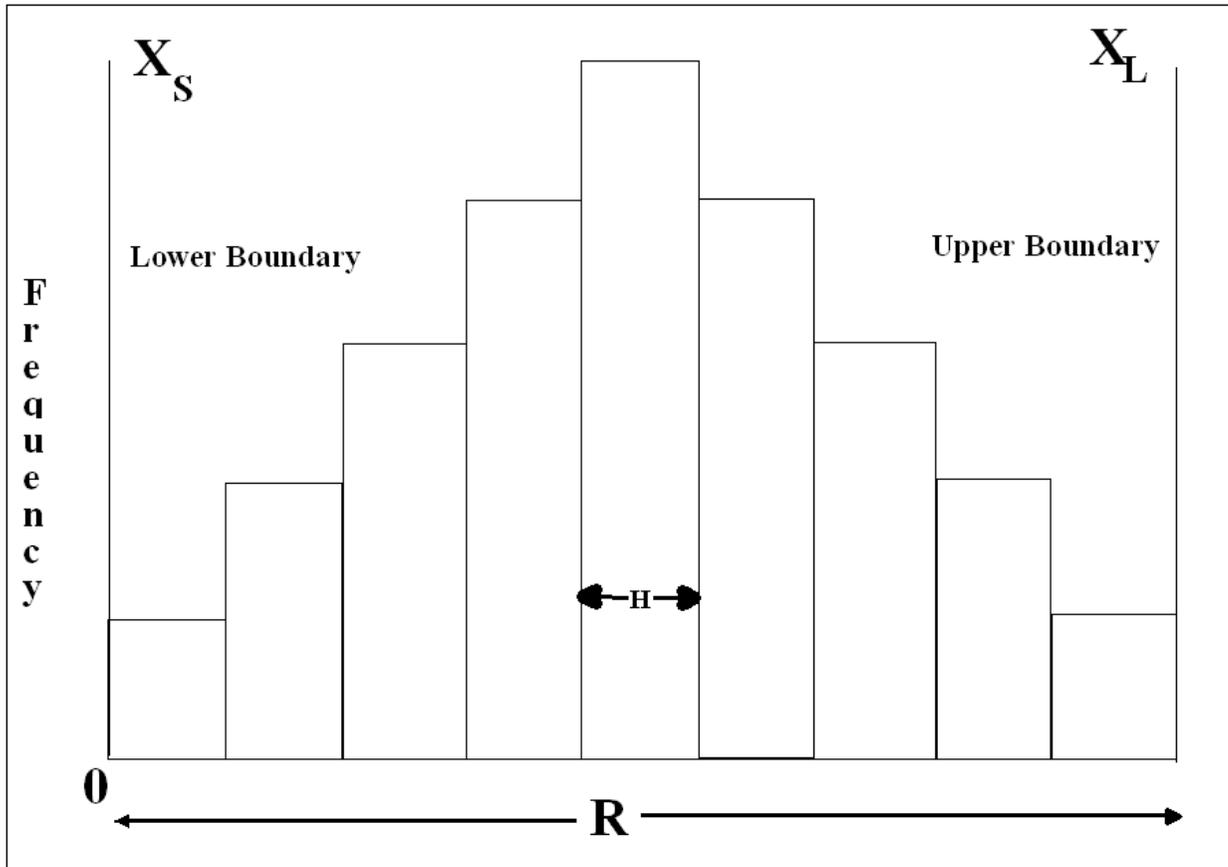
tion. If the activity is a continuing one with several steps, the engineer may make a more detailed analysis by preparing a DD Form 1724. Circle such man-hour totals to mark them for future process analysis.

1.16.2. The answers to the above questions help develop improvement proposals. Prepare a new responsibility chart or distribution chart that shows the recommended process and division of work. This will best display proposed changes and compare them with present procedures. Associated reductions in man-hour requirements should be displayed to support the change.

Section 1E—Histogram Chart

1.17. General Concepts. A Histogram is a graphical representation of the distribution of a series of quantitative observations. The graph is usually a bar chart showing how the same parameter, measured on different components, is distributed within certain minimum and maximum limits. The histogram is constructed by dividing the range of a variable into equal intervals. A bar chart is then drawn showing how many data are located in each of the intervals. A histogram provides information by means of the shape of the distribution and the dispersion. See [Figure 1.5](#).

Figure 1.5. General View of a Histogram.



1.18. Procedures to Develop a Histogram.

1.18.1. Count the number of samples (n) for the process you are analyzing and record the total counts.

7.9	7.3	7.4	7.9	8.1	7.8	7.9	8.1	8.4	7.8	8.3	7.8
7.3	7.8	7.5	8.2	7.9	7.8	7.4	7.0	7.7	7.8	7.3	7.7
8.0	7.4	7.4	7.6	8.3	7.7	7.5	8.0	8.1	7.4	7.5	8.2
7.5	8.3	7.7	7.8	8.0	7.5	7.9	8.0	7.7	8.4	7.6	7.7
7.7	7.7	8.7	7.9	8.2	7.8	7.3	7.6	7.5	7.7	8.1	7.9
7.7	7.8	8.3	7.9	7.7	7.8	7.4	8.1	8.1	8.1	7.2	8.2
7.6	8.7	8.0	(n = 75)								

1.18.2. Identify the range (R) of data you have gathered. This number is the difference between the largest (X_L) and smallest (X_S) value in the data. $R = X_L - X_S = 8.7 - 7.0 = 1.7$

1.18.2.1. Separate the data into classes (K). Use this table to identify the number of classes for different numbers of data points.

Points Counted	Classes (K) To Use
Less than 50	5 - 7
51 - 100	6 - 10
101 - 250	7 - 12
Over 250	10 - 20

1.18.2.2. Determine the width of each class (H) using the formula, $H = R/K$. Since the number of samples in the example is 75, use 10 as a convenient divisor. For the data used in this example, the class width is $1.7/10 = 0.17$. After rounding to the nearest tenth, $H = 0.20$.

1.18.2.3. Identify the boundaries for each of the classes in the Histogram. Begin with the value of X_S , the smallest number in the range of counts, and add the class width H. Continue to add the class width until the number of classes selected in the example is reached. In this example, $X_S = 7.0$ as the lower boundary. Adding 0.20 yields the 1st class ranging from 7.0 to 7.20. The next class begins at 7.20 and extends to 7.40.

NOTE: To avoid having the same point as both the upper value of a class and the lower value of the next class, decrease the upper value by the correct decimal. Therefore, in this example, the range of the 1st class is from $7.0 < X < 7.2$, the 2nd class from $7.20 < X < 7.40$, etc.

1.18.2.4. Identify the number of samples in each class to determine the frequency of occurrence and enable the construction of the Histogram. These counts give a horizontal Histogram.

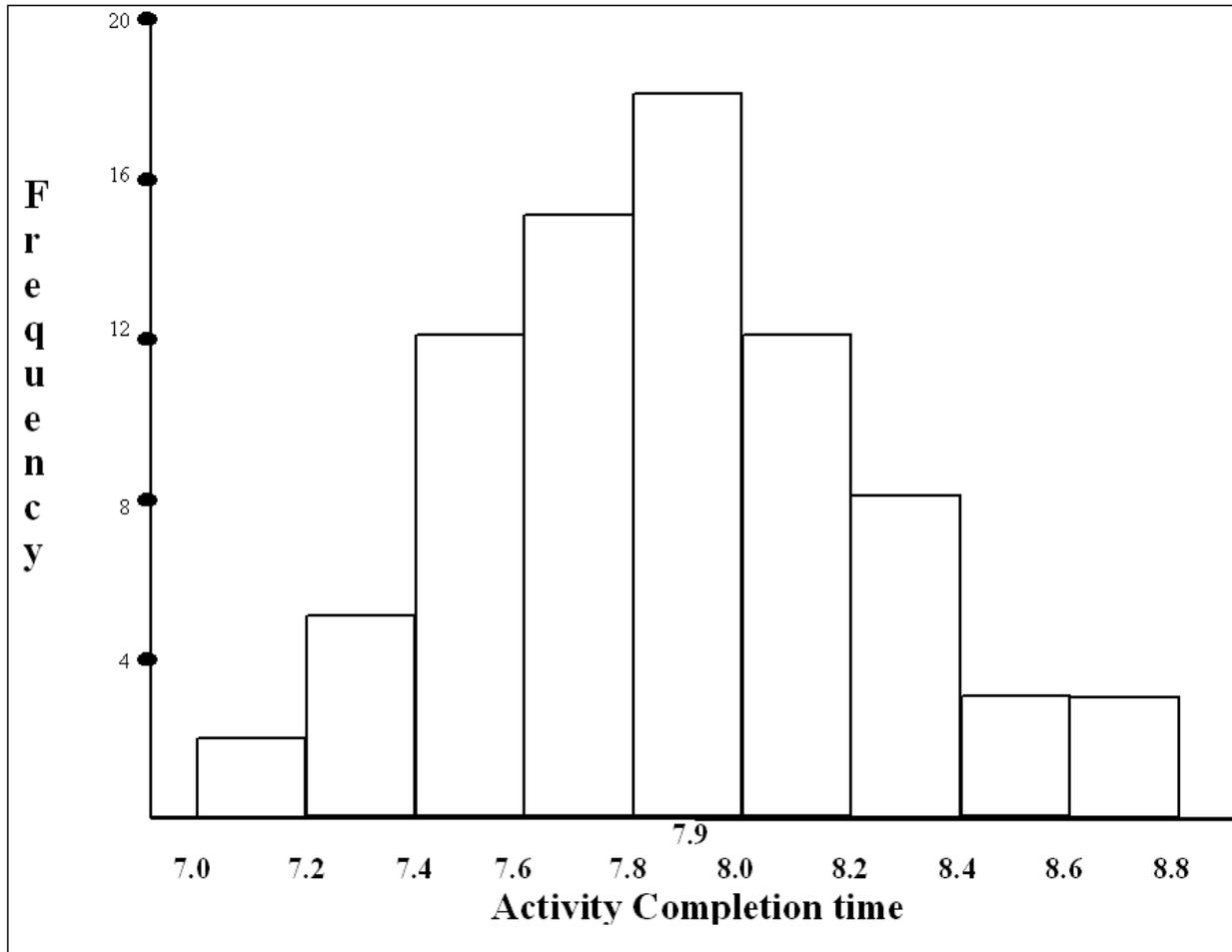
Class	Number of Counts	Total
7.00 - 7.19	/	1
7.20 - 7.39	/////	5
7.40 - 7.59	///// ///// //	12
7.60 - 7.79	///// ///// /////	15
7.80 - 7.99	///// ///// ///// ///	18
8.00 - 8.19	///// ///// //	12
8.20 - 8.39	///// ///	8
8.40 - 8.59	//	2
8.60 - 8.79	//	2

$$n = 75$$

1.18.2.5. Construct the Histogram to show the samples in each class for this example. The data in this example is centered around a value of 7.90 and is very close to a bell shaped curve. The His-

togram gives a view of where the counts are centered and the amount of dispersion of the data. See [Figure 1.6.](#)

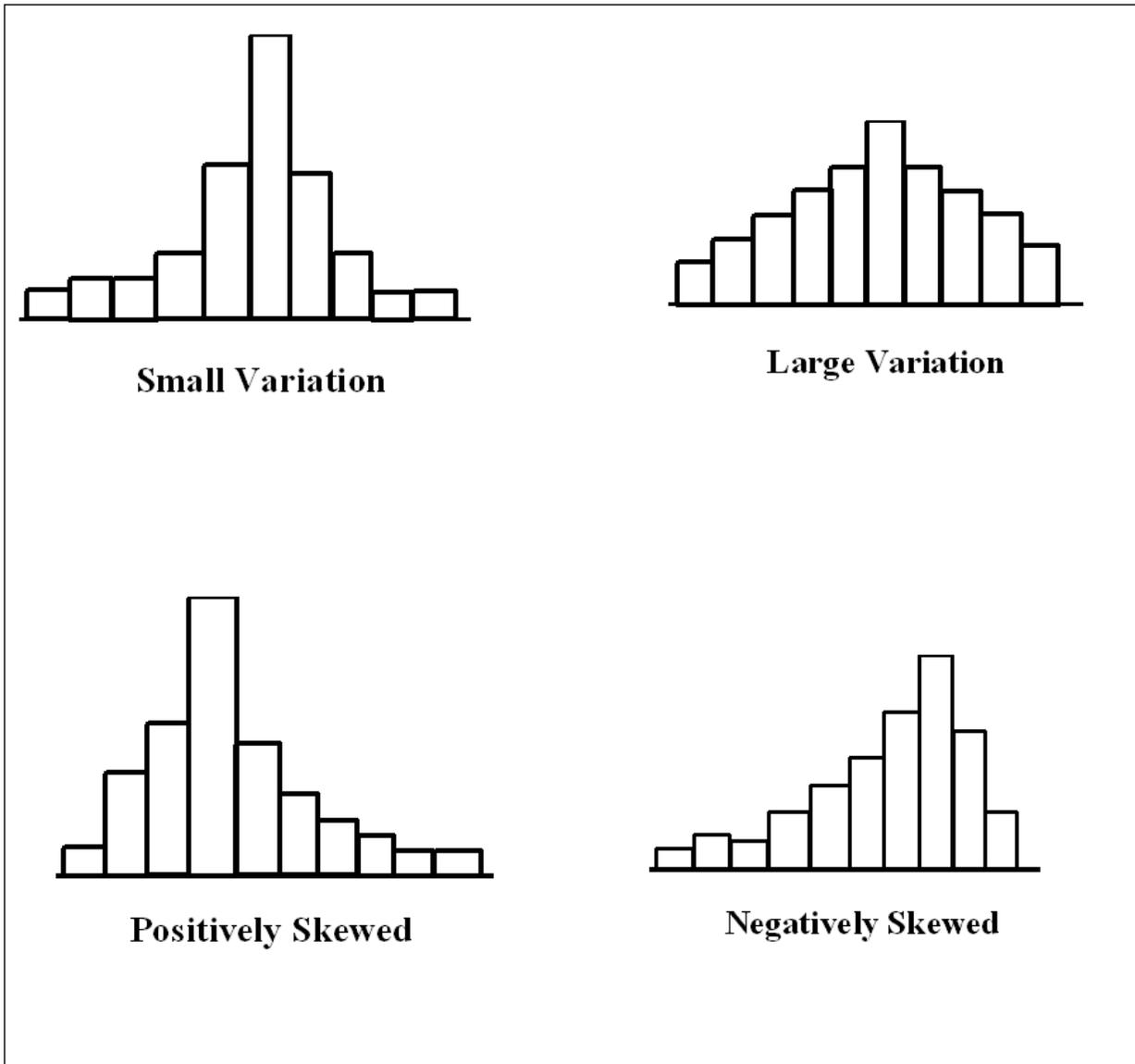
Figure 1.6. Histogram of Data.



1.18.3. The data in a Histogram will not always be symmetrical as depicted in the example. The data could be tightly centered around a point or greatly dispersed, or even bi-modal (having two distinct clusters around separated frequencies) potentially indicating two separate populations under study. In each case, evaluating the results of the chart furnishes useful information about the event or process being analyzed. See [Figure 1.7.](#)

1.18.4. Be aware of twin or multiple peaks. Their appearance indicates that the data is coming from two or more different sources. If this is the case stratify the data so that the histogram uses only one data source.

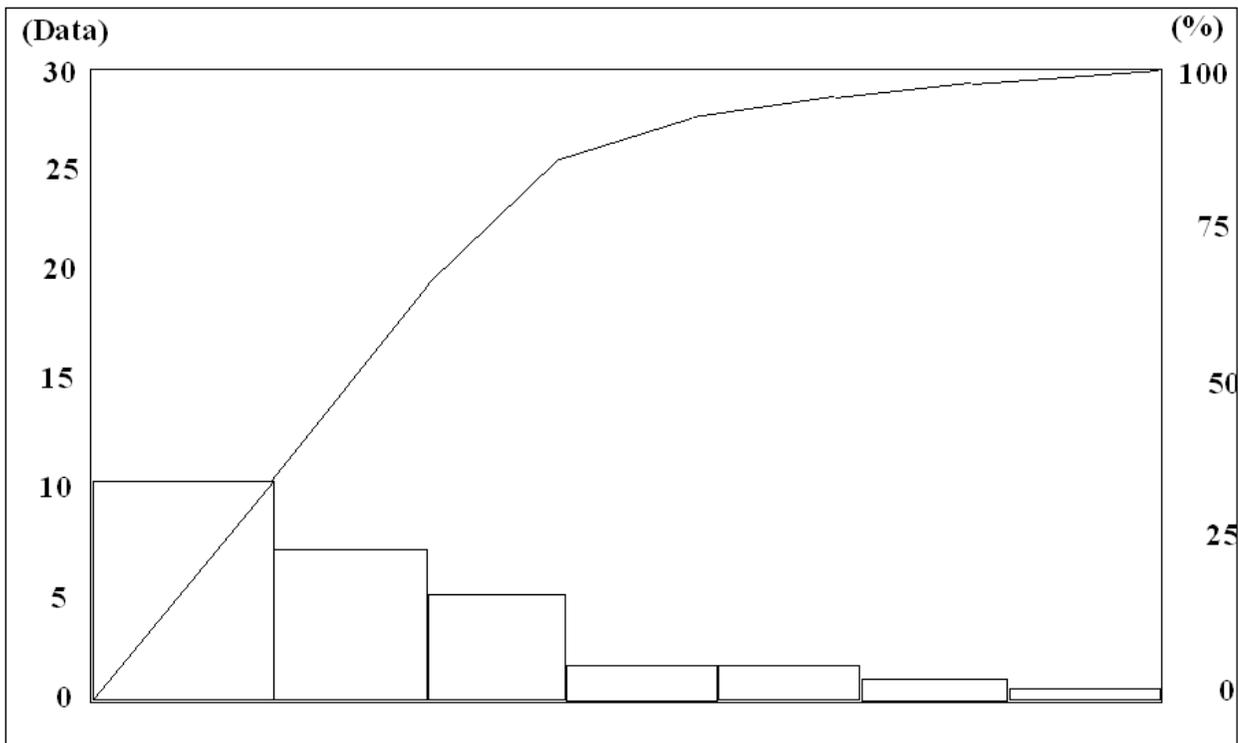
Figure 1.7. Four Histograms Displaying Potential Results.



Section 1F—Pareto Chart

1.19. General Concepts. A Pareto chart identifies the problems that should be solved first in terms of complaints, defects or cost. The Pareto chart is useful because it shows the areas that are experiencing the most problems and should be addressed first for correction. See [Figure 1.8.](#)

Figure 1.8. Pareto Chart.



1.20. Procedures to Construct a Pareto Chart.

1.20.1. Determine what factor (cost, defects, etc.) you want to use to evaluate different processes. The samples for this factor are itemized into the processes you'll evaluate. For example, if errors are occurring in a supply organization you can evaluate the number of errors in the processes of Receiving, Shipping, Storage, Delivery, etc. For documentation and validation purposes, specify the source of all counts.

1.20.2. Select a period of time to evaluate. The time period can range anywhere from a day, week, month, quarter to years. The samples for each process evaluated should come from the same time period for meaningful evaluation.

1.20.3. Draw horizontal and vertical axis for the diagram. The processes are listed along the horizontal line. The samples for the factor being evaluated are scaled on the left vertical axis. Values of 0 to 100% are scaled along the right vertical axis.

1.20.4. Total the samples for each process and use bars to represent the process. The process with the largest total of samples is placed first on the far left. The remaining processes are entered, ranging from those with the largest samples to the smallest. If several processes each have few samples, they can be combined and identified as other.

1.20.5. Use a line to show the cumulative total when adding each additional process. The line goes from the tallest bar to the right and up until it reaches the right axis at the 100% point.

1.20.6. Usually, the tallest bars indicate the largest contributors to the overall problem. Dealing with these areas first is logical. However, most frequent doesn't necessarily equate to most important.

1.21. How to Use a Pareto Chart. Use care when selecting the factor to evaluate different processes as potential candidates for problem solution. Using total defects can show one process as a potential candidate. But, by selecting cost of defects, a different process may show a larger impact. When a change is made to a process as a solution to a problem, draw another Pareto chart after operating under the new process and check if the process has decreased in relation to the other processes evaluated.

Section 1G—Scatter Diagram

1.22. General Concepts. The scatter diagram shows the relationship between two variables. The relationship is termed correlation or the influence one variable has on the other. The variables could come from the potential workload factors of a standard study, a cause-and-effect diagram, or any other source generating variables. The diagram is composed of an x-axis and y-axis. The effected variable is placed on the y-axis and the cause variable is placed on the x-axis.

1.23. Procedures to Develop a Scatter Diagram.

1.23.1. Draw a scatter diagram by collecting the data to plot the samples. The individual samples are formed by the intersection of the (x,y) values.

1.23.2. Collect 50 to 100 (x,y) data pairs that will form the samples on the diagram. See [Figure 1.9.](#) for a partial listing of point pairs.

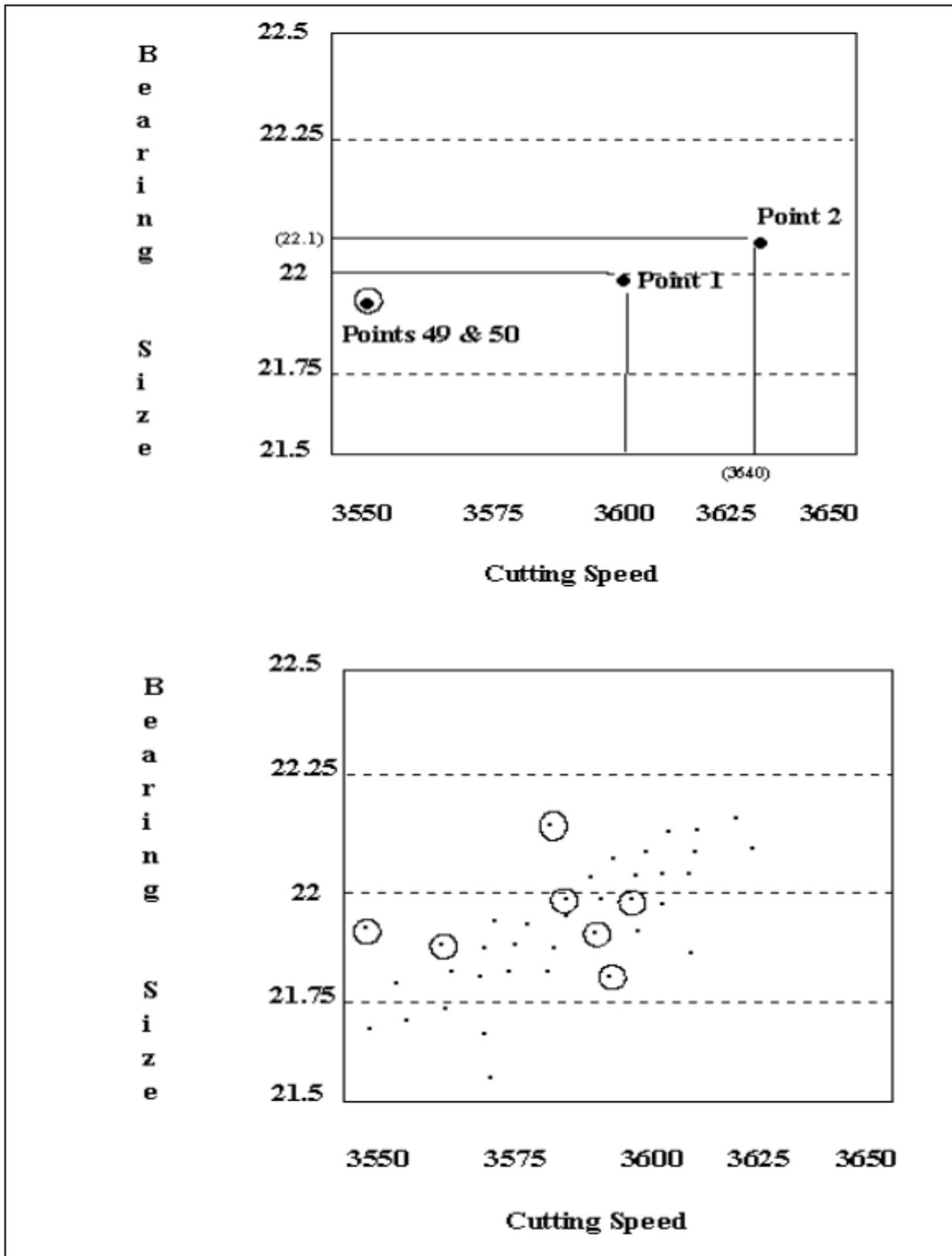
Figure 1.9. A Partial Listing of Data Point Pairs.

Number	Bearing Size (mm)	Cutter Speed (rpm)
1	22.0	3600
2	22.1	3640
...		
49	21.9	3550
50	21.9	3550

1.23.3. Draw and label the x-axis and y-axis.

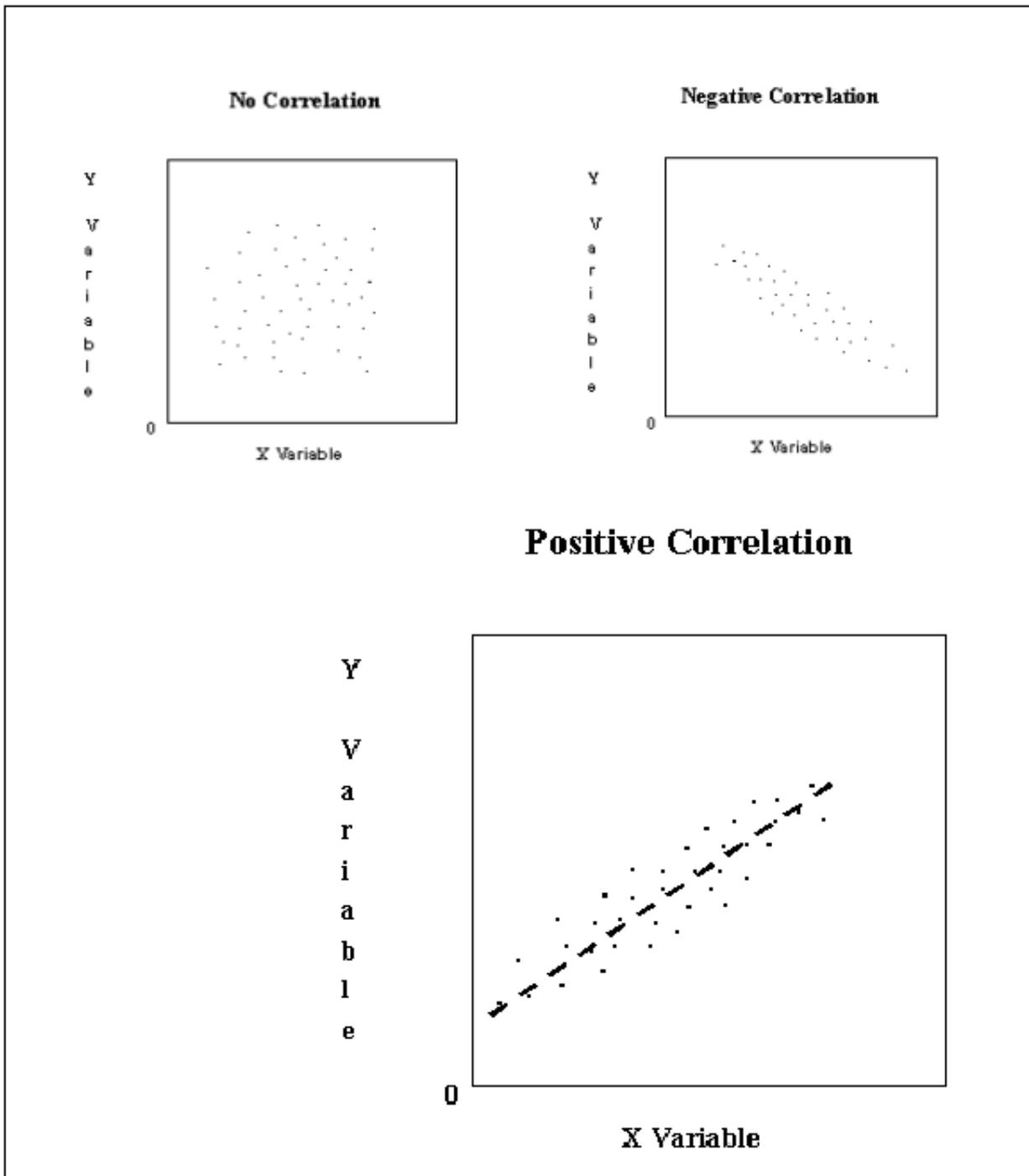
1.23.4. Plot the individual samples on the scatter diagram. If samples overlap, place concentric circles around the point, with a circle representing each additional point. See [Figure 1.10.](#) for an example of how to plot the samples and a scatter diagram.

Figure 1.10. Plotting a Scatter Diagram.



1.24. How to Interpret a Scatter Diagram. After the samples are plotted on the chart, observe if one variable affects the other. See [Figure 1.11](#). for a variety of possible results.

Figure 1.11. Scatter Diagram Outcomes.



1.24.1. If, as one variable increases in value the other also increases, there is a positive relationship or correlation. The closer the samples are to an imaginary line extending from the lower to the higher

samples the stronger is the impact of one variable on the other. The more dispersed the samples from the imaginary line the weaker the relationship.

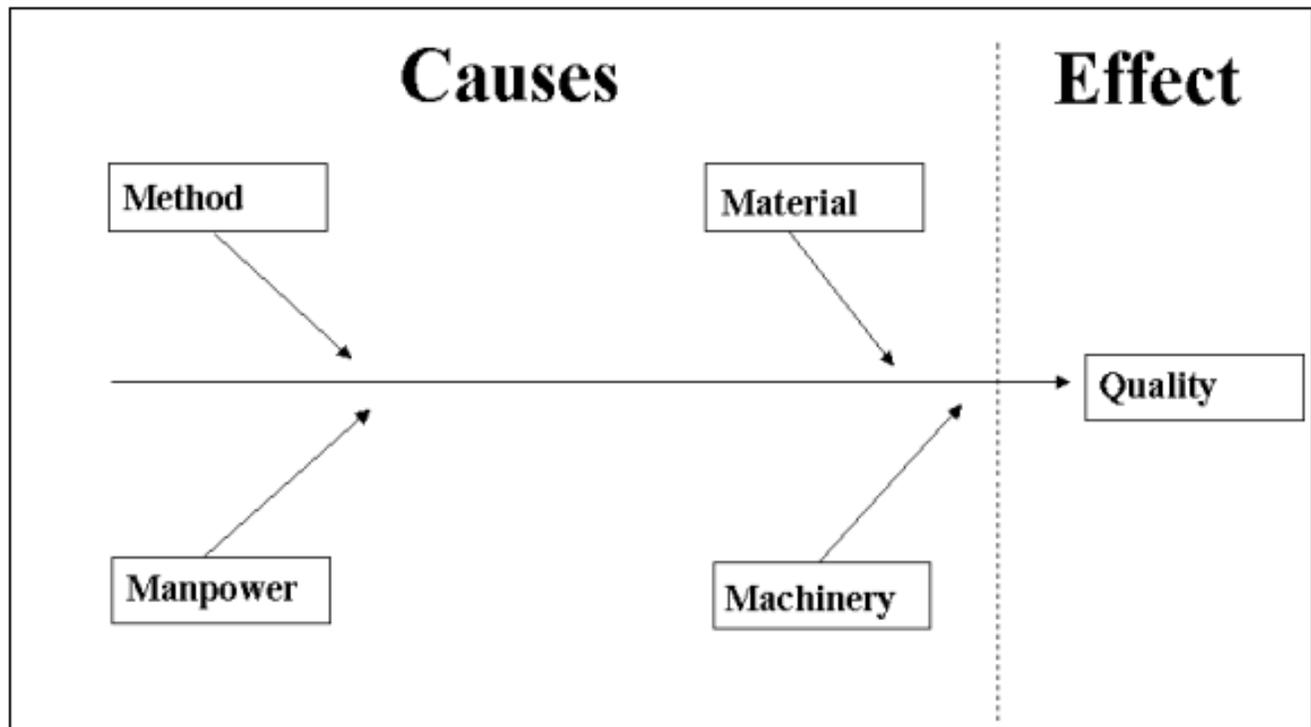
1.24.2. The diagram indicating No Correlation shows the data points scattered all over the diagram. There is no indication of a distinguishable impact of one variable on the other.

1.24.3. The diagram indicating Negative Correlation shows as one variable increases in value, the other decreases. As with Positive Correlation, the closer the samples are to an imaginary line extending from the lower to the higher samples, the stronger the impact of one variable on the other.

Section 1H—Cause-and-Effect Diagram

1.25. General Concepts. A cause-and-effect diagram (also known as an Ishikawa Diagram) is used not only to identify a potential problem but also to analyze it as well. Any problem can have many possible causes. The cause-and-effect diagram allows the user to identify potential causes of a problem in logical groups depending on the problem type. The primary factors that cause a product or service quality problem usually relate to unwanted changes in manpower, work processes, equipment, or raw materials. To find the elements that come into play, follow a logical approach to identify the potential causes of a problem. **Figure 1.12.** illustrates the structure of a cause-and-effect diagram.

Figure 1.12. Cause-and-Effect Diagram.



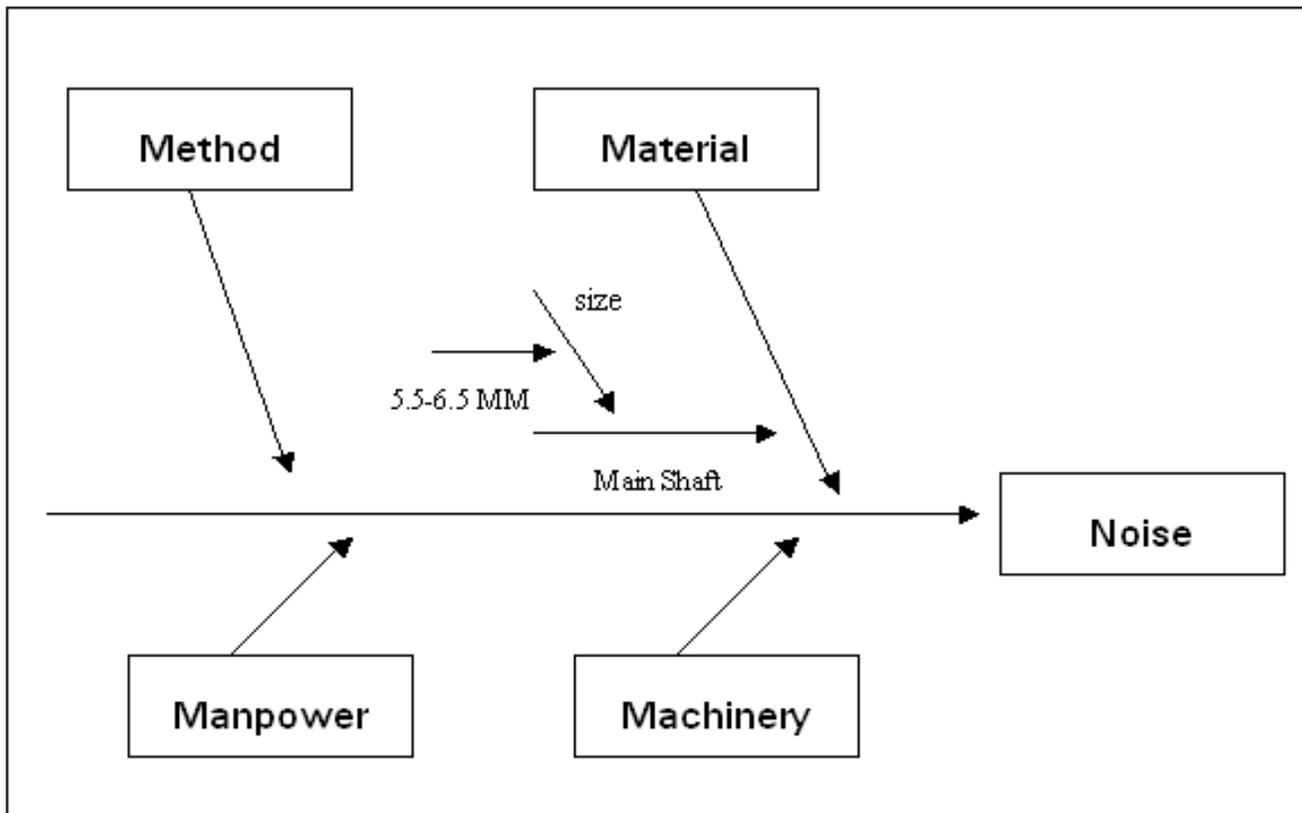
1.26. Procedures to Develop a Cause-and-Effect Diagram.

1.26.1. Identify what the problem is and briefly state it on the right side of the diagram. Enclose this statement in a box. Draw an arrow towards the problem statement extending to the left.

1.26.2. Identify the major categories of causes that potentially could cause the problem. Connect these categories to the line pointing to the problem statement.

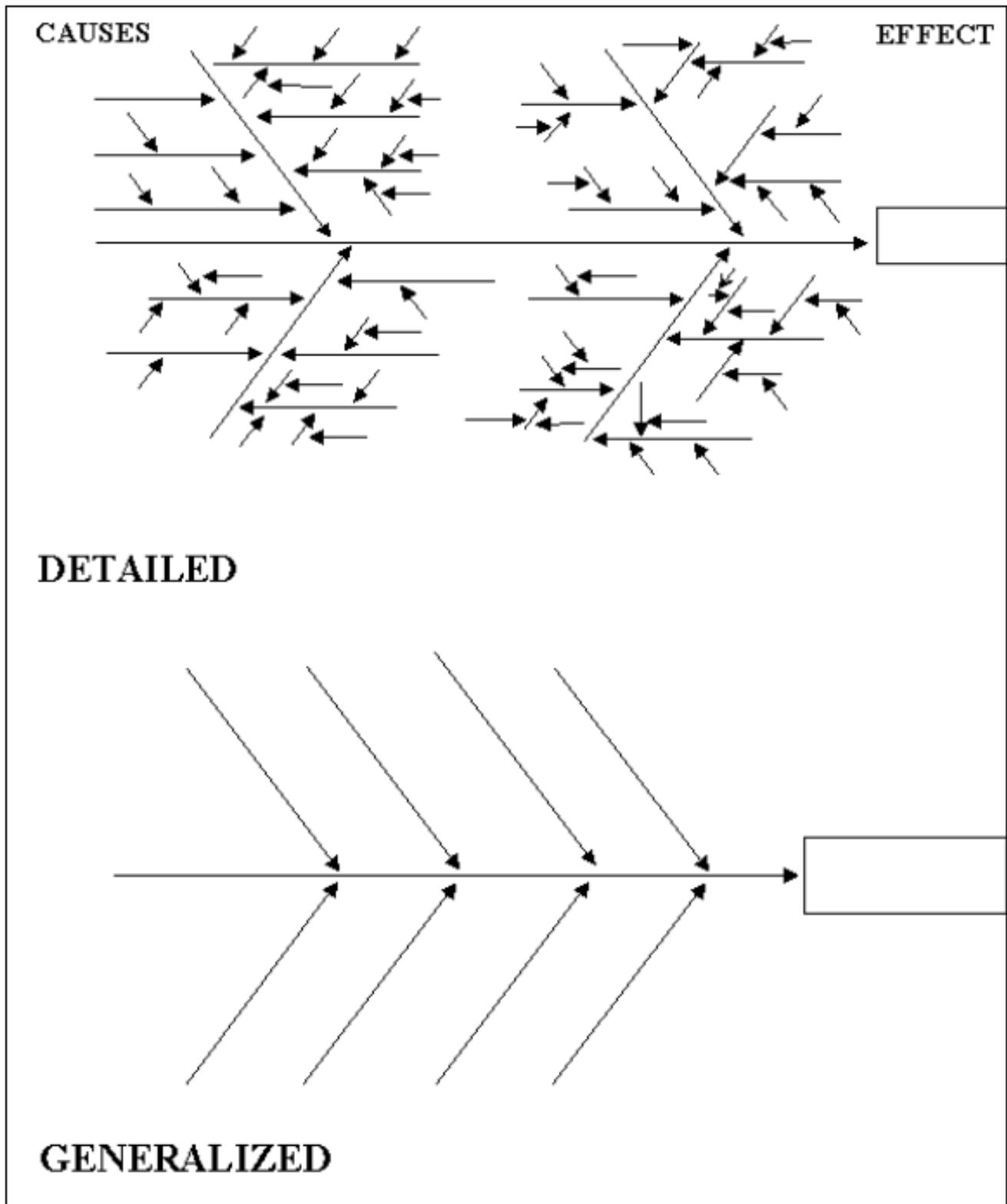
1.26.3. List the factors in each of these categories that could cause the problem, using an idea generating methodology such as the Nominal Group Technique or Brainstorming. Each of these branches can have branches identifying more specific causes of the stated problem. See [Figure 1.13](#). for an example of this branching.

Figure 1.13. Detailed Listing of Causes.



1.26.4. A very important element of identifying the potential causes of a stated problem is to have personnel that are familiar with the needs for completing the product or service. If a knowledgeable group of people is present, a very detailed breakdown of potential causes can be identified. If the personnel are not familiar with the processes or needs, then too generalized a listing of potential causes could result. See [Figure 1.14](#).

Figure 1.14. Detailed and Generalized Listing of Causes.



1.27. Benefits of Using a Cause-and-Effect Diagram.

1.27.1. Any type of problem can be displayed on a cause-and-effect diagram. It doesn't have to relate to quality or timeliness. For example, personnel, safety, and scheduling problems can also be analyzed using this diagram.

1.27.2. The level of knowledge about the factors that influence the problem is soon evident by the level of detailed breakdown of the potential causes of the problem. The more branches to the causes the greater the depth of knowledge of the personnel generating the causes.

1.27.3. The cause-and-effect diagram allows the participants to visually focus on the various categories of causes that could impact a problem. This makes it easier for the group to focus on generating potential causes.

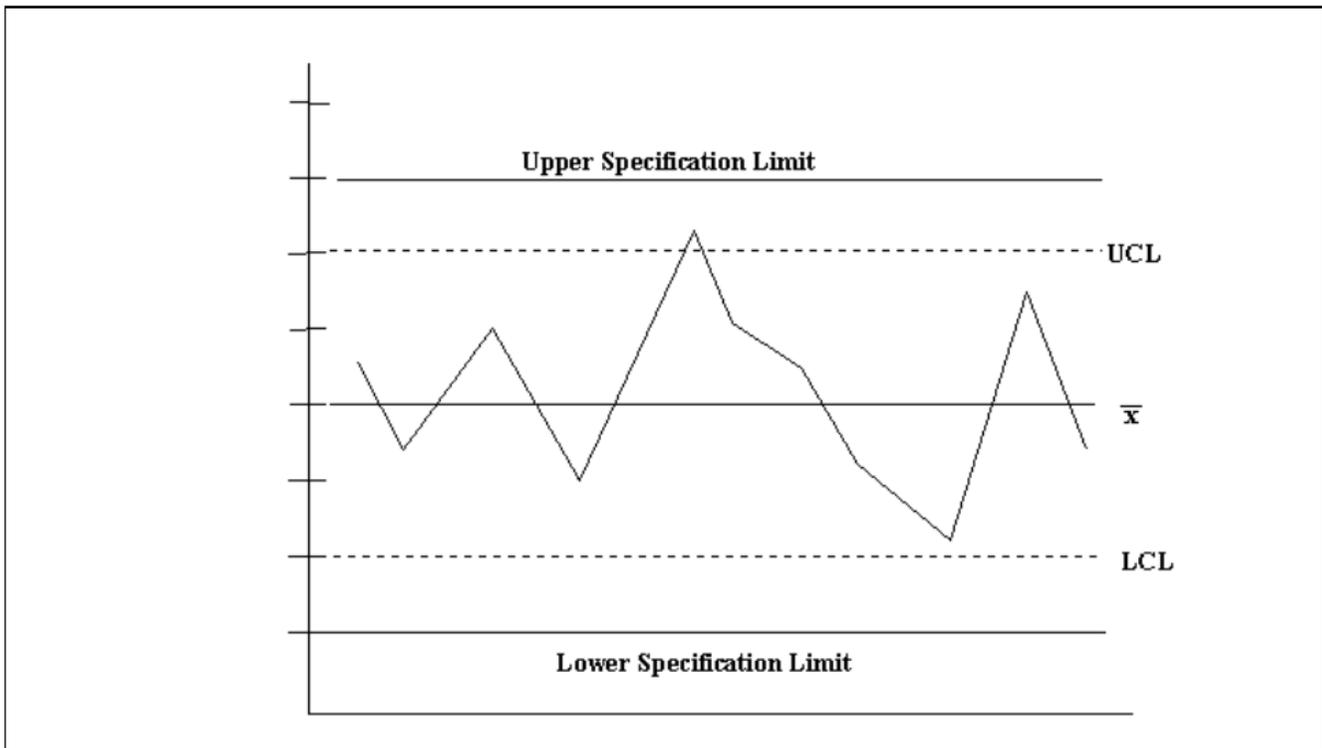
1.27.4. All personnel participating in the analysis gain from the interaction of ideas produced in the group. This interaction not only serves the purpose of generating ideas for solving a problem, but also aids in educating the participants about the various factors that impact the problem being addressed.

Section II—Control Chart

1.28. General Concepts. A control chart is an effective tool for determining if samples come from the same population and if the variation between samples is sufficiently small to allow the use of the mean as the sole descriptive statistic of the population.

1.28.1. Control charts (see [Figure 1.15.](#)) give important graphical information that can help determine where variation in a process might be normal or abnormal with the latter case requiring further analysis. By plotting the sample points in time order (the sequence in which they occurred), control charts can identify unusual changes in the process indicating the need for further analysis. There are several distinct data patterns that indicate whether we should explore data to include in our analysis - these patterns are shown in [Figure 1.18.](#)

Figure 1.15. Examples of a Control Chart.



1.28.2. There are two main types of control charts - for attributes data and for variables data. Attribute control charts are used to plot "go" or "no-go" factors such as an output being in or out of tolerance. Variable control charts plot specific measurements of a variable characteristic such as size, time, or weight of an output.

1.29. Description of Terms.

1.29.1. Assignable Cause. Any force/situation, not deemed part of the defined population that causes a sample to deviate significantly (exceeding established control limits) from the mean. For example, we may define a certain population of proportions as being "the level of daily productivity associated with the production of 40 to 60 units." If one day's productivity exceeded the Upper Control Limit (UCL) and the associated workload was 75 units, we'd know some force, not inherent to the defined population, was at work.

1.29.2. Common Cause. A host of small, independent, and elusive forces that act on events or measurements. Chance is normally responsible for the unassignable variation between elements of a population.

1.29.3. Observation. The selection of one element of a population.

1.29.4. Population. Any set of objects that we may care to define. Each member of a population is called an element.

1.29.5. Range. The difference between the highest and lowest value of any set of elements or observations.

1.29.6. Sample. In this context, sample is assumed to be a random sample. A random sample is the selection of one or more elements of a population - each element having the same probability of being selected.

1.29.7. Sample Size (n). A sample may consist of one or more observations - the number of observations is the size of the sample. For example: 23 (sample size is 1); 23, 27, 22, 21 (sample size is 4); and 20, 22 (sample size is 2).

1.29.8. Standard Deviation. The square root of the variance. The formula is $s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}}$

1.29.9. Variance (s^2). The average of the squared deviation from the mean. It's written as $\frac{\sum(x - \bar{x})^2}{n}$ or $\frac{\sum(x - \bar{x})^2}{n - 1}$. Use n-1 when the sample size is 30 or less. The formula is

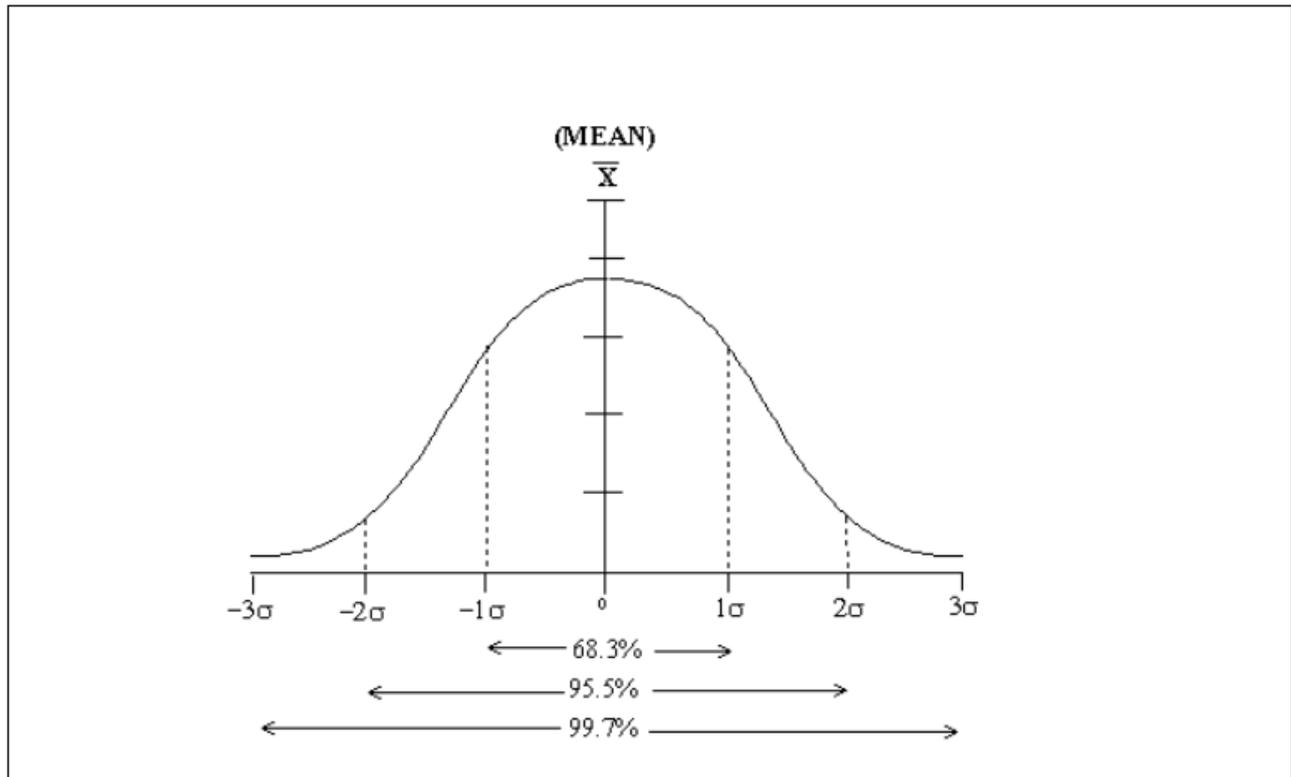
$$s^2 = \frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}$$

1.30. Control Chart Description. Descriptive statistics enable us to compile information in numerical form about populations. Two characteristics of populations lend themselves to numerical description - the central tendency and the dispersion of populations. By combining a visual representation of data with numerical descriptions, control charts enable us to make a visual and numerical analysis of the population.

1.30.1. A control chart is a graph with a centerline, upper and lower control limits (LCL), and sample points. The center line is usually the average (central tendency) of the samples. The control limits are the expected limits of the population based on the number of samples and their dispersion. The most used measure of central tendency is the mean and the measure of dispersion is the standard deviation. Control limits are determined by adding and subtracting one or more standard deviations from the mean (see [Figure 1.15](#)). They are derived mathematically by sampling data from the process. In [Figure 1.15](#), the process is within specifications, but it's not stable. To meet the customer's needs, all process samples should be within the UCL and LCL. The variation displayed in the chart can be decreased further by improving the process used to furnish the product or service to the customer.

1.30.2. The normal curve (see [Figure 1.16](#)) has 68.3% of the data points falling within one standard deviation (plus or minus) from the mean; 95.5% of the data points fall within two standard deviations from the mean; and 99.7% of the data points fall within three standard deviations. Construct a control chart to display data samples using the steps outlined below.

Figure 1.16. Standard Deviation Curve.



1.30.2.1. Get samples from the process being monitored.

1.30.2.2. Compute the mean by summing all data values together and then dividing that total by the number of counts.

1.30.2.3. Compute the Control Limits (UCL & LCL). The formula used will vary depending on which chart you are using. Refer to [Table 1.1](#) for the formulas.

Table 1.1. Control Chart Center Line and Control Limits.

L	A	B	C	D	E	F
L I N E	For Control Chart	with center line	first compute SYX or mean using	Next compute control limits using UCL LCL		NOTES
1	p	\bar{p}	$s = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$	$\bar{p}+3s$	$\bar{p}-3s$	$p = \frac{\text{\# of rejects (subgroups)}}{\text{\# Inspected (subgroups)}}$
2	np	$n\bar{p}$	$s = \sqrt{n\bar{p}(1-\bar{p})}$	$n\bar{p}+3s$	$n\bar{p}-3s$	$\bar{p} = \frac{\text{Total \# Rejects}}{\text{Total \# Inspected}}$
3	C	\bar{c}	$s = \sqrt{\bar{c}}$	$\bar{c} + 3s$	$\bar{c} - 3s$	$\bar{c} = \frac{\text{Total \# Defects per sample}}{\text{Total \# Sample Days}}$
4	U	\bar{u}	$s = \sqrt{\frac{\bar{u}}{n}}$	$\bar{u} + 3s$	$\bar{u} - 3s$	
5	x	\bar{x}	$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n}$	$\bar{x} + A_2\bar{R}$	$\bar{x} - A_2\bar{R}$	$n = \text{\# of samples}$ $A_2 = \left(\frac{3}{d_2\sqrt{n}} \right)$
			$\bar{x} = \frac{\bar{x}_1 + \bar{x}_2 + \dots + \bar{x}_k}{k}$			$k = \text{\# of subgroups}$ (20-25 groups)
6	R	R	$R = x_{\max} - x_{\min}$	$\bar{R}D_4$	$\bar{R}D_3$	
			$\bar{R} = \frac{R_1 + R_2 \dots R_n}{k}$			$R = x_{\max} - x_{\min}$

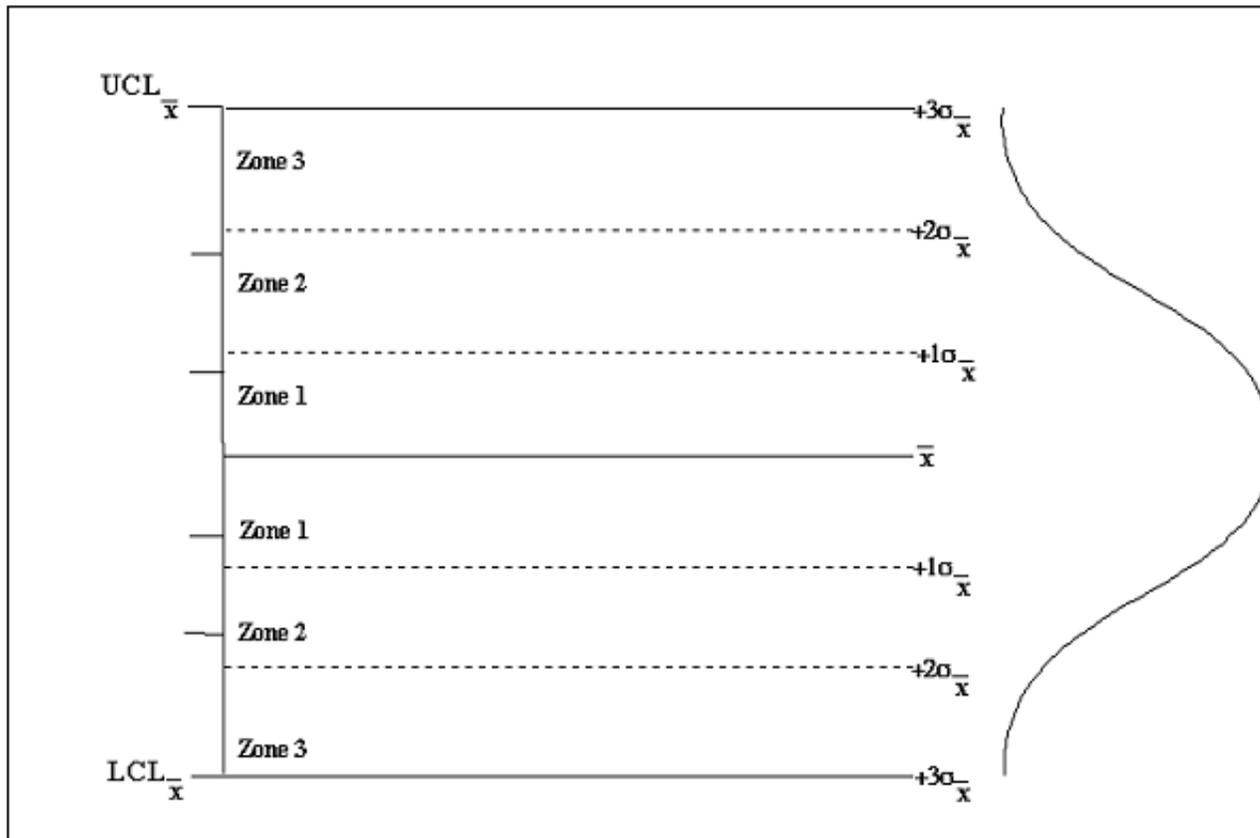
1.30.2.4. Calculate the Standard Deviation. Each standard deviation is identified as a zone.

1.30.2.4.1. Add three standard deviations to the process average (mean) for the zone limits 1, 2, and 3 above the center line.

1.30.2.4.2. Subtract three standard deviations from the process average for the limits 1, 2, and 3 below the center line.

1.30.2.5. Draw the X, and Y axis; process center line; UCL, LCL, and Zones (1, 2, and 3) on the control chart. See [Figure 1.17.](#)

Figure 1.17. Control Chart with Three Standard Deviations.



1.30.2.6. Plot and connect the sample data points.

1.30.2.7. Analyze the data by looking for out-of-control and unnatural conditions.

1.30.3. If samples are within three standard deviations, analyze their variation to determine if the mean can be used as the sole descriptive statistic of the population. Some populations have such broad limits that the mean alone has little value as a description of the population. Observe how the standard deviation compares to the size of the mean. If the standard deviation is small compared to the mean, the mean can be used as the sole descriptive statistic of the population.

1.31. Analyzing Control Charts. After building a control chart and plotting the data on it, analyze what the data is saying about the process. As mentioned earlier, if the data on the control chart forms a normal curve (natural pattern), the points will fluctuate at random and settle around the mean (center line). A few points may fall near the control limits (UCL, LCL), but none of the points should exceed the control lim-

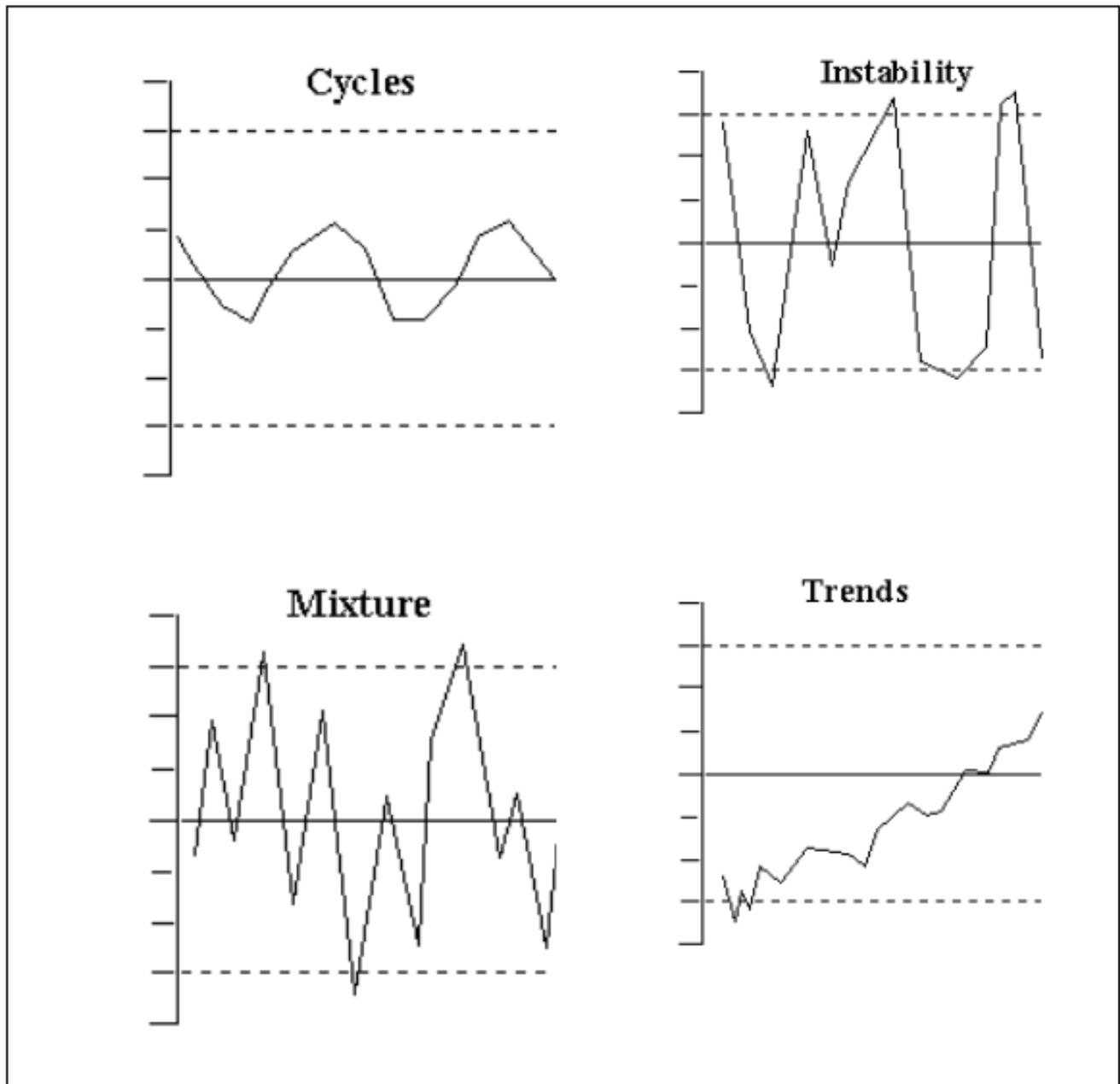
its. A normal curve shows there is a steady, stable process that is not being disturbed by assignable causes from outside the process.

1.31.1. If one of the data points exceeds the UCL or falls below the LCL, the process is "out-of-control". When this condition exists, investigate the process to identify the cause of the variation and correct it. Assignable causes of variation (e.g., machine out of alignment, fatigued worker, etc.) can be corrected bringing the process back into control.

1.31.2. When the correction or adjustment for assignable cause is made, the process variation should resume its normal distribution pattern between the UCL and LCL of the control chart. This normal amount of variation (normal distribution) is due to common causes of variation. Common causes of variation, unlike assignable causes, cannot be entirely eliminated from a process. However, management can take action to improve the overall process and reduce the amount of variation due to common causes by setting up process action teams, or providing training.

1.31.3. Having data points fall outside of the control limits is not the only indicator of an out-of-control condition. Data that fluctuates too widely or fails to fall around the mean can be classified as unnatural patterns of variation. An unnatural pattern usually shows that an abnormal condition is occurring or beginning to occur in the process. It needs to be investigated as a problem source or area of concern. There are several types of unnatural patterns of variation (see [Figure 1.18](#)).

Figure 1.18. Examples of Unnatural Patterns of Variation.



1.31.3.1. Cycles. A short trend in the data that occurs in a repeated pattern where the pattern becomes predictable or systematic. This is an indication of an assignable cause because a characteristic of a normal (random) pattern is that it does not repeat. A cycle is caused by a process variable that comes and goes on a regular basis.

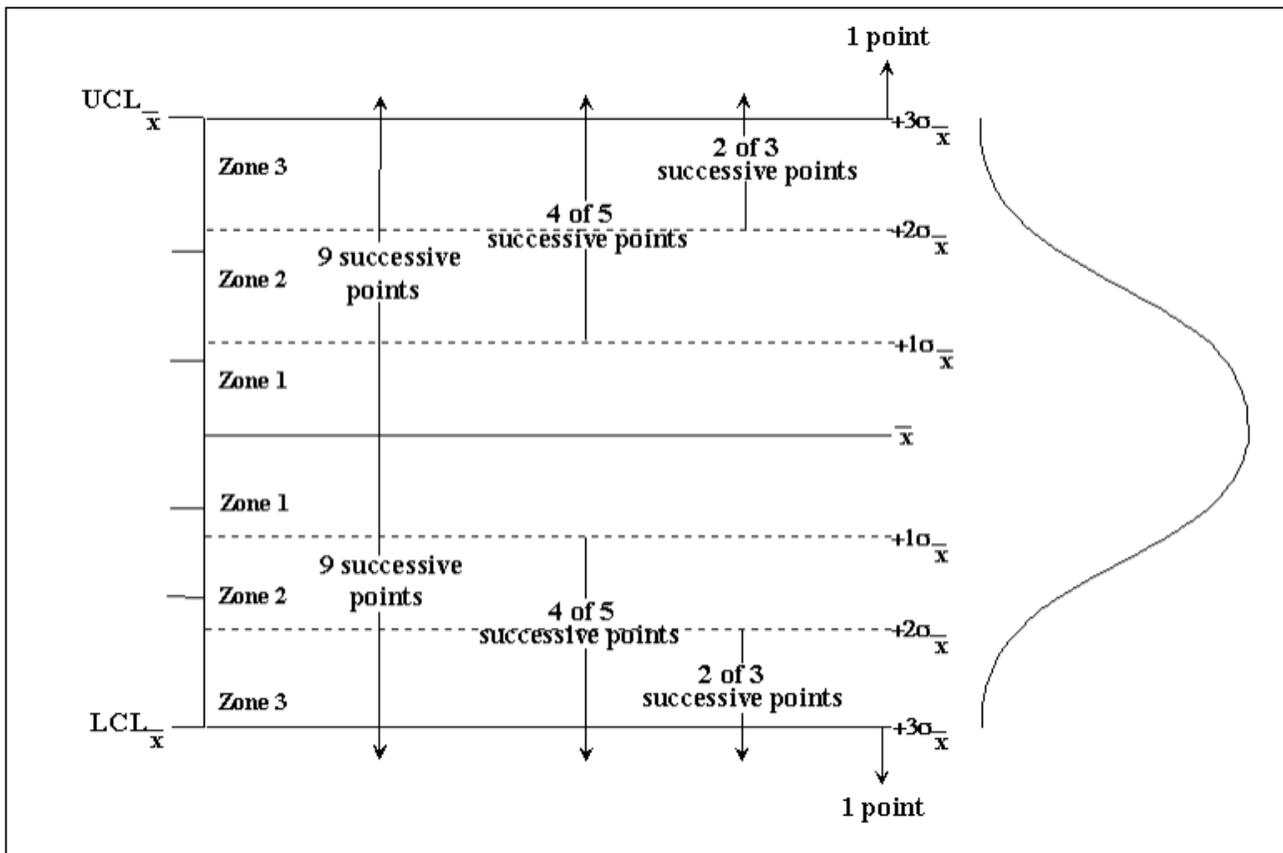
1.31.3.2. Instability. Is identified by wholly erratic fluctuations that go beyond the control limits or show erratic upward and downward movement.

1.31.3.3. Mixture. A pattern that falls near the control limits with an absence of points near the center line. This pattern is more commonly known as the "sawtooth" effect. A mixture is actually a combination of two different populations on the same chart.

1.31.3.4. Trends. A series of points showing a steady change in one direction, either up or down the control chart. Even if there is up and down movement of successive points, if the general direction of the points exhibit either an upward or downward movement, it can also be considered a trend.

1.31.4. There are some other out-of-control or abnormal condition indicators. They each show that something unusual is happening in the process that needs to be investigated (see [Figure 1.19](#)).

Figure 1.19. Abnormal Data Point Occurrences.



1.31.4.1. Two out of three successive points in Zone 3, on the same side of the center line.

1.31.4.2. Four out of five successive points in Zone 2 or beyond, on the same side of the center line.

1.31.4.3. Nine successive points on one side of the center line.

1.31.5. After building the control chart, plotting the data points, and interpreting the results, if no out of control conditions are found, the process is considered in control and free of assignable causes of variation. Continue using control charts to monitor the process and make sure it stays in control. Con-

centrate your efforts on reducing the common (random) causes of variation. This is how to achieve continuous improvement in a process.

1.31.6. This brief introduction on control charts with respect to their construction and use, gives enough information to allow us to look at some specific types of control charts. The number of samples used in each example shouldn't be considered to be a "sufficient" number for analysis. Strong analyses and conclusions depend on many more samples than used in the examples.

1.32. Control Charts for Attribute Data. Attribute data are usually obtained by counting the number of items in one of two categories; e.g., go or no-go, pass or fail. For example, a light bulb either lights up or it doesn't light. In attributes data, the item either has the characteristic or it doesn't.

1.32.1. Attribute control charts are useful in analyzing factors such as effectiveness, efficiency, document errors, reducing backlog and other forms of manpower analysis. These charts are useful when there are many processes to monitor. There are basically four types of attribute control charts: two types count the number of nonconforming parts or items, and two types count the number of nonconformities on a particular part or item.

1.32.1.1. The two types of attribute control charts that count nonconforming parts or items are the NP and the P-Charts. The NP-Chart plots the number of nonconforming parts or items in a sample and is used when the sample size is constant (5 items repaired each day). The P-Chart plots the percentage of nonconforming parts or items and is used when the sample size varies (15 items on day 1, 20 items on day 2, 25 items on day 3, etc.).

1.32.1.2. The two types of attribute control charts that count the number of nonconformities on a particular part or item are the C-Chart and the U-Chart. The C-Chart plots the number of nonconformities per sample and is used when the sample size is constant. The U-Chart plots the number of nonconformities per individual unit and is used when the sample size varies such as comparing documents that differ in size.

1.32.2. Using a P-Chart. The P-Chart should be used when it's necessary to determine if sample proportions come from the same population. For example, we use the P-Chart in work sampling to analyze the stability of daily productivity (the daily ratio of productive time to available or assigned time); and we can use the P-Chart to determine what proportion of a given number of items we can expect to be effective. The latter use is valuable if a work center's output is produced by defective items; we can take samples of the items, plot the sample proportions of defective items to total items, evaluate the P-Chart, and arrive at a reasonable conclusion about the stability of the mean and dispersion of the population. As an example, let's analyze the proportions of defective widgets produced at an Air Force base. There are 800 widgets produced each day of the study ($n = 800$).

SAMPLE (DAYS)	NO. OF DEFECTIVES (x)	p (x/800)
1	36	0.0450
2	42	0.0525
3	42	0.0525
4	40	0.0500
5	42	0.0525
6	40	0.0500
7	60	0.0750
8	40	0.0500
9	26	0.0325
N=10	<u>66</u>	0.0825
	$\Sigma x = 434$	

1.32.2.1. Calculate the mean proportion.

$$\bar{p} = \frac{\Sigma x}{Nn}$$

$$\bar{p} = \frac{434}{10 \times (800)}$$

$$\bar{p} = 0.0543$$

1.32.2.2. Calculate the standard deviation.

$$s^2 = \frac{\bar{p}(1-\bar{p})}{n}$$

$$s^2 = \frac{0.0543(0.9458)}{800}$$

$$s^2 = 0.000064$$

$$s = 0.0080$$

1.32.2.3. Calculate the control limits.

$$UCL = \bar{p} + 3s$$

$$LCL = \bar{p} - 3s$$

$$UCL = 0.0543 + 3(0.0080)$$

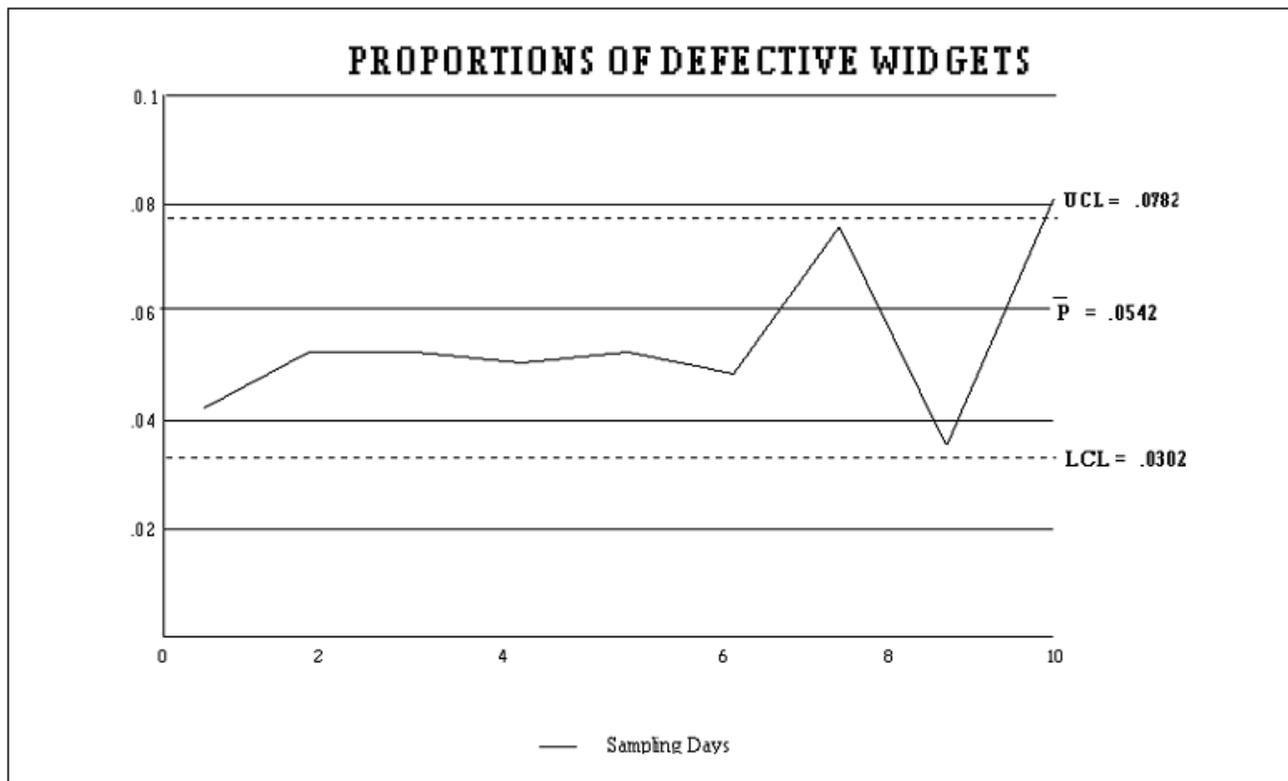
$$LCL = 0.0543 - 3(0.0080)$$

$$UCL = 0.0783$$

$$LCL = 0.0303$$

1.32.2.4. Plot the \bar{P} control chart (Figure 1.20.).

Figure 1.20. Example of a \bar{P} Control Chart.



1.32.2.5. Analyze the control chart.

1.32.3. Using a C-Chart. Another type of control chart for attribute data is the C-Chart. The letter c denotes the number of defects per item or group of items. The \bar{c} symbol (c-bar) represents the mean number of defects. The standard deviation of the population is estimated by the square root of \bar{c} .

1.32.3.1. Use the C-Chart when these two conditions are present: first, the average number of defects are far less than could occur if everything went wrong; and second, the area of opportunity for defects is the same. The latter condition means that when you group elements, always use the same number of elements per group.

1.32.3.2. As an example, let's analyze the number of defects per group of five ARC-34s bench checked by the personnel of a Com/Nav work center. We meet the conditions described above because each group of five ARC-34s bench checked have considerably fewer defects than they

could have if everything went wrong, and each group of five units gives a constant area of opportunity.

SAMPLE (DAYS)	NO. DEFECTS PER SAMPLE (C WHEN N = 5)
1	3
2	0
3	4
4	1
5	6
6	8
7	3
8	2
9	1
n = 10	<u>4</u>
	$\Sigma C = 32$

1.32.3.2.1. Compute the mean number of defects.

$$\bar{c} = \frac{\sum c}{n}$$

$$\bar{c} = \frac{32}{10}$$

$$\bar{c} = 3.2$$

1.32.3.2.2. Compute the standard deviation.

$$s^2 = \bar{c}$$

$$s = 1.8$$

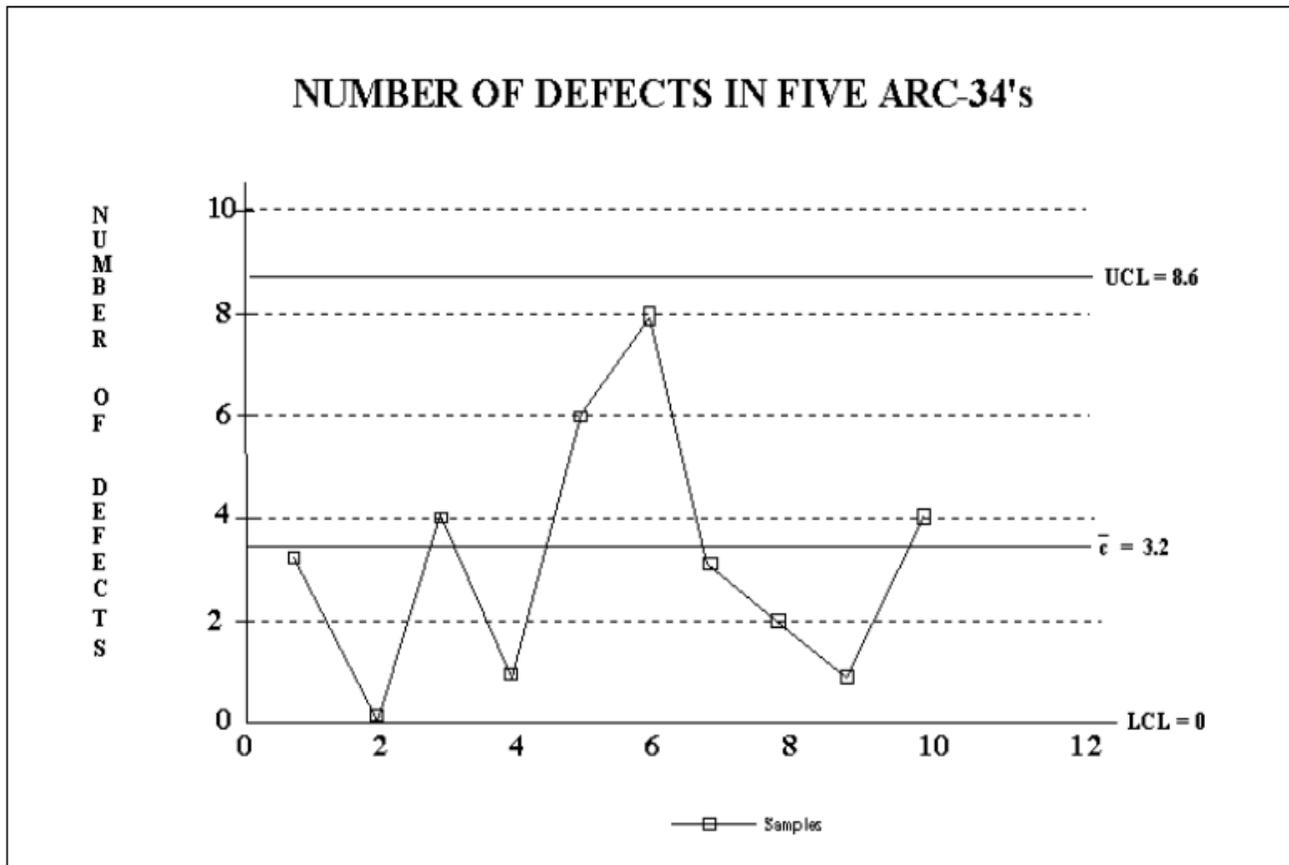
1.32.3.2.3. Compute the control limits.

$$\begin{aligned} UCL &= \bar{c} + 3s & LCL &= \bar{c} - 3s \\ UCL &= 3.2 + 3(1.8) & LCL &= 3.2 - 3(1.8) \\ UCL &= 8.6 & LCL &= -2.2 \end{aligned}$$

(for our purposes - LCL = 0)

1.32.3.2.4. Plot the C control chart (Figure 1.21).

Figure 1.21. Example of a C Control Chart.



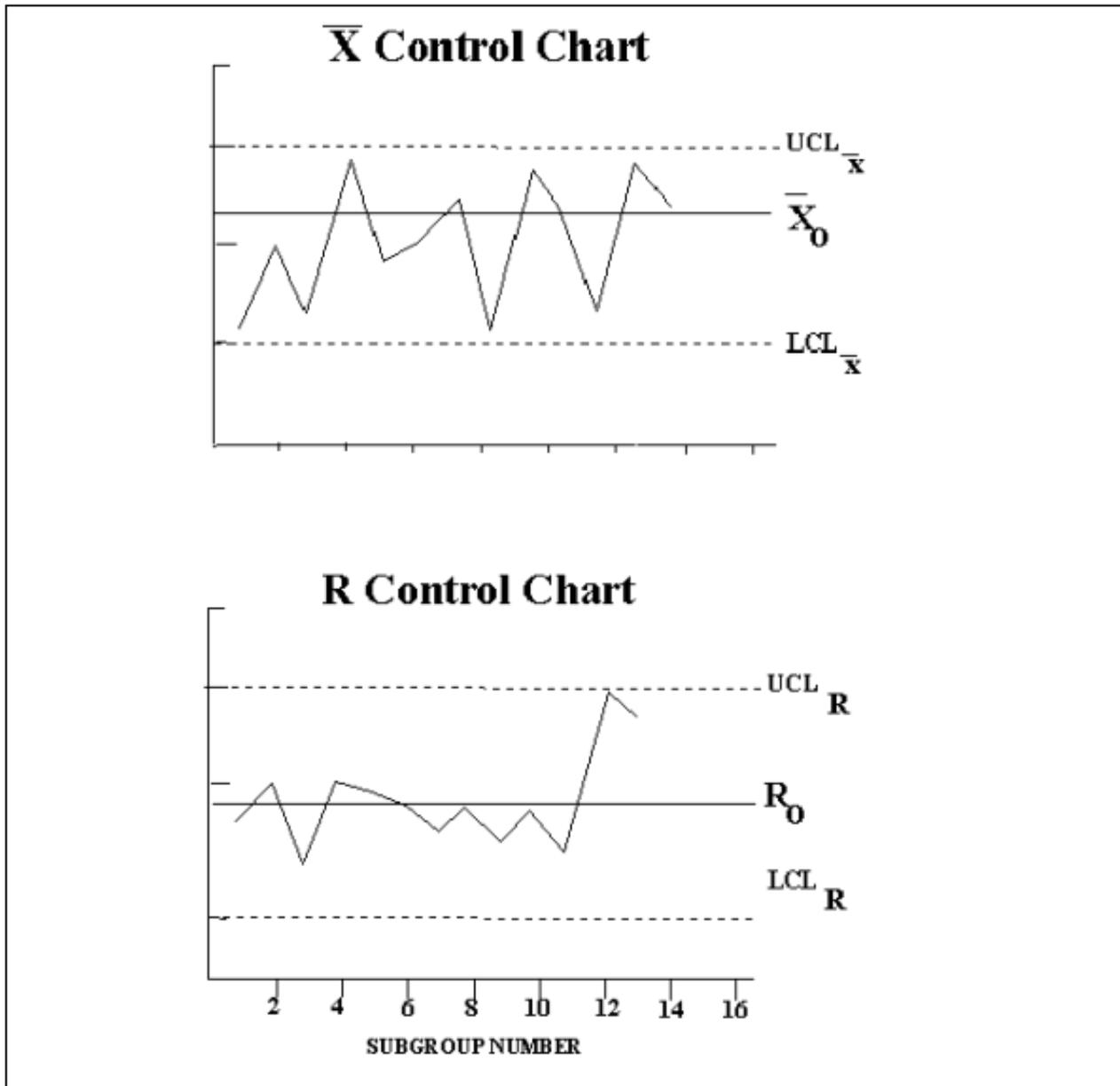
1.32.3.2.5. Analyze the control chart.

1.33. Control Charts for Measurement Data. Measurement data are recorded observations of the extent or amount of a characteristic associated with a given element or group of elements. Some fundamental characteristics are length, weight, and time. Workload data such as units produced, sorties flown, or items received can also be considered measurement data. The two types of variables control charts used in quality improvement are the \bar{X} (X-bar) and R charts. The bar above the X means an average is used and the chart is called an "X-bar" chart. The R stands for range. The \bar{X} charts are created separately but are used together since they each measure a different aspect of the process. The chart plots the average or

mean of measurements in a sample. The R chart plots the range or variation of measurements in the sample.

1.33.1. Typical \bar{X} -bar and R charts are shown in [Figure 1.22](#). They include basic elements common to all control charts; i.e., the mean (center line), UCL and LCL. The \bar{X} and R control charts are often used, since they give more information on the variation within a process than the charts that measure attributes. [Figure 1.22](#) shows a fairly stable process. All the points are within the calculated control limits and move in a random pattern.

Figure 1.22. Typical \bar{X} and R Control Charts.



1.33.2. If the plotted values of \bar{X} and R fall on or above the UCL, or fall on or below the LCL, an unexpected event has occurred and should be investigated. It might be due to worn machine parts,

deviating from accepted methods of processing, a change in material, or fatigue on the part of the worker.

1.33.3. Constructing an \bar{X} Chart. The steps in constructing an \bar{X} chart are:

1.33.3.1. Collect the data.

1.33.3.2. Compute the mean. Each mean is the sum of the measurements for the sampling period (i.e., daily, weekly, etc.) divided by the number of measurements taken during the sampling period.

1.33.3.3. Compute the range, or R for each data point. For each sample, the range is determined by subtracting the smallest value from the largest value.

1.33.3.4. Compute the center line (mean) for each chart. Add all the values of the \bar{X} data and divide by the number of \bar{X} data points. Each sample size should be the same size. Do the same for the R data points.

1.33.3.5. Compute the control limits (UCL, LCL) for each chart (\bar{X} and R) by using the formulas that apply. (See [Table 1.1.](#))

1.33.3.6. Draw the x (horizontal) axis and y (vertical) axis for each chart. Mark the scale on the x-axis of each chart. (The distance between the control limits on the \bar{X} chart is roughly similar to the control limits of the R chart.)

1.33.3.7. Draw the \bar{X} and R center lines and draw the control limits for each chart.

1.33.3.8. Plot the \bar{X} and R values on the chart.

1.33.3.9. Analyze the control charts.

1.33.4. Using the \bar{X} and Range Charts. These steps show the development of an \bar{X} chart and R chart for five weeks of daily numbers of work orders completed. (See [Table 1.2.](#) for constant values A_2 , D_3 , & D_4)

Table 1.2. Factors for \bar{X} and R Charts.

L	A	B	C	D
I	For			
N	Observations		Factors for R Chart	
E	in Sample, n	Factors for X Chart A2	Lower D3	Upper D4
1	2	1.88	0	3.267
2	3	1.023	0	2.574
3	4	0.729	0	2.282
4	5	0.577	0	2.114
5	6	0.483	0	2.004
6	7	0.419	0.076	1.924
7	8	0.373	0.136	1.864
8	9	0.337	0.148	1.816
9	10	0.308	0.223	1.777
10	11	0.285	0.256	1.744
11	12	0.266	0.283	1.717
12	13	0.249	0.307	1.693
13	14	0.235	0.328	1.672
14	15	0.223	0.347	1.653
15	16	0.212	0.363	1.637
16	17	0.203	0.378	1.622
17	18	0.194	0.391	1.608
18	19	0.187	0.403	1.597
19	20	0.18	0.415	1.585
20	21	0.173	0.425	1.575
21	22	0.167	0.434	1.566
22	23	0.162	0.443	1.557
23	24	0.157	0.451	1.548
24	25	0.153	0.459	1.541

<u>WEEK 1</u>	<u>WEEK 2</u>	<u>WEEK 3</u>	<u>WEEK 4</u>	<u>WEEK 5</u>
11	17	15	19	15
17	18	12	11	14
16	12	13	20	14
13	20	21	11	15
<u>18</u>	<u>17</u>	<u>16</u>	<u>15</u>	<u>12</u>
75	84	77	76	70

1.33.4.1. Calculate the mean of each sample.

$$\bar{X} = \Sigma X/N$$

$$\bar{X}_1 = 75/5 = 15.0$$

$$\bar{X}_2 = 84/5 = 16.8$$

$$\bar{X}_3 = 77/5 = 15.4$$

$$\bar{X}_4 = 76/5 = 15.2$$

$$\bar{X}_5 = 70/5 = 14.0$$

1.33.4.2. Calculate the average of the means.

$$\bar{\bar{X}} = \frac{\Sigma \bar{x}}{Nn}$$

$$\bar{\bar{X}} = \frac{382}{5(5)}$$

$$\bar{\bar{X}} = 15.28$$

1.33.4.3. Calculate the range of each sample.

$$R = \text{largest value} - \text{smallest value}$$

$$R_1 = 18 - 11 = 7$$

$$R_2 = 20 - 12 = 8$$

$$R_3 = 21 - 12 = 9$$

$$R_4 = 20 - 11 = 9$$

$$R_5 = 15 - 12 = 3$$

1.33.4.4. Calculate the average of the ranges.

$$\bar{R} = \frac{\sum R}{N}$$

$$\bar{R} = \frac{36}{5}$$

$$\bar{R} = 7.2$$

1.33.4.5. Calculate control limits — Chart.

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R}$$

$$A_2 = 0.577 \text{ (for } n = 5)$$

$$UCL_{\bar{X}} = 15.28 + 0.577(7.2)$$

$$UCL_{\bar{X}} = 19.43$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R}$$

$$LCL_{\bar{X}} = 15.28 - 0.577(7.2)$$

$$LCL_{\bar{X}} = 11.13$$

1.33.4.6. Calculate control limits — R Chart:

$$UCL_R = D_4 \bar{R}$$

$$D_4 = 2.114 \text{ (for } n = 5\text{)}$$

$$UCL_R = 2.114(7.2)$$

$$UCL_R = 15.2$$

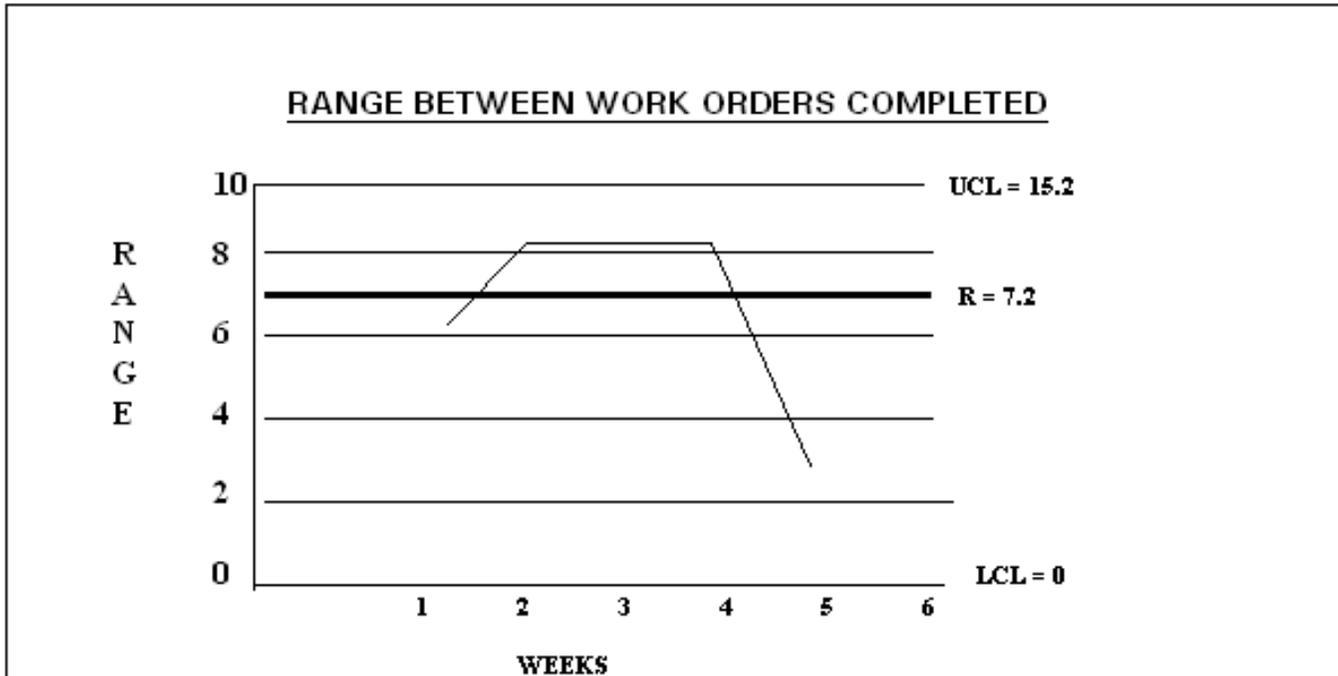
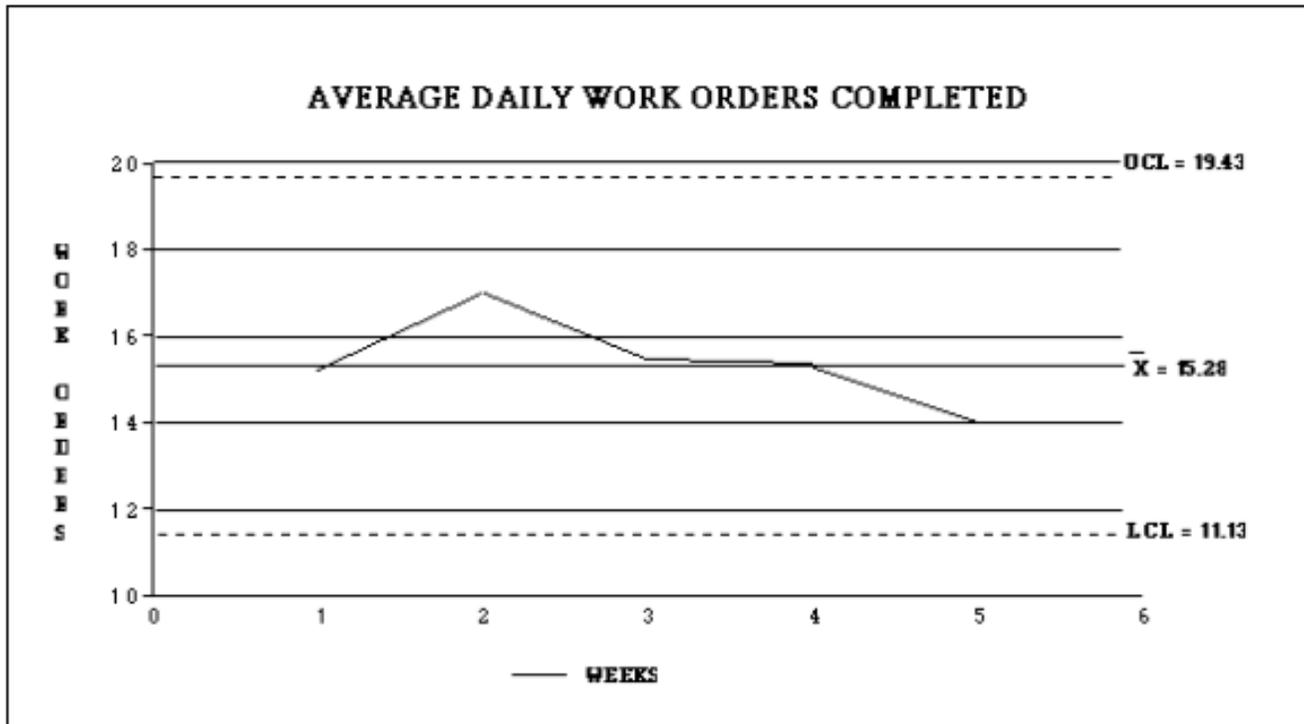
$$LCL_R = D_3 \bar{R}$$

$$D_3 = 0$$

$$LCL_R = 0.(6.8)$$

$$LCL_R = 0$$

1.33.4.7. Plot the control charts. Plot the R Chart below, and in line with, the \bar{X} Chart. Each range will then be in line with the mean of its respective sample (see [Figure 1.23](#)).

Figure 1.23. Examples of \bar{X} and R Control Charts.

1.33.4.8. Analyze the control charts. Each chart should be analyzed for data "in control" before the data is assumed to come from the same population.

1.33.5. Advantages and Disadvantages of X-bar & R Charts.

1.33.5.1. The main advantage of the \bar{X} and R chart is that it gives specific data about a single characteristic of a product or process that gives clues on how to isolate a particular problem.

1.33.5.2. A disadvantage of the \bar{X} and R chart is that, if used to measure products or processes that have many variables, many charts are needed (One for each variable that is considered important). This can be very costly, so the \bar{X} and R control charts are often used together with attributes control charts.

1.34. When To Use Control Charts. Deciding when to use control charts and which type to use isn't always easy. It's not economical nor is there enough time to chart every variable for every process. Therefore, determine which key areas or characteristics of a process really need to be monitored and concentrate on them. Take these steps:

1.34.1. Flow chart the process. Identify the key areas or elements.

1.34.2. Select the key areas or elements to monitor. Focus your efforts to prevent defects rather than just detecting them.

1.34.3. Select the pertinent control chart and determine the sample size. Then begin collecting data.

1.34.4. Construct a control chart and analyze the information.

1.34.5. Continue monitoring the process. Constantly seek ways to reduce assignable and random causes of variation.

1.34.6. Periodically reevaluate how closely you need to monitor the process using the control chart selected and the results being achieved. If there is too much variation in the process, work on improving it and eventually providing increased customer service and satisfaction.

Section 1J—Group Ware

1.35. Group Ware.

1.35.1. Recently a technology has become available which can support and enhance the traditional workshop data collection process. "Group Ware" is a term used to describe technology which integrates multiple computers so that communication, data collection, and decision making can be accomplished more efficiently. Familiar Group Ware tools include e-mail, conference call, video teleconferences, while less familiar Group Ware programs may be online (Internet-based) brainstorming tools or software-based data collection and consensus tools used in traditional face-to-face meetings.

1.35.2. Several types of Group Ware meeting options are possible, based on the time and location of participant involvement.

1.35.2.1. Synchronous/Face-to-face: Participants are working at the same time, in the same location (e.g., meeting room).

1.35.2.2. Synchronous/Distributed. Participants are working at the same time, but are located in different places. Imagine brainstorming with people located all over the world, and all of your inputs are showing up on everyone else's computer screens immediately.

1.35.2.3. Asynchronous. Participants are making their inputs at different times (e.g., whenever their schedules permit, over the course of a week), typically done in a distributed manner.

1.35.3. These consensus tools (both Internet-based and in face-to-face environments) potentially offer the most promise. An example of a face-to-face Group Ware system would be a conference room where each participant has his or her own computer which is networked to all the others by a server. The individual respondents enter their respective data, ideas, opinions, or comments, and this information is combined as appropriate for decision making, and presented to the group for discussion. The benefits of Group Ware workshops of this type are:

1.35.3.1. Cost savings. Recently, many Group Ware products have been made Internet-ready, so that actual meetings or data collection (part of a meeting) can be conducted on-line with participants from anywhere in the world. Obviously, travel costs can be greatly reduced. Many organizations use such a capability for collecting data prior to workshops, such as having participants complete on-line surveys, brainstorm, prioritize, vote, or make comments using this Internet interface, so that the group's information is consolidated and summarized when the traditional workshop begins.

1.35.3.2. Increased anonymity. Respondent ideas can be contributed for group discussion without the author being identified. The group addresses the content of the submitted idea, without much of the personality or rank dynamic present in open brainstorming.

1.35.3.3. Increased speed of data collection and analysis. Rather than verbally commenting one person at a time (often allowing more "vocal" or "aggressive" individuals to monopolize the time), a Group Ware workshop lets people contribute their perspective simultaneously (through the keyboard). Substantially more information can be collected in the same amount of time as traditional open discussion. Additionally, the computer involvement allows for immediate documentation and calculations to be performed, eliminating much of the administrative burden of the workshop. The group can get to the point of discussion much faster and have an automatic running log of the data and decision points reached by the group.

1.35.3.4. More control over the workshop. The Group Ware programs often restrict participants from drifting away from the workshop agenda or topic by controlling what they are working on and the way they can input data. Likewise, statistical analysis is usually available in Group Ware programs that "flags" data which meets a criteria set by the meeting owner, such as low level of consensus by the group or data points which exceed a certain standard deviation.

1.35.4. With some level of technical insight and effort, traditional desktop programs can be networked together to create a Group Ware platform. For example, AFMIA has developed an Excel program for collecting PAT and Frequency data from a group of people by networking computers and creating "macros" which automatically consolidate the inputs. Other more "off the shelf" programs are designed to consolidate multiple inputs, but are less "manpower focused," which may or may not be an issue.

1.35.5. In all cases, this technology requires adequate planning and competency to implement. The cost savings, time savings, increased buy-in, and better documentation are all very valuable outcomes, but they will not be achieved if the tool is not properly understood and utilized.

Chapter 2

DATA ANALYSIS AND COMPUTATIONS

Section 2A—Correlation and Regression (C&R) Analysis

2.1. General Concepts.

2.1.1. There are many uses for C&R analysis in the MEP. Some of these are the selection of workload factors and the development of man-hour equations, functional estimating equations, and functional models.

2.1.2. Before starting C&R, verify the accuracy of the input data and purge it of any collection errors. The use of previously discussed techniques, such as control charts and scattergrams, will aid you in determining if data is good and logical. The end result of C&R is only as good as the data it's based on.

2.1.3. Although correlation and regression are separate processes, they are usually done together. Regression statistics yield the equation and correlation statistics tell how good the equation is.

2.1.4. Use C&R to evaluate the mathematical relationship between variables. Regression results in a linear or curvilinear equation that can be used for prediction purposes. For example, suppose that the number of line items processed in a base supply activity affects the number of man-hours needed in that function. The man-hours can then be expressed as a mathematical function of the number of line items processed.

2.2. Equation Forms.

2.2.1. Introduction to Equation Forms. A mathematical equation provides useful information about the relationship between varying levels of workloads and measured man-hours. The equation can be used to predict man-hours. There are various forms the equation can take. Each form has a dependent variable (Y). This is the variable you are trying to predict. Y usually stands for man-hours. Each form also has one or more independent variable (X or Xs), that are used to help predict the dependent variable. X usually stands for workload. The equations also have a set number of coefficients (a, b₁, b₂, ..., b_n) that are developed with regression analysis. Commonly used equation forms and their individual characteristics follow.

2.2.2. Linear Equation. The most direct relationship between two variables is the linear equation $Y = a + bX$. This equation shows a constant slope (b) in a line. A linear equation has two coefficients, "a" and "b", to be estimated with regression.

2.2.3. Parabolic Equation. A relationship between two variables that allows for a change in the way X is influencing Y can be represented by a parabola, $Y = a + bX + cX^2$. This allows the straight line, $Y = a + bX$, to curve up if the value of c is positive, or down if the value of c is negative. This equation form has three coefficients (a, b, and c) that will be estimated with regression analysis.

2.2.4. Multivariate Equation.

2.2.4.1. The equation form for two independent variables is $Y = a + b_1X_1 + b_2X_2$; for three variables, $Y = a + b_1X_1 + b_2X_2 + b_3X_3$; and for any number (n) of variables, $Y = a + b_1X_1 + b_2X_2 \dots + b_nX_n$.

2.2.4.2. Each coefficient (b-value) of the individual independent variables represents an amount of influence from its corresponding X-variable given that all of the other independent variables (Xs) are held at a constant value. For example, the coefficient for X_1 in the equation $Y = a + b_1X_1$ would not be the same as the coefficient estimated for the same X_1 in the equation $Y = a + b_1X_1 + b_2X_2$.

2.2.4.3. Negative values for the coefficients may occur even when correlation between the dependent variables is positive. This may occur due to multicollinearity explained in paragraph 2.2.4.4. Negative b-values are acceptable, providing they pass the t-test of significance that shows if a particular independent variable should be included in the model.

2.2.4.4. Sometimes two or more of the independent variables are highly correlated. This is called multicollinearity. In such situations, these independent variables add similar information to the model. Since the model is used for prediction, don't do anything if the correlation between the independent variables continues into the future.

2.2.5. Special Equation Forms.

2.2.5.1. The two special curvilinear forms are the ratio and power. Use them with caution. Each restricts the prediction line through the origin and can unduly influence the form of the line. These forms must meet the same statistical criteria as for the linear and parabola.

2.2.5.1.1. Ratio. This is a hyperbolic curve, $Y = X/(a + bX)$, that requires the dependent variable (Y) of a line, to be transformed to (X/Y) . Convert the ratio to a linear form by taking the reciprocal of both sides of the equation and then multiply each side by X. The resulting equation is $X/Y = a + bX$.

2.2.5.1.2. Power. This is an exponential curve, $Y = aX^b$, that requires both the dependent and independent variables to be transformed. Transform the equation by taking the log of each side. The resulting equation becomes $\log Y = \log a + b(\log X)$.

2.2.5.2. While the ratio and power curves are legitimate mathematical forms, they cannot be directly compared statistically to the linear and parabolic forms because of the transformations involved. Transformation changes the distributional properties that the statistical tests are based upon. Therefore, use these models with caution. Use a special equation form when:

2.2.5.2.1. A parabola fits the data better than a linear equation, and the apex is within the data range. One of the special curved equation forms may represent the data in the same manner as the parabola but without an apex.

2.2.5.2.2. A parabola fits the data better than a linear equation, and the apex is just outside the data range. The parabola in this case restricts the utility of the standard and should not be used. However, one of the special curve forms may fit the data almost as well and give an acceptable extrapolation range.

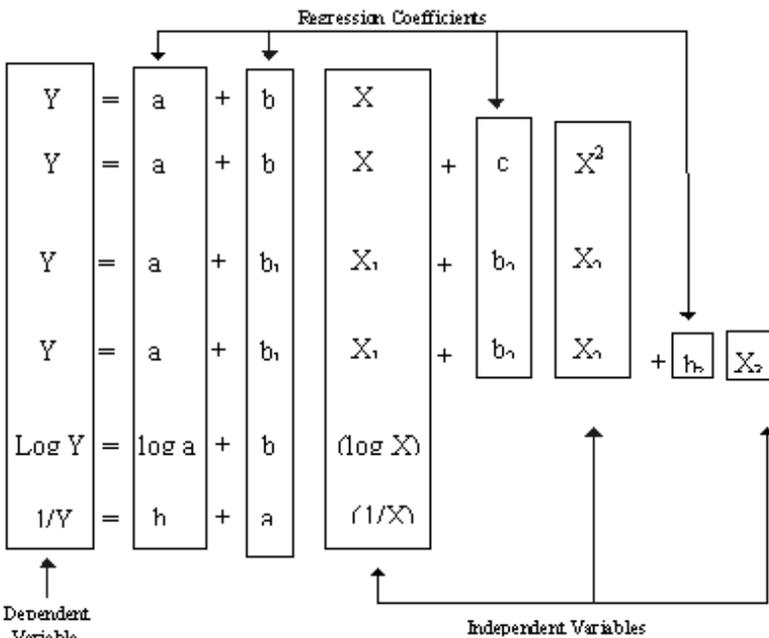
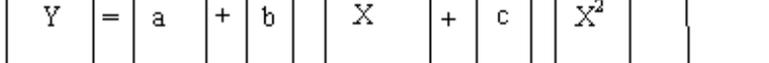
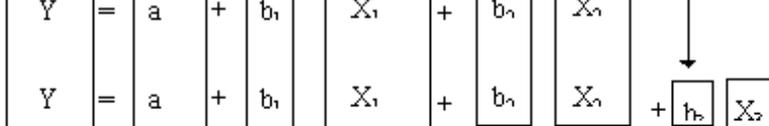
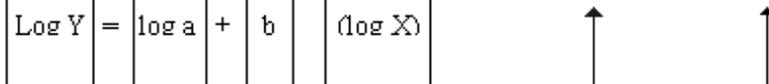
2.2.5.3. No-Intercept Equation. In situations where the range of the observed data is near zero, the use of a no-intercept model ($Y = bX$) can be supported statistically. The intercept (a) from a linear equation must not be significantly different from zero for a no-intercept form to be used.

2.3. Regression Analysis.

2.3.1. Least Squares Criteria. The regression technique used in the MEP is based on the "least squares" criterion for determining the equation (Y_c) that best fits the observed data (Y). This method estimates the regression coefficients (a, b_1, b_2, \dots, b_n) of the general equation $Y_c = b_1x_1 + b_2x_2 \dots b_kx_k$ in such a manner as to guarantee the quantity $\sum(Y - Y_c)^2$ is minimized—hence, the name "least squares" regression..

2.3.2. Specific Terms. Specific terms are used in regression analysis. **Figure 2.1.** shows the relationship between the equation forms and the regression analysis terms.

Figure 2.1. Relationships Between Equation Forms and the Regression Analysis Terms.

EQUATION	TERMS USED IN REGRESSION ANALYSIS	VALUE OF m (Regression Coefficients)
LINEAR		$m = 2$ (a, b)
PARABOLIC		$m = 3$ (a, b, c)
MULTIVARIATE -- two independent variables		$m = 3$ (a, b1, b2)
— three independent variables		$m = 4$ (a, b1, b2, b3)
POWER (after transformation)		$m = 2$ (log a, b)
RATIO (after transformation)		$m = 2$ (b, a)

2.3.3. The Dependent Variable. In regression analysis, the dependent variable is the variable of interest. The notation for this is "Y." Most commonly in the MEP, the dependent variable is man-hours. However, it could be any type of measurement about which a prediction is needed. Measured man-hours for the dependent variable are usually costly to get. Therefore, try to find a relationship with a more easily obtainable variable that can be used to predict the dependent variable without measurement.

2.3.4. The Independent Variable. Independent variables mathematically change with the dependent variable. Therefore, they can be used to predict the dependent variable. Notation for the independent variable is "X." These can either be the actual measurements of the independent variable or a transformation of the independent variable, for example, X^2 , $\log X$, $1/X$, or X .

2.3.5. Regression Coefficients. Regression coefficients are the values resulting from regression analysis and are used to form the regression equation. In the general equation form,

$Y = a + b_1X_1 + b_2X_2 + \dots + b_kX_k$, there are m regression coefficients (where $m = k + 1$). The m -coefficients (a, b_1, b_2, \dots, b_k) include the "b" coefficients for the independent variables, as well as the "a," that is the Y-intercept.

2.3.6. Regression Analysis Assumptions.

2.3.6.1. The form of the equation is linear with respect to the coefficients (b). This still allows for the transformation of the independent variables (X) into a power (X^2), reciprocal ($1/X$), or log X as needed for an equation form.

2.3.6.2. The values of the independent variables can be measured with little or no variability.

2.3.6.3. The residuals are defined as the difference between the observed and calculated man-hours ($Y - Y_c$). Assumptions regarding residuals follow.

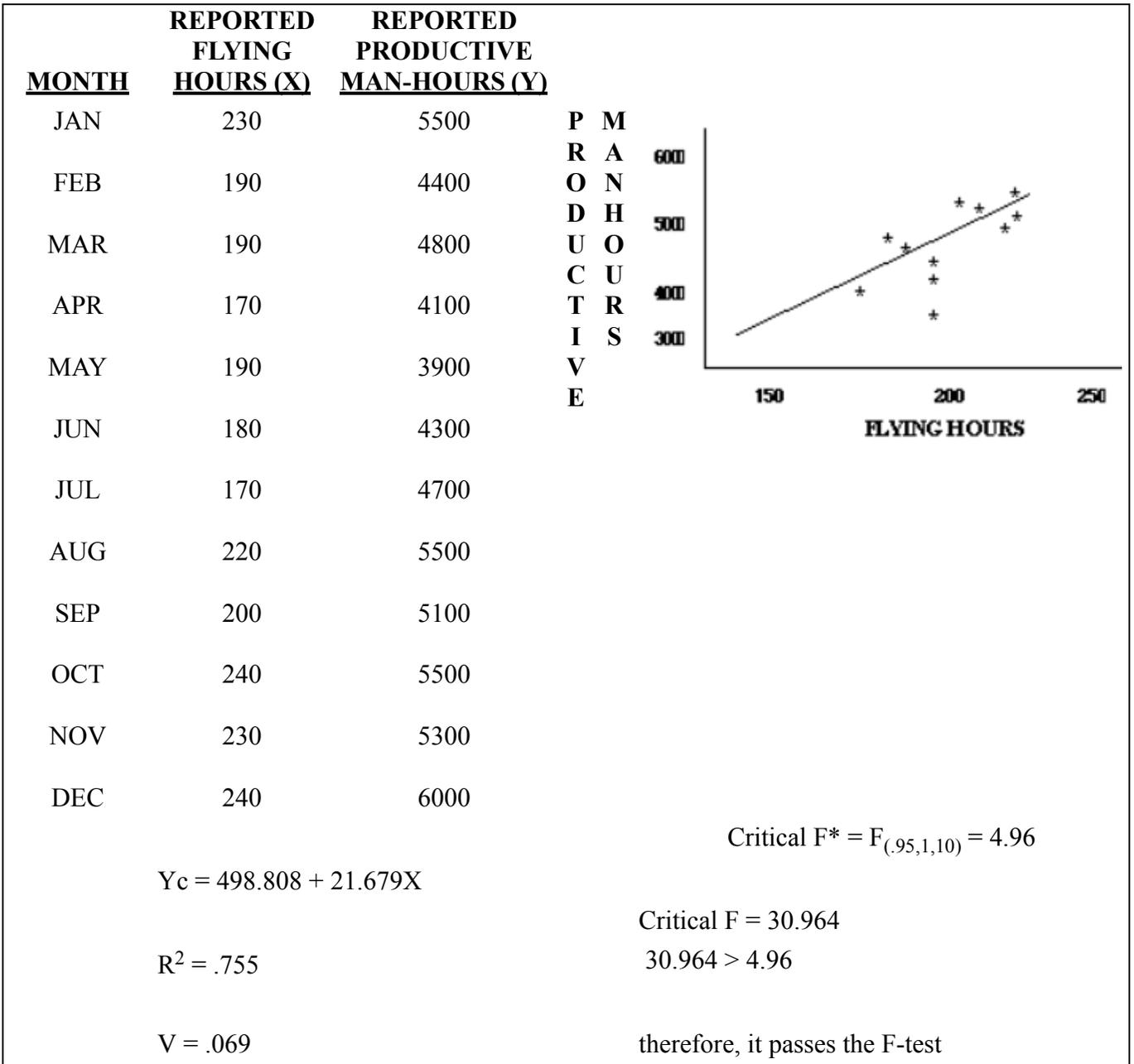
2.3.6.3.1. Residuals are independent of each other.

2.3.6.3.2. Residuals are normally distributed and have the same variance regardless of the value of the independent variable.

2.3.7. Single Location Regression Analysis. Use time series regression when multiple data sets can be obtained by one of these methods.

2.3.7.1. Use historical data when reliable monthly man-hour and workload accounting records exist. Regress a minimum of 6 months, preferably 12 months, historical man-hour data against monthly workload data for each of the monthly periods. An example is a base that has accurate reporting systems for flying hours (X) and productive man-hours (Y). Use the historical data for the past year to get an equation that relates flying hours to productive man-hours. Evaluate the equation with the R^2 and V criteria, and the F-test. **Figure 2.2.** shows an example of this use of regression analysis.

Figure 2.2. Example Using Regression Analysis and Historical Data for a Single Location Standard.



2.3.7.2. The second way to get multiple data sets is to set up a collection cycle to gather the necessary measurement data over a given time period.

2.4. Number of Input Points.

2.4.1. The number of input points in regression analysis becomes important in testing the significance of the regression line. To have a meaningful test, there should be enough inputs to allow a good estimation of the variability within the data after the coefficients are estimated.

2.4.2. Using only the statistic R^2 (coefficient of determination) as a measure of “goodness” can be misleading when the number of coefficients is very near the number of input data sets. Mathematically, any number of points can be fit exactly with enough coefficients in the equation. For example, three points fit exactly an equation with three coefficients ($Y = a + bX + cX^2$), thus producing $R^2 = 1$.

2.4.3. Input points are needed for regression analysis.

2.4.3.1. When the total number of locations is two, three, or four, it is a small population. Measure all locations. Statistical tests (F-test and t-test) are not needed.

2.4.3.2. When the total population consists of five or more locations, use the minimum number of inputs, outlined in AFMAN 38-208, Volume 1, **Table 3.4**, as a guide and get one or two more if possible.

2.4.3.3. In regression analysis, statistical tests are based on $(n-1)$ and $(n-m)$, called degrees of freedom. The total number of observations or data points is n , and m is the total number of coefficients. Therefore, the more points in the sample, the more information for the statistical test.

2.4.3.4. The inputs should adequately portray the behavior of the data at various levels of workload.

2.5. Correlation Analysis.

2.5.1. Correlation Statistics. The statistics (R^2 , S_{yx} , and V) are needed to evaluate how well an equation represents the observed data (Y). These measures are derived from the variation within the measured man-hours. The sums of squares and the types of variation used to form these overall statistics are presented here and summarized in **Figure 2.3.**

Figure 2.3. Basic Relationship for Overall Statistics.

DATA						EQUATION
X	Y	Y_c	$(Y - \bar{Y})$	$(Y_c - \bar{Y})$	$(Y - Y_c)$	
3	2	2.97554	-5.37500	-4.39946	-0.97554	$Y_c = 1.375 + .5333 X$
8	4	5.64183	-3.37500	-1.73312	-1.64188	
5	6	4.04207	-1.37500	-3.33293	1.95793	$S_{yx} = \sqrt{\frac{SSE}{n - m}}$
9	8	6.17515	.62500	-1.19985	1.82485	$S_{yx} = \sqrt{\frac{25.2172}{8 - 2}} = 2.050$
13	6	8.30822	-1.37500	.93322	-2.30822	
14	10	8.84149	2.62500	1.46649	1.15851	$R^2 = \frac{SSR}{TSS} = \frac{72.6578}{97.8750}$
18	9	10.97456	1.62500	3.59956	-1.97456	$R^2 = .742$
20	14	12.04110	6.62500	4.66610	1.95890	

SUM OF SQUARES		
(continued on next page)		
$TSS = \Sigma(Y - \bar{Y})^2$	$SSR = \Sigma(Y_c - \bar{Y})^2$	$SSE = \Sigma(Y - Y_c)^2$
TSS = 97.8750	SSR = 72.6578	SSE = 25.2172
Total Sum of Squares	Sum of Squares Explained by the Regression	Sum of Squares Unexplained by the Regression

2.5.2. Total Sum of Squares (TSS). When it is necessary to predict man-hours (Y), the best predictor is Y-bar, the mean of measured man-hours. Hence, the total variation within the system is associated with the total sum of the squared deviations (TSS) of the Y-values about its mean.

$$TSS = \Sigma \{Y - \bar{Y}\}^2$$

2.5.3. Standard Deviation of Y (s_y). The standard deviation of the measured man-hours (Y) is estimated by the square root of TSS divided by the degrees of freedom (n-1).

$$s_y = \sqrt{\frac{\sum (Y - \bar{Y})^2}{n - 1}} = \sqrt{\frac{TSS}{(n - 1)}}$$

This expression can be put in a form that is easier to compute:

$$\sum (Y - \bar{Y})^2 = \frac{n \sum Y^2 - (\sum Y)^2}{n}$$

2.5.4. Sum of Squares Explained by Regression (SSR). When the information in the X-values is used to form a prediction equation ($Y_c = a + bX$), the best estimate of a new Y-value is Y_c instead of \bar{Y} . The amount of reduction is defined as the SSR. The degrees of freedom for SSR are (m-1).

$$SSR = \sum (Y_c - \bar{Y})^2$$

2.5.5. Sum of Squares Unexplained by Regression (SSE). The remaining variation in Y is defined as the SSE.

$$SSE = \sum (Y - Y_c)^2$$

2.5.6. Standard Error of the Estimate (S_{yx}). When SSE is divided by the degrees of freedom (n-m), the variation that remains in the regression system is estimated. The square root of this is defined as the standard error of the estimate. This is used to calculate the coefficient of variation.

$$S_{yx} = \sqrt{\frac{\sum (Y - Y_c)^2}{(n - m)}} = \sqrt{\frac{SSE}{(n - m)}}$$

2.5.7. Coefficient of Variation (V). The standard error of the estimate gives a measure of how the observed data is scattered about the regression line. To compare this information between different equations, a relative measure is needed. Hence, the coefficient of variation is defined as the standard error of the estimate divided by the average man-hours. This indicates how large the standard deviation is with relation to the mean.

$$V = \frac{S_{yx}}{\bar{Y}}$$

This yields a measure that has no dimension and can be used to set up criteria for the levels of acceptable variability in an equation.

2.5.8. Coefficient of Determination (R^2). When the coefficients in the equation are estimated with the "least squares" method, an additional relationship exists between these sum of squares. By dividing both sides of the equation by the total sum of the squares (TSS), two proportions result that sum to one.

$$\sum \{Y - \bar{Y}\}^2 = \sum \{Y - Y_c\}^2 + \sum \{Y_c - \bar{Y}\}^2, \text{ or}$$

$$\frac{\text{TSS}}{\text{TSS}} = \frac{\text{SSE}}{\text{TSS}} + \frac{\text{SSR}}{\text{TSS}}$$

$$1 = \frac{\text{SSE}}{\text{TSS}} + \frac{\text{SSR}}{\text{TSS}}$$

R^2 is defined as the proportion of the total variation that is explained by the regression line. R^2 values range from zero to one.

$$R^2 = \text{EXPLAINED/TOTAL} = \text{SSR/TSS}$$

When the regression explains most of the variation, R^2 approaches the value of one. When there is a large amount of unexplained variation, R^2 approach zero. The square root of the coefficient of determination (R) is defined as the coefficient of correlation. Correlation ranges from a minus one to a plus one.

2.6. Significance Tests.

2.6.1. The F-test.

2.6.1.1. To be useful in prediction, an equation must explain or account for more of the variability in the man-hours than is left unexplained. The F-test is used for this determination. To do the F-test, two values are needed; the test statistic (F) and the critical value (F^*).

2.6.1.2. The test statistic (F) is the ratio of the variance explained by regression to the unexplained variance. Variances are obtained by dividing sum of squares with their respective degrees of freedom.

$$F = \text{SSR}/(m-1)$$

$$\text{SSE}/(n-m)$$

F, expressed as a function of R^2 is:

$$F = \left(\frac{R^2}{1 - R^2} \right) \left(\frac{n - m}{m - 1} \right)$$

2.6.1.3. The critical value for the F-test, [$F^* = F(1-\alpha, m-1, n-m)$], comes from the f-Table at [Attachment 2](#). The degrees of freedom for the numerator (m-1) are arrayed across the top of the Table and the degrees of freedom for the denominator (n-m) are listed down the left side.

2.6.1.4. If the test statistic is larger or equal to the critical value ($F \geq F^*$), the equation explains a significant amount of variation of man-hours.

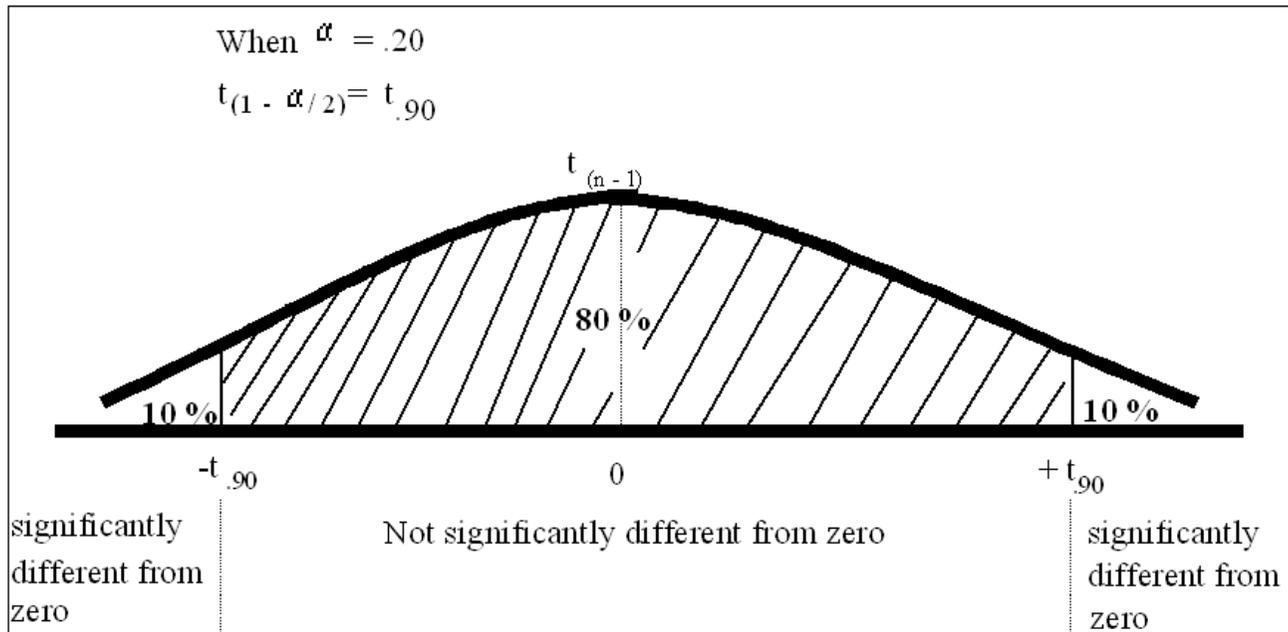
2.6.2. The t-test.

2.6.2.1. The t-test determines if the individual coefficients of an equation are significantly different from zero. A value whose coefficient is not significantly different from zero contributes nothing to the prediction equation and should not be retained. As with the F-test, a test statistic and a critical value are needed to do this test.

2.6.2.2. The test statistic for multivariate coefficients (t_b) is usually calculated by automated statistical routines; however, in the case of only two independent variables (X_1 and X_2), it may be calculated manually. In other multivariate situations (more than two independent variables), use of a reliable automated statistical package to calculate and print out these t-values (confidence levels) will be acceptable.

2.6.2.3. The critical value, [$t^* = t(1-\alpha/2, n-1)$], comes from the t-Table at [Attachment 2](#). The confidence level ($1-\alpha$) is set at 80%, ($= 0.20$). This is based on the decision that to drop a variable out of the equation when it may be valuable is more damaging than to leave a variable in the equation when it may be of little value. Because the t-test is two tailed (concerned with values positively and negatively different from zero (see [Figure 2.4.](#))), the alpha-level is split and the critical value becomes [$t^* = t_{(.90, n-1)}$].

Figure 2.4. Decision Rule for the t-test.



2.6.2.4. If the test statistic (t) calculated from the data (considering its absolute value) is greater than or equal to the critical value (Table value), the coefficient in question is significantly different from zero and should be used in the equation.

2.7. Evaluation of the Results and Model Selection.

2.7.1. The most common use of regression analysis in the MEP is to develop equations that express the required man-hours for a work center in terms of one or more workload factors (WLFs). For one work center, several equations may be developed. The selection of one of these equations to be the manpower model for that work center needs a balance between several different factors. The major considerations are highlighted here.

2.7.2. Make sure the selected equation is built with logical workload factors.

2.7.3. Select one equation from a group of equations based on both the overall statistics of the equations and the simplicity of the equation form itself.

2.7.3.1. The equation with the best overall statistics (largest R^2 and smallest V) is the equation that most closely fits the data. Such an equation is favored in the selection process.

2.7.3.2. When the overall statistics for equations are close in value, select the simplest equation.

2.7.4. Before selecting a regression model, it must pass the F-test (that is, it must explain a significant portion of the variability).

2.7.5. The coefficients for the parabola and multivariate equations should pass the t-test (be significantly different from zero) to be kept in the equation. However, there may be situations that favor keeping a variable in the equation that does not pass the t-test. The worst consequence of such a decision is the retention of a variable that contributes very little statistically to the equation, yet manpower is expended to collect WLF data.

2.7.6. An equation must also meet both the realistic and the economic criteria to be acceptable as a manpower model. An equation is realistic when it has a positive slope, with no net loss of man-hours for an increase in workload within the extrapolation range of the model. Negative Y-intercepts in the model are allowed. However, exclude negative values of Y from the extrapolation range.

2.7.7. An equation is economical if, at any point in the model, a unit increase in workload causes an increase in manpower when compared to all previous per unit changes in manpower.

2.7.8. Man-hour equation coefficients meet both the realistic and economic criteria when:

2.7.8.1. The linear model ($Y = a + bX$) b-coefficient is positive. Increases in workload result in a constant positive increase in manpower.

2.7.8.2. The parabolic model ($Y = a + bX + cX^2$) b-coefficient is positive, and the c-coefficient is negative, and workload values do not exceed the point where $X = -b/2c$ (apex). If the b and c conditions are met and workload is greater than $-b/2c$, increasing workload after the apex results in decreasing manpower and the model is not realistic.

2.7.8.3. The power model ($Y = aX^b$) a-coefficient is positive and b-coefficient is between zero and one. This restricts the model to an increasing function where Y increases more slowly as X increases.

2.7.8.4. The ratio model [$Y = X/(a + bX)$] a-coefficient and b-coefficient are greater than zero.

2.7.9. **Figure 2.5.** , Realistic and Economic Criteria, summarizes the preceding discussion.

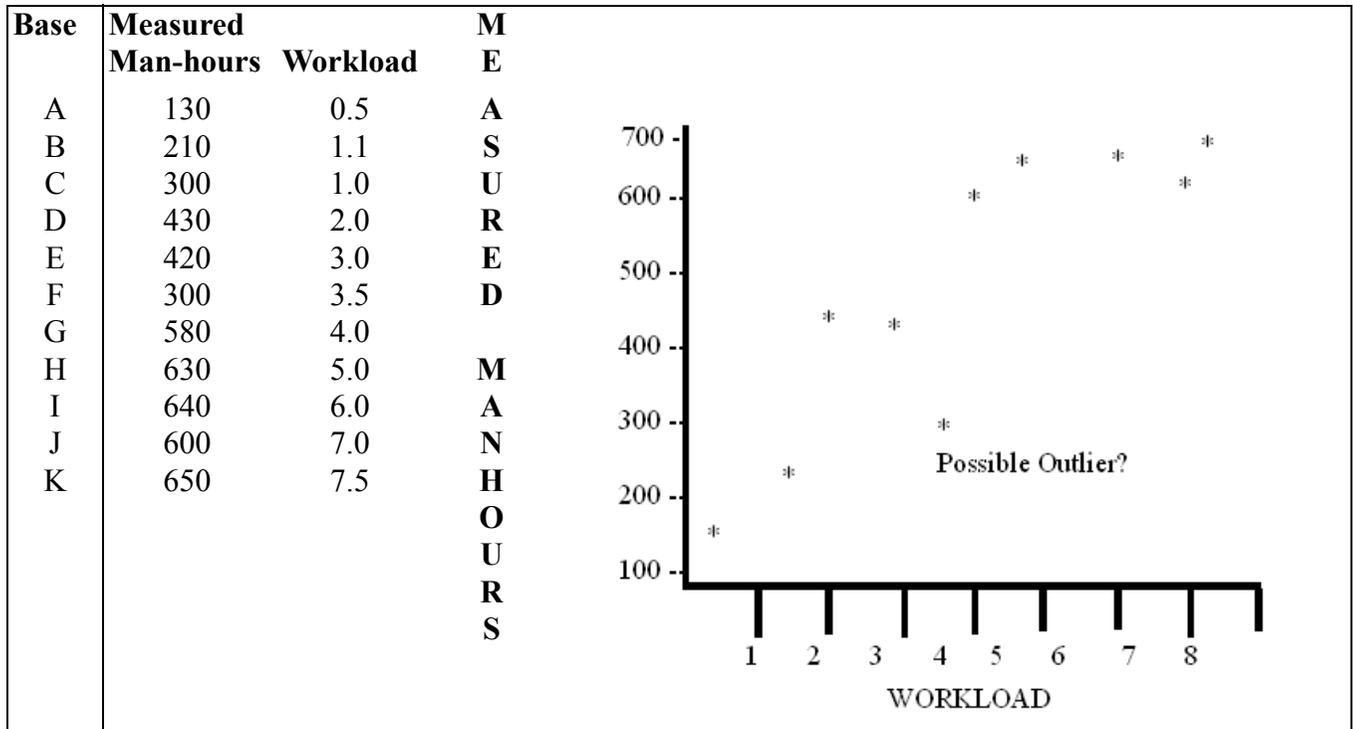
Figure 2.5. Realistic and Economic Criteria.

		The manpower model	is realistic when:	is economic when:
S P E C I F I C A T I O N	F O R M	Linear: $Y = a + bX$	$b \geq 0$	realistic criteria is met
		Parabola: $Y = a + bX + cX^2$	$b \geq 0$ and $X_u \leq \frac{-b}{2c}$	
	I M P L I C A T I O N	Power: $Y = aX^b$	$a < 0$ and, $0 \leq b \leq 1$	realistic criteria is met
		Ratio: $Y = \frac{x}{a + bX}$	$a > 0$ $Y_u < \frac{1}{b}$	$b \geq 0$

2.8. Using Scattergrams. The most useful tool to analyze C&R computations is the scattergram. The scattergram is merely an X-Y graph of the plotted input points. Develop a scattergram before or in conjunction with regression computations. Use this chart to graphically identify outliers that influence other input points. **Figure 2.6.** gives example data and associated scattergram for the calculations in the next

paragraph. Note that base "F" (sixth input point) represents an outlier and was not used in these computations.

Figure 2.6. Example Data and Associated Scattergram.



2.9. General Calculations. Use of an automated statistical package (see note below) for computing regression equations will be acceptable. Manual computation procedures may also be used and are shown to illustrate the process and to aid interpretation of the results. **Table 2.1.** illustrates the computation process for regression coefficients with one dependent variable. **Table 2.2.** illustrates the computation process for the multivariate model with two independent variables and the parabolic model with one independent variable. These two models are combined in **Table 2.2.** because of their similarity of computations. When doing manual computations, carry as many decimal places as possible and round only for the final answer. When using one answer in further computations, for example, using "b" to compute "a," use the unrounded value.

NOTE: AFMIA does not advocate any particular automated statistical application. Reliable results can be produced with most MS Windows-based packages. Text and graphics should be exportable to your word processor.

Table 2.1. Regression Analysis for Linear Model (Y = a + bX).

STEP	A Action	B Formula		C Example
1	Compute summary statistics	$n \quad \Sigma X \quad \Sigma X^2$ $\Sigma XY \quad \Sigma Y \quad \Sigma Y^2$		(from data in Figure 2.6.) $n = 10 \quad \Sigma Y = 4590.0$ $\Sigma X = 37.10 \quad \Sigma Y^2 = 2437700.0$ $\Sigma X^2 = 197.710 \quad \Sigma XY = 21101.0$
2	Estimate summary coefficients	$b = \frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{n(\Sigma X^2) - (\Sigma X)^2}$		$b = \frac{10(21101.0) - (37.10)(4590.0)}{10(197.710) - (37.10)^2}$ $b = 67.79037440 = 67.79$
		$a = \frac{\Sigma Y - b \Sigma X}{n}$		$a = \frac{(4590.0) - (67.7903744)(37.10)}{10}$ $a = 207.4977110 = 207.5$
3	Compute the sums of squares to use in the overall statistics and the associated degrees of freedom (df). NOTE: Throughout this Table, m = 2	Sum of Squares $TSS = \Sigma Y^2 - \frac{(\Sigma Y)^2}{n}$	df n - 1	$TSS = (2437700.0) - \frac{(4590.0)^2}{10}$ $TSS = 330890.00 \quad df = 9$
		$SSE = \Sigma Y^2 - a \Sigma Y - b \Sigma XY$	n - 2	$SSE = (2437700) - (207.497711)(4590) - (67.7903744)(21101.0)$ $SSE = 54840.8170 \quad df = 8$
		$SSR = TSS - SSE$	1	$SSR = 330890.00 - 54840.8170$ $SSR = 276049.1830 \quad df = 1$
4	Calculate overall statistics	$S_{yx} = \sqrt{\frac{SSE}{n - 2}}$		$S_{yx} = \sqrt{\frac{54840.8170}{8}}$ $S_{yx} = 82.7955 = 82.796$
		$R^2 = \frac{SSR}{TSS}$	$R^2 = \frac{276049.1830}{330890.0}$ $R^2 = .8343 = .834$	
		$V = \frac{S_{yx}}{\bar{Y}}$ where $\bar{Y} = \frac{\Sigma Y}{n}$	$V = \frac{82.7955}{(4590)/10}$ $V = .1804 = .180$	
5	Compute the test statistic for the F-test (F)	$F = \frac{SSR/1}{SSE/n-2} = \frac{SSR(n-2)}{SSE}$		$F = \frac{276049.1830 (8)}{54840.8170}$ $F = 40.269$
6	Obtain critical value (F*) from the F-Table in Attachment 2	$F^* = F(1-A, 1, n-2)$		$F^* = F_{(.95, 1, 8)}$ $F^* = 5.32$

S T E P	A	B		C
	Action	Formula		Example
7	Compare test statistics (F) with critical value (F*)	If	Then the Equation	$F = 40.269$ $F^* = 5.32$ $F > F^*$ Therefore, this equation passes the F-test.
		$F < F^*$	Fails the F-test and does not account for enough of the variation. It cannot be used.	
		$F > F^*$	Passes the F-test and accounts for a significant amount of the variation. It can be used.	

Table 2.2. Regression Analysis for Multivariate (two independent variables) or Parabola.

STEP	A	B		C
	Action	Formula		Example
1	Compute summary statistics from the data.	n $\sum Y$ $\sum Y^2$		(from data in Figure 2.6) $n = 10$ $\sum Y = 4590.0$ $\sum Y^2 = 2437700.0$
		Multivariate Notation	Parabola Notation	
		$\sum X_1 = \sum X$ $\sum X_2 = \sum X^2$ $\sum X_1^2 = \sum X^2$ $\sum X_2^2 = \sum X^4$ $\sum X_1 X_2 = \sum X^3$ $\sum X_1 Y = \sum XY$ $\sum X_2 Y = \sum X^2 Y$		$\sum X = 37.10000$ $\sum X^2 = 197.71000$ $\sum X^2 = 197.71000$ $\sum X^4 = 7841.58910$ $\sum X^3 = 1207.33100$ $\sum XY = 2110.100000$ $\sum X^2 Y = 120119.10000$
2	Combine summary statistics to get quantities (K, P, Q, S, and T) to be used to simplify further computations.	$K = \sum X_1^2 - \frac{(\sum X_1)^2}{n}$		$K = 197.71 - \frac{(37.1)^2}{10}$ $K = 60.0690$
		$P = \sum X_2^2 - \frac{(\sum X_2)^2}{n}$		$P = 7841.5891 - \frac{(197.71)^2}{10}$ $P = 3932.66469$
	(continued on next page)	$Q = \sum X_1 X_2 - \frac{(\sum X_1)(\sum X_2)}{n}$		$Q = 1207.331 - \frac{(37.1)(197.71)}{10}$ $Q = 473.82690$

STEP	A	B	C
	Action	Formula	Example
		$S = \sum X_1 Y - \frac{(\sum X_1)(\sum Y)}{n}$	$S = 21101.0 - \frac{(37.1)(4590)}{10}$ $S = 4072.10$
		$T = \sum X_2 Y - \frac{(\sum X_2)(4590)}{n}$	$T = 120119.10 - \frac{(197.71)(4590)}{10}$ $T = 29370.21000$
3	Combine further to simplify next step.	No additional formulas are needed, just specific groupings of the constants K, P, Q, S, and T.	$SP = (4072.1)(3932.66469)$ $SP = 16014203.88$ $QT = (473.8269)(29370.21)$ $QT = 13916395.56$ $KT = (60.069)(29370.21)$ $KT = 1764239.144$ $QS = (473.8269)(4072.1)$ $QS = 1929470.519$ $KP = (60.069)(3932.66469)$ $KP = 236231.2353$ $Q^2 = (473.8269)^2$ $Q^2 = 224511.9312$ $KP - Q^2 = 236231.2353 - 224511.9312$ $KP - Q^2 = 11719.30410$
	(continued on next page)		

S T	A	B		C
E P	Action	Formula		Example
4	Estimate the regression coefficients.	$b_1 = \frac{SP - QT}{KP - Q^2}$		$b_1 = \frac{16014203.88 - 13916395.56}{11719.30410}$ $b_1 = 179.0045127 = 179.0$
		$b_2 = \frac{KT - QS}{KP - Q^2}$ <p>("c" for a parabola)</p>		$b_2 = \frac{1764239.144 - 1929470.519}{11719.30410}$ $b_2 = -14.09907735 = -14.10$
		$a = \frac{\sum Y - b_1 \sum X_1 - b_2 \sum X_2}{n}$		$a = \frac{1}{10} [4590 - (179.0045127)(37.1) - (-14.09907735)(197.71)]$ $a = 736461162 = 73.65$
5	Compute the sums of	Sum of Squares	df	
	the squares and the associated degrees of freedom (df).	$TSS = \sum Y^2 - \frac{(\sum Y)^2}{n}$	n - 1	$TSS = \{2437700\} - \frac{\{4590\}^2}{10}$ $TSS = 330890.00 \quad df = 9$
	NOTE: In this Table M is equal to three. (M = 3)	$SSR = b1S + b2T$	2	$SSR = \{179.0045127\}\{4072.10\} + \{-14.09907735\}\{29370.210\}$ $SSR = 3148314136 \quad df = 2$
		$SSE = TSS - SSR$	n - 3	$SSE = 330890 - 3148314136$ $SSE = 16058.58640 \quad df = 7$
6	Calculate overall statistics. (continued on next page)	$S_{yx} = \sqrt{\frac{SSE}{n - 3}}$		$S_{yx} = \sqrt{\frac{16058.5864}{7}}$ $S_{yx} = 47.89659457 = 47.897$

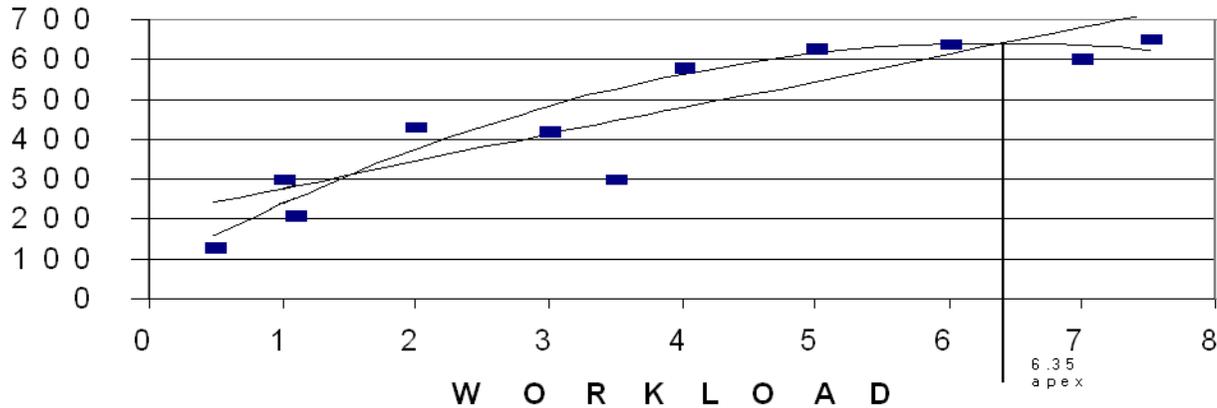
S T	A	B		C
E P	Action	Formula		Example
		$R^2 = \frac{SSR}{TSS}$		$R^2 = \frac{314831.4136}{330890}$ $R^2 = .9514685 = .951$
		$V = \frac{S_{yx}}{\bar{Y}}$	where: $\bar{Y} = \frac{\sum Y}{n}$	$V = \frac{47.89659457}{\{4590\}/10}$ $V = .104$
7	Compute the test statistic for the F-test (F).	$F = \frac{SSR / 2}{SSE / n - 3} = \frac{\{SSR\}\{n - 3\}}{\{SSE\}\{2\}}$		$F = \frac{\{314831.4136\}\{7\}}{\{16058.5864\}\{2\}}$ $F = 68.618$
8	Obtain critical value (F*) from the F-Table.	$F^* = F_{(1-\alpha, 2, n-3)}$		$F^* = F_{(.95, 2, 7)}$ $F^* = 4.74$
9	Compare test statistic	IF	THEN	
	(F) with the critical value (F*).	$F < F^*$	Fails the F-test. The equation does not account for enough of the variation. It cannot be used.	$F = 68.618$ $F^* = 4.74$ $F > F^*$
		$F \geq F^*$	Passes the F-test. The equation accounts for a significant amount of the variation. It can be used.	Therefore this equation passes the F-test.
10	Compute additional values from which the t-statistic will be computed.	$S_{X_1}^2 = \frac{1}{n - 1} \left[\sum X_1^2 - \frac{(\sum X_1)^2}{n} \right]$		$S_{X_1}^2 = \frac{1}{9} \left[197.71 - \frac{(37.1)^2}{10} \right] = 6.674333$
		$S_{X_2}^2 = \frac{1}{n - 1} \left[\sum X_2^2 - \frac{(\sum X_2)^2}{n} \right]$		$S_{X_2}^2 = \frac{1}{9} \left[7841.589 - \frac{(197.71)^2}{10} \right] = 436.96274$
	(continued on next page)	$r_{X_1X_2} = \frac{n \sum X_1X_2 - (\sum X_1)(\sum X_2)}{n(n-1)\sqrt{S_{X_1}^2 S_{X_2}^2}}$		$r_{X_1X_2} = \frac{\{10\}\{1207.331\} - \{37.1\}\{197.71\}}{\{10\}\{9\}\sqrt{\{6.674333\}\{436.962743\}}} = .97488$

ST	A	B		C
E P	Action	Formula		Example
11	Select b_1 to be tested. For a multivariate equation, test both b_1 and b_2 . For a parabolic equation, test only b_2 . (This is because b_2 is the “c” coefficient for the X^2 term.)	(No formula needed.)		Since this is a parabolic equation, the “c” coefficient will be tested. Hence, test b_2 .
12	Compute the standard error of the estimate for the coefficient being tested for significance.	$S_{b_i} = \frac{S_{yx}}{\sqrt{(n-1)S^2 X_1 [1 - (r_{X_1 X_2})^2]}}$		$S_{b_2} = \frac{47.89659}{\sqrt{(9)(436.92743)[1 - (.97488)^2]}}$ $S_{b_2} = 3.429245$
13	Calculate the test statistic (t_{bi}) for the b_i being tested.	$t_{bi} = \left \frac{b_i}{S_{b_i}} \right $		$t_{b_2} = \left \frac{-14.09907735}{3.429245} \right $ $t_{b_2} = 4.111$
14	Obtain critical value (t^*) from the t-Table.	$t^* = t_{(90, n-3)}$		$t^* = t_{(90, 7)} = 1.415$
15	Compare the test statistic (t_{bi}) with the critical value (t^*).	IF	THEN	
		$t_{bi} < t^*$	Fails the t-test. The associated variable does not contribute significantly to the equation and is to be ommitted.	$t_{b_2} = 4.111$ $t^* = 1.415$ $t_{b_2} > t^*$
		$t_{bi} \geq t^*$	Passes the t-test. The associated variable contributes significantly to the equation and is retained.	Therefore b_2 passes the t-test.

2.10. Interpretation of Computations.

2.10.1. The linear and parabolic curves computed in [Table 2.1.](#) and [Table 2.2.](#) are shown in [2.7.](#) This figure summarizes the results of the computations and includes a graph that superimposes the two curves on the same scattergram.

Figure 2.7. Results of the Computations for the Example Data.



LINEAR EQUATION

$$Y_c = 207.5 + 67.79X$$

$$F = 40.269$$

$$R^2 = .834$$

$$V = .180$$

$$S_{yx} = 82.796$$

PARABOLIC EQUATION

$$Y_c = 73.65 + 179.0X - 14.10X^2$$

$$F = 68.618$$

$$R^2 = .951$$

$$V = .104$$

$$S_{yx} = 47.897$$

2.10.2. Both the linear and parabolic equations explain a significant portion of the variance because each equation passes the F-test.

2.10.3. The squared term in the parabolic equation has a coefficient that is significantly different from zero. It passes the t-test.

2.10.4. The equations are also evaluated by the realistic and economic criteria.

2.10.4.1. The linear equation passes both of these tests because it has a slope that is positive and constant.

2.10.4.2. The parabolic equation passes the first part of the realistic test because the "b" is greater than zero and "c" is negative. However, it fails the second part because the apex is within the data range.

2.10.4.2.1. The highest X-value for the input data points is 7.5.

$$2.10.4.2.2. \text{ Apex} = \frac{-b}{2c} = \frac{-[179.0045]}{2[-14.099077]} = 6.348$$

2.10.4.2.3. Since 6.348 is less than 7.5, the parabolic equation should not be used. A special equation form such as the ratio or power curve may fit better in this case.

2.11. Calculations for the Special Equation Forms.

2.11.1. Power Curve. When the general equation $Y = aX^b$ is transformed using logarithms, it becomes $\log Y = \log a + b(\log X)$. These transformed values can then be used in the general formulas for linear regression to find a and b. This procedure only gives an approximation of the true a and b values. Using these transformed values in the general equation for R^2 can yield negative values for R^2 , that are theoretically impossible since R^2 must range between zero and one. A better estimate of these coefficients (a and b) is obtained by computing these coefficients through an iterative process using Taylor's series approximations. Once these new coefficients have been found, they can be used in the general formula for R^2 . This procedure gives an unbiased estimate of a and b and reduces the occurrence of negative R^2 values. Further discussion of the iteration process for transformed linear models can be found in Neter, Applied Linear and Statistical Models.

2.11.2. Ratio Curve. When the general equation $Y = X/(a + bX)$ is transformed, it becomes $X/Y = a + bX$. The transformed values (X/Y ratios) can be used in the general formula for linear regression in lieu of Y-values as was done with the power curve.

2.12. Calculations for Multivariate Models. Calculations for multivariate models having more than two independent variables are generally done with computers and are beyond the scope of this publication.

2.13. Rounding Procedures.

2.13.1. As a general rule, do all computations using the capability of your computing device. For example, if that device is a calculator with seven-decimal capability, then use seven decimals. Round only the final result to the number of decimal places shown in [Table 2.3](#).

Table 2.3. Rounding Rules.

R U L E	A	B
	If the number to be rounded is	then round it to
1	reported man-hour values	2 decimal places
2	average workload values	2 decimal places
3	leveling factor	2 decimal places
4	statistical measure such as: accuracy, mean and standard deviation, standard error of the estimate, coefficient of determination, coefficient of variation, or test statistics (F&t)	3 decimal places
5	functional estimating equation, percentage factors	3 decimal places
6	fractional manpower values	3 decimal places
7	coefficients for manpower models (including regression equations, single location equations, simulation equations, etc.)	at least 4 significant digits. For example, 1.352 or 0.53322

2.13.2. Once the number of decimal places is decided, discard all of the digits to the right of that point. Do not change any digits to the left of that point. Round the last digit to be kept up only if the digit to the right of it is greater than or equal to 5. Examples of rounding numbers to three decimal places are:

2.13.2.1. 27.16346...becomes 27.163 because 4 is less than 5.

2.13.2.2. 31.39461...becomes 31.395 because 6 is greater than 5.

2.13.2.3. 16.48450...becomes 16.485 because 5 is equal to 5.

Section 2B—Analysis and Adjustments

2.14. General Concepts. Variations in data can be expected even in the most carefully designed study. However, some variation may be due to levels of service or poor measurement. Regardless of the reasons, the data must be analyzed to make sure required work is done at an acceptable level. This section describes procedures for doing data analysis and adjustments.

2.15. Data Correction and Data Adjustment Differences. Although data corrections and data adjustments are similar, there is a distinct difference.

2.15.1. Data Corrections. Make mathematical corrections before doing C&R. Corrections consist of administrative errors such as incorrectly transcribing the data, using improper frequencies, or not following measurement instructions in the measurement plan. Corrections also consist of computational errors. Most corrections have relatively minor impact on measured man-hours and do not need coordination with the functional OPR. Audit trails of all corrections, including computational errors and rounding differences, are kept in the study team's backup files but are not documented in the final report.

2.15.2. Data Adjustments. Make data adjustments only after investigation has identified the reason for extreme data and the need for adjustment. The lead study craftsman makes adjustments to normalize the level of service only when the senior functional manager concurs with the adjustment. Document adjustments in the final report and keep an audit trail for adjustments in the final report backup data file. Do not make adjustments solely to improve statistics.

2.16. Study Team Responsibilities.

2.16.1. Do a 100% math check of all input computations. For computerized products, make sure that numerical data have been transferred into your statistical package correctly.

2.16.2. Check each input for consistency.

2.16.3. Investigate the representativeness of reported work counts.

2.16.4. Check work center comments.

2.16.5. Keep a record of all significant information and rationale used to analyze the input data.

2.16.6. Document all mathematical corrections on the forms.

2.16.7. Make sure that adjustments are based on sound logic and expert opinions.

2.17. Statistical Analysis. (See Statistical Tables at [Attachment 2](#) for R^2 and V criteria.)

2.17.1. Use your statistical package (see Note below) and this section to begin data analysis.

2.17.2. Set up your initial C&R data using man-hours for the Y-variable. For the X-variable, use only logical and acceptable potential WLF values. For example, "hospital beds" may be logical, but if all input locations don't have hospital beds, then the WLF is not acceptable.

2.17.3. Run initial multivariate C&R and detail based on one standard error. Many inferences can be made from this first run. For example, does the work center display standardization? Is the data statistically acceptable with minor adjustments? Which bases are exerting the most influence on the data? Follow this chronological sequence.

2.17.3.1. Assume the first C&R run with five potential WLFs yields the statistics and detail shown in [Figure 2.8.](#)

NOTE: *The more substantive statistical packages produce the Table of R Values and Order of Entry Statistics. The new MSDS C&R module incorporates these statistics and will operate in Windows as an Excel add-on.*

Figure 2.8. Initial Multivariate C&R Analysis.

TABLE OF R VALUES BETWEEN VARIABLES						
(R) OF	TO Y	TO X1	TO X2	TO X3	TO X4	TO X5
X1	.2863	1.0000				
X2	.3011	.6059	1.0000			
X3	.6059	-.0924	.0777	1.0000		
X4	.4804	.2618	.3586	.1399	1.0000	
X5	.7135	.4233	.6254	.1228	.5423	1.000
X ORDER OF ENTRY	INTERMEDIATE R VALUES		R ² VALUES			
X5		.7135	.5090			
X3		.8842	.7818			
X2		.9037	.8166			
X1		.9218	.8497			
X4		.9239	.8535			
A	R	R ²	SY	V	F	
-96.5522	.9239	.8535	29.9684	.2670	9.3249	
X (I)	B(I)	T(I)	SIG LEV			
1	8.97540600	1.320	.223432			
2	-18.21396000	-1.861	.099765			
3	21.40704000	3.980	.004059			
4	1.48872200	.461	.657297			
5	19.35436000	3.824	.005060			
SEQU	LINE	ACTUAL Y	PREDICTED Y	DEVIATION	OUTSIDE +/- 1.00 S _{yx}	
1	101	160.000	146.498	-13.502	.000	
2	102	173.000	161.004	-11.996	.000	
3	103	130.000	113.199	-16.801	.000	
4	104	56.000	104.944	48.944	18.975	
5	105	82.000	39.139	-42.861	-12.893	
6	106	142.800	126.898	-15.902	.000	
7	107	76.000	77.658	1.658	.000	
8	108	39.000	53.378	14.378	.000	
9	109	28.000	27.126	-.874	.000	
10	110	35.000	61.117	26.117	.000	
11	111	223.500	201.140	-22.360	.000	
12	112	146.000	159.011	13.011	.000	
13	113	177.700	200.552	22.852	.000	
14	114	97.500	94.837	-2.663	.000	

2.17.3.2. The objective of initial analysis is to find an acceptable equation using minimum variables. Does an acceptable equation exist with one or a combination of the five independent variables in [Figure 2.8](#)? The answer is, "probably yes." Inspection of the Table of r-values shows that only one WLF (X) passes the criteria for a bivariate relationship. This criteria is .7071 or $\sqrt{.5}$.

2.17.3.3. Run a bivariate C&R analysis using the WLF that had the highest r-value greater than .7071. If no r-values are higher than .7071, do not waste time running bivariate analysis - the improvement between bivariate models is insignificant at this point. In **Figure 2.8.**, the WLF for X5 against Y has an r-value of .7135; however, the bivariate relationship for this WLF does not yield a desired v-value.

2.17.3.4. Pay particular attention to the order of entry (see **Figure 2.8.**). The multivariate program is based on stepwise regression analysis. This means that the first X entered into the equation (X5) is the one with the highest R. The second X entered into the equation (X3) is the one that, in combination with the one already entered, improves the equation the most, and so on. The next run to try would be multivariate with Y versus X5 and X3 (see **Figure 2.9.**). Although this run is significantly better than the bivariate run (not shown), the v-value is still greater than the desired maximum .250.

Figure 2.9. Second Multivariate C&R Analysis.

TABLE OF R VALUES BETWEEN VARIABLES						
(R) OF	TO Y	TO X5	TO X3			
X5	.7135	1.0000	1.0000			
X3	.6059	.1228				
X ORDER OF ENTRY	INTERMEDIATE R VALUES		R ² VALUES			
X5	.7135		.5090			
X3	.8842		.7818			
A	R	R ²	SY	V	F	
-131.9857	.8842	.7818	31.1972	.2788	19.7031	
X (I)	B(I)	T(I)	SIG LEV			
5	16.98708000	4.572	.000801			
3	20.31130000	3.708	.003454			
SEQU	LINE	ACTUAL Y	PREDICTED Y	DEVIATION	OUTSIDE +/- 1.00 S _{YX}	
1	101	160.000	176.625	116.625	.000	
2	102	173.000	140.064	-32.936	-1.738	
3	103	130.000	106.206	-23.794	.000	
4	104	56.000	106.206	50.206	19.008	
5	105	82.000	48.449	-33.551	-2.353	
6	106	142.800	140.064	-2.736	.000	
7	107	76.000	82.308	6.308	.000	
8	108	39.000	82.308	43.308	12.111	
9	109	28.000	21.115	-6.845	.000	
10	110	35.000	48.449	13.449	.000	
11	111	223.500	176.625	-46.875	-15.678	
12	112	146.000	147.186	1.186	.000	
13	113	177.700	203.700	26.000	.000	
14	114	97.500	87.154	-10.346	.000	

2.17.3.5. Compare the standard error detail between [Figure 2.9.](#) and [Figure 2.10.](#). Note that the fourth point is the furthest out in both cases.

Figure 2.10. Third Multivariate C&R Analysis.

TABLE OF R VALUES BETWEEN VARIABLES						
(R) OF	TO Y	TO X5	TO X3	TO X2		
X5	.7135	1.0000	1.0000	1.0000		
X3	.6059	.1228	.0777			
X2	.3011	.6254				
X ORDER OF ENTRY	INTERMEDIATE R VALUES		R ² VALUES			
X5		.7135		.5090		
X3		.8842		.7818		
X2		.9037		.8166		
A	R	R ²	SY	V	F	
-78.4954	.9037	.8166	29.9964	.2681	14.8408	
X (I)	B(I)	T(I)	SIG LEV			
5	20.90170000	4.579	.001012			
3	20.32020000	3.858	.003170			
2	-11.77228000	-1.378	.1983180			
SEQU	LINE	ACTUAL Y	PREDICTED Y	DEVIATION	OUTSIDE +/- 1.00 S _{yx}	
1	101	160.000	159.464	-.536	.000	
2	102	173.000	142.512	-30.488	-.491	
3	103	130.000	108.639	-21.361	.000	
4	104	56.000	108.639	52.639	22.642	
5	105	82.000	37.573	-44.427	-14.431	
6	106	142.800	142.512	-.288	.000	
7	107	76.000	87.139	11.139	.000	
8	108	39.000	71.447	32.447	2.450	
9	109	28.000	11.893	-16.107	.000	
10	110	35.000	53.265	18.265	.000	
11	111	223.500	194.781	-28.719	.000	
12	112	146.000	158.558	12.558	.000	
13	113	177.700	186.551	8.851	.000	
14	114	97.500	103.527	6.027	.000	

2.17.3.6. Next, run multivariate C&R using Y, X5, X3, and X2. In this case, all three b-values pass the significance test, and the v is further improved. However, v is still larger than .250 (see [Figure 2.10.](#)).

2.17.3.7. Continue running multivariate C&R as above until an acceptable equation is reached or there are no more Xs. For this data set, the best combination is Y against X5, X3, X2, X1 (see [Figure 2.11.](#)).

Figure 2.11. Fourth Multivariate C&R Analysis.

TABLE OF R VALUES BETWEEN VARIABLES						
(R) OF	TO Y	TO X5	TO X3	TO X2	TO X1	
X1	.7135	1.0000				
X2	.6059	.1228	1.0000			
X3	.3011	.6254	.0777	1.0000		
X4	.2863	.4233	-.0924	.6059	1.0000	
X ORDER OF ENTRY	INTERMEDIATE R VALUES		R ² VALUES			
X5		.7135	.5090			
X3		.8842	.7818			
X2		.9037	.8166			
X1		.9218	.8497			
A	R	R ²	SY	V	F	
-99.5372	.9218	.8497	28.6267	.2558	12.7162	
X (I)	B(I)	T(I)	SIG LEV			
5	20.34741000	4.652	.001199			
3	21.64378000	4.232	.002199			
2	-18.20578000	-1.947	.083310			
1	9.12969400	1.407	.192992			
SEQU	LINE	ACTUAL Y	PREDICTED Y	DEVIATION	OUTSIDE +/- 1.00 S _{yx}	
1	101	160.000	152.628	-7.372	.000	
2	102	173.000	159.238	-13.762	.000	
3	103	130.000	107.938	-22.062	.000	
4	104	56.000	107.938	51.938	23.312	
5	105	82.000	38.757	-43.243	-14.616	
6	106	142.800	124.545	-18.255	.000	
7	107	76.000	79.632	3.632	.000	
8	108	39.000	55.364	16.364	.000	
9	109	28.000	25.855	-2.145	.000	
10	110	35.000	63.026	28.026	.000	
11	111	223.500	207.246	-16.254	.000	
12	112	146.000	152.510	6.510	.000	
13	113	177.700	196.699	18.999	.000	
14	114	97.500	95.124	-2.376	.000	

2.17.3.8. As a result of the analysis this far, we know:

2.17.3.8.1. With only minor adjustments, satisfactory statistics can be achieved.

- 2.17.3.8.2. The most suspect point for questioning of input data is base number 4, that is outside one S_{yx} by 23.312 man-hours.
- 2.17.3.9. The next step is to do C&R at the next lower level; that is, use direct rather than total man-hours against workload. The purpose of this analysis is to identify outliers only.
- 2.17.3.10. After this step, continue with ratio analysis. First, use the ratio of direct-to-indirect time at each location. This analysis may be done with the work unit time standard routine or a hand-held calculator. Second, use ratio analysis for process times and work units.
- 2.17.4. At this stage in data analysis, you should know what data needs questioning and investigating and the process that needs further analysis.
- 2.17.4.1. When process level analysis shows problems with the data, do a more detailed step analysis. Step analysis of operational audit data can help with identifying extreme values that affect process results. Even if initial C&R is acceptable, you should still do analysis at the process level for OA studies. Do this to verify that there is no erroneous data hidden by the wash effect of overall C&R.
- 2.17.4.2. Consider data outside two standard errors (two standard deviations if using work unit times) as candidates for investigation and possible adjustment. This assumes all administrative and logic data corrections have already been made to the data base.
- 2.17.4.3. Making proper data adjustments can be quite difficult and controversial. Therefore, you need a high degree of coordination and documentation. Although statistical procedures are used to identify adjustment candidates, failing statistical accuracy is not an acceptable reason for adjusting data. When there is a logical cause for the dispersion, the data point will be considered either representative or not representative. If representative, include the data point in the final equation development. If not representative, consider it for variance development. Normalize extremes when they are abnormal and illogical, but do not adjust the data when extreme values occur for a valid reason. Do logic analysis as follows:
- 2.17.4.3.1. Compare per accomplishment times (PATs) and activity frequencies (FREs) to benchmark times or frequency reports.
- 2.17.4.3.2. Question the reasons for the high or low PATs and FREs (for example, low skilled personnel or recent transfers).
- 2.17.4.3.3. Check for any patterns in the data (for example, high data for an entire input base).
- 2.17.4.3.4. Evaluate the effect of the Statement of Conditions (SOC) on the PATs and FREs.
- 2.17.4.3.5. Solicit the input craftsman's opinion of the data and particular problems encountered during measurement. Request clarification or re-measurement, if needed.
- 2.17.4.3.6. Solicit the functional OPR's opinion of the measured data. Request help in clarifying controversial issues. For example: Identifying a step being done in a variety of ways in the field, thereby causing extreme values in the collected data, is a difficult problem. Staff this problem with the functional OPR to make sure the correct level of service is included in the standard.
- 2.17.4.3.7. Coordinate all adjustments.
- 2.17.4.3.8. Record all data adjustments in Part Three of the final report.

2.17.4.4. Adjust data as follows:

2.17.4.4.1. Develop an acceptable data range for PATs or work unit times based on study team evaluation of measurement data. Once developed, this data range should be explained and coordinated with the OPR. Adjust unexplainable data points above this range to the upper limit of the range and adjust unexplainable data points below the range to the lower limit of the range.

2.17.4.4.2. As a benchmark, make sure the sum of all data adjustments (excluding administrative corrections) does not exceed five percent of the measured man-hours for the study total. If adjustments exceed the five percent threshold, informally coordinate recommended data adjustments.

2.17.4.4.3. The study team saves the data used to develop the final equation. This data can be saved on computer disks or a copy of the measurement report can be placed in the data files.

2.18. Initiative or Option Measurement Data. All initiatives or options not included in the study should be documented and included as an attachment to the final report. Pay careful attention to make sure that each item is documented so that it may be incorporated into the standard at a later date. Make sure that enough data is available to change the standard once senior management approves the inclusion of the initiative or option.

Section 2C—Extrapolation Limits

2.19. General Concepts. Extrapolation is defined as extending the regression line beyond the range of the input data. Any extrapolation involves an element of statistical risk. However, to increase standards' utility, expand standards' applicability, and prevent rapid obsolescence due to workload changes, the MEP uses 25% above and below the largest and smallest Y_c value. These limits represent the maximum amount an equation can be extended. They do not preclude the use of more limited extrapolation when the total amount would be unrealistic.

2.20. Factors Affecting Extrapolation.

2.20.1. Several factors increase confidence in the extrapolation limits built into the standard. These factors are low standard error, high number of input locations, even distribution of WLF volumes, and absence of extreme values.

2.20.2. An equation that represents a sharp curve near the low or high end of the input data range or an equation that has rapidly leveling slopes may not allow the full 25% extrapolation.

2.20.3. Statistical procedures, however complex and exacting, are not a substitute for analysis of data points falling in the extended range of applicability. Regardless of the method used in computing this range, logical considerations must also be looked at when the standard is extended.

2.21. Computation of Extrapolation Limits. Use the steps in [Table 2.4.](#), [Table 2.5.](#), and [Table 2.6.](#) to compute the selected equations extrapolation limits. See [Figure 2.12.](#), [Figure 2.13.](#), and [Figure 2.14.](#) for the data base and graph for these models. Carry four or more decimal places during computations, then round the final answer to two decimal places. Insert the statistical printout in the final report to show extrapolation limits.

Table 2.4. Computation of Extrapolation Limits for Linear Equations.

S T E P	A	B
	Action	Example
1	Determine the following from data in Figure 2.11. and equation: max Y_c = highest predicted man-hours min Y_c = lowest predicted man-hours	max Y_c = 2232.256 min Y_c = 926.523
2	Calculate the upper extrapolation limit (Y_u): $Y_u = (\max Y_c) (1.25)$	$Y_u = (2232.256)(1.25)$ $Y_u = 2790.3200$ $Y_u = 2790.32$
3	Calculate the lower extrapolation limit (Y_l) $Y_l = (\min Y_c) (.75)$	$Y_l = (926.523)(.75)$ $Y_l = 694.8923$ $Y_l = 694.89$
4	If this equation is selected as the man-hour equation, then enter the lower (Y_l) and upper (Y_u) man-hour values on the AF Form 1113, "Standard Applicability Man-Hour Range" block.	694.89 - 2790.32

Table 2.5. Computation of Extrapolation Limits for Hyperbolic Equations.

STEP	A	B
	Action	Example
1	Determine the following from data in Figure 2.12. and equation: max Y_c = highest predicted man-hours min Y_c = lowest predicted man-hours	max $Y_c = 2239.679$ min $Y_c = 903.022$
2	Calculate the upper extrapolation limit (Y_u): $Y_u = (\max Y_c)(1.25)$ (continued on next page)	$Y_u = (2239.679)(1.25)$ $Y_u = 2799.5988$ $Y_u = 2799.60$
3	Calculate the lower extrapolation limit (Y_l): $Y_l = (\min Y_c)(.75)$	$Y_l = (903.022)(.75)$ $Y_l = 677.2655$ $Y_l = 677.27$
4	Calculate the Y-Asymptote: $Y - Asymptote = \frac{1}{b}$	$Y - Asymptote = \frac{1}{.00002430}$ $Y - Asymptote = 41152.2630$
5	Compute Y-Asymptote with Y_u and make one of the following decisions: (1) If Y-Asymptote is less than Y_u , then consider using the next best acceptable model. (2) If Y-Asymptote is greater than Y_u , then use Y_u as upper extrapolation limit if this equation is selected as the man-hour equation.	Y-Asymptote 41,152.2630 Y_u 2799.60 In this example, the Y-Asymptote is greater than Y_u , therefore Y_u remains the upper extrapolation limit.
6	Calculate the upper workload range: $X = \frac{aY_u}{1 - bY_u}$	$X = \frac{1.02677\{2799.60\}}{1 - .00002430\{2799.60\}}$ $X = \frac{2874.5452}{.9320}$ $X = 3084.2759 = 3084.28$
7	If this equation is selected as the man-hour equation, then enter the lower (Y_l) and upper (Y_u) man-hour values, and the upper workload data range on the AF Form 1113, "Standard Applicability Man-Hour Range" block.	677.27 - 2799.60 (Upper Workload Value = 3084.28)

Table 2.6. Computation of Extrapolation Limits for Parabolic Equations.

STEP	A	B										
	Action	Example										
1	Determine the following from data in Figure 2.13. and equation: max Y_c = highest predicted man-hours min Y_c = lowest predicted man-hours	$\max Y_c = 1164.698$ $\min Y_c = 391.515$										
2	Calculate the upper extrapolation limit (Y_u): $Y_u = (\max Y_c) (1.25)$	$Y_u = (1164.698)(1.25)$ $Y_u = 1455.8725$ $Y_u = 1455.87$										
3	Calculate the lower extrapolation limit (Y_l): $Y_l = (\min Y_c) (.75)$	$Y_l = (391.515)(.75)$ $Y_l = 293.6363$ $Y_l = 293.64$										
4	Calculate the X-value corresponding to the X-Apex: $X - Apex = \frac{-b}{2c}$	$X - Apex = \frac{-1196}{2(-0.02521)}$ $X - Apex = 237.2075 = 237.21$										
5	Calculate the Y-value corresponding to the Y-Apex using the X-Apex value: $Y - Apex = a+bX+cX^2$	$Y - Apex = 173.33 + 11.96(237.21) - 0.02521(237.21^2)$ $Y - Apex = 173.33 + 2837.0316 - 1418.5310$ $Y - Apex = 1591.8306 = 1591.83$										
6	Compare the Y-Apex to the max Y_c and Y_u and make one of the following decisions: (1) If the Y-Apex is less than the max Y_c , then the parabola is not acceptable. (2) If the Y-Apex is greater than Y_u , then Y_u remains the upper extrapolation limit. (3) If the Y-Apex is between Y_c and Y_u , then the apex becomes the upper extrapolation limit. However, since the extrapolation range is limited, the next best acceptable equation should be selected.	<table style="width: 100%; border: none;"> <tr> <td style="width: 60%;"></td> <td style="text-align: right;">1591.83</td> </tr> <tr> <td></td> <td style="text-align: right;">Y-Apex</td> </tr> <tr> <td></td> <td style="text-align: right;">1455.87</td> </tr> <tr> <td></td> <td style="text-align: right;">Y_u 1164.6975</td> </tr> <tr> <td style="vertical-align: middle;">Max Y_c</td> <td></td> </tr> </table> <p>In this example, the Y-Apex is greater than Y_u, therefore Y_u remains the upper extrapolation limit.</p>		1591.83		Y-Apex		1455.87		Y_u 1164.6975	Max Y_c	
	1591.83											
	Y-Apex											
	1455.87											
	Y_u 1164.6975											
Max Y_c												

S T E P	A	B
	Action	Example
7	Calculate the upper workload data range: $X = \frac{-b + \sqrt{b^2 - 4c(a - Y_u)}}{2c}$	$X = \frac{-1196 + \sqrt{1196^2 - [4(-0.02521)](173.33 - 1455.87)}}{2(-0.02521)}$ $X = \frac{-1196 + 3703}{-0.05042}$ $X = \frac{-8257}{-0.05042} = 163764 = 163.76$
8	If this equation is selected as the man-hour equation, then enter the lower (Y_l) and upper (Y_u) man-hour values, and the upper workload data range on the AF Form 1113, "Standard Applicability Man-Hour Range" block.	293.64 - 1455.64 (Upper Workload Value = 163.63)

Figure 2.12. Data and Extrapolation Limits for Linear Equation.

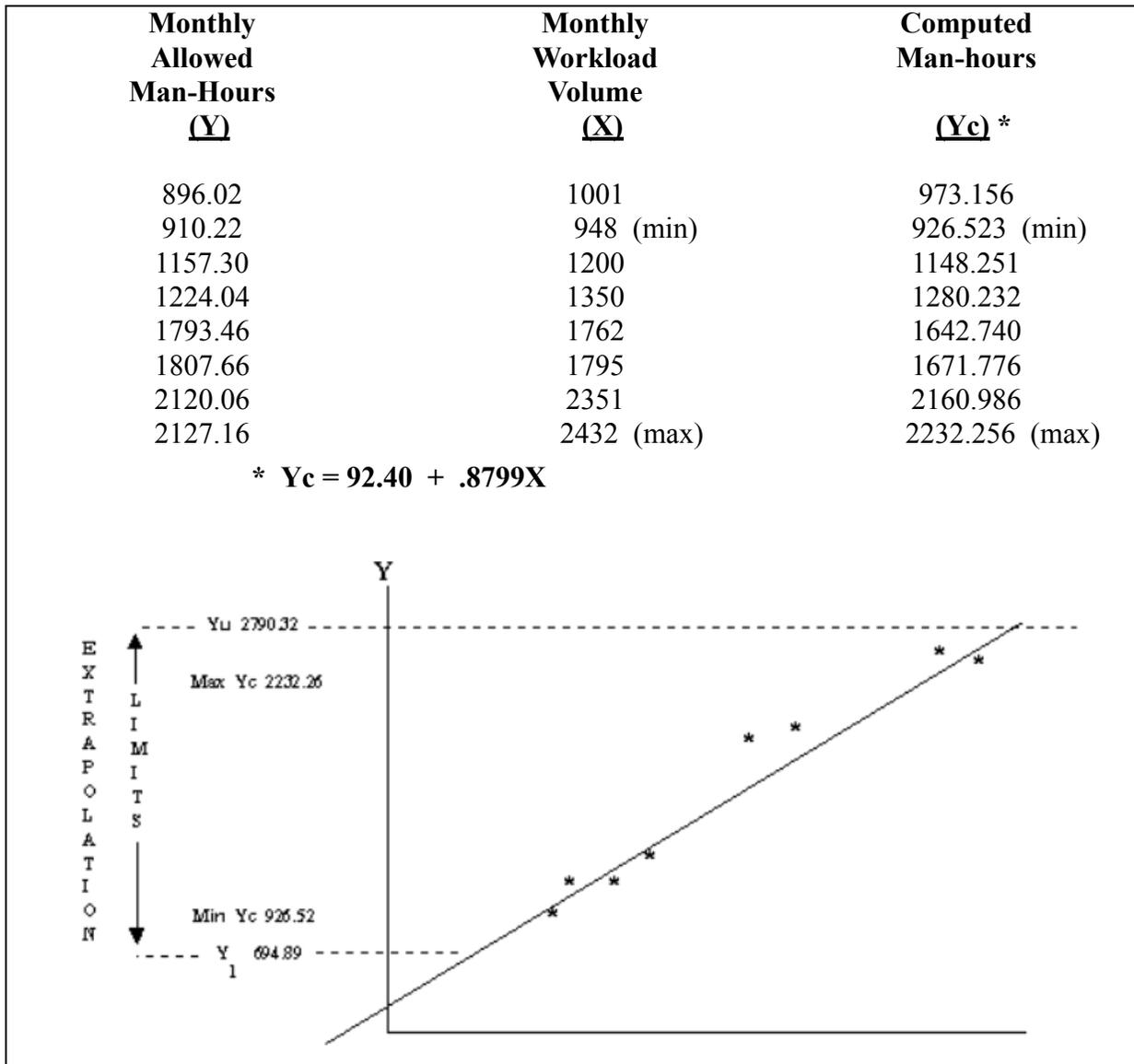


Figure 2.13. Data and Extrapolation Limits for Hyperbolic Equation.

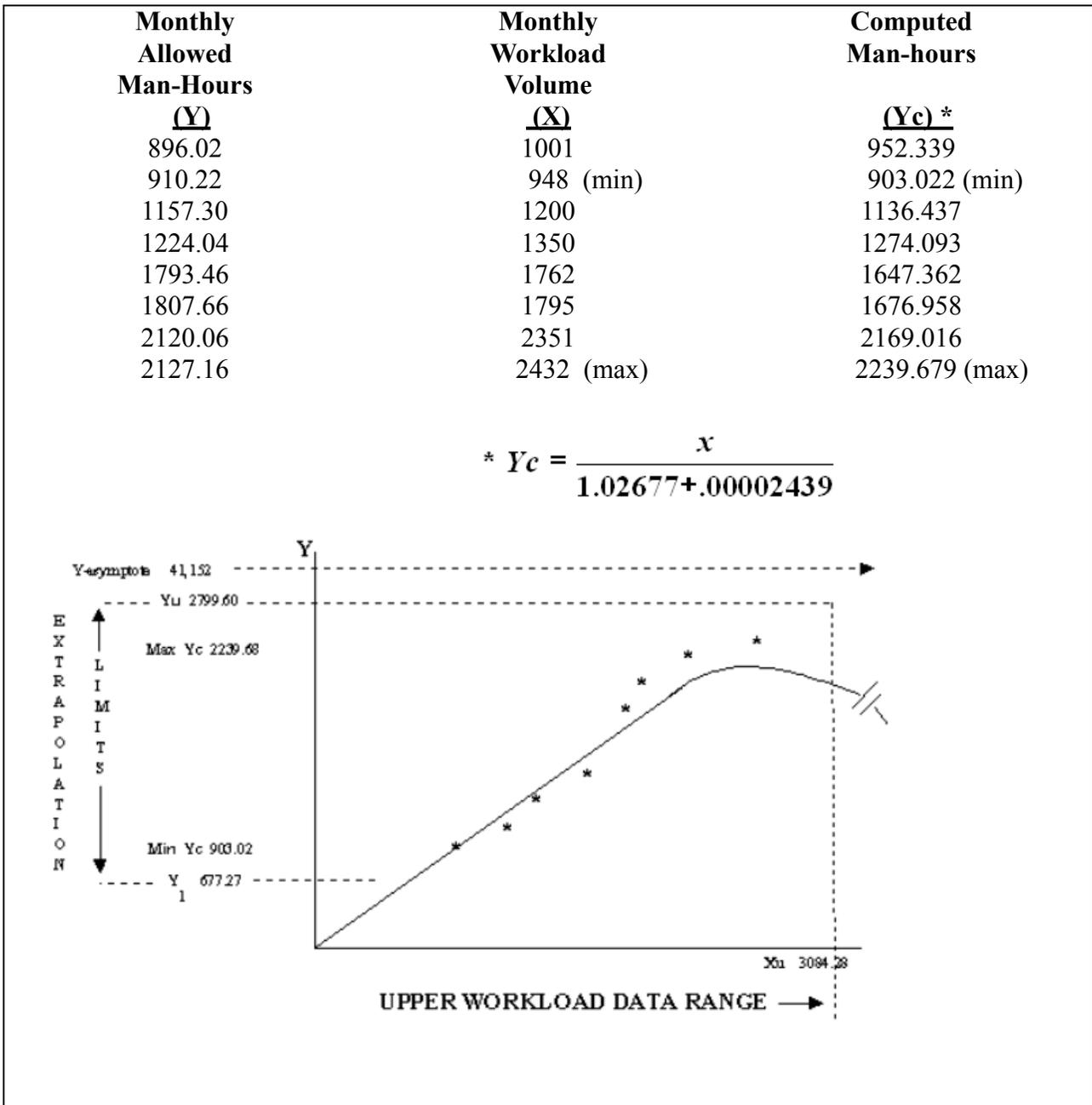
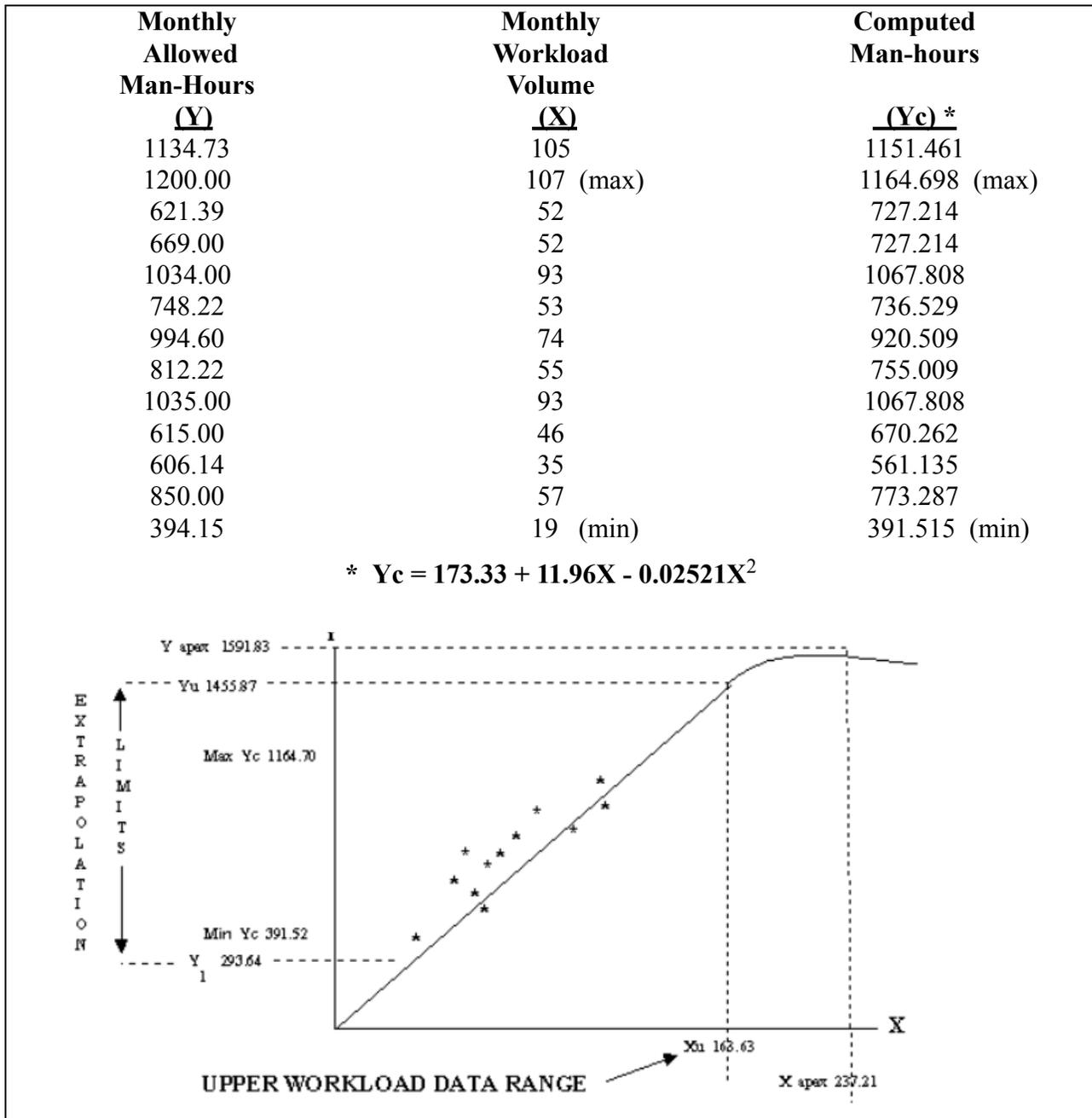


Figure 2.14. Data and Extrapolation Limits for Parabolic Equation.



2.22. Special Consideration in Extrapolation.

2.22.1. Lower Extrapolation Limit. For bivariate linear equations, parabolic equations, and multivariate equations with positive coefficients, the lower extrapolation limit must be greater than or equal to the a-value in the equation.

2.22.2. Multivariate Equations. The extrapolation limits for multivariate equations are based on predicted man-hours only (Y_u and Y_l from steps 2 and 3 of [Table 2.4](#)).

2.22.3. Single Location Standards. Extrapolation for a single location standard is based on $\pm 25\%$ of the calculated man-hours. Hence, the limits are $Y_l = .75Y_c$ and $Y_u = 1.25Y_c$. Note that in single location standards, the measures Y , Y_c , and \bar{Y} should be approximately equal.

2.22.4. Modular Equations. To find the extrapolation limits for modular equations, compute the limits for each module as outlined in paragraph 2.21. and Table 2.4., Table 2.5., or Table 2.6..

2.22.5. Power Model. Follow the procedures for a linear equation. No special considerations are needed.

2.22.6. Special Calculation Procedures for Computing Workload Data Range. The two models that need an upper workload value to be stated are:

2.22.6.1. Parabolic model. Because the equation for this model starts to decrease after the apex value, there will be some large workload values that yield man-hours within the acceptable extrapolation range that are unusable. To illustrate, refer to the parabolic equation in 2.14. A workload factor value of 350, when substituted in the parabolic equation yields 1271.11 man-hours - 1271.11 man-hours is in the acceptable extrapolation range, but it is on the decreasing segment of the curve. The formula for computing the upper workload data range for a parabolic model is in Table 2.6..

2.22.6.2. Hyperbolic (ratio) model. Because the equation for this model approaches, but never crosses, an asymptote, workload can increase endlessly (after a certain point) and never yield any additional man-hours. The formula for computing the upper workload data range for a hyperbolic model is in Table 2.5..

2.23. Use of Extrapolation Limits. After the extrapolation limits are computed, report them as the "Standard Applicability Man-Hour Range" on AF Form 1113, **Standard Manpower Table**. For those standards with more than one man-hour equation, record the standard applicability man-hour range for each equation in Application Instructions of the AFMS. Always state this range in man-hours.

Section 2D—Skill and Grade Determination

2.24. General Concepts. The process of skill and grade determination converts total manpower standard requirements into units of manpower with the skills and grades necessary to do the defined work center mission. Skill and grade determination must not be affected by external constraints or funding limitations. The minimum essential work center requirements must be engineered and documented independently of resource availability. Other methods may be used, but the specific procedure and data source must be documented in the manpower standard final report.

2.25. Skill and Grade Determination without C&R.

2.25.1. Step 1. Derive Total Man-Hours for Each Location. Total man-hours are derived by summing the direct and indirect man-hours.

2.25.2. Step 2. Compute Recommended Manpower Requirements for Each Location. Divide the man-hours in step 1 by the correct man-hour availability factor (MAF) and overload factor (military MAF, if work center is mixed). For example, $663.60 / (151.5 \times 1.077) = 4.067$. Round the resulting fractional manpower requirement to the correct whole manpower requirement IAW AFI 38-201.

2.25.3. Step 3. Estimate Required Grades and Skills for Each Location. The input craftsman consults with the work center supervisor and local OPR to get a proposed distribution. Record the recommended distribution as directed by the study team. For example,

AFSC(1)				AFSC(2)				AFSC(3)
9	7	5	3	9	7	5	3	CG
1MSG	1SSG	1TSG	1SSG					1CPT

2.25.4. Step 4. Determine Grades and Skills for AF Form 1113. The study team checks input recommendations and rationale, averages the input team recommendations for each level on the manpower table, and completes the table. The study team reconciles any grade inversion on the manpower table. For example, the number for a particular grade and skill should not decrease when compared to the previous column on the manpower table.

2.25.5. Step 5. Coordinate Proposed Grade and Skill Distribution. The study team coordinates the manpower table with the OPR as part of the final report.

2.26. Skill and Grade Determination with C&R.

2.26.1. Study Planning. During this phase of standards development, the study team and the functional OPR predetermine the Air Force Specialty Codes (AFSCs) based on steps shown in the process oriented description (POD). Skill distribution is also decided and shown as a percentage of each step. Study teams:

2.26.1.1. Investigate manpower currently used in the work center including current authorized and assigned military and DoD civilian strengths along with their respective grades and skills by MAJCOM, by base. The Manpower Data System (MDS) is a source for military and civilian authorizations while local base products will give assigned strength data.

2.26.1.2. Check corresponding Air Force Specialty (AFS) descriptions in AFMANs 36-2105, *Officer Classification*, and 36-2108, *Airman Classification*, and specialty training standards (STSs).

2.26.1.3. Identify steps that, by directive, need to be done by a specific AFS, skill level, or grade.

2.26.1.4. Analyze the POD and, based on research and interviews with the functional OPR, identify the AFSC needed to do the step.

2.26.1.4.1. The concept that workers spend most of their work time performing at their highest skill level governs what skills are needed. Identifying and distributing skills catalogs the total manpower requirement into the proper types and qualifications of workers.

2.26.1.4.2. Give particular attention to picking the proper category of manpower requirements. Make sure that rated specialties are needed only when the duties involved clearly justify such action. It is Air Force policy to use senior noncommissioned officers in lieu of lower

grade commissioned officers when practical and feasible. Officer requirements must be justified by responsibilities or duties specifically needing an officer.

2.26.1.5. Document the skill percentage requirement in matrix format for each step as displayed in **Figure 2.15**. Note that some steps can be done entirely by a given AFSC while the varying complexity of others may need more experience. Show officer requirements in the company grade or field grade category. Show colonel (0-6) requirements separately.

Figure 2.15. AFSC Percent Distribution.

Process/ Step	ENLISTED								OFFICER		
	AFS AAAXX				AFS BBBXX				AFS CCXX		
	9	7	5	3	9	7	5	3	6	FG	CG
1.1.	40										60
1.2.	10	80									10
1.3.	10	60	30								
2.		60	40								
3.1.						40	30	30			
3.2.						10	30	60			
3.3.					20	30	50				

2.26.1.6. Make sure the skill level percentages for each step equal 100.

2.26.1.7. Include a completed matrix in the measurement plan.

2.26.2. Work Measurement. During work measurement, input teams:

2.26.2.1. Determine the distribution of total step man-hours (direct and indirect) by AFS and skill level. Compute this distribution by multiplying the total measured step man-hours by the corresponding percent shown in the matrix. The result will be a similar matrix with man-hours instead of percentages as shown in **Figure 2.16**.

Figure 2.16. AFSC Man-Hour Matrix.

BASE A	ENLISTED									OFFICER		
	Process/ Step	Total Measured Man- Hours	AFS AAAXX				AFS BBBXX				AFS CCXX	
9			7	5	3	9	7	5	3	6	FG	CG
1.1.	50.00	20.00										30.00
1.2.	65.00	6.50	52.00									6.50
1.3.	37.00	3.70	22.20	11.10								
2.	125.00		75.00	50.00								
3.1.	302.30						120.92	90.69	90.69			
3.2.	66.18						6.62	19.85	39.71			
3.3.	18.12					3.62	5.44	9.06				
TOTALS	663.60	30.2	149.20	61.1		3.62	132.98	119.60	130.40			36.5

2.26.2.2. Total all man-hours by AFSC. This is the last line on the AFSC man-hour matrix (Figure 2.16.). It is also the first line on Figure 2.17. that shows the computed and recommended man-power.

Figure 2.17. Computed and Recommended Manpower by AFSC.

BASE A	ENLISTED									OFFICER			TOTAL
	AFS AAAXX				AFS BBBXX				AFS CCXX				
	9	7	5	3	9	7	5	3	6	FG	CG		
Total Man-hours by AFSC	30.20	149.20	61.10		3.62	132.98	119.60	130.40			36.50	663.60	
Computed Fractional Manpower (MAF x OLF; MAF = 151.5, OLF = 1.077)	0.185	0.914	0.374		.022	0.814	0.733	0.799			0.224	4.065	
Recommended Fractional Manpower	0.000	1.089	0.374		0.000	0.836	0.733	0.799			0.224	4.065	

2.26.2.3. Divide the total man-hours for each AFSC by the correct MAF times the overload factor to arrive at the computed fractional manpower needed. Where a military and civilian mix occurs, use the military MAF times the overload factor as the divisor.

2.26.2.4. Analyze the resulting distribution and check computed requirements with the functional OPR. Work center size and workload may need adjustments to the computed requirements. Show any necessary changes as recommended fractional manpower requirements. The total computed requirement must equal the total recommended requirement with minor variations because of rounding. Any change from computed to recommended for a given AFS that is more than .5 of a whole person requirement must be documented to show rationale for the change.

2.26.2.5. Submit grade recommendations to the study team for consideration only on an exception basis. Submit narrative recommendations to supplement the quantitative skill level input.

2.26.2.6. Send the completed Computed and Recommended Manpower by AFSC to the study team. A sample format is shown at [Figure 2.17.](#)

2.26.3. Data Analysis and Computation. During this activity of standards development, the study team analyzes recommended AFSCs sent by the input teams and, along with the OPR, decides the grade requirements. Use these analysis procedures.

2.26.3.1. Record the recommended fractional manpower for each base on a separate chart for each AFS. For example, the recommended fractional manpower for AFS BBBXX from Base A ([Figure 2.16.](#)) is recorded as the first line of [Figure 2.17.](#) The first column of [Figure 2.18.](#) is the total manpower recommended for that AFS (sum of the skill levels).

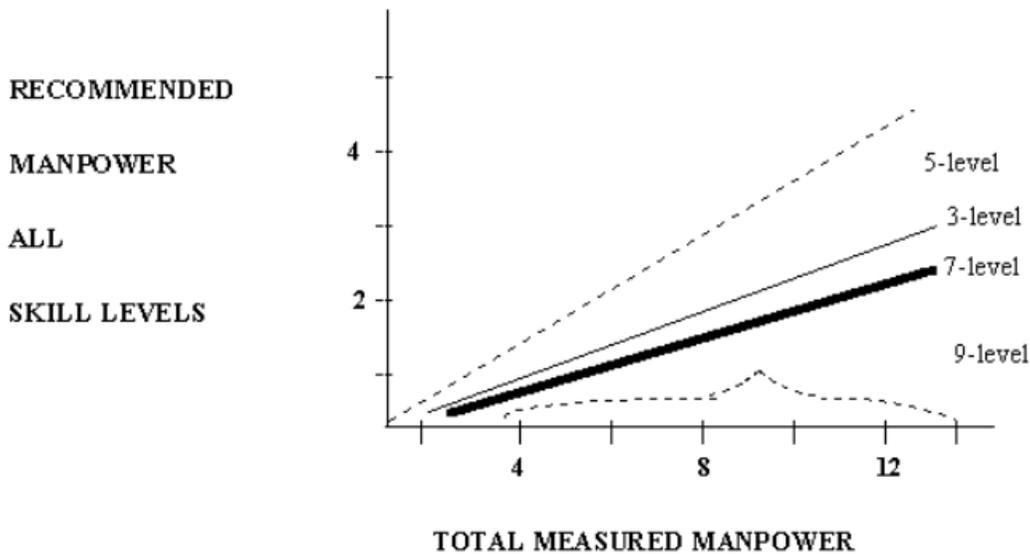
Figure 2.18. Regression Analysis Results - AFS BBBXX.

BASE	TOTAL MPWR REQUIRED	9 LEVEL REQMTS	7 LEVEL RQMTS	5 LEVEL REQMTS	3 LEVEL REQMTS
A	2.368	0.000	0.836	0.733	0.799
B	4.676	0.000	0.831	3.000	0.845
C	7.129	0.933	1.987	2.135	2.074
D	9.456	2.108	2.033	3.194	2.121
E	11.258	1.909	2.035	4.268	3.046
F	14.610	2.053	3.174	5.204	4.179

Computing each skill level (dependent variable) separately, results in the following equations:

Skill Level	Equation Form	Equation
9	Parabola	$Y_9 = -1.244 + 0.4297X - 0.01X^2$
7	Linear	$Y_7 = 0.2709 + 0.1873X$
5	Linear	$Y_5 = .04074 + 0.3251X$
3	Linear	$Y_3 = -0.1639 + 0.2838X$

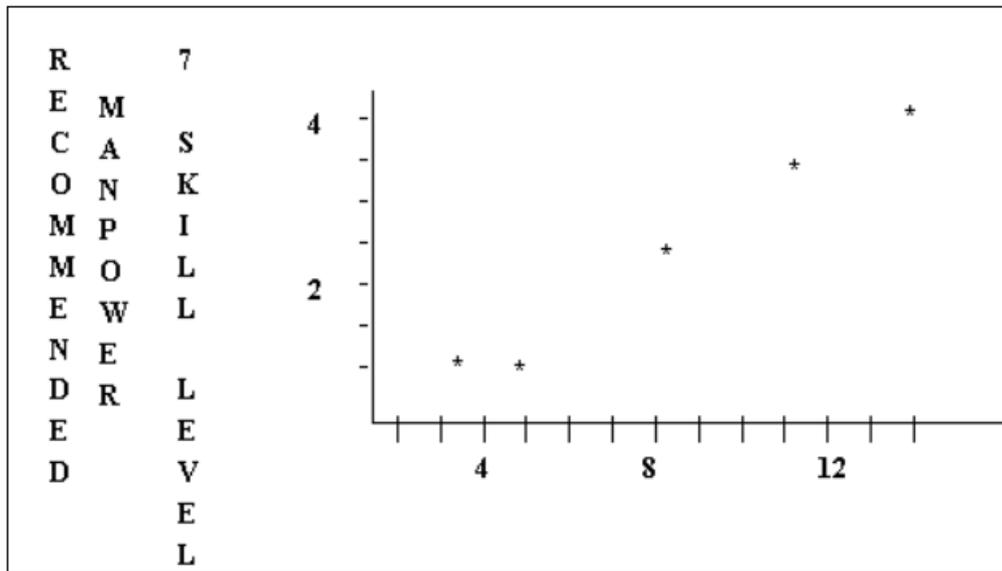
NOTE: Do not combine equations. Separate equations retain the skill level identity.



2.26.3.2. Plot a scattergram for each AFSC, for example, 3S090, 3SO71, 3S051, 3SO31. Put the total measured fractional manpower on the horizontal (X) axis and recommended fractional manpower for the skill level being analyzed on the vertical (Y) axis. **Figure 2.19.** shows a scattergram of the 7-skill level recommendations for AFS BBBXX. A scattergram aids in spotting any obvious

inconsistencies in recommended skills. If there are inconsistencies, they may be explained in the input team's comments. If not, talk to the input team to determine the rationale for their recommendations. Adjust specialty and skill distribution percentage data, as needed. Document the reason for adjustment.

Figure 2.19. Fractional Manpower & Skill Level Scattergram.



2.26.3.3. Fit a regression line to the data for each AFSC (see [Figure 2.18](#)). This aids both in statistically identifying the best skill level model and in picking the phase points for increasing the manpower for each AFSC.

2.26.3.4. Study the data array and the scattergram to find the man-hour values when there are significant changes (any amount of additional manpower) in either specialty or skill requirements. The incremental changes can be found by working each equation for the desired manpower value. Some examples of these are: the point that an officer requirement first takes place; the point that a staff-officer AFSC is first needed; similar points for 3, 5, 7, or 9-skill level requirements; and the point that multiple requirements for any of the foregoing first occur.

2.27. Procedures for Grade Requirements.

2.27.1. The study team, jointly with the OPR, analyzes the resulting manpower skill level distribution to set grade requirements. These considerations are addressed by the study team before setting grade requirements.

2.27.1.1. Read AFI 36-2618, *Enlisted Force Structure*, and AFI 36-2611, *Officer Professional Development Guide*, to get an understanding of the particular AFSs and their relationships within the functional area under study. Also read AFD 36-14, *Position Management and Classification*, for treatment of civilian positions.

2.27.1.2. Check the need to keep career field experience. The effect of promotion opportunities within each skill level should be checked to reduce the experience loss caused by retraining from one career field to another. In an ideal situation, these grade percentages exist for each skill level.

9-level: 33% CMSgt and 67% SMSgt

7-level: 40% MSgt and 60% TSgt

5-level: 50% SSgt and 50% SrA

Also, look at the latest profile for the entire career progression group. Base a decision to significantly deviate from the profile on specific needs of the work center as projected to the total population of the Air Force specialty.

NOTE: Both CMSgt and SMSgt grades are identified with the 9-skill level for purposes of grade distribution percentage. However, the CMSgt grade is reported with a chief enlisted manager (CEM) AFSC XXX00.

2.27.1.3. Analyze the current usage of personnel within the career field, and purge it of any mathematical errors. This is a separate and distinct process from analysis and adjustment covered in **Section 2B**. The end result of C&R is only as good as the data it's based on.

2.27.2. Identify the steps within an AFSC in a relative order as to experience and ability needed, in terms of grades.

2.27.3. Find those points in each step list where the transition is made from one grade to another. Assume the lowest grade specified for each AFSC is needed to do the lowest ranking step identified on that AFSC's step list.

2.27.4. Using the lowest ranking step for each AFSC as a point of departure, estimate the amount of time needed in the functional area to get the necessary experience to satisfactorily do the succeeding higher-ranking steps. Base these estimates on the anticipated experience of an average individual progressing through a typical technical education, on-the-job training, and career progression pattern.

2.27.5. Check each list with the measurement data to find the man-hours spent at the different levels of step difficulty.

2.27.6. Check the working relationship between the work center and other agencies. The scope and sensitivity of these interfaces may need some degree of grade comparability between working counterparts. Evaluate input team grade comments that may influence the grade requirement.

2.28. AFSC and Grade Documentation.

2.28.1. Compute and document the AFSC and grade distributions needed for varying manpower totals on an AF Form 1113.

2.28.2. Use each AFS equation resulting from regression analysis to compute the total personnel needed for each skill level.

2.28.2.1. The independent variable in each equation (X value) is the incremental manpower requirement (4, 5,...9, etc.).

2.28.2.2. Thus, to compute the manpower distribution for a total of nine spaces, using the skill level equations in [Figure 2.18.](#)

$$Y9 = -1.244 + 0.4297(9) - 0.01(9)^2$$

$$Y9 = 1.813 \text{ or } 2 \text{ 9-levels}$$

$$Y7 = 0.2709 + 0.1873(9)$$

$$Y7 = 1.957 \text{ or } 2 \text{ 7-levels}$$

$$Y5 = 0.4074 + 0.3251(9)$$

$$Y5 = 3.333 \text{ or } 3 \text{ 5-levels}$$

$$Y3 = -0.1639 + 0.2838(9)$$

$$Y3 = 2.390 \text{ or } 2 \text{ 3-levels}$$

2.28.3. Due to rounding, strict use of the fractional manpower breakpoints may yield more or less than the total work center requirement (X-value). Together, the study team and functional OPR find the correct rounding point that maintains the total requirement.

Chapter 3

CORE MODELING

3.1. General Concepts.

3.1.1. Core modeling is a study technique designed to capture common core workload and related manpower requirements for a particular function. The process still allows for differences (variances) caused by mission, technological, or environmental factors. In the past, it was difficult to obtain our customer's or functional OPR's concurrence because of the uncertainty of whether or not credit was given for all work (including unique or peculiar situations) done by the function. Core modeling may be used with almost any measurement method, except work sampling. It is particularly suited to workshop measurement when using flow procedures charting, operational audit, and staffing pattern methods to determine requirements. For our purposes, core workload is the most important part of a work center's or function's workload that must be completed to accomplish the mission.

3.1.2. A depiction of core modeling would be:

3.1.2.1. Functional core man-hours with variance man-hours for individual differences. The total man-hours are then used to determine total work center man-hours.

3.1.2.2. Then, total work center man-hours are divided by the man-hour availability factor (MAF) to find the total work center requirements.

3.2. Specific Procedures. The procedures for developing a core modeling manpower standard are basically the same steps as any other standard, but the sequence of the operations are different. The steps are as follows:

3.2.1. Develop the core POD identifying only minimum requirements necessary to perform the work center's mission. This should be a coordinated effort between the functional and manpower communities, and all customers should give full participation.

3.2.2. Verify the POD and obtain approval of the core POD with all customers. Also request that they start identifying their differences (variances) and unique situations that are not included in the core POD, but essential to mission completion. Keep in mind, that variances are only for environmental, technological, or mission differences, not for nice-to-have programs, indirect work, additional duties, etc.

3.2.3. The study team develops and measures the core model. Use whatever measurement method is most conducive for the function.

3.2.4. The study team prepares a final report with only the core model equations identified, and requests that the customers identify and quantify their variance requirements. The manpower community normally quantifies the variances, as well as prices out the core model. Core man-hours and variance man-hours are used to find total work center requirements. The total package, including comments is sent to the study team.

3.2.5. The study team and the Senior Functional Manager review and analyze each variance to determine its validity. See AFMAN 38-208, Volume 1, paragraph **3.27** for processing variances.

3.2.6. The study team determines the overall impact of the manpower standard, provides feedback to all customers relative to their variance disposition, revises the final report if necessary, and briefs the total estimated impact.

3.2.7. The MAJCOM Manpower and Organization Directorate submits the core model and variances to AFMIA to be published as the manpower standard.

3.3. Benefits of Core Modeling.

3.3.1. One benefit of using the core modeling technique is that our functional OPRs or customers view this type of technique as "fair and equitable" because their unique workloads have been addressed as part of the formal study process.

3.3.2. Another benefit of using this technique is that the study isn't "bogged down" during data analysis, trying to address outlying data points and individual base concerns. This normally reduces the overall study time.

3.3.3. Core Modeling gives our functional managers or customers a tool to decide what level of service they can afford.

3.3.4. This study technique is particularly useful in nonstandardized functions where mode of operations differ, in functions with undefined levels of service, or in work centers where previous tries to develop manpower standards proved unsuccessful. Examples would be Budget, Cost Analysis, and Operational Contracting.

3.4. Disadvantages of Core Modeling. The major disadvantage of core modeling is the additional workload taskings on the manpower community to collect and quantify the variance workload in the beginning. This can be alleviated if the manpower and functional communities are involved in the study process from the beginning, are briefed on what has been captured as core workload, and are briefed on what needs to be identified as variance workload. This allows them to get a head start on the process, and eliminates potential misunderstandings and confusion.

Chapter 4

FLOW PROCEDURES (FP) CHARTING

4.1. General Concepts.

4.1.1. In the past, obtaining concurrence on measurement data was difficult due to functional OPR uncertainty that the level of detail of the measurement included all work being accomplished in the work center. FP charting displays a level of detail so specific that our customer or functional manager can determine what work is being performed, who's doing the work, how much time a process takes to perform, and where the delays in the process take place. This chapter provides an overview of the FP charting process and its use within the manpower or functional community.

4.1.2. FP charting may be used in practically any work center, but is particularly suited to process-oriented work centers. A process is a series of actions that bring about an end or result. For our purposes, a process is a procedure with a definitive input and output product. Examples would be: TDY travel vouchers, supply requisitions, contract orders, etc.

4.1.3. FP charting is especially helpful in areas where extremely long work cycles would preclude work sampling.

4.1.4. If the study team is unable to get acceptable statistics from the measurement data, FP charting provides an alternate course of action. Since the data is already aligned procedurally, "b" coefficients are easily developed.

4.2. Benefits of FP Charting.

4.2.1. The FP charting method is a good starting point for a most effective organization study. It provides a tool allowing both the functional customer and manpower community to depict and analyze a work center under the current mode of operation, identify problems and improve the current operation, and adopt an MEO. It also provides a performance measures tool that the function can use to monitor internal performance.

4.2.2. FP charting segregates technical, administrative, and supervisory duties within the measurement data. This is particularly helpful in the development of the skills and grades matrix.

4.2.3. Standard maintenance is greatly simplified. Because of the measurement detail provided in FP charts, changes to existing procedures are easily identified and quantified.

4.2.4. FP charts can be used as forecasting tools to price out or determine the manpower impact of policy changes levied on a work center in advance.

4.3. Specific Characteristics. As with the OA method of measurement, FP charting uses activity time values at the process, step, or even beyond to obtain measured man-hours. The primary difference between OA measurement and FP charting is in the arraying of the measurement data. Some of the similarities and differences are outlined as follows:

4.3.1. Measurement Data. FP charting arrays data both vertically and horizontally. Each procedure identified has its own set of charts. A procedure may begin at whatever level of detail the study requires. Break each step down to the level the study team has determined will provide the best measurement data.

4.3.2. Per Accomplishment Time (PAT) Data. Obtain PAT data using the same procedures outlined in the chapter for operational audit ([Chapter 9](#)).

4.3.3. Frequency data. Although frequency data may be obtained using the same methods as OA measurement, that is where the similarity ends. By aligning the work center steps procedurally, only a single frequency count (excluding conditional factors) needs to be collected for each procedure charted.

4.3.4. Conditional Factors. Conditional factors relate to frequencies of a step and are those parts of a procedure that do not always occur with each repetition of a given work cycle or occur more than once per repetition. In order to account for these factors within a procedure's total time, the percentage of occurrence of that factor must be computed. The percentage of occurrence is obtained by dividing the number of times a given factor occurred within a procedure by the number of times it could have occurred. For example, if the work center frequency is service contracts processed for the service contract procedure, and if the second step in the procedure only occurs with 1 out of every 10 contracts, a percentage of occurrence would be determined as follows: $1 \text{ divided by } 10 = 10\%$. This percentage or factor is then multiplied by the step time to obtain a constructed PAT. Thus, instead of giving full time for this step for only the cycles in which it would occur (something that might be difficult to measure), partial time is provided for the step in every cycle. This allows for a constructed time to be developed for even the most difficult or lengthy procedures. Also, as most conditional factors will be associated with rework, they clearly identify to functional management the areas on which to focus quality improvement efforts.

4.3.5. Format. AF Form 3576, **Flow/Procedures Chart**, are designed based on the needs of each study. Charts will have a basic format for processes that are one page or chart and an extension format for processes that are over one page or chart. All processes should begin with the basic format chart. The following are specific chart characteristics:

4.3.5.1. The page number of the chart should be identified in the top right hand corner.

4.3.5.2. The upper left corner is general information about the procedure and should be completed by the study team or study manager.

4.3.5.3. In the upper right corner are the chart symbols. See [Figure 1.3](#) for symbol definitions.

4.3.5.4. Next, determine how the positions or people involved in the procedure should be depicted on the chart.

4.3.5.5. Use the extension sheet for a procedure over one page.

4.4. Precharting Activities.

4.4.1. The guidelines for developing an FP chart are relatively simple as the technique provides maximum flexibility in allowing the study team to express its measurement needs concisely to the input locations in the field.

4.4.2. The first step in chart development is to become very familiar with the work center and to draft a step-by-step word description for those steps in the POD that are being considered for FP measurement. The study team must make sure that they fully understand the real procedures of the work center, as well as the respective input and output documents.

4.4.3. The word description should depict the actions of work center personnel as they interact with the product or process being charted.

4.4.4. As with other measurement methods, each step should have easily recognizable beginning and ending points for ease of measurement.

4.4.5. Flow process chart items can be broken up into three types.

4.4.5.1. Measurable Items. These are the steps in the procedure that will require measurement. Identify the type of method to be used in quantifying this step by using an alpha character below the step number. When choosing alpha characters to designate the measurement method, use the letter code shown in **Table 9.1**, Box 5H.

4.4.5.2. Nonmeasurable Items. Nonmeasurable items are steps that do not expend work center man-hours but are charted in order to maintain process continuity. Some examples of nonmeasurable items are origination and gap symbols. Another example would be when a measurable step is referenced elsewhere in another set of charts. This occurs when certain steps cross procedural boundaries. If this is the case and a separate work count for each procedure cannot be obtained, then develop another set of charts for each of the affected procedures. Since the man-hours for that step are accounted for elsewhere, this step becomes nonmeasurable in that procedure.

4.4.5.3. Informational Items. The only items on an FP chart that do not have step numbers or symbols are informational items. These items are placed on the charts to clarify certain procedures or supply specific information designed to aid the input craftsman during measurement. Besides the normal step descriptions, informational items supply an additional avenue for the study team to describe occurrences in the process that may not otherwise be evident. This provides the input craftsman with a greater understanding of the procedure and what the measurement needs are.

4.4.6. Once the word description has been finalized, the work must then be broken out by position. Although the manner in which work center positions are broken out depends on the study team, the most common type of breakout is by craftsman, administration, and supervisor. Dividing the workload along these lines allows the study team to determine the impact of administrative and supervisory personnel on direct workload. Further breaking out the craftsman process by skill level provides for analysis of craftsman grade structures as well.

4.4.7. Once the position breakout has been done, procedures steps within those positions have been categorized, and process symbols have been assigned, the draft charts are then prepared.

4.5. FP Chart Preparation.

4.5.1. The following steps are required to prepare a FP chart:

4.5.1.1. Determine the procedure to be charted and its input and output documents.

4.5.1.2. Determine how many people are involved in the process, the type of work they do, and interactions among personnel.

4.5.1.3. Select the appropriate chart format in terms of the number of people needed in the process.

4.5.1.4. Complete the top left portion of the chart and fill in column headings for required personnel.

4.5.1.5. Start the process with an origination symbol under the appropriate column where the document will be received.

4.5.1.6. Select a symbol to depict the next step or action taken in the procedure. Each symbol should be accompanied with a brief narrative statement.

4.5.1.7. Continue to identify and depict each step with a symbol and narrative. For all measurable steps, the narrative statement should match the narrative on the POD. Only measurable steps will be identified on the POD; however, all measurable and nonmeasurable steps should have a step number.

4.5.1.8. Make sure that all steps in the process are captured from start to finish.

4.5.1.9. After all procedures in the work center have been captured, get together with the functional manager or other team members and review and analyze the current procedures. Your major objective is to determine where inefficiencies exist in the current mode of operation. The functional manager can be of tremendous help while doing this analysis. You should look at ways of changing the procedure by reducing variation and step complexity. Things to consider are: multiple review levels, rework, scrap, avoidable delays, and nonvalue added steps.

4.5.1.10. After the procedure charts have been improved and streamlined, make the necessary changes and redo the charts. After the charts have been updated, go back and update the POD to reflect the new improved mode of operation.

4.5.1.11. Begin measurement. Measure only the steps with an alpha character below the step number. The study team should decide the best type of measurement for each step. The alpha characters should show the type of OA measurement used. Place the measured time in the standard time (ST) block of the form. If a delay is involved in the task, include the time in the delay time (DT) column of the form. **NOTE:** Delay time does not always add measurable man-hours to a process, but is important to consider for process improvement.

4.5.1.12. Identify steps that have conditional factors. These are measurable steps that do not occur in every cycle. Compute as follows:

$$\begin{array}{r} \text{Original} \\ \text{PAT} \end{array} \quad \times \quad \begin{array}{r} \text{Percent of} \\ \text{Occurrence} \\ \text{Adjustment} \end{array} = \text{Adjusted PAT}$$

Example: 100 minutes x .10 = 10 minutes

4.5.1.13. After measurement has been completed, always re-check your frequency source of count and accuracy.

4.5.1.14. Add the total step times for the process and transfer this total to the upper left corner of the first page of the FP charts.

4.5.2. You do not have to follow these steps exactly to successfully complete a FP chart. The type of work center under study will determine if you can consolidate or eliminate certain steps.

4.6. MEO Development Using FP Charting.

4.6.1. Work center MEOs can be developed very easily using FP charting because the work is broken down into small steps by person. This is done by first completing FP charts for each procedure or process within a work center under its current mode of operation. The main objective is to have a visual display of all work being performed by work center personnel. Remember that before you can improve or manage a process, you have to understand the process. Array the data for easy analysis. Now, the functional manager and study team should start reviewing and analyzing the data from an organizational standpoint. Examples of this type of analysis include the following:

4.6.1.1. Why do separate branches perform the same type of work?

4.6.1.2. Is there duplication of effort among branches?

4.6.1.3. What are individual branch missions? Does the work performed support their mission?

4.6.1.4. Who are external and internal customers?

4.6.1.5. Are there excessive branch-level reviews on products or services with no real value-added?

4.6.1.6. What is the cost of operating each branch versus the real benefits received?

4.6.1.7. Have volume of work, equipment, and physical layout been considered?

4.6.2. After this analysis is completed, any organizational inefficiencies should be apparent. With the help of the functional manager, determine the best way to modify the structure to be more responsive to the customer. After changes to the organizational structure have been recommended and approved, implement the new organizational structure. This will be the organizational structure used for measuring the function. Any changes should be made to the POD as well as the individual FP charts.

4.6.3. Next, go through each process or procedure from a step standpoint and look at ways of changing the process by reducing variation and step complexity. For each step in the process, consider the following:

4.6.3.1. Why is it being performed?

4.6.3.2. What value does it add to the overall product?

4.6.3.3. Why is this person doing it?

4.6.3.4. Who should be doing it?

4.6.3.5. Are conditional factors built for rework or errors and does management know what the error rate is?

4.6.3.6. Why are errors taking place?

4.6.3.7. At what stage in the process do most of the errors occur?

4.6.3.8. Are too many people looking at the same document?

4.6.3.9. Can certain steps be automated?

4.6.3.10. Can certain steps be eliminated?

4.6.3.11. What are the governing publications for each step?

4.6.3.12. Can any steps be simplified?

4.6.4. After analyzing each step, determine what the real problems are within the procedures and correct them. Then redo the FP charts under the new or proposed mode of operation. This is in essence your MEO and should be documented as such.

4.7. Manpower Standard Development Using FP Charting. You can develop a manpower standard using FP charting in a manner very similar to the OA method of measurement. Two ways to do this are as follows:

4.7.1. Statistical manpower standards using correlation and regression (C&R) analysis are developed by transferring FP chart procedure times to an AF Form 1040, **Operational Audit Data**. The following steps should take place:

4.7.1.1. Determine the total time that one complete procedure takes. This total time should be located on the first page of the FP charts for each procedure. For example, the total time for Procedure 2 (Processes Service Contract) is 300 man-hours.

4.7.1.2. Normally, each separate procedure is a separate process of work, or separate step on the POD. For example, Process 2 on the Operational Contracting POD is: Processes Service Contract. This is the same as Procedure 2.

4.7.1.3. Then determine how many service contracts were processed or awarded per month for the last 12 months. Let's assume we have an average of 10 service contracts awarded per month.

4.7.1.4. Now, you would prepare an AF Form 1040 for each location, by completing the frequencies (10 per month), and PAT (300 man-hours), then computing total Process 2 man-hours (3000 man-hours). Do this for each process to determine the total work center man-hours.

4.7.1.5. At this point, regular C&R can be performed at the process level, step level, or for the total work center.

4.7.1.6. Determine standard indirect allowed man-hours (SIAM) by using the SIAM data sheets published with AFMS 00AA. These man-hours can then be added to the man-hour equation for total work center requirements.

4.7.2. Develop the "b" Coefficient. Functional modeling, as well as functional estimating equations, may also be used. If satisfactory statistics cannot be achieved with C&R analysis, simply use the average total FP chart time (or total procedure time) as the "b" coefficient. An example is provided below.

BASE	1	2	3	4	5	6	7	AVERAGE
------	---	---	---	---	---	---	---	---------

Pros 2

PATs	315	320	280	275	290	305	300	297.86
------	-----	-----	-----	-----	-----	-----	-----	--------

Equation format: $Y = 297.86X_2$ (add SIAM man-hours)

4.7.3. The other phases of the Manpower Standard Process remain the same.

4.8. Skill and Grade Matrix Development Using FP Charting. By identifying workload by position on the FP chart, you can determine the percentage of work performed by each position and specialty, then develop a skill and grade matrix. This is done by adding the total time per position from the FP chart for a procedure, and then determining the procedure's total impact on the work center. For example, the Operational Contracting work center process 2 or procedure 2 would be presented as follows:

4.8.1. Step 1. Time to process one Service Contract is 300 man-hours broken down by the following positions:

POSITIONS	MAN-HOURS PER PROCEDURE	PERCENT OF PROCEDURE
Craft/6C0S1	200	67%
Supervisor/64PQ	70	23%
Admin/3A1S1	$\frac{30}{300}$	$\frac{10\%}{100\%}$

4.8.2. Step 2. Determine the overall man-hour impact that Procedure 2 has on the work center. Let's assume that the work center measured a total of 5,000 monthly man-hours and Procedure 2 takes a total of 3,000 monthly man-hours (10 service contracts awarded per month x 300 man-hours per contract). In this case, Procedure 2 impact on the overall work center man-hours would be: 3,000 divided by 5,000 = 60%.

4.8.3. Step 3. Now multiply Procedure 2 position percentages by its overall impact on the work center percentage to determine the overall percentage that should be allocated to each position.

POSITIONS	PERCENT OF PROCEDURE	POD PERCENT IMPACT	PERCENT ALLOCATED
6C0S1	67%	60%	40%
64PQ	23%	60%	14%
3A1S1	10%	60%	6%

4.8.4. Step 4. Repeat this for each procedure in the work center that has been measured, making sure that the percents allocated account for 100% of the work center requirements.

4.8.5. Step 5. There will be situations in which a position is comprised of 3, 5, and 7 level work. If this occurs, determine what percent is 3 level, 5 level, and 7 level prior to doing the calculations, and extrapolate this percent to the position percentages.

4.8.6. Step 6. Consider officer grade ceilings and career progression factors when preparing the skill and grade matrix.

4.9. Functional Measures Tracking. Work center performance can be measured using the FP charts as the standard procedure and time to perform work center processes. Effectiveness and efficiency indices can be developed to track and measure performance. For example, the standard time to process a service contract is 300 man-hours. Suppose the work center is taking 330 man-hours to process a service contract, exceeding the standard allowed time by 10% ($30 \text{ divided by } 300 = 10\%$). Management should investigate this variance to determine the causes for exceeding the standard time. Reference the chapter on performance measures for specific details of how to develop performance indices.

Chapter 5

FUNCTIONAL ESTIMATING EQUATIONS (FEE)

Section 5A—Forecasting Manpower Requirements

5.1. General Concepts. The purpose of this chapter is to show how work center manpower standards form the basis for FEEs and how they are built. These equations are quantitative tools designed to be used at all organizational levels to forecast manpower requirements. FEEs are optional and are used to supplement other forecasting methods.

5.2. Air Force Program Element Structure.

5.2.1. Manpower management personnel build the quantitative tools (models) needed to develop the manpower programming part of the planning, programming, and budgeting system. To be effective, these models must parallel the DoD programming system embodied in the Air Force part of the Future Years Defense Program (FYDP).

5.2.1.1. The broadest and most basic structural element of the FYDP is the major force program. Major force programs (see [Figure 5.1.](#)) represent broad aggregations of smaller or specific missions that are closely related.

Figure 5.1. Major Force Programs in the FYDP.

MAJOR FORCE PROGRAMS (MFP)	
PROGRAM	TITLE
1	Strategic Forces
2	General Purpose Forces
3	C3I and Space
4	Airlift/Sealift
5	Guard and Reserve Forces
6	Research and Development
7	Central Supply and Maintenance
8	Training, Medical, and Other General Personnel Activities
9	Administration and Associated Activities
10	Support of Other Nations
11	Special Operations Forces

5.2.1.2. Each major force program is subdivided into more specific mission breakdowns called program elements.

5.2.1.2.1. Program elements represent a combination of manpower, equipment, and facilities that constitute a military capability or support activity. They give full descriptions of the mission and are the smallest program cost-collection unit that OSD requires DoD components to furnish information on a regular basis. Program elements are used throughout DoD and they identify every type of organization.

5.2.1.2.2. Each program element is identified by a program element code (PEC) consisting of six characters. The first character represents the Major Force Program. The first five characters are always numeric (for example, 41896) except "a" used for MFP 10 and "b" used for MFP 11. The sixth is always alphabetic. At the DoD level, this sixth character identifies the DoD component (F means Air Force) (see [Figure 5.2.](#)). When used within the Air Force, this sixth character is replaced by other alphabetic characters (for example, 41896A, 41896B)

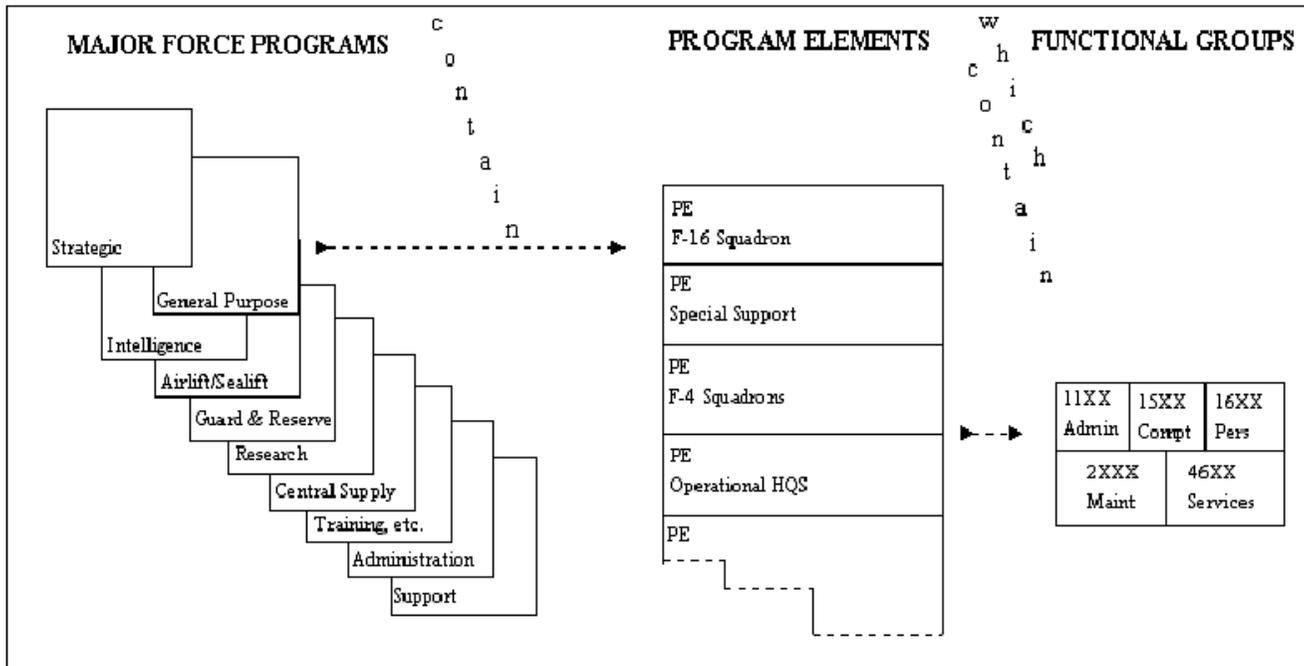
other than F that is reserved for DoD use. This is done when it is necessary to shred-out the DoD PEC to account for resources at a lower level. Program element code shreds are established by HQ USAF/XPM.

Figure 5.2. Air Force PECs Within Major Force Program 2.

MAJOR FORCE PROGRAM 2			
(partial list)			
PROGRAM ELEMENT CODES	TITLE	PROGRAM ELEMENT CODES	TITLE
21006A	Special Support	27596A	Base Ops-TAC AF
21114A	PACOM - Service Spt	27596D	Manpower Office
21115A	USSOUTHCOM - Service Spt	27597A	TAF-Lead-In Misc Pipeline Student
27133H	Aircrew Tng Devices	27969E	Cbt Spt EAF Support Backfill
27133A	F-16 Squadrons	28038A	Contingency Hospital
27236A	Operational Hqs (TAF)	28090A	Instl Audiovisual Spt (Tactical)
27581A	Joint Stars Ops	28719A	Child Development
27588A	Air Base Gnd Def	28720A	Family Center
		28720R	Family Center (REIMB)

5.2.1.2.3. Within a program element, there can be one or more functional groups. A functional group is defined by the first two digits of a functional account code (FAC). For example, PEC 27236A includes work centers in 11XX Administration, 15XX Comptroller, 16XX Personnel, 2XXX Maintenance, and 46XX Services (see [Figure 5.3.](#)).

Figure 5.3. Relationship Between Major Force Program, Program Elements, and Functional Groups.



5.2.2. To meet the objective of building manpower forecasting tools, a FEE is built for each functional group within each MAJCOM.

Section 5B—Functional Estimating Equation Development

5.3. Building a FEE.

5.3.1. Each FEE is made up of two major parts.

5.3.1.1. A mathematical equation showing the relationship between the function's total manpower requirement and a selected program estimating factor (PEF). All of the PEFs are variables that are specifically programmed in the FYDP. The PEFs used to build FEEs are:

- 5.3.1.1.1. Flying hours.
- 5.3.1.1.2. Number of aircraft.
- 5.3.1.1.3. Number of missiles.
- 5.3.1.1.4. Students.
- 5.3.1.1.5. Base population.
- 5.3.1.1.6. Number of vehicles.

5.3.1.2. Percentage factors that break a function's total manpower requirements into various PECs and manpower categories at MAJCOM, base, and work center levels. These percentage factors identify what part of a function's total manpower requirements, as shown by application of the

mathematical equation, are in various PECs. There are also factors that further identify what part of a PEC's manpower requirements are in various manpower categories. These categories include officers, airmen, United States direct-hire civilians, foreign national direct-hire civilians, foreign national indirect-hire civilians, nonchargeable civilians on UAF but not in FYDP, and contract manpower equivalents (CME).

5.3.2. Build at least one FEE for each functional area. Functional areas are defined by the first or first and second digit of Air Force FACs (for example, 5XXX defines the medical functional area while 41XX defines the supply functional area). However, if manpower resources need to be programmed at a lower functional level (for example, 44EX), then build FEEs at these levels.

5.3.3. Normally use regression analysis to build the mathematical equation of a FEE. This analysis uses the function's total required manpower and actual historical values for selected program estimating factors from each relevant location in the MAJCOM.

5.3.3.1. Make sure all mathematical equations are linear (bivariate or multivariate).

5.3.3.2. Get the function's required manpower total at each location by applying all manpower standards that cover work centers in the function (use whole numbers for the manpower values).

5.3.3.2.1. The monthly WLF values used in these applications are the result of analysis done on the 12 most current months of historical data. If 12 months of data is not available, use 6 months of data at the minimum.

5.3.3.2.2. Include in the function's total manpower requirements any CMEs that are relevant. Track these numbers separately on the Unit Manpower Document (UMD). They will eventually be identified as a CME percentage factor.

5.3.3.3. Use PEFs in FEEs like WLFs are used in work center manpower standards. PEF values are average monthly values obtained from analysis of historical data for each location in the MAJCOM. Take this historical data from the same time period as the workload data used to apply the standards.

5.3.3.4. See [Table 5.1](#) for specific instructions for building the mathematical equation of a FEE by using regression analysis. An example of data used to build a FEE is shown in [Figure 5.4](#).

Table 5.1. Construction of the Mathematical Equation for a FEE.

STEP	A	B								
	Action	Example								
1	Identify all work centers within a functional area.	Within functional area 81XX there are four work centers: 81A1, 81B1, 81C1, and 81D1.								
2	Identify all locations in the MAJCOM which have work centers from this functional area.	There are twenty locations in command ABC that have this functional area.								
3	Identify which of the locations identified in step 2 can be grouped together to build a FEE. However, if circumstances dictate more than one grouping of bases (e.g., locations where the MAJCOM is host versus locations where the MAJCOM is a tenant) build a FEE for each grouping. Each location can be in only one grouping.	Assume all twenty locations in command ABC can be treated as one group. This will result in the building of only one FEE.								
4	Select the PEFs to be tested for each of the groupings of locations identified in step 3.	Base population will be tested for this function.								
5	At each MAJCOM location, obtain the manpower requirements for each work center in the function by applying its manpower standard.	At base 1, the following requirements were obtained. <div style="text-align: center;"> WORK CENTER REQUIREMENTS <table style="margin-left: auto; margin-right: auto;"> <tr> <td style="padding-right: 20px;">A</td> <td>22</td> </tr> <tr> <td>B</td> <td>15</td> </tr> <tr> <td>C</td> <td>10</td> </tr> <tr> <td>D</td> <td>18</td> </tr> </table> </div>	A	22	B	15	C	10	D	18
A	22									
B	15									
C	10									
D	18									
6	At each location, sum the results of step 5 to get the total functional requirements.	Base 1 total functional requirements = 22 + 15 + 10 + 18 = 65.								
7	At each location, determine a monthly PEF value from analysis of actual values experienced during the same time period as the workload data used to apply the standards.	For base 1, the monthly base population value is 2528.								
8	Fit the regression line to the data.	See Figure 5.4 .								

Figure 5.4. Example of Data Used to Build a FEE.

TITLE: FEE DATA PAIRS		
MAJCOM: ABC		
PEF AND WLF TIME FRAME:		
JANUARY 1987 - DECEMBER 1988		
PEF SOURCE: PM (31 December 1988)		
BASE	REQUIRED MANPOWER	PEF VALUE
1	65	2528
2	47	2171
3	67	4145
4	64	4270
5	39	1360
6	71	4894
7	51	1603
8	64	2420
9	71	5214
10	49	1850
11	53	3004
12	106	10551
13	39	1586
14	72	3498
15	62	4216
16	61	403
17	64	4493
18	82	4829
19	37	1231
20	43	2147

EQUATION:

$$Y = 38.83 + .006482(X)$$

$$R^2 = .751$$

$$S_{YX} = 8.505$$

$$V = .140$$

5.3.3.5. There are no classification categories for a FEE. However, a FEE built using regression analysis must satisfy the statistical criteria of the measurement method selected. (See **Attachment 2, Table 2.3.**, Data Source and Statistical Analysis for criteria.) If it does not, then use an equation in the form of $Y = bX$, where:

Y = Manpower Requirements for a Functional Area

b = Standard Application Requirements
Historical Monthly PEF Value

X = Programmed PEF Value

5.3.3.6. When a FEE applies to four or less locations in a MAJCOM, build the mathematical equation for the FEE using instructions for the single location and small population standard in **Chapter 11**.

5.3.4. Build the adjustment and percentage factors of a FEE using information from application of the work center standards, data found in the UMD, and values resulting from the development of the FEE's mathematical equation.

5.3.4.1. Compute the adjustment factor for each location in the MAJCOM (see **Figure 5.5.**). This value identifies how much each location's manpower requirement total, obtained from application of the function's manpower standards, is different from the manpower requirement total obtained from application of the FEE. Apply both the FEE and the standard to get this factor. Round the adjustment factor to three decimal places.

Figure 5.5. Computation of Base Adjustment Factors for a FEE.

TITLE: FEE ADJUSTMENT FACTOR CALCULATION					
MAJCOM: ABC					
BASE	STANDARD APPLICATION REQUIREMENTS	minus	FEE REQUIREMENTS	equals	ADJUSTMENT FACTOR
1	65.000	-	55.212	=	+9.788
2	47.000	-	52.897	=	-5.897
3	67.000	-	65.694	=	+1.306
4	64.000	-	66.504	=	-2.504
5	39.000	-	47.640	=	-8.640
6	71.000	-	70.549	=	+451
7	51.000	-	49.215	=	+1.785
8	64.000	-	54.512	=	+9.488
9	71.000	-	72.624	=	-1.624
10	49.000	-	50.817	=	-1.817
11	53.000	-	58.297	=	-5.297
12	106.000	-	107.220	=	-1.220
13	39.000	-	49.105	=	-10.105
14	72.000	-	61.500	=	+10.500
15	62.000	-	66.154	=	-4.154
16	61.000	-	41.436	=	+19.564
17	64.000	-	67.950	=	-3.950
18	82.000	-	70.128	=	+11.872
19	37.000	-	46.804	=	-9.804
20	43.000	-	52.742	=	-9.742

5.3.4.2. The remaining FEE factors are percentages that show what percent of the total functional area requirements is in each PEC and what percent is in other various manpower categories. Compute different factors for the work center, base, and MAJCOM levels. There are three kinds of percentage factors needed for each base in a MAJCOM.

5.3.4.2.1. The first are percentages of the total manpower requirements represented by each PEC. Percentages are needed for the overall function as well as for each work center in the function. Instructions for building these percentages are shown in [Table 5.2.](#), and an example is shown in [Figure 5.6.](#)

Table 5.2. PEC Percentage Factor Calculation (see note).

STEP	A	B			
	Action	Example			
1	Within each work center at a location, identify the program element codes (PEC) that cover the requirements shown in the unit manpower document (UMD).	At base 16, all requirements fall into either PEC 91212A or PEC 27596A.			
2	For the fiscal quarter in which the standard applications are done, identify the number of requirements in each PEC for each work center.	WORK CENTER	PEC	REQUIREMENTS	
		A	27596A	4	
			91212A	16	
		B	91212A	12	
		C	91212A	17	
		D	91212A	12	
3	Determine the PEC percentages for each work center. Divide each PEC requirement total by the work center's total requirements (all PECs added together). Keep the percentages in terms of decimals rounded to three decimal places.	WORK CENTER	PEC	WORK CENTER (BASE LEVEL) PEC PERCENTAGE	
		A	27596A	$\frac{4}{20} = .200$	
			91212A	$\frac{16}{20} = .800$	
4	For each location, compute the function's total requirements by PEC by adding the work center results in step 2.	WORK CENTER	27596A	91212A	TOTAL FUNCTIONAL REQUIREMENTS
		A	4	16	20
		B		12	12
		C		17	17
		D		<u>12</u>	<u>12</u>
		TOTAL	<u>4</u>	<u>57</u>	<u>61</u>
5	Determine the PEC percentages for the function at each location. Divide each PEC requirement total by the function's total requirement (all PECs added together). Keep the results in terms of decimals rounded to three decimal places.	LOCATION	PEC	FUNCTIONAL (BASE LEVEL) PEC PERCENTAGE	
		Base 16	27596A	$\frac{4}{61} = .066$	
			91212A	$\frac{57}{61} = .934$	
	(continued on next page)			61	

STEP	A	B		
	Action	Example		
6	For the overall command, compute the function's total requirements within each PEC by adding the functional results obtained in step 4 for each location (see Figure 5.7.).	PEC	FUNCTION'S TOTAL REQUIREMENT	
		27596A	1106	
		91212A	57	
		41896A	2	
		31196A	39	
		11896A	<u>....3</u>	
		Overall Total	1207	
7	Determine the PEC percentages for the function at MAJCOM level. Divide each PEC UMD requirement total by the function's total UMD requirements (all PECs added together). Keep the percentages in terms of decimals rounded to three decimal places.	MAJCOM	PEC	FUNCTIONAL (MAJCOM LEVEL) PEC PERCENTAGE
		ABC	27596A	$\frac{1106}{1207} = .916$
			91212A	$\frac{57}{1207} = .047$
			41896A	$\frac{2}{1207} = .002$
			31196A	$\frac{39}{1207} = .032$
			11896A	$\frac{3}{1207} = .002$
NOTE: PEC percentage factors are determined for three levels; work center at base level, functional at base level, and functional at MAJCOM level.				

Figure 5.6. Example of Base Level PEC Percentages and the Overall MAJCOM PEC Percentages.

BASE	PEC 11896A		PEC 27596A		PEC 31196A		PEC 41896A		PEC 91212A		TOTAL
	RQMTS	%	RQMTS	%	RQMTS	%	RQMTS	%	RQMTS	%	RQMTS
1			65	1.000							65
2			47	1.000							47
3			67	1.000							67
4			64	1.000							64
5			39	1.000							39
6			71	1.000							71
7			51	1.000							51
8			64	1.000							64
9			71	1.000							71
10			49	1.000							49
11			53	1.000							53
12			104	.981			2	.019			106
13					39	1.000					39
14			72	1.000							72
15			62	1.000							62
16			4	.066					57	.934	61
17			64	1.000							64
18	3	.037	79	.963							82
19			37	1.000							37
20			43	1.000							43
MAJCOM FUNC- TIONAL TOTALS	3	.002	1106	.916	39	.032	2	.002	57	.047	1207

5.3.4.2.2. Next are percentages of the function's total manpower requirements represented by each work center. Instructions for building these percentages are shown in [Table 5.3.](#)

Table 5.3. Work Center Percentage Factor Calculation.

S T E P	A	B										
	Action	Example										
1	Identify all work centers within a functional area.	Within functional area 81XX there are four work centers: 81A1, 81B1, 81C1, and 81D1.										
2	Identify all locations in the MAJCOM which have work centers in this functional area.	There are twenty locations in command ABC that have this functional area.										
3	At each MAJCOM location, obtain the manpower requirements for each work center in the function by applying the manpower standards.	At base 1, the following requirements were obtained. <table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>WORK CENTER</th> <th>REQUIREMENTS</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>22</td> </tr> <tr> <td>B</td> <td>15</td> </tr> <tr> <td>C</td> <td>10</td> </tr> <tr> <td>D</td> <td>18</td> </tr> </tbody> </table>	WORK CENTER	REQUIREMENTS	A	22	B	15	C	10	D	18
WORK CENTER	REQUIREMENTS											
A	22											
B	15											
C	10											
D	18											
4	At each location, sum the results of step 3 to get the total functional requirements.	Base 1 total functional requirements = 22 + 15 + 10 + 18 = 65.										
5	To get the work center percentage factors for each location in the MAJCOM, divide each work center requirement total found in step 3 by the total found in step 4. Keep the percentages in terms of decimals rounded to three decimal places.	<table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>WORK CENTER</th> <th>PERCENTAGE</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>$\frac{22}{65} = .338$</td> </tr> <tr> <td>B</td> <td>$\frac{15}{65} = .231$</td> </tr> <tr> <td>C</td> <td>$\frac{10}{65} = .154$</td> </tr> <tr> <td>D</td> <td>$\frac{18}{65} = .277$</td> </tr> </tbody> </table>	WORK CENTER	PERCENTAGE	A	$\frac{22}{65} = .338$	B	$\frac{15}{65} = .231$	C	$\frac{10}{65} = .154$	D	$\frac{18}{65} = .277$
WORK CENTER	PERCENTAGE											
A	$\frac{22}{65} = .338$											
B	$\frac{15}{65} = .231$											
C	$\frac{10}{65} = .154$											
D	$\frac{18}{65} = .277$											

5.3.4.2.3. The final kinds are percentages of officers, airmen, United States direct-hire civilians, foreign national direct-hire civilians, foreign national indirect-hire civilians, and CMEs within each PEC at the overall functional level. Develop these percentages for each PEC in each work center. Instructions for building these percentages are shown in [Table 5.4.](#), and an example is shown in [Figure 5.7.](#)

Table 5.4. Manpower Category Percentage Factor Calculation.

S T E P	A	B
	Action	Example
1	Identify the manpower categories that are present within each work center at a MAJCOM location. These categories include officers, airmen, USDH civilians, FNDH civilians, and contract manpower equivalents (CME).	At base 12, in work center C, there are officers, airmen, and USDH civilians.

STEP	A	B																																																												
	Action	Example																																																												
2	Determine the total work center requirements for each of the manpower categories found in step 1. These requirements are obtained from application of the work center's standard.	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">BASE 12 WORK CENTER</td> <td style="width: 10%;"></td> <td style="width: 10%;">USDH OFF ENL CIV TOTAL</td> </tr> <tr> <td style="text-align: center;">C</td> <td style="text-align: center;">1</td> <td style="text-align: center;">21</td> <td style="text-align: center;">1</td> <td colspan="4"></td> <td style="text-align: center;">23</td> </tr> </table>	BASE 12 WORK CENTER								USDH OFF ENL CIV TOTAL	C	1	21	1					23																																										
BASE 12 WORK CENTER								USDH OFF ENL CIV TOTAL																																																						
C	1	21	1					23																																																						
3	Determine the PECs that are in the work center of interest. This is the same as determined in Table 5.2 .	In this work center there are two PECs: 27596A 41896A																																																												
4	Multiply the total work center requirements found in step 2 by the work center (base level) PEC percentages found in Table 5.2 , step 3, to obtain the requirement for each PEC in the work center.	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%;">WORK CENTER (Base Level)</td> <td style="width: 10%;"></td> <td style="width: 10%;">REQUIREMENT PER PEC</td> </tr> <tr> <td style="text-align: center;"><u>PEC %</u></td> <td></td> <td style="text-align: center;"><u>TOTAL</u></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: center;">.913</td> <td style="text-align: center;">x</td> <td style="text-align: center;">23</td> <td style="text-align: center;">=</td> <td colspan="4"></td> <td style="text-align: center;">21</td> </tr> <tr> <td style="text-align: center;">.087</td> <td style="text-align: center;">x</td> <td style="text-align: center;">23</td> <td style="text-align: center;">=</td> <td colspan="4"></td> <td style="text-align: center;">2</td> </tr> </table>	WORK CENTER (Base Level)								REQUIREMENT PER PEC	<u>PEC %</u>		<u>TOTAL</u>							.913	x	23	=					21	.087	x	23	=					2																								
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5	Analyze the work center UMD requirements to see what manpower categories are in each PEC. From this analysis and other guidance that may be appropriate, split the manpower category totals found in step 2 into the appropriate PECs.	<p>The UMD shows all requirements in PEC 41896A are airmen. Maintaining this finding, the PEC split by manpower category becomes:</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="5" style="text-align: center;">MANPOWER CATEGORY TOTALS (BY BASE BY WORK CENTER)</td> </tr> <tr> <td style="text-align: center;"><u>PEC</u></td> <td style="text-align: center;"><u>OFF</u></td> <td style="text-align: center;"><u>ENL</u></td> <td style="text-align: center;"><u>USDH CIV</u></td> <td style="text-align: center;"><u>TOTAL</u></td> </tr> <tr> <td style="text-align: center;">27596A</td> <td style="text-align: center;">1</td> <td style="text-align: center;">19</td> <td style="text-align: center;">1</td> <td style="text-align: center;">21</td> </tr> <tr> <td style="text-align: center;">41896A</td> <td></td> <td style="text-align: center;">2</td> <td></td> <td style="text-align: center;">2</td> </tr> </table>	MANPOWER CATEGORY TOTALS (BY BASE BY WORK CENTER)					<u>PEC</u>	<u>OFF</u>	<u>ENL</u>	<u>USDH CIV</u>	<u>TOTAL</u>	27596A	1	19	1	21	41896A		2		2																																								
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6	Determine the manpower category percentages for each PEC within each work center. Divide each manpower category requirement within a PEC by that PEC's total work center requirement. Combine the officer and airmen requirements to compute a military percentage instead of a percentage for each. Keep the percentages in terms of decimals rounded to three decimal places.	<p>MANPOWER CATEGORY PERCENTAGES (BY BASE BY WORK CENTER)</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%;"><u>PEC</u></td> <td style="width: 10%;"></td> <td style="width: 10%;"><u>MILITARY</u></td> <td style="width: 10%;"></td> <td style="width: 10%;"></td> <td style="width: 10%;"><u>USDH CIVILIAN</u></td> </tr> <tr> <td style="text-align: center;">27596A</td> <td></td> <td style="text-align: center;"><u>1 + 19</u></td> <td style="text-align: center;">=</td> <td style="text-align: center;">.952</td> <td></td> <td style="text-align: center;"><u>1</u></td> <td style="text-align: center;">=</td> <td style="text-align: center;">048</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td style="text-align: center;">21</td> <td></td> <td></td> <td></td> <td style="text-align: center;">21</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: center;">41896A</td> <td></td> <td style="text-align: center;"><u>2</u></td> <td style="text-align: center;">=</td> <td style="text-align: center;">1.000</td> <td></td> <td></td> <td></td> <td style="text-align: center;">N/A</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td style="text-align: center;">2</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	<u>PEC</u>								<u>MILITARY</u>			<u>USDH CIVILIAN</u>	27596A		<u>1 + 19</u>	=	.952		<u>1</u>	=	048						21				21						41896A		<u>2</u>	=	1.000				N/A						2									
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91212A	<u>4</u>	<u>53</u>			<u>57</u>																																							
	90	1084	32	1	1207																																							
10	Determine the manpower category percentages within a PEC at MAJCOM level. Divide each manpower category requirement total within a PEC by the function's total requirements for that PEC. Keep the officer and airmen categories separate. Keep the percentages in terms of decimals rounded to three decimal places.	<p>MANPOWER CATEGORY PERCENTAGES (BY MAJCOM BY FUNCTION)</p> <table> <thead> <tr> <th>PEC</th> <th>OFF</th> <th>ENL</th> <th>USDH CIV</th> <th>FNDH CIV</th> </tr> </thead> <tbody> <tr> <td>11896A</td> <td></td> <td>$\frac{3}{3} = 1.000$</td> <td></td> <td></td> </tr> <tr> <td>27596A</td> <td>$\frac{82}{1106} = .074$</td> <td>$\frac{993}{1106} = .898$</td> <td>$\frac{30}{1106} = .027$</td> <td>$\frac{1}{1106} = .001$</td> </tr> <tr> <td>31196A</td> <td>$\frac{4}{39} = .103$</td> <td>$\frac{33}{39} = .846$</td> <td>$\frac{2}{39} = .051$</td> <td></td> </tr> <tr> <td>41896A</td> <td></td> <td>$\frac{2}{2} = 1.000$</td> <td></td> <td></td> </tr> <tr> <td>91212A</td> <td>$\frac{4}{57} = .070$</td> <td>$\frac{53}{57} = .930$</td> <td></td> <td></td> </tr> </tbody> </table>	PEC	OFF	ENL	USDH CIV	FNDH CIV	11896A		$\frac{3}{3} = 1.000$			27596A	$\frac{82}{1106} = .074$	$\frac{993}{1106} = .898$	$\frac{30}{1106} = .027$	$\frac{1}{1106} = .001$	31196A	$\frac{4}{39} = .103$	$\frac{33}{39} = .846$	$\frac{2}{39} = .051$		41896A		$\frac{2}{2} = 1.000$			91212A	$\frac{4}{57} = .070$	$\frac{53}{57} = .930$														
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Figure 5.7. Example of Manpower Category Percentages for One PEC.

MANPOWER CATEGORY PERCENTAGES FOR PEC 27596A									
BASE	OFFICERS		AIRMEN		USDH CIVILIANS		FNDH CIVILIANS		TOTAL
	RQMTS	%	RQMTS	%	RQMTS	%	RQMTS	%	
1	5	.077	56	.862	4	.062			65
2	4	.085	42	.894			1	.021	47
3	5	.075	61	.910	1	.015			67
4	5	.078	57	.891	2	.031			64
5	3	.077	35	.897	1	.026			39
6	5	.070	65	.915	1	.014			71
7	4	.078	45	.882	2	.039			51
8	5	.078	58	.906	1	.016			64
9	5	.070	64	.901	2	.208			71
10	4	.082	43	.878	2	.041			49
11	4	.075	45	.849	4	.075			53
12	6	.058	96	.923	2	.019			104
13*									
14	5	.069	65	.903	2	.028			72
15	5	.081	56	.903	1	.016			62
16			4	1.000					4
17	5	.078	58	.906	1	.016			64
18	6	.076	71	.899	2	.025			79
19	2	.054	34	.919	1	.027			37
20	4	.093	38	.884	1	.023			43
*Data not available									
MAJCOM									
FUNCTIONAL	82	.074	993	.898	30	.027	1	.001	1106
TOTALS									

5.4. Using a FEE.

5.4.1. FEEs project manpower requirements for a function. They can be applied at either base or MAJCOM level.

5.4.2. PEC data used to apply a FEE always represents the fourth quarter value for a given fiscal year.

5.4.3. How a FEE is applied depends on the level that the equation is used and whether zero-based or incremental requirements are being determined.

Chapter 6

FUNCTIONAL MODEL

6.1. Functional Model Uses.

6.1.1. The functional model is a mathematical equation that relates the current distribution of man-power to a specific workload. The relationship may not provide accurate manpower requirements since the current distribution of manpower may not be correct.

6.1.2. The functional model is a method used to develop manpower equations, estimate wartime requirements, and analyze potential workload factors.

6.2. Standards Development.

6.2.1. Before model construction, analyze and adjust authorized and assigned data to reflect approved initiatives. An example of constructing a model and incorporating initiatives is shown in **Figure 6.1.**

Figure 6.1. Functional Model Standard Development.

Functional model example:

Step 1. Develop model equation using assigned or authorized man-hours as the dependent variable (Y). The decision to use authorized or assigned is made in consultation with the OPR. Regress this variable against six to twelve months of average workload.

MAF	BASE	AUTH	(Y ₁)	ASGN	(Y ₂)	WLF (X)
151.5	A	5	815.83	6	978.99	740
(1.077)	B	8	1305.32	7	1142.16	980
	C	11	1794.82	11	1794.82	1270
	D	9	1468.49	9	1468.49	1100
	E	14	2284.32	13	2121.15	1560
	F	7	1142.16	6	978.99	890
	G	13	2121.15	13	2121.15	1500
	H	<u>10</u>	<u>1631.66</u>	<u>11</u>	<u>1794.82</u>	1225
		77	12563.75	76	12400.57	

Authorized Man-hours:	Assigned Man-hours:
$Y_1 = -411.6479 + 1.7115X$	$Y_2 = -331.5796 + 1.6247X$
$r^2 = .994$	$r^2 = .954$
$S_{yx} = 40.463$	$S_{yx} = 110.8374$
$V = .026$	$V = .072$

(continued on next page)

Step 2. Equation Selection. Because the difference between authorized and assigned strength represents less than ten percent of the total authorized, $(77 - 76) / 77 = 1.3\%$, and because the OPR did not state a preference, the authorized man-hour equation was selected as the functional model because of the better statistics.

Step 3. Establish Baseline. Use selected equation to determine calculated man-hours. These calculated man-hours will be used as the baseline for the functional model.

BASE	(Y ₁)	WLF(X)	CALCULATED (Y _c)
A	815.83	740	854.86
B	1305.32	980	1265.13
C	1794.82	1270	1761.96
D	1468.49	1100	1471.00
E	2284.32	1560	2258.29
F	1142.16	890	1111.59
G	2121.15	1500	2155.60
H	1631.66	1225	1684.94

Step 4. Determine man-hour adjustment for each initiative. Compute the change between man-hours measured for current operations and the enhanced operations.

BASE	CURR M-HRS	NEW M-HRS	CHANGE
A	250	180	-70
B	300	210	-90
C	275	170	-105
D	410	280	-130
E	360	265	-95
F	380	270	-110
G	290	205	-85
H	335	240	-95
		TOTAL:	-780
		AVERAGE:	-97.50

This information shows an average reduction of 97.5 man-hours per base.

Step 5. Calculate enhanced equation for the functional model. Regress revised total man-hours (reduced for change) against the selected workload factor.

BASE	AUTH M-HRS	CHANGE	REVISED M-HRS	WLF (X)	CALCULATE D
A	854.86	-70	784.86	740	759.42
B	1265.13	-90	1175.13	980	1168.98
C	1761.96	-105	1656.96	1270	1663.87
D	1471.00	-130	1341.00	1100	1373.76
E	2258.29	-95	2163.29	1560	2158.75
F	1111.59	-110	1001.59	890	1015.40
G	2155.60	-85	2070.60	1500	2056.36
H	1684.94	-95	1589.94	1225	1587.07

Enhanced Equation: $Y_c = -503.3893 + 1.7065X$

(continued on next page)

$$\begin{aligned}r^2 &= .999 \\S_{yx} &= 19.270 \\V &= .013\end{aligned}$$

This same procedure can be used when adjusting a single location manpower standard developed using regression analysis and historical data. In this instance, data from the different months would be adjusted rather than the different bases.

6.2.2. The dependent variable (Y) used in the functional model may be either assigned or authorized man-hours. Convert assigned or authorized strength to man-hours by multiplying by the pertinent MAF and overload factor.

6.2.3. Consult with the OPR and decide whether to use authorized or assigned man-hours. When there is a large difference between the two, discuss this disparity with the OPR, and select the proper dependent variable. Correlate the dependent variable with the independent workload variables.

6.2.4. In situations where authorized and assigned man-hours are closely compatible, use the analysis of variation and correlation criteria to select the best dependent variable (Y). When these statistical criteria are used, assigned strengths should not differ from authorized strengths by more than 10 percent when input points are totaled.

6.2.5. Make sure the minimum number of input locations is satisfied when developing the functional model.

6.2.6. Use the selected equation to calculate required man-hours. Make sure a representative period of workload data is used to apply the equation. This sets up the man-hour data base for the first equation. After setting up the data base, subtract the man-hours saved due to initiatives. Regress adjusted man-hours against workload (same x-values) to develop the final man-hour equation.

6.3. Wartime Requirements Modeling.

6.3.1. Periodically, wartime manpower requirements are estimated for each Air Force support activity. MAJCOMs identify and document deployment requirements, in-place requirements, shortfalls, and untasked resources. Deployment requirements are based on force requirements identified in a force sizing exercise (such as Total Force Assessment) Time Phased Force Deployment Document. In-place manpower requirements are based on programmed wartime workload and wartime man-hour availability factors. The requirement data is grouped by specialty, skill, and manpower resource category.

6.3.2. Construct a functional model for wartime based on the above manpower requirements and workload available from each MAJCOM. Follow the same procedures and sequence used for analyzing peacetime requirements.

6.3.3. Use stated wartime manpower requirements as the dependent variable.

6.3.4. Use wartime-related workload values as the independent variable.

6.3.5. Analyze separate models for the two wartime populations.

6.3.5.1. In-place units not deploying to a combat theater.

6.3.5.2. Combat theater units and units deploying to a combat theater under a force sizing scenario.

6.3.6. When using a functional model for wartime requirements pending standards development, furnish this additional information.

6.3.6.1. Specialty and skill requirements.

6.3.6.2. Functional statement of wartime responsibilities. Get responsibilities from the functional guidance included in the United States Air Force War and Mobilization Plan, Volume 1; Base Support Plan, Volumes 1 and 2; and Total Force Assessment guidance.

6.4. Using a Functional Model to Analyze Potential Workload Factors.

6.4.1. During study familiarization, use the functional model to analyze potential WLFs. The size of the standard error and the number of extreme deviations from the line often show the degree of reliability. Other means of evaluation such as activity analysis charts, discussions with the functional OPR, and logical analysis help refine the list of potential workload factors.

6.4.2. The following steps identify the procedures which should be followed when using a functional model to analyze potential workload factors:

6.4.2.1. Step 1. Pick the work center or functional area to be analyzed.

6.4.2.2. Step 2. Pick candidate workload and program variables that logically relate to manpower authorizations in the UMD and for data available from programming documents or formal reports.

6.4.2.3. Step 3. Get the manpower data from the UMD for each location and time period under consideration. Use the volume of the selected variables for the same time periods.

6.4.2.4. Step 4. Analyze data.

6.4.2.4.1. Check manpower and workload data with the functional OPR and revise any data that both parties agree is incorrect.

6.4.2.4.2. Plot the data pairs on a scattergram and analyze the relative position of each plot with respect to a trend or pattern of the overall display. Prepare the plot manually or by computer.

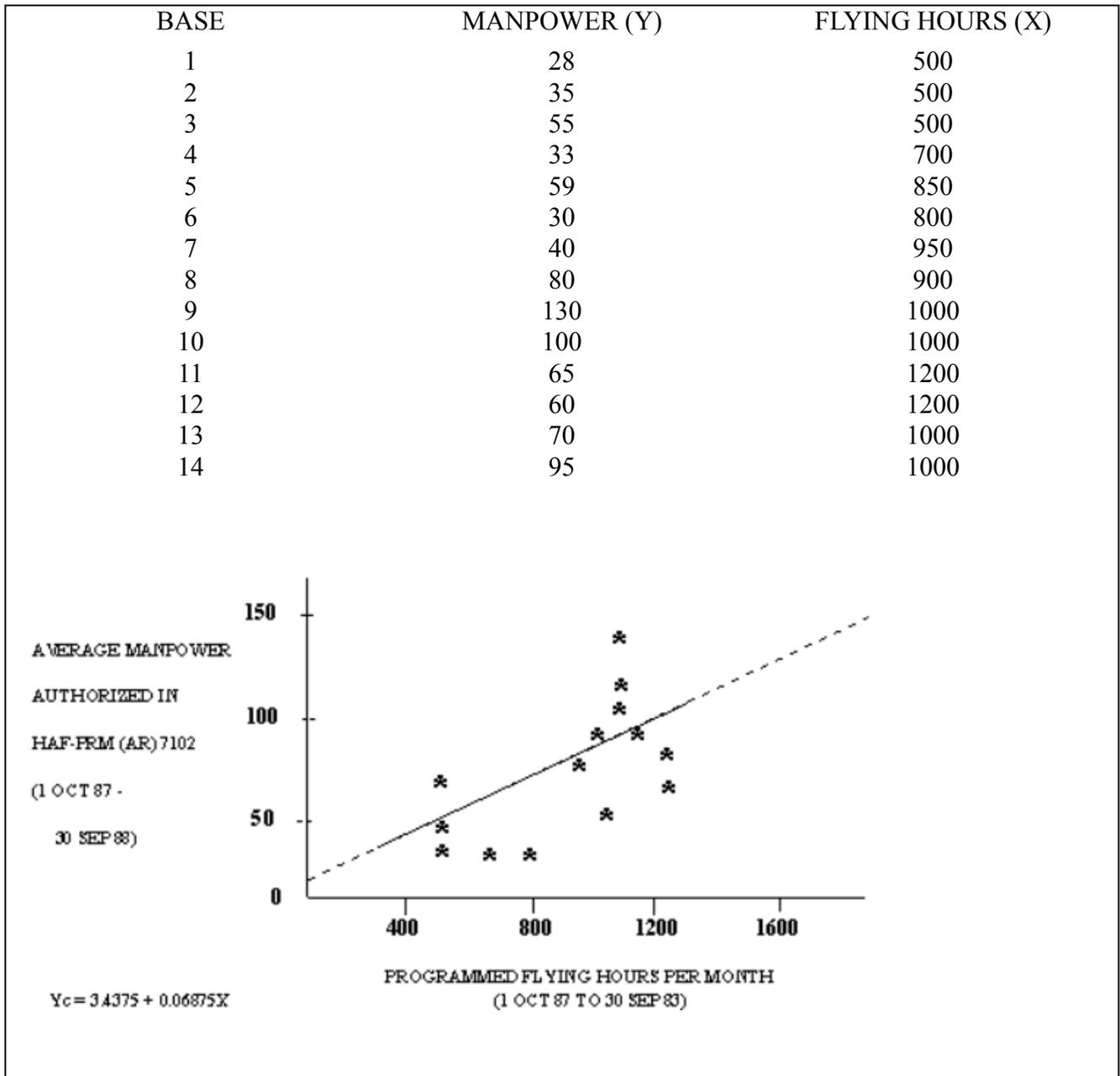
6.4.2.4.3. Do regression analysis to find the relationship between manpower authorizations and the candidate workload variables. Regression analysis procedures and interpretation of the results are in [Chapter 2](#).

6.4.2.4.4. Investigate any extreme deviation in the data points. The purpose of this investigation is to find whether a high standard error (deviation) is due to management design or well-documented reasons. If so, include those reasons as part of the functional model backup data. Typical reasons are: mixed data from different organizational levels, incorrectly defined FACs, and organizational structure codes, geographic population differences, use of contract services at some locations, differences in management philosophy and personnel utilization, organizational structure differences, and lack of a quantitative relationship between manpower and the tested workload variables. The investigation should give some clues to the expected benefit of alternative study approaches. A full study of the functions at selected locations may be needed to identify the reasons for large deviations. Separate standards may be needed to show multiple populations that are shown by the scattergram.

6.4.2.5. Step 5. Repeat steps 2 through 4 to evaluate alternative workload variables. Additional models using assigned strength or wartime manpower distributions instead of authorizations may give more insight into manpower requirements, variations by location or condition, and potential WLFs. For example, analysis of assigned strength and the historical workload relate to a productivity index and show the work done by expended manpower. Given consistent workload and efficient operations, expended resources should relate to future requirements. Models are also valuable for analyzing the potential differences that may need different populations for standard coverage.

6.5. Example of a Functional Model. **Figure 6.2.** is an example of a functional model. Note that the equation and all data points are plotted for ease of analysis. The functional model shown doesn't show a good relationship between manpower and the tested workload variable. Although this relationship doesn't require discarding the potential WLF, it does show the absence of a strong relationship.

Figure 6.2. Functional Model Example of Manpower and Flying Hours.



Chapter 7

MINIMUM MANPOWER, STANDBY DETERMINATION, AND MAN-HOUR SHIFT PROFILE ANALYSIS

Section 7A—Minimum Manpower

7.1. General Concepts.

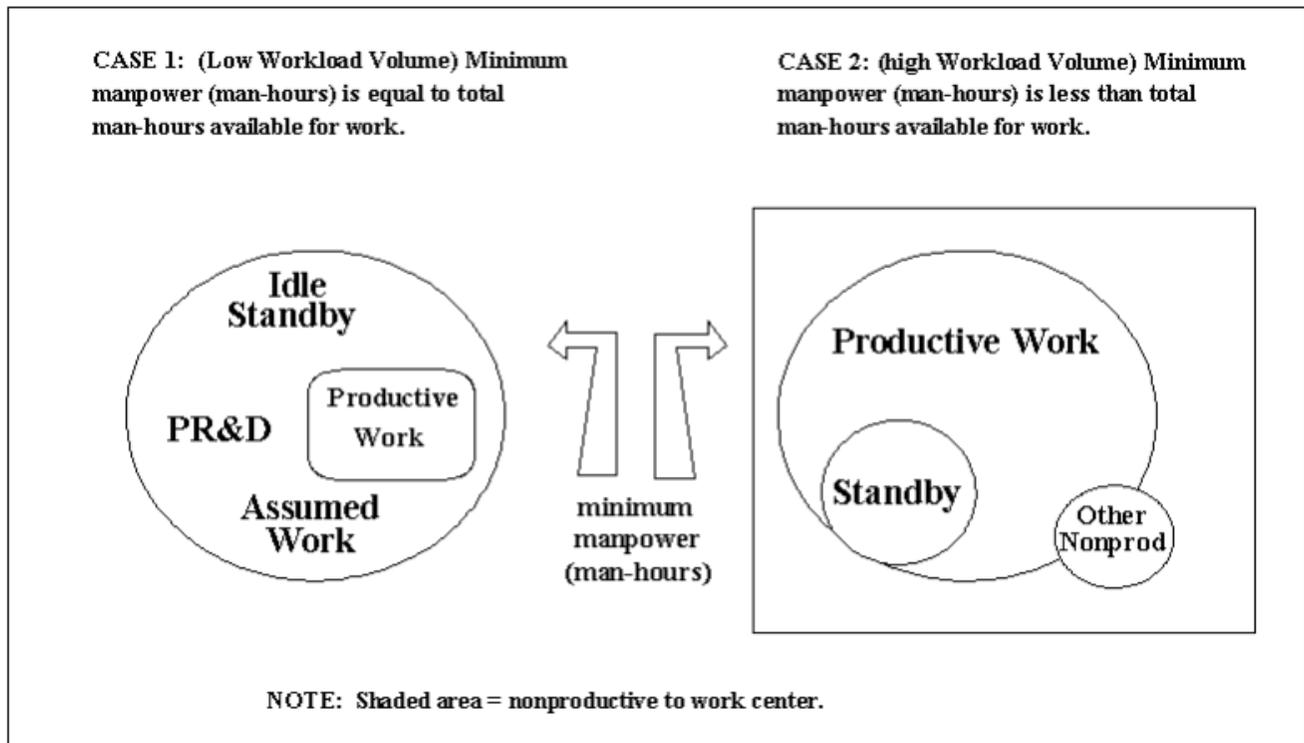
7.1.1. Importance of Minimum Manpower and Standby. Management decisions often produce minimum manpower levels that drive standby time. Since all standby time included in a manpower standard is nonproductive and costly, it must be justified. Mission-essential standby time is allowed in manpower studies; however, to merely show the computations used to derive standby time is not enough. Validate management decisions leading to minimum manpower requirements and associated standby time.

7.1.2. Standby Levels.

7.1.2.1. Standby, delay, and on-call time are defined in [Attachment 1, Terms](#). Standby time can occur at any workload volume, and minimum manpower requirements may change from location to location.

7.1.2.2. [Figure 7.1](#) is a Venn Diagram that depicts minimum manpower requirements at low (case 1) and high (case 2) workload volumes. In both cases, the minimum manpower requirements are considered constant and are represented by circles of the same size. In case 1, the minimum manpower requirement is equal to the total man-hours available to do work, that is, the universe is equal to man-hours required by minimum manpower requirements. Standby is the difference between man-hours required by minimum manpower and man-hours required by productive work.

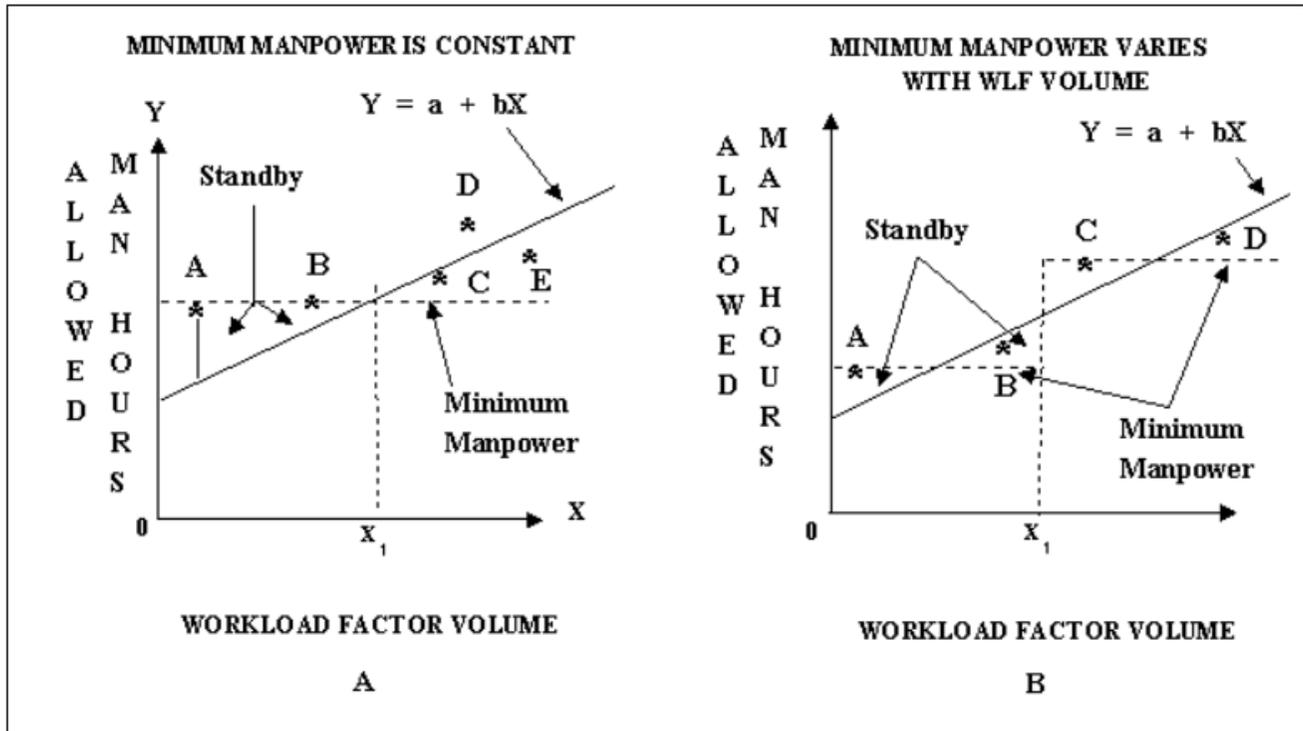
Figure 7.1. Depiction of Input Measurement Data.



7.1.2.3. In case 2, [Figure 7.1.](#), the minimum manpower requirement is less than total man-hours available for productive work. That is, the universe is equal to total hours available to do productive work. Derivation of standby in this case is more difficult.

7.1.2.4. [Figure 7.2.](#) shows another situation similar to [Figure 7.1.](#). In situation I, bases A and B whose workload volume is less than X_i , represent a case 1 situation. Bases C, D, and E whose workload volume is greater than X_i , represent case 2. For case 1 (bases A and B), derive standby time as shown in the previous paragraph. At bases C, D, and E, however, this procedure cannot be applied. In situation II, bases A and C represent a case 1 situation.

Figure 7.2. Minimum Manpower Relationships.



7.1.2.5. Minimum manpower requirements may be constant for each shift (**Figure 7.1. and Figure 7.2., A**, show this condition), or they may vary with workload volume. **Figure 7.2., B**, shows minimum manpower at two levels: one for workload volumes less than X_i , and one for workload volumes greater than X_i . This situation is possible, for example, in an aircraft loading operation where a second load crew is needed to meet specified turnaround or ground time. Note in **Figure 7.2., B**, that bases A and C on the chart show varying amounts of standby time. The standby time is derived and computed as part of the allowed man-hours. It is not dependent on the regression line.

7.1.2.6. When the regression equation excludes standby time, a particular location may not have enough man-hours to cover the directed standby requirement. This location would receive credit for either the computed man-hours or measured man-hours (work center man-hours plus standby), whichever is greater. This standby time is referred to as derived standby. Document the minimum manpower condition in the application instructions in the manpower standard.

7.1.3. Observations Regarding Standby Time.

7.1.3.1. Minimum manpower requirements may be the same at all locations or may change with workload volume.

7.1.3.2. Identify minimum manpower requirements by MEP work measurement methods if levels of service are properly defined before measurement.

7.1.3.3. Allow only standby necessary for mission accomplishment.

7.1.3.4. Reduce standby time by transferring productive work to replace measured standby man-hours.

7.1.3.5. Classify standby work inherent in one's assigned duty (for example, a craftsman continuously observing instruments) as productive work.

7.2. Rationale for Minimum Manpower.

7.2.1. Contributing Factors. Numerous factors contribute to establishing minimum manpower requirements. Some of these factors, often a result of management decisions, are:

7.2.1.1. Mission needs.

7.2.1.2. Performance standards.

7.2.1.3. Machine design.

7.2.1.4. Facility limitations.

7.2.1.5. Hours of operation.

7.2.1.6. Shift size and necessity.

7.2.1.7. Crew size.

7.2.1.8. Post-manpower requirements.

7.2.1.9. Safety.

7.2.1.10. Security.

7.2.2. Evaluating Minimum Manpower Requirements. Carefully check the need for minimum manpower. Question the basic need. Offer alternatives and clearly define the cost of such service. Study documentation must contain rationale to justify minimum manpower requirements. After the functional OPR confirms minimum manpower requirements, quantifying standby time is generally straightforward. Reduce or minimize standby time through improved shift scheduling, reorganization, planning, and workload control techniques. MEP personnel must be ready to show the manager how to meet the needed performance standards with minimum standby time. When standby time is minimized, the total manpower requirement is also minimized.

7.2.3. Minimum Manpower Computations.

7.2.3.1. In those situations that meet the criteria, you can use the minimum manpower factor (MMF) method to develop a standard. This method uses predetermined manpower factors to compute manpower requirements for an OPR-approved position. Compute the factor by dividing the man-hours for position coverage by the pertinent man-hour availability factor (MAF) times the overload factor (for military). Adjust the MAF to allow for additional man-hours associated with position coverage. These additional man-hours fall into two categories.

7.2.3.1.1. The first category consists of man-hours needed for processes that must be done either before or after the position coverage starts. In the case of security police guard posts, for example, the security police officer must get a weapon and ammunition from the armory and attend guard mount before assuming the post. Likewise, at the end of the shift, the officer must turn in the weapon and ammunition to the armory. The time associated with this work is in addition to the time needed for post duty and should be measured as such.

7.2.3.1.2. The second category of additional man-hours consists of recurring training time needed to keep an individual qualified to fill the position. This is training that cannot be received while the individual is actually on position duty. An example of this type of training is proficiency or refresher training needed by all security police officers such as weapons training. Before developing a special allowance, make sure such training has not already been credited in the MAF.

7.2.3.1.3. When additional allowances are given for these two types of position-related man-hours, derive the man-hours used in computing the allowances from work measurement.

7.2.3.2. To compute required manpower, divide the position coverage in man-hours by the MAF times the overload factor. For example, a position requiring coverage 7 days a week (including holidays), 24 hours a day, by one individual generates a requirement for 730.464 monthly man-hours. If the work force is military, on a 40-hour workweek, the manpower requirement is 4.476 (730.464/(151.5 x 1.077)). However, if the work force is military on a 6-day, 60-hour workweek, the manpower factor is 2.971 (730.464/(245.9 x 1.012)). These numbers, 4.476 and 2.971, are minimum manpower factors. Standby time is normally an inherent part of positions based on minimum manpower factor application, such as security police assigned to a base access gate and firefighters.

7.2.3.3. Use this equation to compute minimum manpower factors. Use continuous calculations, i.e., don't round until all calculations are done.

$$\text{MMF} = \frac{(\text{Days/Wk})(\text{Hrs/Day})(4.348 \text{ Wks/Mo}^*)(\text{DRF}^{**}) (\text{Crew Size})}{\text{Man-hour Available Factor} \times \text{Overload Factor}}$$

*Use the pertinent weekly conversion factor based on the number of days per week and whether or not federal holidays are worked. (See [Table 9.2.](#))

**The directed requirement factor (DRF) is a constant man-hour requirement directed by higher headquarters policy in addition to duties for a minimum manpower situation. The DRF is equal to 1.000 unless the work is not part of the duties for a minimum manpower situation. For example, if each person must receive 2.50 hours per month of proficiency or refresher training, and training cannot be received while the person is on the job, then compute the DRF as follows:

$$\text{DRF} = 1 + [(T/(\text{MAF}-T))]$$

where T = required training hours

If T = 2.5 and MAF = 151.5, then

$$\text{DRF} = 1 + [2.5/(151.5 - 2.5)] = 1.017$$

When the DRF and crew size are both equal to 1, the minimum manpower factor values are the same as the post manning factor values identified in AFI 38-201.

7.2.3.4. Furnish the minimum manpower factor computations per paragraph [7.2.3.3.](#) as backup.

7.2.3.5. Certain functions such as security police need adjustments to these procedures. In this case, compute a minimum manpower requirement for each position; sum the minimum manpower requirements; and, round up to whole manpower requirements. For example, a small Air Force base in Texas has three gates. Main gate duties are assumed by two security police officers, 24 hours a day, 7 days a week. East gate duties are assumed by one security police officer, 8 hours a

day, 5 days a week. West gate duties are assumed by one security police officer, 4 hours a day (all in one shift), 5 days a week. The east and west gates are closed for holidays (10 days a year). The security police work center that has the mission of providing manpower for these gates is on a 40-hour workweek. Position-coverage associated work requires 0.669 hours per shift as determined by work measurement (see para 7.2.3.1.1. for explanation) and recurring training that cannot be done while at the positions requires 5.40 hours per month per person. The total manpower requirement for these three gates is as follows:

7.2.3.5.1. Calculate the DRF for training.

$$\text{DRF} = 1 + [T/(\text{MAF} - T)] = 1 + [5.40/(\text{MAF} - 5.40)]$$

Since the MAF for a military 40-hour workweek is 151.5,

$$\text{DRF} = 1 + [5.40/(151.5 - 5.40)] = 1.037.$$

Apply this factor to the total man-hours required to fill the post, that is, to both the basic position coverage and the position-coverage associated work. Since the main gate has three shifts, the total daily man-hours for position-coverage associated work is $3(0.669) = 2.007$. Adding this result to the 24 man-hours of position coverage per day equals 26.007. This result (26.007) is the entry for the "hours/day" item in the MMF formula for the main gate.

$$\text{MMF} = \frac{(\text{Days/Wk})(\text{Hrs/Day})(4.348 \text{ Wks/Mo})(\text{DRF})(\text{Crew Size})}{\text{Man-hour Available Factor} \times \text{Overload Factor}}$$

$$\text{MMF} = \frac{(7)(26.007)(4.348)(1.037)(2)}{151.5 \times 1.077} = 10.061$$

7.2.3.5.2. East gate duties are assumed by one security police officer, 8 hours a day, 5 days a week. This position coverage only needs one shift so the total entry for the "hours/day" item in the minimum manpower factor formula is $8 + 0.669 = 8.669$. But there is another problem. This position is not filled during holidays (10 days a year), and the conversion factor (4.348 weeks/month) will add unneeded man-hours to the position coverage because it includes holidays. Derive this conversion factor as follows:

$$365.25 \text{ days/Yr} - \text{weekend days not worked} - \text{federal holidays not worked} = \text{duty days/year}$$

$$\text{duty days/year} / 12 \text{ months} = \text{duty days/month}$$

duty days/month / normal duty days/week = weekly conversion factor

Since position coverage does not include holidays, do not add a false cost. Therefore, replace this conversion factor with a new one that does not include the 10 holidays as follows:

365.25 days/year - 104.36 (weekend days not worked) - 10 (federal holidays) = 250.89 duty days/year

250.89 / 12 = 20.9075

20.9075 / 5 (normal duty days/week) = 4.182 weeks/Mo

Now the minimum manpower factor formula for the east gate is:

$$\text{MMF} = \frac{(\text{Days/Wk})(\text{Hrs/Day})(4.182 \text{ Wks/Mo})(\text{DRF})(\text{Crew Size})}{\text{Man-hour Available Factor} \times \text{Overload Factor}}$$

$$\text{MMF} = \frac{(5)(8.669)(4.182)(1.037)(1)}{151.5 \times 1.077} = 1.152$$

7.2.3.5.3. West gate duties are assumed by one security police officer, 4 hours a day, 5 days per week. The gate is closed on holidays. Although 4 hours is not a complete shift, 0.669 hours are still associated with the shift because the same work would apply to a partial shift as to a whole shift. The entry for the hours per day item in the minimum manpower factor formula is 4.669, and the MMF is calculated as follows:

$$\text{MMF} = \frac{(\text{Days/Wk})(\text{Hrs/Day})(4.182 \text{ Wks/Mo})(\text{DRF})(\text{Crew Size})}{\text{Man-hour Available Factor} \times \text{Overload Factor}}$$

$$\text{MMF} = \frac{(5)(4.669)(4.182)(1.037)(1)}{151.5 \times 1.077} = 0.620$$

7.2.3.5.4. To find total manpower requirement for assuming the duties for the three gates, add the three MMFs: $10.061 + 1.152 + 0.620 = 11.833$. Round 11.833 up to 12 manpower requirements.

7.2.3.6. When determining minimum manpower factors for multiple posts of the same make-up in hours of operation, crew size, DRF, etc., compute the minimum manpower equation for a single post and multiply the result by the number of posts authorized for the function under study.

7.2.3.7. Document minimum manpower as follows:

7.2.3.7.1. When the minimum manpower computation is not the sole measurement method for the work center, compute the man-hours by multiplying the rounded minimum manpower requirement by the pertinent MAF multiplied by the overload factor.

7.2.3.7.2. When the minimum manpower computation is the sole measurement method for the work center, furnish only the minimum manpower factor computation. There is no need to convert the rounded minimum manpower into man-hours.

(NOTE: A chart documenting minimum manpower for various work weeks and MAFs is located at the AFMIA home page, <https://www.afmia.randolph.af.mil>. Go to MO Library>Manpower Standards>Tech Guidance & Forms>Spreadsheets> Minimum Manpower Example.)

Section 7B—Standby Determination with Man-Hour Collection Method

7.3. Study Design.

7.3.1. A well-designed study accurately shows minimum manpower requirements and true standby time. The measurement plan tells how to measure minimum manpower requirements and how to identify standby time. Necessary standby man-hours cannot be identified during standards development, when it is grouped in with other nonproductive categories of time and when the minimum manpower requirements have not been accurately documented.

7.3.2. Clearly define the method for measuring standby when the possibility of standby time exists. Use MEP standard data collection and work measurement procedures to identify standby; however, some innovation is needed with these methods. Do not simply state queuing or shift profile analysis will be used to quantify standby time; tell how inputs use these techniques. Standby time is discussed in conjunction with various data collection and analysis procedures in the paragraphs that follow.

7.3.3. Include standby time computed according to procedures of this section as input to regression analysis when developing the standard man-hour equation. Build a variance for applicable locations if standby time does not exist at all locations.

7.4. Data Collection and Analysis Procedures. Use a man-hour shift profile chart to aid in analyzing standby time when work sampling or queuing is used and standby time exists (see **Section 7C**).

7.4.1. Queuing Analysis. Queuing data does not directly identify allowed standby time. The percentage of server time in productive direct work may be determined with the queuing utilization factor after an acceptable level of service has been determined (for example, the number of taxi drivers needed to give a 4 minute response time). Queuing also shows when servers are not busy, including

standby time. Design the study to collect queuing data on standby time if queuing is used. Details describing queuing techniques are in [Chapter 16](#).

7.4.2. Work Sampling.

7.4.2.1. Identify standby time during Work Sampling observation rounds when minimum manpower requirements are previously defined. For example, suppose a finance office requires that customers with pay inquiries be waited on within 30 minutes of customer arrival. It has been predetermined that two finance clerks are necessary to give this level of service at the finance counter between 0900 and 1500.

7.4.2.2. Make provisions to isolate and identify the required standby time when the work sampler knows this information before the study begins. On each observation round, the work sampler records each worker in the respective process. The observer may enter a maximum of two standby tallies during each observation round but this would occur only if both service clerks were awaiting customers.

7.4.2.3. Use standby time derived in this manner to show management the manpower cost of providing this level of service. Analysis of WS observation sheets and waiting time data (for example, the time finance customers actually wait for service) may reveal that the specified level of service has been exceeded or that the second server is needed only during peak periods, such as pay days.

7.4.2.4. Standby time collected in this manner represents adjusted or derived standby time required to support a predetermined level of service. Record it on an AF Form 308, **Standard Input Data Computation**, per [Table 7.1](#). However, if the level of service is not clearly defined, it is impossible to identify whether the worker should be sampled as idle or standby. Build a man-hour shift profile chart to find required standby when this is the case.

Table 7.1. How to Prepare AF Form 308, Standard Input Data Computation.

B O X	Enter
1	Appropriate title.
2	Major command and the measurement location.
3	Date the form is prepared.
4A	Productive processes in the order listed in POD, TOTAL DIRECT, TOTAL INDIRECT, and PRODUCTIVE TOTAL headings are also entered (see note 1).
4B	Process adjusted man-hours and the total from the AF Form 1111, Work Sampling Record.
4C	Monthly allowed man-hours, by process, from the AF Form 313, Time Study Record.
4D	Monthly allowed man-hours, by process, from the AF Form 1040, Operational Audit Data, for activities that were measured by operational audit techniques.
4E	Monthly allowed man-hours, by process, from either AF Form 1040 or other supporting man-hour documentation for activities that were measured (determined) by minimum manpower, queuing, position manpower, or other specialized methods. Identify the types of measurements conducted in REMARKS (see note 2).
4F	Sum of entries in boxes 4B, 4C, 4D, and 4E by process to establish monthly allowed man-hours for the work center.
5	Total man-hours in boxes 4B, 4C, 4D, 4E, and 4F.
6	Man-hour Availability Factor (MAF). Use the military MAF times the overload factor for mixed work centers.
7	Results of box 5F divided by box 6.
8	Explanation of the method used in box 4E or any other pertinent data. Attach supporting documents and rationale as necessary.
NOTES:	
<ol style="list-style-type: none"> 1. If standby time was sampled, enter "Standby Time" below the PRODUCTIVE TOTAL heading and explain in REMARKS, Block 8. Enter measured man-hours under the appropriate measurement method (Block 4B, 4C, or 4D) that was used to determine the time. If it was derived through other measurement methods, then enter time under "Other", Block 4E. 2. Reference specialized man-hour computations in REMARKS, Block 8, and attach supporting data. 3. An example of a completed AF Form 308 is located on the AFMIA home page, https://www.afmia.randolph.af.mil. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples. 	

7.4.2.5. Show the standby time derived through this procedure on the AF Form 1111, **Work Sampling Record**. Do not level or apply allowances to this time. Use standby time to reduce personal and rest allowances for other productive process man-hours.

7.4.3. Operational Audit (OA).

7.4.3.1. Include enough rationale in the final report to support the minimum manpower requirement when using OA as the primary work measurement method. It is not necessary to measure standby time if the minimum manpower requirement represents the total man-hour universe as in case 1, **Figure 7.1.**

7.4.3.2. Minimize and fully explain all standby allowed in the study when the total man-hour universe is greater than the minimum manpower requirement (case 2, **Figure 7.1.**). Developing a man-hour shift profile chart from OA measurement may be difficult because process times are not associated with each hour of the duty day. Therefore, consider using short-cycle WS to collect man-hours for a man-hour shift profile chart. Use the WS as back-up for the OA man-hours. **Section 7C** describes procedures for the man-hour shift profile chart.

Section 7C—Man-Hour Shift Profile Analysis

7.5. Introduction to the Man-Hour Shift Profile Chart. Man-hour shift profile charts are an effective way to identify and minimize standby time. They aid the analyst in defining the minimum essential manpower levels by:

- 7.5.1. Leveling workloads to economize on nonproductive standby periods.
- 7.5.2. Identifying minimum standby time based on the accepted level of service.

7.6. Use of the Man-Hour Shift Profile Chart.

7.6.1. The man-hour shift profile chart helps functional managers realize economies of operation and helps MEP personnel build accurate manpower standards. Use this process as a data analysis technique during management consultant studies or with other data collection methods during a manpower standards study.

7.6.2. The man-hour shift profile is used by manpower management personnel to justify standby requirements. Input teams use the chart to find the proper amounts of standby time to include in measurement reports when:

- 7.6.2.1. Queuing analysis is the primary standard development technique, or
- 7.6.2.2. WS is the primary work measurement method and standby time cannot be distinguished from other nonproductive categories during the sampling period.

7.7. How to Develop the Present Man-Hour Shift Profile Chart.

7.7.1. Only construct the profile chart from data obtained during work measurement if certain provisions are taken during data collection. That is, collect data so it can be summarized by process on a stratified time basis (normally, hour-by-hour).

7.7.2. Identify work in the POD as transferable and nontransferable when a man-hour shift profile chart is needed. This helps in making the shift profile chart that shows productive work for the stratified time increments.

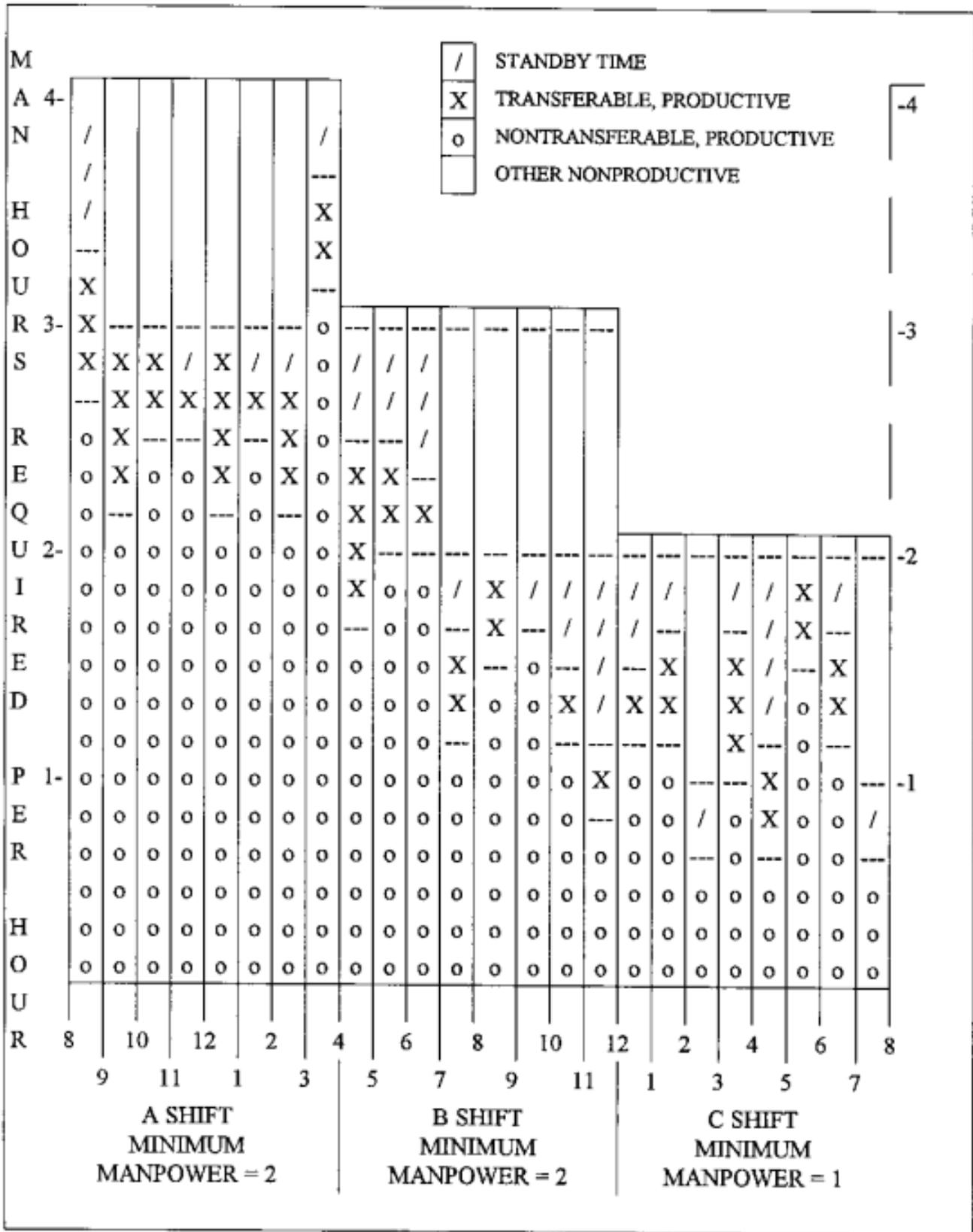
7.7.3. The basic steps in developing man-hour shift profile charts are collecting necessary data, doing end-of-study computations, and constructing the chart. Derive the average man-hours for each hour of the day that are used in the profile chart from queuing analysis or from WS data. When using the shift profile chart to minimize standby time, make sure the sample size is large enough to support recom-

mendations based on the profile chart. The procedures for developing a shift profile chart using WS data follow:

7.7.3.1. Accumulate the transferable and nontransferable time on a daily basis for each hour or half-hour of each shift. Average this time for the study period. Extract this time from the AF Form 1157, **Work Sampling Recapitulation**. On some occasions, a separate WS study may be needed to develop the profile chart. When this is so, take enough samples to reach desired accuracy and collect only the productive time. Classify the productive work into transferable or nontransferable work. Consult work center personnel to make this classification if the POD has not been marked.

7.7.3.2. Construct the present man-hour shift profile chart on graph paper (see [Figure 7.3.](#)) as follows:

Figure 7.3. Man-Hour Shift Profile, Present.

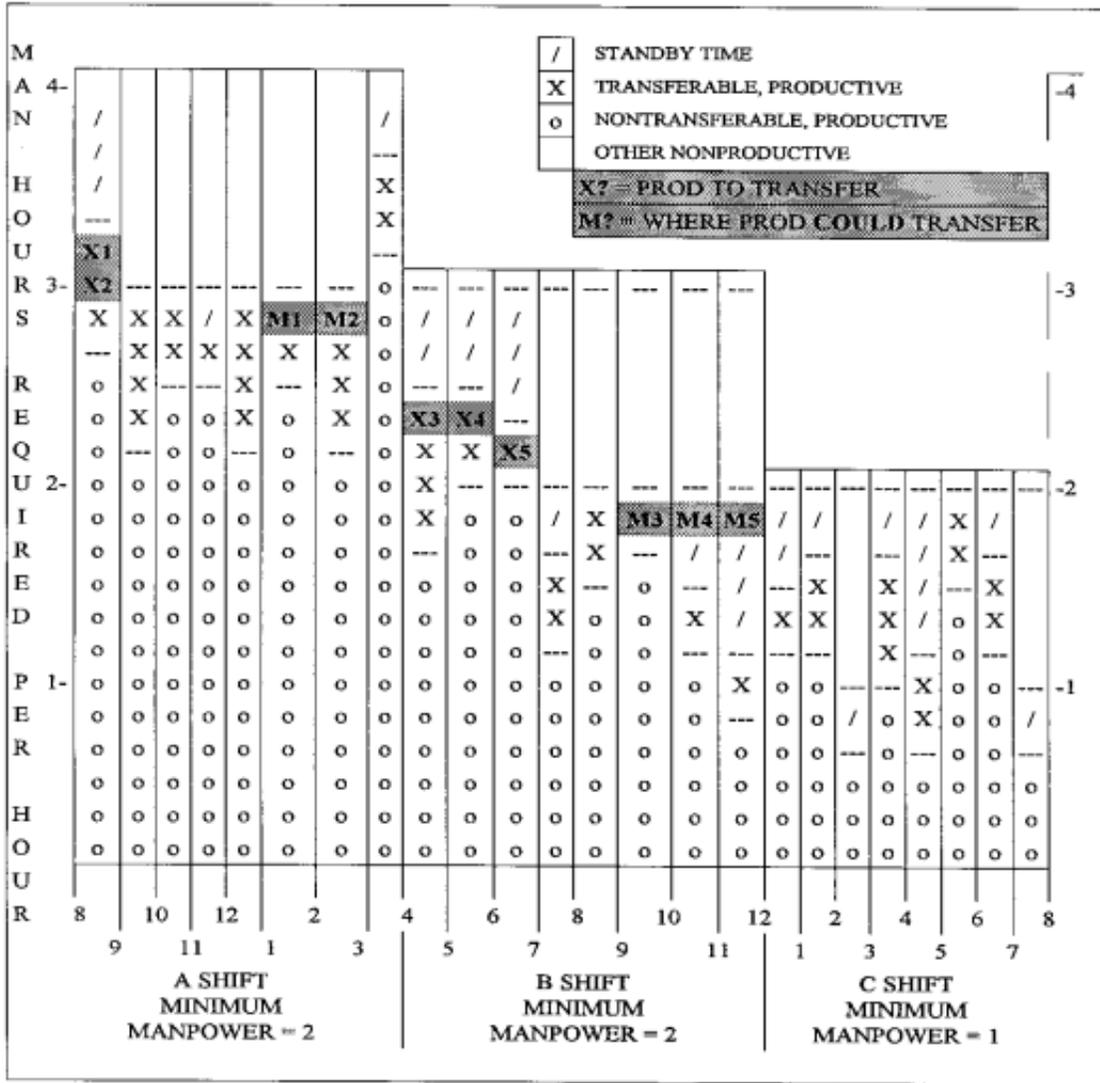


- 7.7.3.2.1. Identify average man-hours per hour on the vertical axis.
- 7.7.3.2.2. Identify each stratified period for each shift (hour or half hour) on the horizontal axis.
- 7.7.3.2.3. Extend a vertical line downward from the duty hour corresponding to each shift change, and state the minimum manpower requirement for that shift.
- 7.7.3.2.4. Plot, from bottom to top, the average nontransferable and transferable man-hours computed for each stratified period.
- 7.7.3.2.5. Identify the nontransferable and transferable time within each stratified period. Colored pencils are helpful in this identification when the charts do not have to be reproduced.
- 7.7.3.2.6. Group the various periods that make up each existing shift. Find the largest requirement within each shift and extend a dark horizontal line over the entire shift.
- 7.7.3.2.7. Extend vertical lines from each stratified period up to the next whole hour above the plots for transferable time. When there is only nontransferable time within the strata, extend the vertical line from that plot to the next whole hour. The extended portion of the column is potential standby time. In most cases, the total man-hours per shift period include both potential standby time and other nonproductive time.
- 7.7.3.2.8. Prepare a legend for the chart that identifies nontransferable, transferable, standby time, and other nonproductive time.

7.8. How to Analyze the Man-Hour Shift Profile Chart.

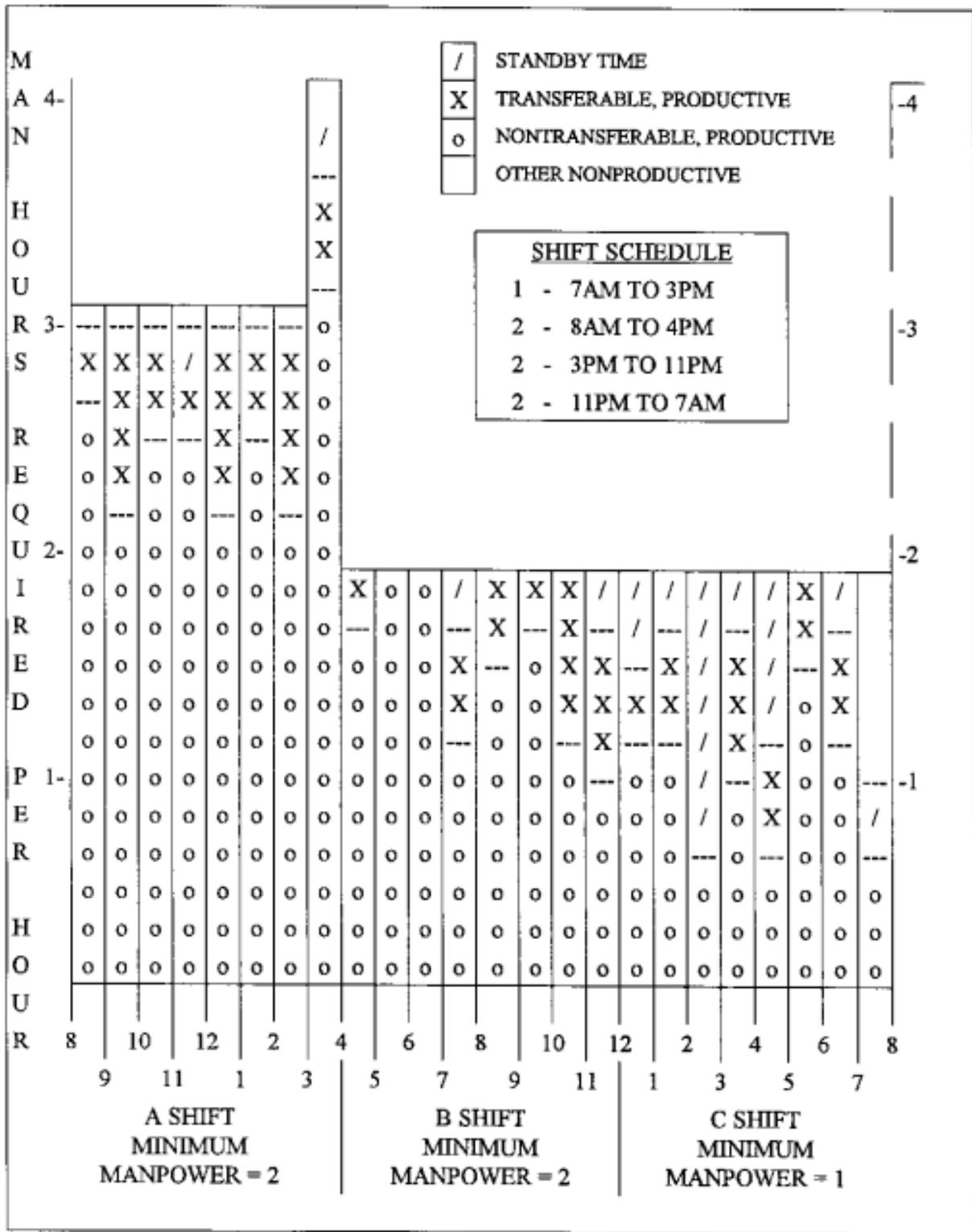
- 7.8.1. Shift profile analysis can point out deficiencies in scheduling practices, or it can point out excessive minimum manpower levels. Further study of the actual shift profile chart may lead to additional benefits such as more efficient choices for shift hours.
- 7.8.2. Input teams analyze the actual shift profile chart to find the proper adjustments to make to standby time before constructing the proposed shift profile chart. An analysis of the chart may show the need for overlapping or split shifts. Although split shifts are sometimes necessary, they should be kept to a minimum. During analysis, remember:
 - 7.8.2.1. An evenly spread workload often reduces manpower needs.
 - 7.8.2.2. A related work center with standby man-hours may be able to accept some transferable work. This can take place only if the work can be done by the individuals receiving the work.
 - 7.8.2.3. Adjustments to existing standby time should be coordinated with local OPRs. Adjustments must not add man-hours to exceed the stated level of service.
- 7.8.3. Study teams analyze the charts sent by measurement teams. A large amount of standby time at one location may mean a variance is needed at that location. On the other hand, it may mean the input team did not properly adjust the standby time. The study team must not adjust standby time without coordinating with the input team. This prevents dual adjustments of the same time. The study team does not average or prorate standby time during data analysis.
- 7.8.4. **Figure 7.4.** shows a properly constructed man-hour shift profile chart that identifies recommended time movements.

Figure 7.4. Man-Hour Shift Profile, Time Movements.



7.9. How to Develop the Proposed Man-Hour Shift Profile Chart. Construct a proposed shift profile chart when an improvement can be made to the actual shift profile. Construct this chart the same way as the present profile chart, but do it in conjunction with the analysis step. The proposed chart often uncovers faults with analysis of the present profile chart. These steps tell how to develop a proposed profile chart (see [Figure 7.5.](#)).

Figure 7.5. Man-Hour Shift Profile, Proposed.



7.9.1. Step 1. For purposes of this example, assume that the pre-stated minimum manpower required for the A and B shift is two and the minimum manpower required for the C shift is one. The proposed

chart must accommodate this minimum manpower requirement.

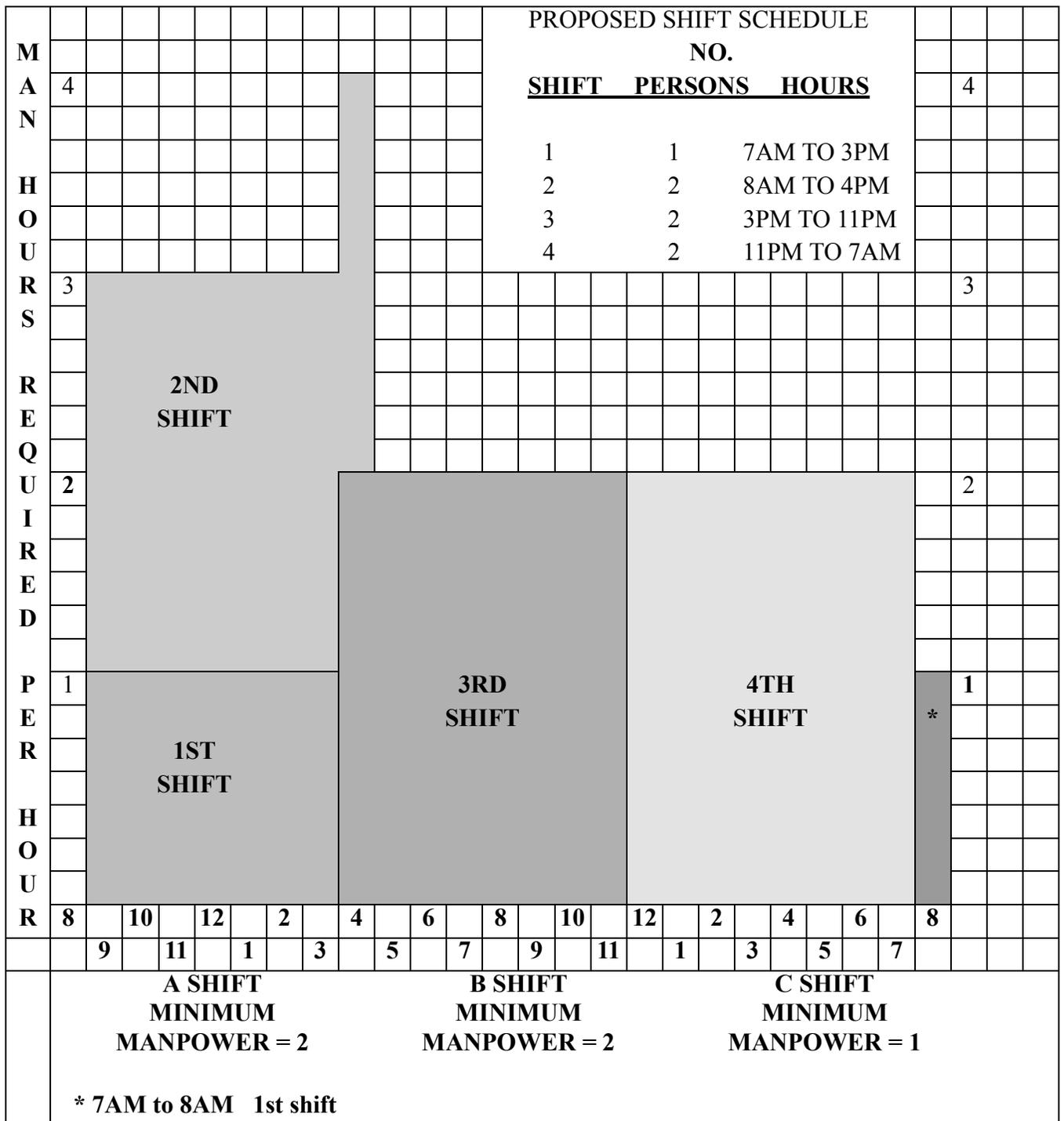
7.9.2. Step 2. Examine the present man-hour shift profile. In **Figure 7.3.**, examination shows large standby and nonproductive time within shifts A and B. This is a logical place to look for improvements.

7.9.3. Step 3. Experiment with different arrangements by moving transferable man-hours into periods with large amounts of standby. Move the transferable time to nearby hours within the same shift if possible. The objective is to reduce the nonproductive time that results when each column on the chart is extended up to the total man-hours required per shift line.

7.9.4. Step 4. Experiment with different shift hours or with overlapping shifts to reduce nonproductive time. Consider this possibility when a large man-hour required per shift column exists near a proposed shift change period. **Figure 7.5.**, Man-Hour Shift Profile, Proposed, shows where transferable man-hours were moved within the same shift. **Figure 7.6.**, Proposed Shift Schedule, shows how overlapping shifts were used to reduce man-hours required per shift.

7.9.5. Step 5. Compute the derived standby time from the proposed chart.

Figure 7.6. Proposed Shift Schedule.



7.10. Comparison of the Present and Proposed Charts.

7.10.1. Compare the proposed chart with the present chart to determine:

7.10.1.1. If the proposed chart fully accounts for all transferable and nontransferable time.

7.10.1.2. If minimum manpower requirements have been satisfied for all shifts.

7.10.1.3. The extent of shift man-hour savings on the proposed chart.

7.10.2. A comparison of man-hour savings for the present and proposed charts (**Figure 7.3.** and **Figure 7.5.**) is summarized in **Table 7.2.** This comparison shows a man-hour savings of 16 hours per day or 487.04 man-hours per month ($16 \times 30.44 = 487.04$).

Table 7.2. Shift Comparison.

SHIFT	PRESENT		PROPOSED		SHIFT
	ACTUAL PERSONNEL	SHIFT HOURS	PROPOSED PERSONNEL	SHIFT HOURS	HOURLY DIFFERENCE
A	4	32	2	16	- 16
B	3	24	2	16	- 8
C	2	16	2	16	0
D	-	-	1	8	+ 8
TOTALS	9	72	7	56	- 16

7.10.3. Input teams use the proposed man-hour shift profile chart to:

7.10.3.1. Support the standby time included in the measurement input.

7.10.3.2. Justify the derived (reduced) standby time to the local OPR.

7.11. Wartime Operation Measurement. Functions having definite wartime capability requirements supported by Air Force policy are prime candidates for minimum manpower factor manning. Examples of these functions include aircraft security, perimeter defense, and tactical air control system operations. Fully explain the use and justification of minimum manpower factor manning. Quantify standby man-hours and use them to accomplish associated work of another work center or processes of work driven by other than minimum manpower factor manning requirements. Consider using standby time between work centers when minimum manpower factor manning is used.

Section 7D—Deriving Standby Using Minimum Manpower and Measured Man-Hours

7.12. General Concepts. Use an AF Form 308 to account for man-hour data obtained from work sampling, operational audit, time study, and other specialized measurement methods. Use the form to add sampled standby time with measured data.

7.12.1. Follow the full instructions in **Table 7.1.** when completing the AF Form 308.

7.12.2. The derivation of standby is shown in **Figure 7.7.** In this figure, the difference between the total allowed time and the minimum man-hour requirement is standby time. Derive standby time for work sampling studies with the man-hour shift profile chart. Attach the standby computation to the AF Form 308 when this form is used to consolidate work measurement methods. Include the standby computation in Part Four of the final report when AF Form 308 is not used.

Figure 7.7. Deriving Standby Using Minimum Manpower and Measured Man-Hours.

The following minimum manpower computation (based on the minimum manpower factor equation) supports the derived standby time:

Shift A 0800-1600 5 days/week excluding holidays
 $[(5 \text{ days/wk})(8 \text{ hrs/day})(4.182 \text{ wks/mo})(1.00 \text{ DRF}^*)] 4(\text{persons rqd}) = 669.12$

Shift B 0800-1600 7 days/week including holidays
 $[(7 \text{ days/wk})(8 \text{ hrs/day})(4.348 \text{ wks/mo})(1.00 \text{ DRF})] 2(\text{persons rqd}) = 486.98$

Shift C 1600-2400 7 days/week including holidays
 $[(7 \text{ days/wk})(8 \text{ hrs/day})(4.348 \text{ wks/mo})(1.00 \text{ DRF})] 2(\text{persons rqd}) = 486.98$

Shift D 2400-0800 7 days/week including holidays
 $[(7 \text{ days/wk})(8 \text{ hrs/day})(4.348 \text{ wks/mo})(1.00 \text{ DRF})] 2(\text{persons rqd}) = 486.98$

Total Minimum Man-hours Per Month = 2130.06

Total Allowed Man-hours = 2032.73

Minimum Man-hours/Month = 2130.06

Less Total Allowed Man-hours = 2032.73

Derived Standby Time = 97.33

*Directed requirement factor (DRF) is a constant man-hour requirement directed by higher headquarters policy in addition to duties for a minimum manpower situation. (The DRF is equal to 1.00 unless otherwise required.)

Chapter 8

MODULAR EQUATIONS

8.1. General Concepts. Modular equations are a series of separate equations rather than one single equation. These individual equations represent independent processes that comprise the required man-hours for the work center. While this type of representation is not right, nor needed for every work center, it does give visibility to the required man-hours for a work center by process. Attributes of the modular equation to consider are:

8.1.1. Develop modular equations for individual processes that represent different levels of service furnished to the customer. Based on these level of service modules, the OPR has the flexibility to choose the pertinent module for a given location or situation.

8.1.2. As work center requirements change (processes added, deleted, or modified), change the individual modules (insert or remove) to show the new work center requirements. This makes it relatively easy and cost-effective to maintain the standard.

8.1.3. By virtue of design, calculate a "man-hour cost" associated with each process when using modular equations.

8.1.4. Modular equations make it easy to analyze a work center for "what-ifs."

8.1.5. Represent individual processes not performed at all locations with a standard at the process level. Development of variances is therefore eliminated.

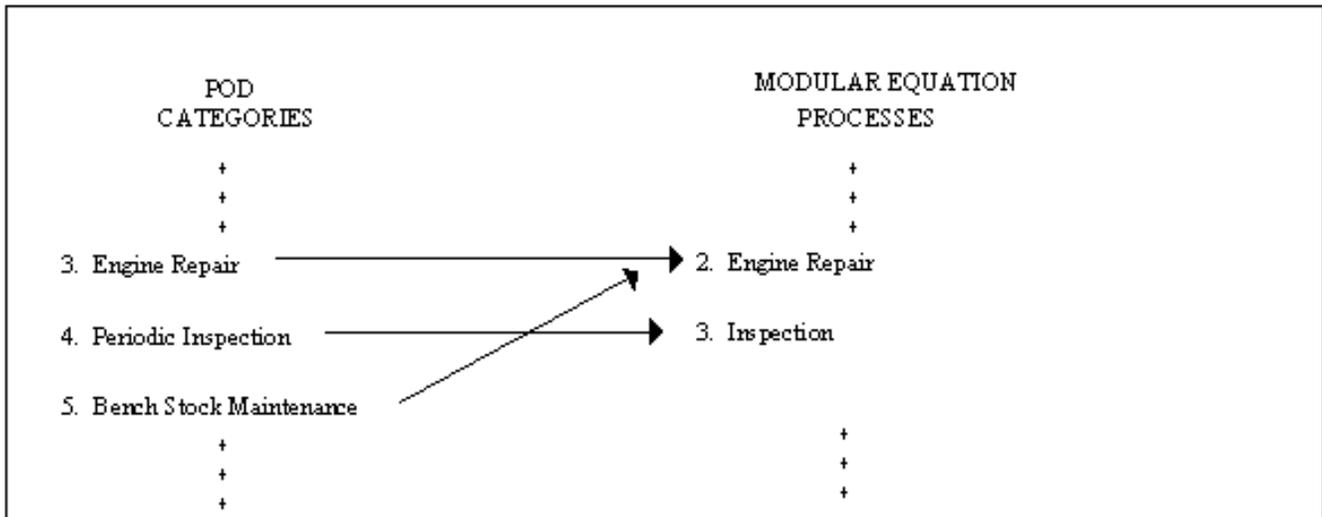
8.2. Specific Design Considerations.

8.2.1. The first and perhaps the most critical step in using a modular equation in standards development is the initial research. Carefully research the nature and function of the work center to determine the suitability and feasibility of describing the work center as a composite of independent processes. Use the modular equations procedure only when the man-hours needed for a work center can be subdivided into independent modules of work that account for all man-hours. These modules may represent one or more processes as defined in a POD. Limit the number of modules to a minimum to reduce the complexity involved in using such a standard.

8.2.1.1. A module of work is independent if it can be added to or removed from the work center without imposing an increase or decrease in man-hours in another module. Thus, it can be considered a module in a modular equation. To rephrase this idea of independence, a work center that needs a given number of hours to do the work within module A is not expected to experience a change in these hours due to increases or decreases in the work in module B.

8.2.1.2. See [Figure 8.1](#) for a simplistic example indicating a potential use for POD processes in a modular equation.

Figure 8.1. Simplistic Example Relationship Between POD and Modular Equation Processes.



8.2.1.2.1. In **Figure 8.1.**, POD processes 3 and 5 are not independent because the amount of time needed to keep bench stock is related to the number of engines to be repaired. Therefore, if the workload is increased in process 3 (that is, more engines to be repaired), the work in both processes would increase. In a modular equation, consider these two processes (and possibly others) in one general process - engine repair.

8.2.1.2.2. POD process 4 is independent of processes 3 and 5 since periodic inspections are done on all engines. The addition (or deletion) of the work would not change the hours needed to do engine repair or keep bench stock supplies. Represent this process with a different module in the modular equation.

8.2.2. Each module must have at least one workload factor that is logically and statistically related to the work described.

8.2.3. Each module must meet the minimum number of input locations.

8.2.3.1. Include as modules of work only those that are present in at least five of the work center locations. Any fewer is considered a variance or a small population.

8.2.3.2. Each module must meet the minimum number of locations for measurement according to AFMAN 38-208, Volume 1, **Table 3.4.**

8.2.3.3. Measure some locations with all modules present. This produces a more accurate statement of the required work. This procedure tends to reduce the number of variances needed for the standard.

8.3. Indirect Man-Hours.

8.3.1. When Operational Audit is the primary measurement method, use SIAMs to credit indirect man-hours. Use SIAMs to form a separate indirect module. Represent this with an equation that expresses the indirect man-hours as a function of the direct man-hours. This can either be a linear or parabolic equation. The indirect equation remains separate from the equations for direct work and is applied only after the direct work is computed. This procedure sets a relationship between indirect and

direct work. Indirect man-hours (Y) are regressed against direct man-hours (X) for each of the input bases. You can develop your SIAM factor as follows:

$$Y = (a+bx)(\text{SIAM Factor})$$

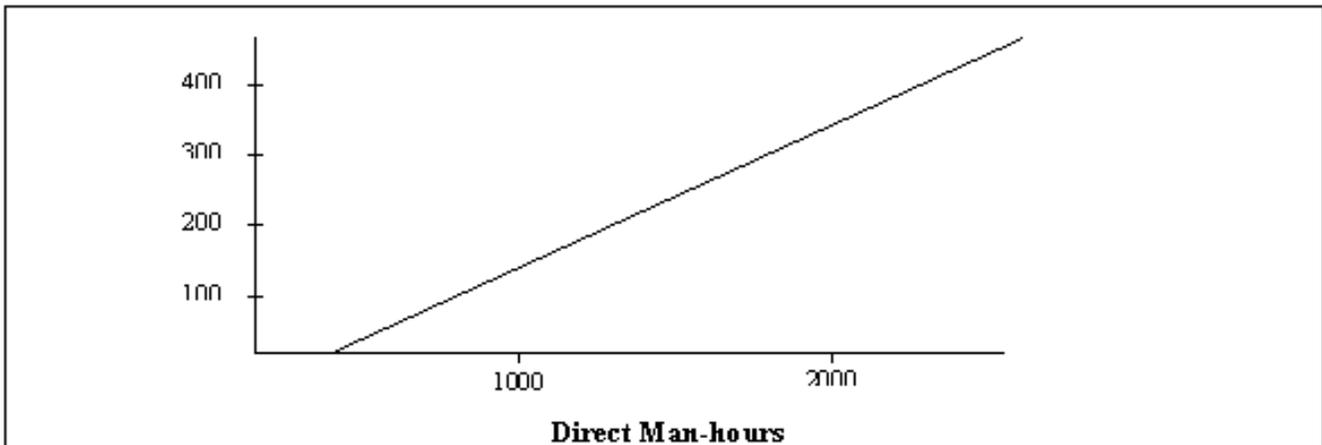
$$\text{SIAM Factor} = 1 + \frac{\text{Measured Indirect Man - Hours}}{\text{Measured Direct Man - Hours}}$$

8.3.2. When work sampling is the primary measurement method in multi-location modular studies, use measured indirect man-hours to form a separate indirect module. Represent this with an equation that expresses the indirect man-hours as a function of the direct man-hours. Equation development and procedures outlined for operational audit also apply to work sampling.

8.3.3. The b-value in the linear case represents the proportion of indirect time to direct time. **Figure 8.2.** shows relationships between direct and indirect percentages. Use this information as a guide. In **Figure 8.3.**, a typical indirect equation was computed to be: $Y_{\text{ind}} = -15.9354 + .1829 (Y_{\text{dir}})$. This allows an additional 18% (approximately) of the direct time for indirect work.

Figure 8.2. Relationship of Indirect to Direct Man-Hours.

If total time is		Then the relationship of indirect to direct is:
% Direct	% Indirect	Indirect/Direct
95	5	.0526
90	10	.1111
85	15	.1765
80	20	.2500
75	25	.3333
70	30	.4286

Figure 8.3. Graph of the Example Indirect Man-Hour Equation.

8.3.4. The a-value determines the line with this slope (the b-value) to use. A negative a-value (as in the example above) does not mean that there is an automatic loss of man-hours. As in any equation, consider the a-value only in combination with the rest of the equation. For a given amount of direct work (for instance 950 hours), compute the hours added for indirect work from the indirect equation.

$$Y_c = -15.9354 + (.1829)(950.0) = 157.82$$

8.4. Developing Modular Equations.

8.4.1. After a work center has met specific design considerations, develop a modular equation as follows:

8.4.1.1. Step 1. Identify all work center outputs (customer needed products or services). For each output, develop a task list of the process or processes needed to produce the unit of work (output). For each output, identify a work unit (end item). Using the output task lists, develop a POD so that each independent process becomes a module and each module has its own work unit. Structure the modules to account for all of the work described in the POD. Be certain each process is included in one and only one module. Identify the relationship between the modules and the associated workload factors. To avoid confusion during equation computation, clearly specify all relationships from the beginning.

8.4.1.2. Step 2. Proceed with the measurement in the usual manner to collect all of the needed man-hours and workload counts. Use normal procedures for data collection and examination.

8.4.1.3. Step 3. Aggregate the data to the levels necessary for the separate modules.

8.4.1.4. Step 4. Do regression analysis for each module using procedures in [Chapter 2](#). Keep the statistics (R^2 , S_{yx} , V) with each equation.

8.4.2. Present the work center standard as a set of individual equations ([Figure 8.4.](#)) that apply to each module of work. During application, compute only the modules that apply to a specific work center.

Figure 8.4. Example of Modular Equation Construction.

BASE	Module 1			Module 2		TOTAL MAN-HOURS
	MAN-HOURS (Y ₁)	WORKLOAD 1 (X ₁)	WORKLOAD 2 (X ₂)	MAN- HOURS (Y ₂)	WORKLOAD 3 (X ₃)	
A	701.23	206.88	218.30	521.76	179.25	1222.99
B	891.48	227.94	960.90	448.87	181.53	1340.35
C	1692.71	343.42	1119.00	--	--	1692.71
D	1540.47	246.17	839.10	--	--	1540.47
E	941.23	151.03	343.80	420.57	148.23	1361.80
F	797.16	143.87	237.10	426.40	137.81	1223.56
G	990.63	184.05	595.30	411.57	133.32	1402.20
H	404.49	15.07	102.90	889.67	257.90	1294.16
I	638.83	162.31	25.20	281.30	102.69	920.13
J	479.16	30.60	669.50	478.92	181.97	958.08
K	718.42	47.90	1097.10	350.08	112.70	1068.50
$Y_1 = 227.8356 + 2.9830X_1 + 0.3286X_2$ $R^2 = .815 \quad S_{YX} = 193.5 \quad V = .217$				$Y_2 = -81.5356 + 3.4575X_3$ $R^2 = .896 \quad S_{YX} = 59.42 \quad V = .126$		
NOTE: Bases C and D are not regressed in Module 2 because the module does not apply to these two bases. Do not use zeros in the regression file.						
MODULAR EQUATION						
MODULE 1: $Y_1 = 227.8356 + 2.9830X_1 + 0.3286X_2$ MODULE 2: $Y_2 = -81.5356 + 3.4575X_3$						
NOTE: Do not compute an overall S_{yx} or V .						

8.4.3. An alternative to developing modular equations as described above is to use ratio unit times. The a-values (fixed man-hours) are developed by computing the mean fixed man-hours of all of the measurement locations. The b-values (variable man-hours) are developed by computing the mean ratio unit times of all of the measurement locations.

Chapter 9

OPERATIONAL AUDIT (OA)

9.1. General Concepts.

9.1.1. The OA measurement method uses activity time values at the process step level. Find these values by the mathematical model $T = f_i t_i$, where T is the man-hours for activity; f_i is the activity frequency, and t_i is the per accomplishment time (PAT).

9.1.2. Use the OA method to set standards in practically any type of work center (production, administration, supervision, etc.).

9.1.3. Also use the OA method to supplement work sampling or time study methods to:

9.1.3.1. Find time values for work not performed during the sampling period.

9.1.3.2. Document requirements for specific processes not suitable for time study due to low frequency or long duration when time study is the primary method.

9.1.4. OA uses four primary data sources: historical records, directed requirement, good operator timing, and technical estimate. Each of these OA techniques is defined as follows:

9.1.4.1. Historical Records Technique. The determination of step frequency or PAT by checking documented past work performances of the work center.

9.1.4.2. Directed Requirement Technique. This technique recognizes and allows some full-time positions established by regulation such as commander or first sergeant. Directed requirements may also apply to directed frequencies, such as monthly inspections, or to directed time values, such as the periodic run-up of a standby electrical power generator.

9.1.4.3. Good Operator Timing Technique. A technique that establishes time values by measuring the time a qualified individual expends on a given activity.

9.1.4.4. Technical Estimate Technique. The determination of the standard hours needed for a given process step, based on an estimate made by individuals technically and professionally competent to judge the needed time.

9.1.5. OA facilitates standards maintenance.

9.2. Preparing for OA Measurement.

9.2.1. The measuring craftsman must prepare in advance for OA to ensure the accuracy and validity of the data.

9.2.2. Check the POD and SOC with work center personnel. Make sure the craftsman and work center supervisor both understand the work to be measured, standards of operation, and variations existing at the specific measurement site.

9.2.3. Get all workload values for the period specified in the measurement plan. Usually 12 months of data is needed; however, the study team makes sure that complete work cycles are covered.

9.2.4. Identify all frequencies and PATs that can be obtained by using techniques other than technical estimates.

- 9.2.5. Identify activities that directly relate to other activities. For example, if activity b is always done as a follow-on to activity a, their frequencies should relate.
- 9.2.6. Identify activities that indirectly relate to other activities. For example, in a maintenance work center, “part replaced” might relate to “part transaction” processed in a supply work center.
- 9.2.7. Find the number and skill of people assigned to the work center in the past 12 months. If 12 months of data is not available, the study team sets minimum data needs.
- 9.2.8. Find out whether man-hours were borrowed, loaned, or spent in overtime.
- 9.2.9. Make sure measured man-hours show required work. Historical workload data and associated man-hours may not show the real work center needs. Overmanning or undermanning affects the level of effort and the historical workload production level. Contracted work, backlog, labor negotiations, or future production schedules might also be a factor. Identify and document the impact of these conditions during measurement.

9.3. Frequency (f_i) Determination.

- 9.3.1. Establish Frequencies. Establish activity frequencies using historical records, directed requirement, or technical estimate. Each technique is discussed below.
- 9.3.2. Historical Record.
- 9.3.2.1. Research historical records such as reports, letters, messages, rosters, etc. Verify data with work center people.
- 9.3.2.2. In some cases, it is possible to relate unknown frequencies to reliable recorded data to find more objective estimates. For example, if there is no record in a work center to show the frequency that a particular part is replaced, a check of supply issue records may verify the frequency.
- 9.3.2.3. Counts of potential WLFs often equate to activity frequencies that can be used to support or verify frequencies through an indirect relationship. Evaluate work counts and workload cycles associated with specific processes to determine the natural frequency period (for example, daily, weekly, monthly, quarterly or yearly), as well as frequency counts.
- 9.3.3. Directed Requirement.
- 9.3.3.1. Use frequencies that are predetermined by directive or policy (for example, inspections).
- 9.3.3.2. The study team documents directed frequencies in the measurement plan. If frequencies are not documented, the input team immediately identifies the source of the requirement to the study team for potential use at other input measurement sites.
- 9.3.4. Technical Estimate.
- 9.3.4.1. Use technical estimates for activity frequency only when no alternative data source is available.
- 9.3.4.2. Exclude extreme estimates when determining average frequency if they are not representative (for example, based on lack of experience or isolated situations). Before discarding a frequency as an extreme value, verify its occurrence by cross-referencing it with other relatable step frequencies. Do not arbitrarily exclude extreme frequencies without justification.

9.3.4.3. Base estimates on judgment and experience. Get a more confident estimate by sampling the judgment and experience of several people in the work center. Where two similar work centers exist at the same base in separate organizations, get estimates from both of them.

9.3.4.4. Use benchmark or expected frequency values included in the measurement plan as a guide for evaluating work center estimates. Expect reasonable variations; however, large variations produced by differences in conditions or levels of service need investigating.

9.4. Per Accomplishment Time (t_j) Determination.

9.4.1. Determine Activity Man-hours. Determine required activity man-hours using directed requirements, good operator, historical records, or technical estimates as follows:

9.4.2. Directed Requirement.

9.4.2.1. Use per accomplishment times that are predetermined by directive, policy, or other performance standards (for example, contract statement of work).

9.4.2.2. The study team documents directed times in the measurement plan. If this has not been done, the input team immediately notifies the study team and identifies the source for potential use at other measurement sites.

9.4.3. Good Operator Timing.

9.4.3.1. Consult with work center supervisor to jointly select a qualified person who does the process at an average pace. (If possible, select more than one good operator.) Selecting an average individual negates the need for pace rating.

9.4.3.2. The study team decides on the number of observations needed.

9.4.3.3. Observe good operator and record time.

9.4.3.4. Apply the personal, rest, and delay (PR&D) allowance factor.

9.4.4. Historical Record.

9.4.4.1. Use recorded historical per accomplishment times only if the method of recording and reporting has been thoroughly checked and validated.

9.4.4.2. Validate a reporting system by examining several recorded times for the same activity and sampling the accuracy of reported data compared to measured times.

9.4.4.3. Make sure that the time recorded for work corresponds exactly to the associated activity in the POD.

9.4.4.4. Use the average historical time based on all representative values.

9.4.4.5. It is not necessary to apply the PR&D allowance factor to PATs determined by this technique. These PATs are averages derived from estimates; not based on timing of the event. Due to the lack of precision associated with estimating, it is assumed the estimated average PAT includes enough time for these allowances.

9.4.5. Technical Estimate.

9.4.5.1. Base time estimates on the judgment and experience of a representative number of work center personnel. Sample three or four people where possible. The more samples used to determine average time, the more credence given to the estimate.

9.4.5.2. When the PAT is affected by varying levels of complexity, derive a weighted average PAT (per estimator) based on percent of occurrence. For example:

Complexity	Percent of Occurrence (must total 100%)	PAT
Difficult	20%	.75
Normal	70%	.50
Easy	10%	.20

$$\begin{aligned}
 \text{Weighted PAT} &= (.20)(.75) + (.70)(.50) + (.10)(.20) \\
 &= .15 + .35 + .02 \\
 &= .52
 \end{aligned}$$

Give estimates in regard to:

9.4.5.2.1. The first estimate, the difficult time, is an estimate of the longest time the step would take under the most adverse conditions (if things go wrong).

9.4.5.2.2. The second estimate, the normal time, is the most realistic estimate of the time it will take to do the step. In most cases, this percentage of occurrence will be higher than either of the other two estimates (difficult & easy) as it represents what normally happens.

9.4.5.2.3. The third estimate, the easy time, is the shortest time that the step can be performed if everything goes well.

9.4.5.2.4. After establishing the average unit time per step (per estimator), sum these averages (see [Figure 9.1.](#)) to attain the PAT per step for each process of the work center.

Figure 9.1. Example Procedure for Deriving the Man-Hours per Process at a Given Base.

PROCESS 6: WIDGET REPAIR. (Times are in monthly man-hours)					
	ESTIMATOR				
	1	2	3	4	MEAN
STEP 1	42.32	52.08	41.23	7.74	35.84
STEP 2	39.06	36.89	28.21	30.38	33.64
STEP 3	8.68	13.02	6.51	8.68	9.22
STEP 4	69.44	65.10	60.00	52.08	61.66
REPORTED PROCESS TOTAL				140.36	

9.5. Data Examination.

9.5.1. When measurement has been completed, check frequencies and times with work center personnel.

9.5.1.1. Begin by checking measured activities and historical workload.

9.5.1.1.1. Compare process frequencies with WLF counts.

9.5.1.1.2. Compare frequencies of related steps. For example, the number of unit production reports completed for each unit produced should relate to the number of units produced.

9.5.1.1.3. When frequencies are generated by input from another work center or by products sent to another work center, check with the other work center. Frequency counts from the receiving work center should match records of the sending work center.

9.5.1.1.4. Compare PATs for similar steps. For example, time differences between preparing a type A report and a type B report should be justified by the characteristics of the reports. If not, question the measured times.

9.5.1.2. Check all measurement data. Each process consists of a certain number of steps. **Figure 9.1.** shows four estimates of the time needed to do each step. Estimates will vary for one reason or another. Therefore, use the average or mean estimate as an expression of the time it takes to do a step. The average will likely be a more accurate estimate than any one of the four individual estimates. When an estimate for a particular step is unlike the other three estimates (**Figure 9.1.**, step 1, estimator 4), the measuring craftsman consults with the estimator and revises or discards it. The craftsman then calculates a new monthly average time for the step and records it on the AF Form 1040. Once all of the steps in a process are analyzed in the above manner, add their averages together to get the average productive time for each process.

9.5.2. Make sure that man-hours show all true requirements, not what was performed or what personnel would like to do in excess of valid requirements. Historical data includes any mistakes or ineffi-

ciencies of past operations. Past performance does not mean that the manpower was used to the best advantage or future work should be done under the same condition.

9.5.3. Remember that each input will be analyzed by the study team and compared with all other input measurements. Furnish supplemental forms and comments to aid the study team. If measurement data appears inconsistent but has been verified based on specific characteristics of the work, relay this information to the study team. If derived weighted averages were used, send the calculations to the study team. The overall quality of the study depends on the input team's measurement.

9.5.4. Get the work center supervisor's concurrence or a specific, documented reason for nonconurrence.

9.5.5. When SIAMs are used, brief the work center supervisor on the use of SIAMs to credit indirect man-hours. [Chapter 13](#) gives details.

9.6. Data Reporting.

9.6.1. Automated spreadsheets that document the same basic information as required for completion of AF Forms 1040 are acceptable. Neat and legible handscribed forms are also acceptable. Preparation instructions for the AF Form 1040 are in [Table 9.1](#). Use continuous calculations and round the last answer to the needed number of decimal places. Round Intermediate calculations - for display purposes only.

Table 9.1. How to Prepare AF Form 1040, Operational Audit Data.

Box	Enter (See note).
1	Appropriate title and functional account code for work center measured.
2	Appropriate command and installation used as the source for measurement data.
3	Date work measurement was completed.
4	Nothing. These codes are used as entries in box 5c for data system use. Frequency codes convert alpha numeric codes to data used for man-hour computation as described in Table 9.2 .
5A	Process and step titles as shown in the process oriented description. The words "DIRECT" and "INDIRECT" must precede the appropriate process groupings. Use the same numeric identifiers and avoid unclear abbreviations.
5B	Whole number occurrence per time period that expresses the actual task frequency (e.g., 1/D1 for one per day for a five workday week). Activities that occur less than one time per year may be reflected as fractional frequencies (e.g., an activity occurring once every two years is shown as .5/YR). Reflect the expected natural rate of occurrence. For example, a quarterly report is shown as 1/QT, but an activity that occurs at four random times throughout the year is shown as 4/YR. Use frequency symbol from Table 9.2 . Fractional frequencies may be used, if derived from historical records.
5C	Frequency code number from box 4 that corresponds with each activity. For example: For an activity frequency based on a 5-day workweek, enter "1."
5D	Applicable conversion factor from Table 9.2 .
5E	Allowed time required to complete one occurrence of the activity. Express time in clock minutes. If time does not include allowances (good operator time), multiply by the appropriate allowance factor and enter the result. Entry includes time for all personnel required to accomplish the activity (if a two-man team requires an elapsed time of 1.00 hour, the correct entry is 120 minutes).
5F	Product of frequency times conversion times per accomplishment time (box 5B)x(box 5D)x(box 5E) divided by 60. This value depicts the allowed man-hours per month required by the work center to perform the activity. Man-hours are entered with two decimal places.
5G	Process man-hour totals. Enter the total monthly allowed man-hours summed for a specific process, on the line below the last activity in the process. Total man-hours are entered with two decimal places. Direct and Indirect Man-hour Totals. Enter immediately under the last applicable process total. Total man-hours entered to two decimal places. If additive man-hours are measured, two totals are entered: enter the standard total and immediately below it, enter the total for the additive. Total man-hours are entered to two decimal places.
5H	Letter code to show how data was obtained for the activity frequency (first code) and per accomplishment time (second code). The following are the appropriate codes: <u>For activity frequency:</u> T - data based on technical estimate (i.e., local records or personal interview) H - data based on historical records S - based on SIAMs D - based on directed requirement <u>For per accomplishment time:</u> T - same as above D - same as above S - based on standard time data P - SIAMs personnel-generated man-hours H - same as above G - based on good operator technique F - SIAMs fixed man-hours V - SIAMs variable man-hours
NOTES.	
1. AF Form 1040 is not required to be typed. Handwritten data must be legible on original or reproduced copies.	
2. An example of a completed AF Form 1040 is located on the AFMIA home page, https://www.afmia.randolph.af.mil . Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples.	

9.6.2. Use supplemental AF Forms 1040 to document derived man-hours for each process requiring further breakdown.

9.6.2.1. When completing a supplemental AF Form 1040, number the processes or steps the same as those on the original AF Form 1040. This gives an easy cross-reference during data analysis.

9.6.2.2. When completing an AF Form 1040 for variance data, complement the numbering system used on the POD. Use a separate AF Form 1040.

9.6.3. Conversion factors for each activity frequency and their related symbols are in [Table 9.2.](#)

Table 9.2. Determination of Symbols and Conversion Factors.

R U L E	A	B	C	D
	If activity frequency is	Then, the symbol is	The code is	And the conversion factor is
1	Per day (5 workdays/week excluding holidays)	D1	1	20.91 *
2	Per day (5.5 workdays/week excluding holidays)	D2	2	23.08
3	Per day (6 workdays/week excluding holidays)	D3	3	25.26
4	Per day (6.5 workdays/week excluding holidays)	D4	4	27.43
5	Per day (7 workdays/week excluding holidays)	D5	5	29.60
6	Per day (5 workdays/week including holidays)	D6	6	21.74
7	Per day (5.5 workdays/week including holidays)	D7	7	23.92
8	Per day (6 workdays/week including holidays)	D8	8	26.09
9	Per day (6.5 workdays/week including holidays)	D9	9	28.26
10	Per day (7 workdays/week including holidays)	D10	10	30.44 *
11	Per week (5 workdays/week excluding holidays)	W1	11	4.182
12	Per week (5.5 workdays/week excluding holidays)	W2	12	4.197
13	Per week (6 workdays/week excluding holidays)	W3	13	4.209
14	Per week (6.5 workdays/week excluding holidays)	W4	14	4.220
15	Per week (7 workdays/week excluding holidays)	W5	15	4.229
16	Per week (Any of the above workweeks including holidays)	W6	16	4.348 *
17	Per month	MO	17	1.000 *
18	Per quarter	QT	18	.3333 *
19	Per year	YR	19	.08333 *
<p>NOTE. Derivation of conversion factors based on other than 12 months can be accomplished as follows. To compute a conversion factor of once per 9 month academic year, for example, the equation would be $1/9$ or .1111 and the activity frequency would read $\frac{1}{\text{ACADEMIC YEAR}}$</p> <p>* Primary Factors to be used. All others are to be used with extreme caution to ensure correct application.</p>				

Chapter 10

FUNCTIONAL MEASURES DEVELOPMENT

10.1. Introduction to Functional Measures Development. All need to know how well they are doing their job. An improvement system that helps assess information important for the user is the best answer.

10.1.1. AFI 90-1102, *Performance Management*, specifically outlines the Air Force's construct for a continual performance improvement process that focuses on the accomplishment of mission essential tasks. Components of the Air Force Performance Management process covered in AFI 90-1102 are goals, mission essential tasks (METs), performance measures, standards and targets, and task assurance. Although this chapter will not cover any aspect of the system outlined in AFI 90-1102, the Performance Management construct of "Plan, Do, Assess" applies to functional measures as well as any other improvement system.

10.1.2. This chapter covers the information any user needs to know to track functional measures. The functional measures development process provides a useful feedback system for all people, especially at the lowest work center level. Work center personnel develop the assessment process themselves and generally use it to continually improve functional measures. The following critical elements are required when developing functional measures:

10.1.2.1. Top level management supports the assessment process.

10.1.2.2. Management identifies an individual who becomes familiar with the functional measures development procedures, outlined in this chapter. This individual will lead work center personnel through the functional measures development.

10.2. Elements of the Functional Measures Tracking System (FMTS). These indicators are needed to track performance in FMTS:

10.2.1. Input - available monthly man-hours.

10.2.2. Output - total output production or services completed each month.

10.2.3. Efficiency - output divided by input.

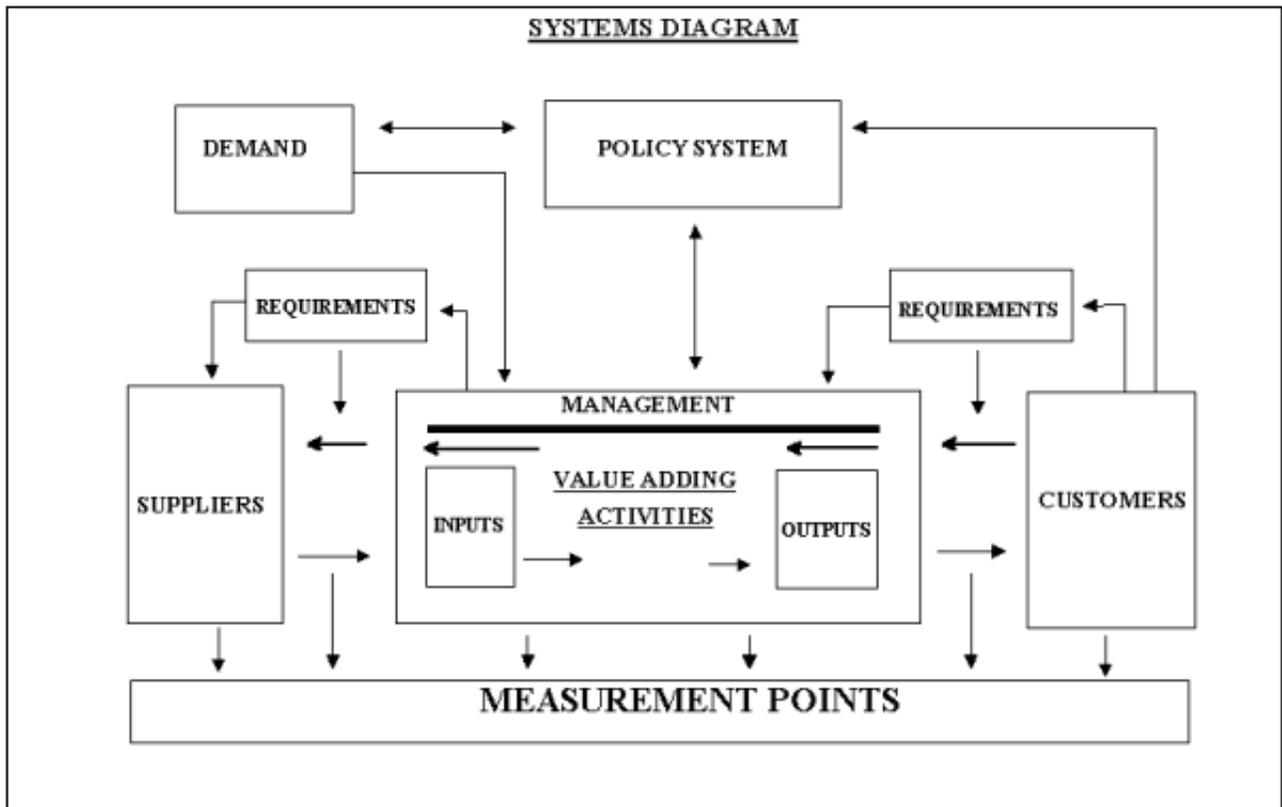
10.2.4. Unit man-hour cost - input divided by output.

10.2.5. Effectiveness indicators furnish feedback information on the quality and timeliness of a work center's performance. Personnel should identify at least one effectiveness indicator for their work center.

10.3. Systems Analysis.

10.3.1. Factors influencing a work center are easy to understand if the work center is viewed as a system and analyzed as such. **Figure 10.1.** shows a system view of any work center or functional activity.

Figure 10.1. Generalized Systems Diagram.



10.3.2. The box in the center of the page represents the work center. This area includes the inputs and processes that produce the products or services that become outputs. The value-adding activities are the processes the work center personnel use to transform the inputs into outputs.

10.3.3. Each work center has customers for the products or services that become outputs.

10.3.3.1. These customers may be internal to the organization that includes the work center. Internal customers receive data or use the work center's output as an input for their value-adding activities.

10.3.3.2. The customers may be external to the work center's organization.

10.3.4. Suppliers supply products or services to the work center. In this case, the work center is a customer of those suppliers.

10.3.5. Customers have needs and expectations for the outputs of their suppliers. Customers decide on the quality of the output of their suppliers by how well the product or service satisfies their needs and expectations. The work center in this system acts both as a customer and supplier. This work center must satisfy its customers' expectations and needs, just as it expects its suppliers to do the same.

10.3.6. Customer needs will determine management's policy on the quality and timeliness for the work center's output.

10.3.7. The work center personnel must have a means of determining how well they are meeting the needs and expectations of their customers. They must also know how effectively their suppliers are

meeting their expectations. This can be done by identifying pertinent effectiveness indicators. Indicators can also be identified to monitor the work center's inputs, processes or value-adding activities, and outputs.

10.4. Components of the Feedback System.

10.4.1. Key Result Areas (KRA). These are the most critical selected areas of a function's responsibilities that, when monitored, state how well the work center is performing its mission requirements.

10.4.1.1. A work center's mission statement identifies its responsibilities in the organization. It also identifies what the work center has to do to support the organization's mission. Work center personnel break their mission statement down into measurable components or KRAs.

10.4.1.2. Select only the number of KRAs that give an adequate overview of the work center's performance. It's not necessary to monitor every process in a work center to know how well its mission is being done.

10.4.2. Functional Measures Indicators. These indicators show a work center's performance in terms of both efficiency and effectiveness. They serve to compare and evaluate effectiveness against established performance levels or goals. A good measurement system:

10.4.2.1. Monitors KRAs of the work center's mission. Choose indicators that monitor the most important needs of the work center's mission. Just one indicator may not give a true picture of a work center's overall performance. Therefore, select the minimum number of indicators that satisfactorily furnish a useful reflection of the work center's efforts.

10.4.2.2. Is easily understood by all function personnel. All indicators should be logical and meaningful to work center personnel.

10.4.2.3. Can be controlled by the work center's actions. That is, actions taken by work center personnel should be shown by a change in input, output, efficiency, effectiveness, or unit man-hour cost indicators. This does not mean that work center personnel should be able to make the indicators say what they want them to say. But the indicators should show when a measurable change has taken place in a work center. Significant changes (positive or negative) should cause the supervisor to ask "why." Corrective action may be necessary depending on the causes identified as a result of a review. These readings are primarily a feedback tool so the supervisor and his people can assess the work center's performance for a given period of time. Work center personnel can then evaluate policies and procedures, job assignments, and worker performance.

10.4.2.4. Includes indicators that show efficiency and effectiveness. Functional measures indicators should track how efficiently a work center is operating and how effectively it is meeting its mission requirements.

10.4.2.5. Can evaluate change. Effectiveness indicators should help management evaluate goals or standards. If an indicator does not show any noticeable change, it may no longer be useful. Also, if an indicator that has been monitored (over a period of time) levels off at an acceptable level to management and appears to have stabilized, work center personnel can select another more critical indicator in its place.

10.4.2.6. Includes indicators that are useful and cost efficient. Indicators should track the major or most representative needs of the work center. However, do not choose an indicator whose cost, in time and effort to get data, is greater than its value for showing the work center's performance.

When possible, use existing reporting systems to extract needed data. If reporting systems are not available, work center personnel should develop interim procedures to aid future collection of the needed data.

10.4.3. **Mission Effectiveness Charts.** Mission effectiveness charts offer a means of developing a potentially nonlinear association between levels of performance shown by an effectiveness indicator with effectiveness points. Work center personnel first identify effectiveness indicators and then associate point values for different levels of performance shown by the indicators. One mission effectiveness chart is developed for each effectiveness indicator.

10.5. The Workshop Facilitation Process. The work center should be viewed as part of a system to show the interactions of the work center with its customers and suppliers. The systems view of the work center assures that all needed elements for performance feedback are covered. The information necessary for the performance feedback system should be developed in a workshop environment. All necessary information can be obtained in the workshop used for an Air Force Process Oriented Review. If functional measures are not developed as part of a Process Oriented Review, two different workshops should be held.

10.5.1. The first workshop consists of upper-level management and immediate subordinates. For example, in a Base Supply organization the workshop members would be composed of the commander, his branch chiefs, and the workshop facilitator. This group identifies customers and checks current mission statements to identify KRAs for the subordinate work centers.

10.5.2. The second workshop consists of the branch chiefs from the first workshop, his or her work center supervisors, and key workers. This group reviews the product of the first workshop and modifies it, if necessary. This group then develops functional measures indicators and associated mission effectiveness charts for their work centers.

10.6. The Nominal Group Technique. The facilitator works with the work center representatives and management, in a workshop environment, to identify work center customers, KRAs, efficiency and effectiveness indicators, and mission effectiveness charts. These elements can be identified using a proven approach called the Nominal Group Technique. This technique is a useful problem-solving and idea-generating strategy. The process begins with the workshop facilitator discussing each step of the process to the workshop participants. The nominal group technique is controlled by the facilitator and includes these steps: silent generation, round robin listing, clarification, and voting and ranking. These steps are described below for identifying the KRAs. These same steps may be used to identify work center customers and functional measures indicators.

10.6.1. **Silent Generation.**

10.6.1.1. The silent generation step typically takes about 10 minutes. During this step, the facilitator writes a carefully worded task statement:

WHAT IS THE PRIMARY SERVICE OR PRODUCT OF THIS WORK CENTER?

Each participant responds to this task statement during the structured group session. It is perhaps the most critical element of the nominal group technique. The task statement is simple, direct, and addresses the subject being pursued. Tell workshop participants to write their responses to the task statement on a sheet of paper. Good opening task statements when developing effectiveness indicators are: Our task is to develop an indicator that will allow us to decide if the work center is

achieving the performance level desired, to determine what quantitative indicators the work center personnel should track on a monthly basis, and to tell if the work center's mission is being effectively accomplished.

10.6.1.2. If the facilitator is asked what is meant by the task statement, it is best to avoid introducing bias by giving examples. Instead, the facilitator might ask several of the participants to give their interpretation of the task statement. If the responses appear to meet the objective and the remainder of the participants grasp the task, it is all right to proceed.

10.6.1.3. Even if most participants appear to stop writing before 10 minutes are up, do not shorten the period. If some talking occurs, the facilitator should tactfully ask for cooperation in letting others think through and record their ideas.

10.6.1.4. Like each of the steps in the nominal group technique, silence is an important element. Research has shown that for generating ideas, individuals are more effective than groups. Silent generation focuses attention on a specific task, frees participants from distractions, and gives them an opportunity to think through their ideas rather than to simply react, thus yielding inputs of greater quality and variety. Participants are motivated by the tension of seeing those around them working hard at the group task. They are forced to pay attention to the task longer, rather than considering the first input suggested to the group. They are freed from all of the inhibiting effects of the usual face-to-face interaction of unstructured groups.

10.6.1.5. When the 10 minutes are up, the facilitator interrupts the silent generation process. (**NOTE:** Additional ideas may also be produced for use following silent generation.)

10.6.2. Round Robin Listing.

10.6.2.1. The facilitator calls on participants, in turn, to read one of their written responses. Participants may pass at any time and may also join in on any later round. A participant may propose only one item at a time, and either the facilitator or an assistant records each item as it is offered. The only discussion allowed is between the facilitator and the participant who proposed the item. The discussion is limited to seeking a concise rephrasing for recording. As each participant responds, the facilitator repeats exactly what has been said, and the assistant records the concise phrase on a sheet. The facilitator may help rephrasing to maintain consistency and achieve session goals as long as the basic idea or concept is not altered. This phase goes on until all the ideas produced by the group are listed and displayed. Judgment of ideas should not take place during this early and crucial portion of the group process.

10.6.2.2. This round robin listing step allows the leader to establish an atmosphere of acceptance and trust. He or she does not unduly rephrase or evaluate the contributions. All responses are equally and prominently displayed before the group. Leader openness and nonevaluative behavior are essential here. Make sure each idea and each participant receives equal attention and acceptance. The process separates ideas from their authors and lets conflicting and incompatible ideas be considered. This step furnishes a written record of the group's efforts and makes later documentation easier.

10.6.3. Clarification of Responses.

10.6.3.1. Once all the items have been recorded, the facilitator calls on the author of each item to offer clarification if needed. This is done so that the other participants understand the item as it has been recorded. During this step, the logic behind items is brought out. Differences of opinion may

be expressed, but only the author of an item can decide if it can be eliminated or joined with another item because it duplicates others.

10.6.3.2. The facilitator keeps the group moving rapidly through the list of items. While the group members are clarifying their ideas with the facilitator, he should control lengthy discussions, arguments, and speech making. Again, the effort is to separate ideas from their authors, to clarify rather than to evaluate, and to ensure full opportunities for participation.

10.6.3.3. The clarification aspect of the nominal group technique has the most impact on the quality of the resulting list of items. If there is a great deal of overlap from item to item and if the group members don't understand what each item means, the next step, voting and ranking, will be invalid. Experience has shown that a certain amount of idea combination is necessary. Careful combining or subtle clarifying during the round robin step helps alleviate clarification difficulties.

10.6.4. Voting and Ranking.

10.6.4.1. This final step gives participants an opportunity to select the most important items and rank them. The items should be visible to all workshop members, either on a chalkboard or large pad of paper. Give the participants blank "3 x 5" cards. The number can vary. If five cards are used, ask each participant to select the five most important items from the list in front of them. A typical list may have 15 to 20 items. To avoid any confusion, ask participants to write the items out in the center of the blank card. Also ask them to write the item numbers in the upper left-hand corner. After this is done, have them spread the five cards out in front of them and follow the next steps that are designed to rank and weigh the items.

10.6.4.1.1. Tell the participants to choose the most important item from the five cards, write the number 5 with a circle around it in the lower right-hand corner of the card, and set the card aside. Another way of phrasing this is "Which of the five items would you select if you could only use one?"

10.6.4.1.2. Then say, "From the remaining four cards, choose the least important item, write the number 1 with a circle around it in the lower right-hand corner of the card, and set the card aside." Another way of phrasing this is "If you could only use three of the four items in front of you, which one item would you throw away?"

10.6.4.1.3. Then state, "From the remaining three cards, choose the most important item, write the number 4 with a circle around it in the lower right-hand corner to the card, and set the card aside."

10.6.4.1.4. Finally, have the participants choose the least important of the remaining two cards and have them write the number 2 with a circle around it in the lower right-hand corner of the card. The remaining card will be numbered with a circled 3.

10.6.4.2. Tabulate the Results. Sort the cards by item number from the original list and record the weights given to each. Display individual weights to show the number of weights given and their variation. This step allows the functional representatives to present their evaluations free of peer pressure. For an example of results, see [Figure 10.2](#). Select no more than the top five KRAs identified by the tabulation results. These KRAs are then checked for possible effectiveness indicators. Remember, if this is a process-oriented review workshop, the participants will identify and develop the effectiveness indicators. If the feedback system is being developed separately, the sec-

ond group identified in paragraph 10.5.2. will identify and develop the effectiveness indicators for their work centers.

Figure 10.2. List of Key Result Areas.

JET ENGINE SHOP		
KEY RESULT AREA	VOTES	TOTAL
Maintain engines to meet mission requirements	5-5-4-4-4	5/22
Make efficient and effective use of all available resources	5-5-4-3-1	5/18
Ensure personnel are properly trained	5-5-4-2	4/16
Assure quality of job by eliminating waste and repetition	5-4-4-2	4/15
Prioritize jobs by need	4-4-2-2	4/12
Maintain tool and equipment in good working order	4-2-2-2-1	5/11
Maintain a safe work environment for all maintenance personnel	5-2-2	3/9
Provide effective status reporting	4-3	2/7
Provide effective liaison with other agencies to assure availability of required resources	3-2	2/5
Comply with Air Force and command regulations and requirements	2-1	2/3
Assure effective supervision is maintained within the function	3	1/3

10.7. Developing a Functional Measures Indicator.

10.7.1. After the workshop participants agree on the KRAs that should be monitored, they decide the best functional measures indicators for each area.

10.7.2. Use care when developing indicators to distinguish between those that address efficiency (output or input) and those that show effectiveness (quality, timeliness, etc.).

10.7.2.1. Efficiency is defined as the ratio of outputs produced to inputs consumed. Input can be unit man-hours, capital, or material. We'll limit our input to available man-hours. For example: Base Supply Parts Issue Section issued 21,000 items during January, using 840 man-hours.

$$\frac{\text{Output}}{\text{Input}} = \frac{21,000 \text{ Items}}{840 \text{ Man-hours}} = 25 \text{ Items Issued Per Man-hour}$$

The result (25) represents the efficiency factor for January. Taken by itself, the number is of little use. But, by comparing it to another time period like the previous month (December) for a base-line yield of 16,000 items in 800 hours or 20 items per hour, January's man-hour efficiency was 25 percent higher (25/20) than the previous month.

10.7.2.2. Another way of treating the output-input relationship is to divide the man-hours used by the output produced to derive unit cost.

$$\frac{\text{Dec Input}}{\text{Output}} = \frac{800}{16,000} = .050 \text{ Man-hours/item issued}$$

$$\frac{\text{Jan Input}}{\text{Output}} = \frac{840}{21,000} = .040 \text{ Man-hours/item issued}$$

10.7.2.3. Effectiveness indicators measure goal attainment, timeliness, quality, etc., and their impact on customers of other functions and organizations. Effectiveness is defined as the ratio of successful events or accomplishments to total accomplishments, a predetermined goal, standard, or baseline. Some examples are:

10.7.2.3.1. Quality. A functional OPR's goal is to maintain a first-time, right-part issue rate of no less than 99.5%. During January, 75 items were returned due to Issue Section errors. The resulting 99.6% rate, therefore, was still acceptable.

$$\text{Quality} = (21,000 - 75)/21,000(100) = 99.6\%$$

10.7.2.3.2. Timeliness. Another possible goal of work center personnel is to reduce walk-in customer waiting time from its FY 99 average of 15 minutes to 10 minutes or less. By putting some of the high-use items closer to the counter, leasing computerized optical scan equipment, and asking the customers to complete certain portions of the request document before reaching the counter, the average waiting time dropped to just 5 minutes per customer in this example.

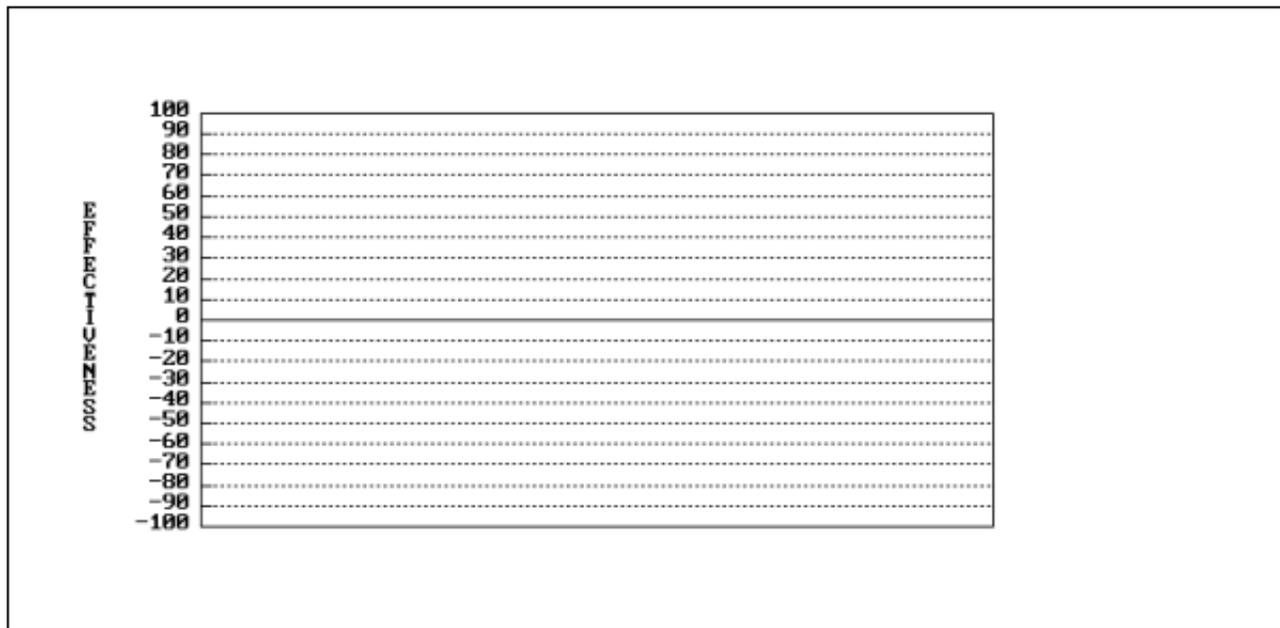
10.7.2.4. Other indicators include, but are not limited to: readiness, reliability, accuracy, safety, security, maintainability, survivability, mobility, sustainability, and flexibility.

10.8. Mission Effectiveness Charts. Mission effectiveness charts allow work center personnel to transform the values earned by effectiveness indicators into effectiveness points. This transformation sets the work center's policy on how important different values earned by an effectiveness indicator is to the work center personnel. The transformation also weighs the importance of different effectiveness indicators.

10.8.1. Developing Mission Effectiveness Charts.

10.8.1.1. Developing mission effectiveness charts, like developing KRAs and indicators, needs consensus among members of the workshop. These charts are developed in the Process Oriented Review workshop. If the feedback system is not developed as part of a process-oriented review, these charts are developed in the second workshop discussed in paragraph 10.5. See Figure 10.3. for a blank Mission Effectiveness Chart. To facilitate developing the mission effectiveness chart, certain information for each effectiveness indicator is needed when it is first identified and defined. This adds a refinement step to the indicator development process discussed previously. It is better to refine indicators at this first stage of developing indicators rather than later, because workshop members have recently completed identifying and defining indicators and will have a clear understanding of their meaning. If this refinement is deferred, some members of the workshop may forget important details about the indicators.

Figure 10.3. General Form of the Mission Effectiveness Chart.



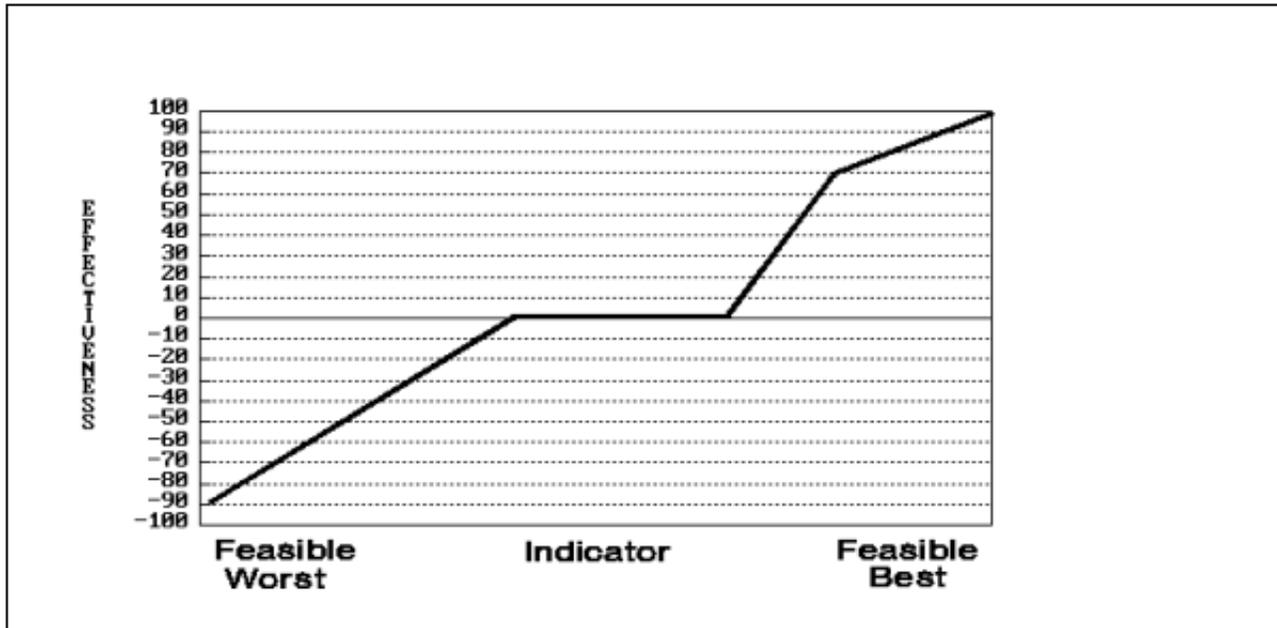
10.8.1.2. The facilitator should lead the workshop members to a consensus on the answers to three questions for each indicator. The first two questions to be used to refine each indicator are as follows:

IF EVERYTHING GOES RIGHT FOR YOUR ORGANIZATION OR WORK CENTER, WHAT IS THE "FEASIBLE BEST" YOU COULD DO ON THIS INDICATOR?

IF EVERYTHING GOES WRONG FOR YOUR ORGANIZATION OR WORK CENTER, WHAT IS THE "FEASIBLE WORST" YOU COULD DO ON THIS INDICATOR?

This pair of values constitutes the best and worst performance possible, considering real-world organizational constraints and environmental peculiarities (see [Figure 10.4](#)).

Figure 10.4. Feasible Best and Worst Locations on the Mission Effectiveness Chart.



10.8.1.3. The facilitator should make sure that workshop members understand that "feasible" best and worst are not the same as "absolute" best and worst. For instance, consider this indicator for customer satisfaction: number of customer inquiries satisfied/number of customer inquiries received (monthly) x 100. The absolute or arithmetic best would be 100%, meaning that all inquiries received are satisfied. This may, however, not be the feasible best if workshop members believe that they regularly receive a few inquiries that can't be satisfied regardless of how hard they try. The feasible best may, thus, be only 95% or even 90%.

The third question to ask is:

BETWEEN THE FEASIBLE BEST AND FEASIBLE WORST, WHAT IS THE LEVEL, POINT, OR ZONE OF PERFORMANCE ON THIS INDICATOR THAT IS NOT GOOD OR NOT BAD, THAT IS THE "BREAK-EVEN" OR "DON'T ROCK THE BOAT" POINT?

The facilitator should tell the workshop members that this is also the safety, expected, or normal performance point. That is, this is the point where the work center supervisor will neither become concerned that performance is too low and commit more resources, nor feel that performance is so good that the work center should be recognized for outstanding effort.

10.8.1.4. For instance, in terms of the customer satisfaction indicator example above, members may feel that satisfying 8 of 10 customer inquiries (80%) would be neither bad nor good. That is, the group may believe that the supervisor will become concerned if performance falls below 80%, but that if performance rises above 80%, the supervisor will begin to recognize that the work cen-

ter is doing a good job. On the other hand, the group may believe that there is no single normal performance point, but instead, there is a range of expected performance represented by a zone of, say, from 75% to 85%. In other words, they believe that the supervisor is not concerned in a zone of 75% to 85% but will become concerned if the percentage falls below 75% or be impressed if the percentage rises above 85%.

10.8.2. Weighting Indicators.

10.8.2.1. The next step is for the facilitator to point out to workshop members the likelihood that their indicators are not of equal importance. The facilitator should use several simple examples to bring out this point. For instance, in assessing the overall performance of a baseball team, which of these indicators would be of greater interest to the team manager: number of home runs hit or number of bats broken? In a military communications/navigation equipment repair shop, would the supervisor be more interested in "radios and radars returned from the flight line for failure to work properly (bounce rate)" or "number of dental checkup appointments missed by personnel?" In answering this second question, remember that although missing dental appointments is serious, the bounce rate directly affects flying capability and is, therefore, of critical interest to the wing commander, whose success depends in large part on getting aircraft into the air. (**NOTE:** The answers are, of course, that the baseball manager is more interested in home runs and the supervisor is more concerned about the bounce rate.) Getting workshop members to achieve consensus on the relative importance of their indicators is the next step in developing mission effectiveness charts. Use an Indicator Weighting Table to identify the relative importance of indicators. (See [Figure 10.5](#)).

Figure 10.5. Format for an Indicator Weighting Table.

Example of an Indicator Weighting Table						
Key Result Areas and Indicators	Feasible Best			Feasible Worst		
	Score (1)	Rank (2)	EP (3)	Score (4)	Rank (5)	EP (6)
KRA #1. Customer Satisfaction Indicator #1. No. of customer inquiries satisfied/ No. of customer inquiries received x 100. Indicator #2. No. of complaints received.	95	3	75	50	3	-50
KRA #2. Timely completion of Taskings Indicator #3. Taskings completed on time/total taskings x 100.	0	3	75	5	4	-70
KRA #3. Ensure Compliance with AFI 65-301. Indicator #4. Exercise ratings passed/total ratings x 100.	90	3	75	60	3	-75
Indicator #5. No. of severe discrepancies found/ no. of discrepancies x 100.	100	1	100	75	1	-90
	0	2	90	80	2	-80

EP = Effectiveness Points

10.8.2.2. On the left-hand side of the Indicator Weighting Table, the facilitator writes the KRA and indicators that were developed for the work center under study. The KRAs and the indicators that measure KRA accomplishment form the rows of the table. At the top of the table, the facilitator enters the column headings shown in **Figure 10.5**. For the first and fourth columns, the facilitator writes, for each indicator, the feasible best and feasible worst values derived earlier in the process of refining indicators. The facilitator should remind workshop members that these feasible best and worst values are their own judgments and are different from the absolute (arithmetic) best and worst.

10.8.2.3. In the example shown in **Figure 10.5**, there are three KRAs and five indicators. For each indicator there is a corresponding set of feasible best and worst values shown in columns (1) and (4). For Indicator #1, workshop members said in the indicator refinement stage that the feasible best the work center could do in satisfying inquiries was 95%; they believed that some peculiarity would always prevent their achieving 100%. They said the feasible worst was 50%. On Indicator #2, the feasible best and worst in terms of number of complaints received were zero and five, respectively; and so on for the feasible best and worst for the other three indicators.

10.8.2.4. Once the facilitator has entered all feasible best and worst values in columns (1) and (4), the next step is to complete column (2) of the Indicator Weighting Table. Column 2 is used to record the consensus judgment of the workshop members as to the relative importance or rank of each feasible best value of the indicators. To identify ranks of the feasible best values for column (2), the facilitator says:

SUPPOSE EVERYTHING IMAGINABLE GOES RIGHT FOR THE WORK CENTER FOR A GIVEN MEASUREMENT PERIOD. YOU ARE STAFFED AT 100 PERCENT. LITTLE SICK

OR ANNUAL LEAVE IS TAKEN. THERE ARE NO READINESS EXERCISES. OTHER ORGANIZATIONS YOU WORK WITH ARE COOPERATIVE. BECAUSE OF THESE AND OTHER POSITIVE INFLUENCES, THE WORK CENTER PERFORMS AT ITS FEASIBLE BEST ON ALL INDICATORS. THE WORK CENTER PERFORMS AT 95% ON CUSTOMER INQUIRIES SATISFIED, 0 ON CUSTOMER COMPLAINTS, AND SO ON. IF THIS WERE TRUE, WHICH OF THE FIVE FEASIBLE BESTS WOULD HAVE THE GREATEST POSITIVE EFFECT ON THE OVERALL PERFORMANCE (MISSION) OF THE WORK CENTER?

Workshop members then discuss alternative answers to this question until the members reach consensus on which indicator is the most important when all show the feasible best value. This indicator is ranked one and a "1" is entered in column (2) for that indicator. (In the [Figure 10.5](#) example, the most important feasible best was that for Indicator #4.) In case of ties between two or more indicators, each of the tied indicators will be assigned the same rank. For instance, if two indicators will equally result in the greatest positive impact, both should receive the rank of one. The facilitator continues:

NOW THAT YOU HAVE IDENTIFIED THE INDICATOR WHOSE FEASIBLE BEST VALUE HAS THE GREATEST POSITIVE IMPACT, WHICH OF THE REMAINING INDICATORS' FEASIBLE BEST HAS THE SECOND GREATEST POSITIVE IMPACT ON THE OVERALL PERFORMANCE OF THE WORK CENTER?

This indicator is ranked two and a "2" is marked in the proper row of column (2). (In [Figure 10.5](#), Indicator #5 is ranked 2). The process continues with workshop members ranking the importance of the feasible best on the remaining indicators.

10.8.2.5. After the feasible bests have been ranked in column (2), the facilitator asks workshop members to change these ranks to effectiveness points for column (3), and says:

IF WE AUTOMATICALLY ASSIGN 100 EFFECTIVENESS POINTS TO THE FEASIBLE BEST FOR THE INDICATOR YOU RANKED FIRST, AS HAVING THE GREATEST POSITIVE MISSION IMPACT, HOW MUCH LESS IS THE IMPACT ON THE OVERALL MISSION OF THE INDICATOR WHOSE FEASIBLE BEST YOU RANKED SECOND?

The facilitator then explains that if the indicator ranked second were only about half as important to the mission as the indicator ranked first, it would be assigned 50 effectiveness points. If it were considered three-fourths as important, it would receive 75 points. If its impact was almost as important as that of the indicator ranked first, an effectiveness rating of 95 or 98 points might be assigned. This process continues until all indicator ranks in column (2) have been transformed to effectiveness points and recorded in column (3).

10.8.2.6. For the indicators shown in [Figure 10.5](#), Indicator #4 (with the rank of one) automatically received 100 effectiveness points. Indicator #5 (with the rank of two) was judged to have 90% as positive an impact on the work center's effectiveness as Indicator #4 and was thus assigned 90 effectiveness points. Finally, Indicators #1, #2, and #3 were tied in column (2) at the rank of three, and workshop members agree that these indicators should receive 75 effectiveness points each.

10.8.2.7. A similar process is then performed to find the ranks (column 5) and effectiveness points (column 6) of the feasible worst values of the indicators. The facilitator begins this process of ranking with workshop members as follows:

SUPPOSE EVERYTHING GOES WRONG FOR THE WORK CENTER FOR A GIVEN MEASUREMENT PERIOD. YOUR MANNING LEVEL IS VERY LOW. THERE IS A BIG SNOWSTORM. THERE IS AN UNEXPECTED READINESS EXERCISE. THE MOON IS FULL. MORALE IS LOW AND THE WORK CENTER WORKS AT ITS FEASIBLE WORST ON ALL 5 INDICATORS. IF THIS WERE TRUE, WHICH OF THE INDICATORS WOULD HAVE THE GREATEST NEGATIVE IMPACT ON THE OVERALL PERFORMANCE (MISSION) OF THE WORK CENTER? WHICH LOW SCORE WOULD HURT YOU THE MOST?

The feasible worst values are ranked in column (5) with "1" for the indicator with the greatest negative impact; again, ties are possible. As shown in column (5) of [Figure 10.5](#), the workshop members judged that Indicator #4 would have the greatest negative impact; Indicator #5, the second greatest negative impact; Indicator #3, the third; Indicator #2, the fourth; and Indicator #1, the fifth.

10.8.2.8. The next step is to transform the ranks in column (5) to negative effectiveness points in column (6). Though the feasible worst will usually receive -100 effectiveness points, the automatic assignment of -100 is not absolutely necessary. For instance, in the case of Indicator #4 in [Figure 10.5](#). (which was ranked one for having the greatest negative impact on the work center), workshop members believe that this indicator was simply not as bad as -100. They saw a difference in the impact on the work center's effectiveness (mission) between the feasible best and worst on this indicator. They believed that -90 was the impact of the feasible worst; therefore, -90 was recorded in column (6) for Indicator #4.

10.8.2.9. Once the negative effectiveness point rating is decided for the indicator ranked number one, the process continues, with members coming to consensus regarding the ratings for the remaining indicators. In the [Figure 10.5](#). example, workshop members decide that the next feasible worst indicator (#5) should receive -80 effectiveness points and that the other three indicators (#3, #2, and #1) should be assigned effectiveness points of -75, -70, and -50, respectively.

10.8.2.10. Note that the effectiveness points for the feasible best values are always positive (e.g., 100, 90, and 75), and the effectiveness points for the feasible worst values are always negative (e.g., -90, -80, -75, -70, and -50). If a work center has only one indicator, its feasible best is assigned 100 effectiveness points and its feasible worst is assigned -100 effectiveness points.

10.8.3. Plotting Known Values for Mission Effectiveness Charts.

10.8.3.1. After refining the indicators and assigning relative weights to each, as suggested previously, the facilitator proceeds to the last step in developing a mission effectiveness chart for each indicator. He helps workshop members identify the slopes of the curves for each chart. The facilitator begins by showing members how to plot the previously determined values on the chart.

10.8.3.2. The general form of a mission effectiveness chart is shown in [Figure 10.3](#). The vertical axis of a mission effectiveness chart shows an indicator's overall effectiveness or mission impact and is scaled from -100 through 0 to +100 in increments of ten. The vertical axis is the same for all mission effectiveness charts. The horizontal axis is used to record those values specific to a given indicator; these values will range from the feasible worst to the feasible best for that particular indicator. It is recommended that the facilitator prepare a transparency of the chart for use on an overhead projector to help in plotting these values.

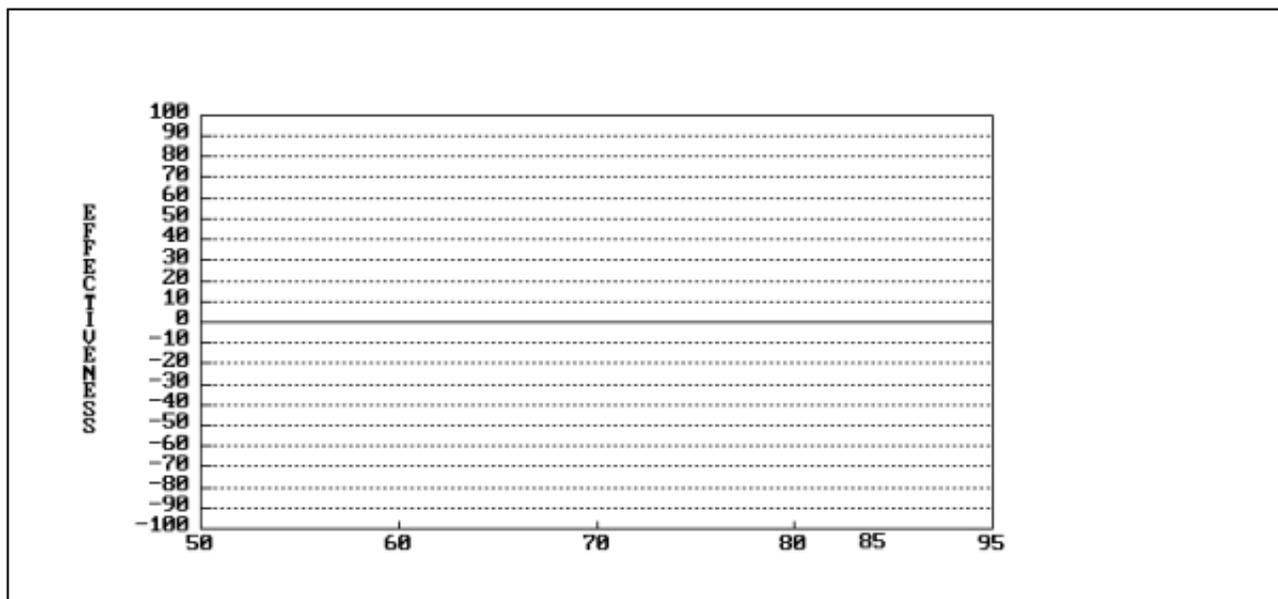
10.8.3.3. Using a transparency of the chart from [Figure 10.3](#)., as an example, the facilitator tells workshop members that they are at last ready to construct a mission effectiveness chart for their

Indicator #1, "Customer Satisfaction." The facilitator further explains that this chart will serve as a vehicle for providing feedback to them on their performance for this indicator. He also shows how their level of performance impacts the overall performance (mission) of the work center according to the values earned on the vertical axis.

10.8.3.4. Workshop members are then shown that they made some important decisions about the chart when they defined the feasible best and worst for the indicator, in that these values represent the "end-points" of its horizontal axis. The facilitator labels the horizontal axis with the name of the indicator in question. He then marks the feasible best as the point (to the right) on the horizontal axis, and the feasible worst as the point (to the left) on the horizontal axis.

10.8.3.5. Next, the facilitator fills in the intervals along the horizontal axis between the feasible worst and the feasible best. When under pressure to keep the process going, the facilitator may find it difficult to precisely scale between the two extremes, but workshop members will be understanding and satisfied with a series of approximations. Later, when the mission effectiveness charts are automated or typed, an exact horizontal scale can be developed and the entire mission effectiveness chart can be presented for workshop review. **Figure 10.6.** shows such a scaling of the horizontal axis of Indicator #1 from **Figure 10.5.**

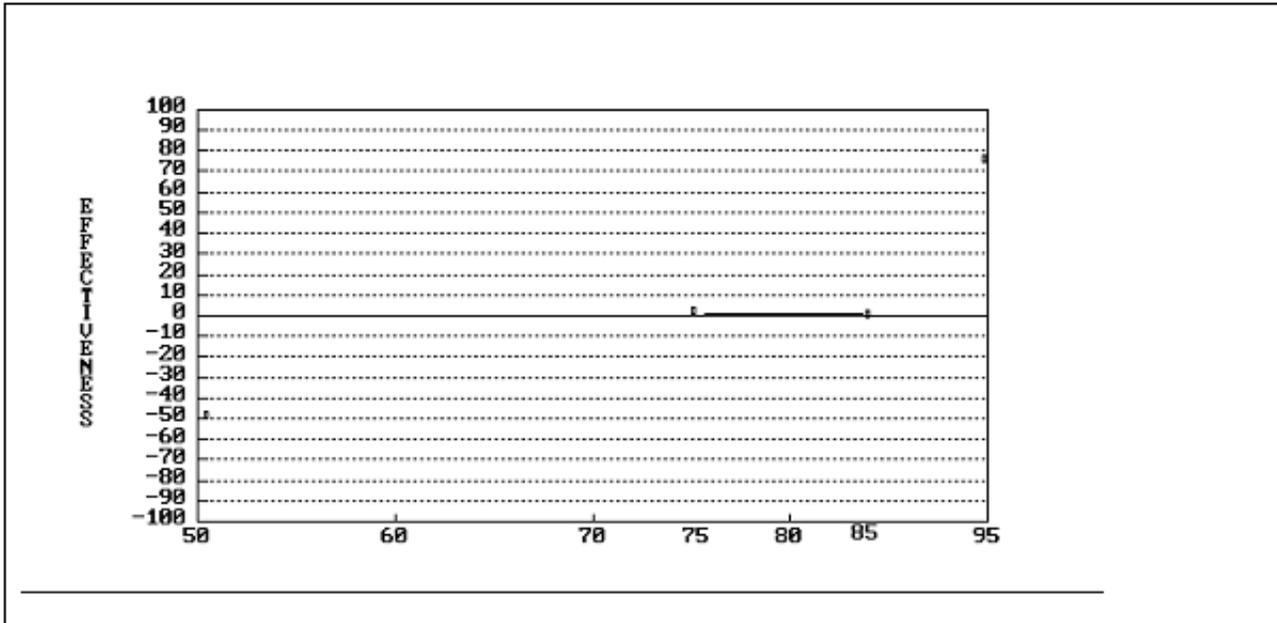
Figure 10.6. Customer Satisfaction Mission Effectiveness Chart with Horizontal Axis Scaled.



10.8.3.6. Next, the facilitator tells workshop members that they have already developed three points for the mission effectiveness chart that represent three levels of performance on the indicator. These points are the normal performance point (or range) and effectiveness values for the feasible worst and best discussed previously.

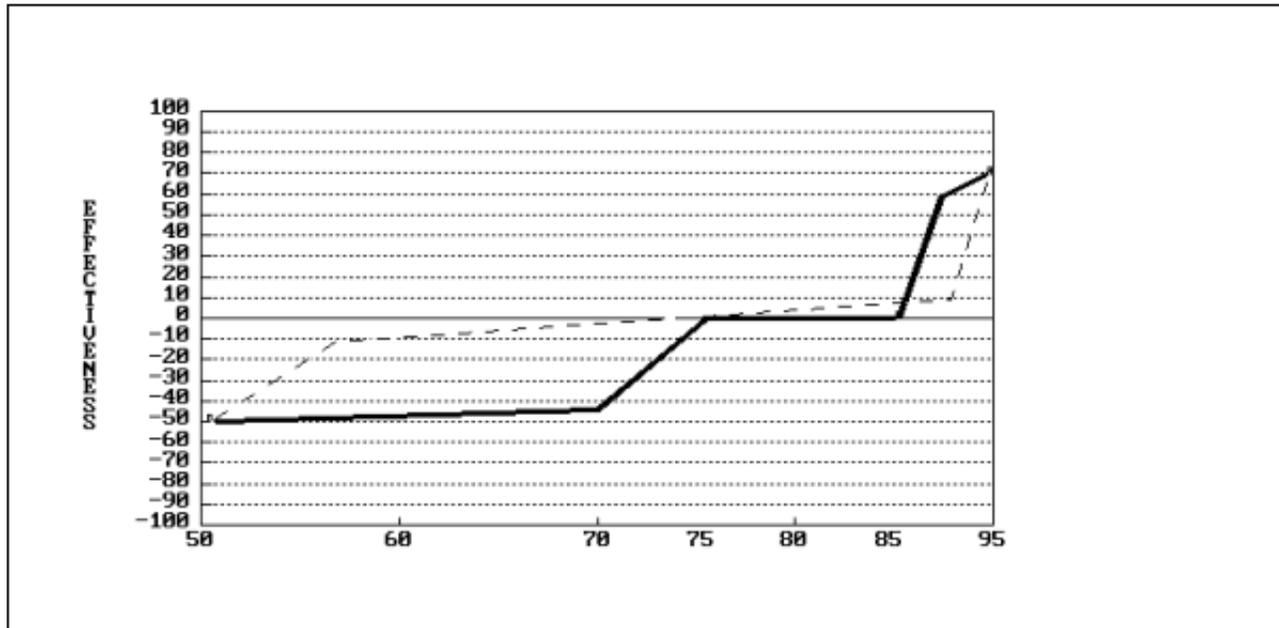
10.8.3.7. **Figure 10.7.** shows these three parts of the curve for the **Figure 10.5.** example. For this particular example, workshop members decided earlier that the range from 75 to 85 would represent the expected performance, (i.e., 0 effectiveness 5, 80, and 85). This example is plotted in **Figure 10.7.**

Figure 10.7. Normal Performance Range, Feasible Worst and Feasible Best Data Points Plotted for Customer Satisfaction.



10.8.3.8. Before asking workshop members to plot the intermediate points for its first chart, the facilitator should furnish and interpret several alternative mission effectiveness chart curves to illustrate the concept. **Figure 10.8.** shows two such alternatives (a dashed-line curve and a solid-line curve), as applied to the three plotted values presented in **Figure 10.7.**

Figure 10.8. Alternative Slopes of Mission Effectiveness Charts for Customer Satisfaction.



10.8.3.9. The dashed-line curve suggests that a very broad range of performance on the indicator (from 55% to 94% inquiries satisfied) has no positive or negative impact on mission, in that the effectiveness points vary only from -10 to 10. Performance above or below this range, however, has a substantial impact on the mission (75 and -50 effectiveness points, respectively).

10.8.3.10. The solid-line curve in [Figure 10.8](#) exhibits a very different pattern. According to this curve, immediately below the normal performance range (less than 75% inquiries satisfied) the mission impact becomes severe, falling from 0 to almost -50 effectiveness points for a mere difference of 5% in indicator performance. Below the 70% level, however, the impact is already so bad that it can get only slightly worse. On the positive side, when performance exceeds the normal performance range (greater than 85%), the positive impact on the mission is dramatic; that is, an increase from 85% to 90% inquiries satisfied produces an increase in effectiveness points from 0 to almost 75. Above the 90% level, the increase in mission impact is positive, but small by comparison. As part of the instruction about these alternatives, the facilitator should stress to workshop members that the slope of the curve is a graphic expression of their policy about the relationship between performance on the indicator and the impact on mission of various levels of performance expressed in effectiveness points.

10.8.3.11. Workshop members learn to come to consensus quickly about the shape of curves for mission effectiveness charts, but the facilitator may wish to begin developing the first chart by asking questions such as these:

IF THE IMPACT ON OVERALL EFFECTIVENESS OF 75% TO 85% INQUIRIES SATISFIED IS ZERO EFFECTIVENESS POINTS, HOW MUCH BETTER IS IT TO HAVE 90% OF INQUIRIES SATISFIED? HOW MUCH WORSE IS IT TO HAVE ONLY 70% SATISFIED, 65% SATISFIED, 60% SATISFIED, ETC.?

Answers to each question form data points that, when connected, result in the mission effectiveness curve. Not every point on the X-axis needs to be addressed. Only those points that show a change in slope.

10.8.3.12. After the mission effectiveness chart for the first indicator is completed, the facilitator guides workshop members in a similar manner, completing the mission effectiveness charts for the remaining indicators.

10.8.4. Checking Mission Effectiveness Charts.

10.8.4.1. Before the facilitator submits the feedback system to management for review, members of the workshop should conduct two "sanity checks" of their mission effectiveness charts to make sure that the charts are both accurate and logical. The first check should come immediately after the charts are put into the form that they will be used for providing feedback to workers and management. (This form can range from a fully automated procedure on a computer to simple typed copies that are photocopied for each measurement period.) At this time, workshop members should check their charts to make sure that all elements have been recorded and reproduced as originally specified.

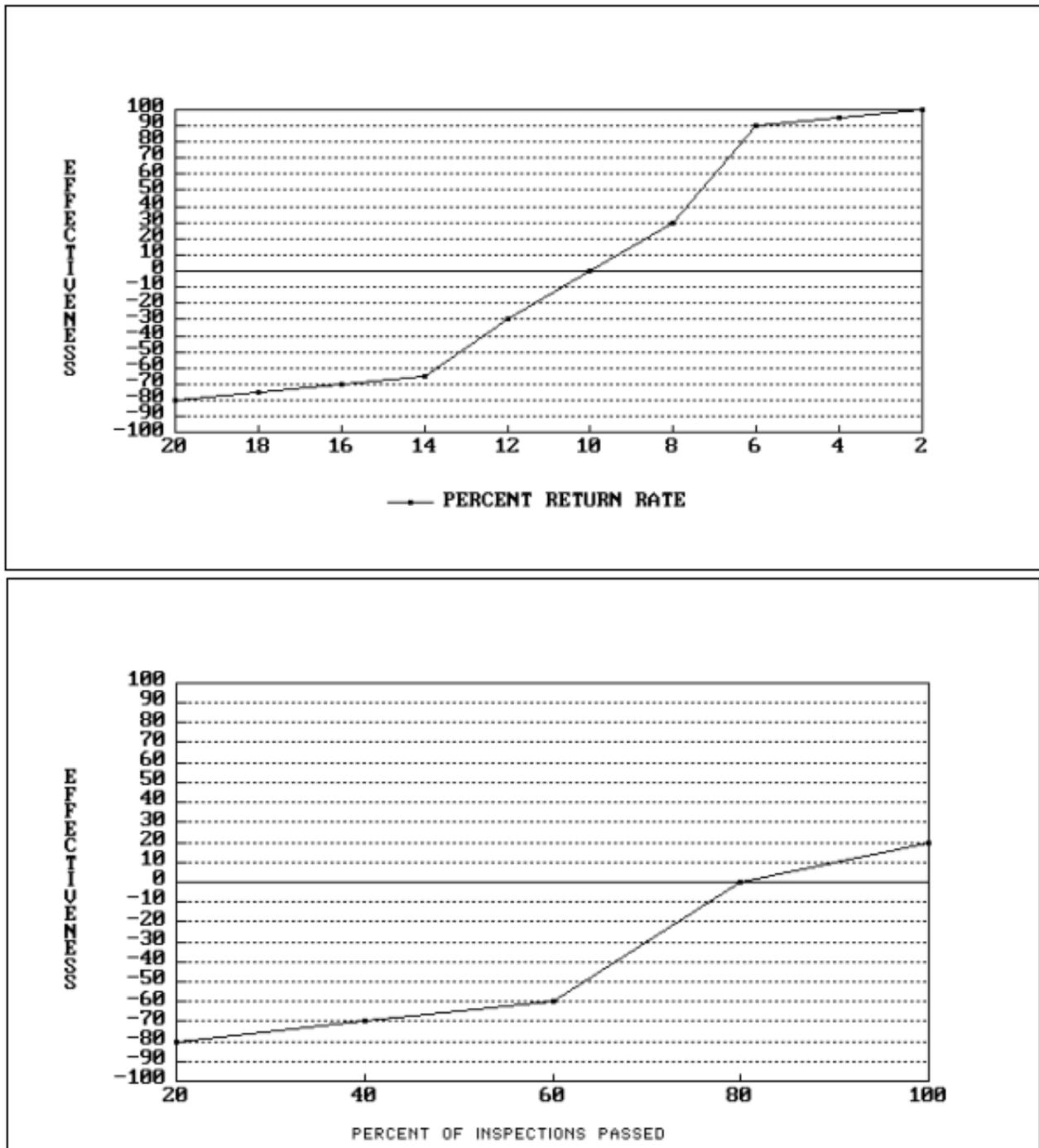
10.8.4.2. Another meeting to correct and change charts should take place when actual performance results on indicators are available from the first measurement period. At this stage, workshop members should feel free to change their mission effectiveness charts in any way necessary.

10.8.4.3. Besides improving the quality of charts, these meetings offer the added benefit of getting organization members into the habit of meeting to discuss their charts. Once the feedback system is in full operation, monthly meetings to check performance on mission effectiveness charts are essential and are the most powerful feature of this process. Feedback is widely believed to be the most important motivation to the improvement of performance. Monthly feedback meetings are also used to identify constraints to performance and to discuss "how to work smarter."

10.8.5. Using Mission Effectiveness Charts.

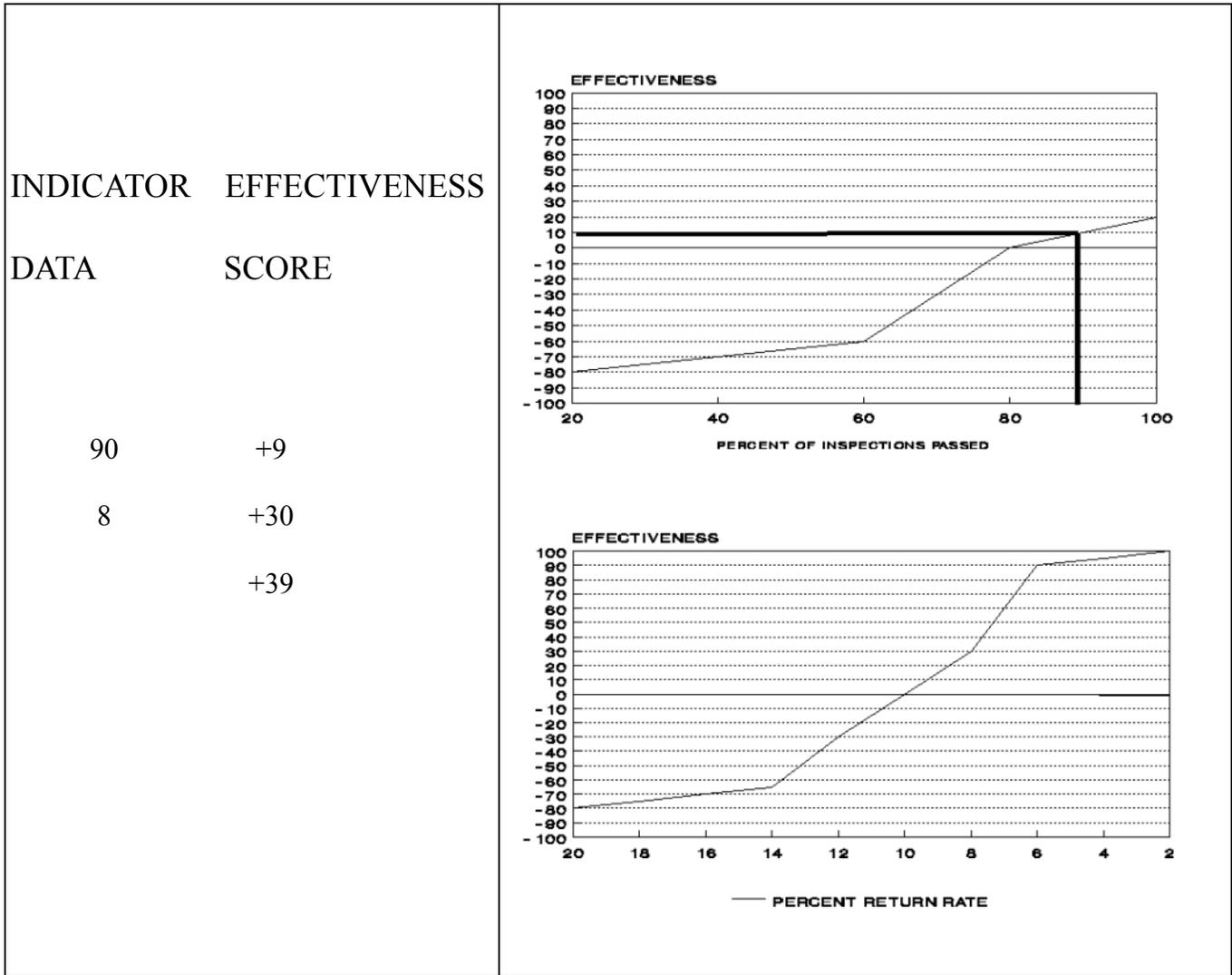
10.8.5.1. A mission effectiveness chart is developed for each effectiveness indicator. Two charts showing a work center policy on "Return Rate of Equipment" and "Inspections Passed" are shown in **Figure 10.9**. The most important of the two indicators is the one for return rate. The slope of the curve on this chart is much steeper and has a greater range than the one for inspections passed. Its point value at feasible best is 100 while at feasible worst is -80. For inspections passed, the points earned for feasible best is 20 and for feasible worst is -80. Therefore, there is a greater impact, in point value, for a change in performance in return rate than for inspections passed.

Figure 10.9. Examples of Mission Effectiveness Charts.



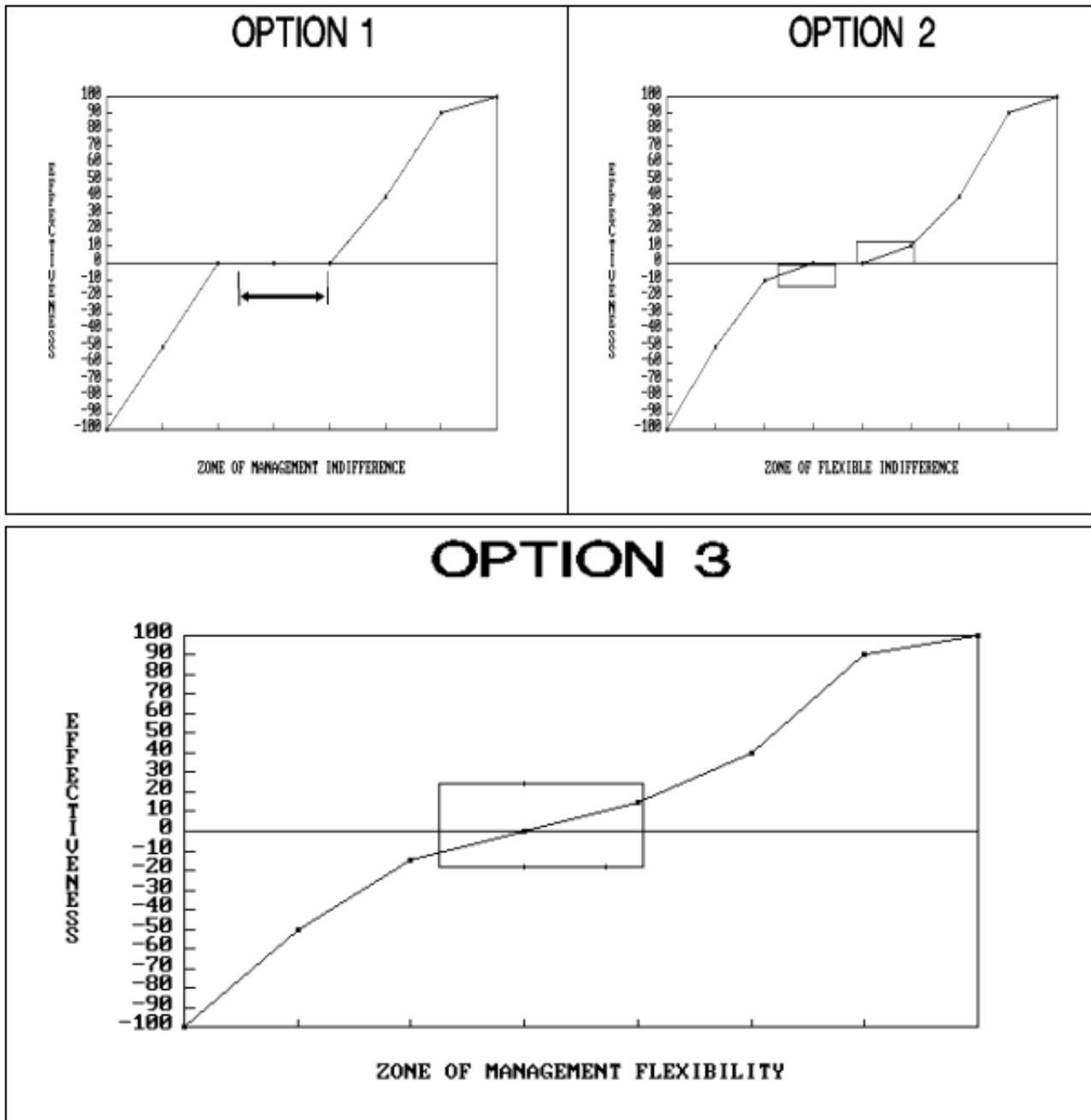
10.8.5.2. A reading is taken for each indicator in a particular month, and its value is read on the X-axis. A vertical line from that reading will intersect the curve and give a point value along the Y-axis. Readings from all the effectiveness charts can be added together to get an overall effectiveness score for the month as shown in [Figure 10.10](#). This score can be compared in time with the score obtained in the baseline period to decide if there has been an improvement.

Figure 10.10. Example of Summing Effectiveness Scores.



10.8.6. Options for Using the Range of Normal Performance. Work center personnel may identify a range of indicator values that they consider representative of normal or expected performance. If this is the case, there are three approaches that can be used to furnish feedback to personnel as shown in [Figure 10.11.](#)

Figure 10.11. Options for the Range of Normal Performance.



10.8.6.1. In option #1, performance is represented horizontally showing a range of normal performance. In this case there is no warning to work center personnel when a negative trend begins. We are not concerned about a change in performance within this range and none is shown.

10.8.6.2. In option #2, a slight turn is made at the ends of this range to show a change in performance in both positive and negative directions. We now gain an early warning of a change in per-

formance within the expected performance range and are able to correct a problem within the operation and stop a significant negative turn before it becomes a major problem.

10.8.6.3. In option #3, the work center rates along the entire range of normal performance. The slope of this range should be slight, 5 or 10 points in either direction. Just enough to give an indication of a trend. In effect, we wind up with a point of expected performance at the center of this range and an early indication of a potential problem.

10.9. Presentation of Functional Measurement Indicator Feedback.

10.9.1. Local managers should be able to use this information to investigate the impact of management decisions they or higher-level managers make on a monthly basis. This allows faster feedback, a more rapid implementation of new ideas, and modification of procedures in work centers where performance is below established, acceptable levels.

10.9.2. Indicators in a work center can be rolled-up for branch-level and top management-level review. Assure that the efficiency indicators are rolled up together and that effectiveness indicators are rolled up together. Each higher-management level would receive one efficiency indicator and one effectiveness indicator that show the performance of the subordinate work centers. One approach for rolling up data is to sum the changes of the individual indicator values for the work centers. The changes are obtained by comparing the value earned by an indicator for a particular month to the value earned in the baseline month or year. Assuming that 100% is a baseline level, each work center is of equal importance, and three separate work centers have these performance percentages:

Work Center	Percentage	Change
A	110%	+10
B	80%	-20
C	140%	+40

Change Total = +30

Add the changes for a total of +30. This total is then added to 100% for a composite result. This result can then be monitored by work center personnel to compare the level of achievement in relation to established goals or past results. If the three work centers above were not of equal importance, suitable factors would be developed to scale the work centers to their level of importance before adding the changes together. If the same type of activity is present in several installations, subordinate work center performance can be rolled up to the organization level at each installation. This information could then be rolled up to the relevant command for review. The values for each command can be summed and used by the Air Staff OPR to evaluate changes in policy, procedures, and effectiveness of guid-

ance in relation to established goals or past performance. Also, this data can be used to develop portions of the annual Federal Productivity Report for the function.

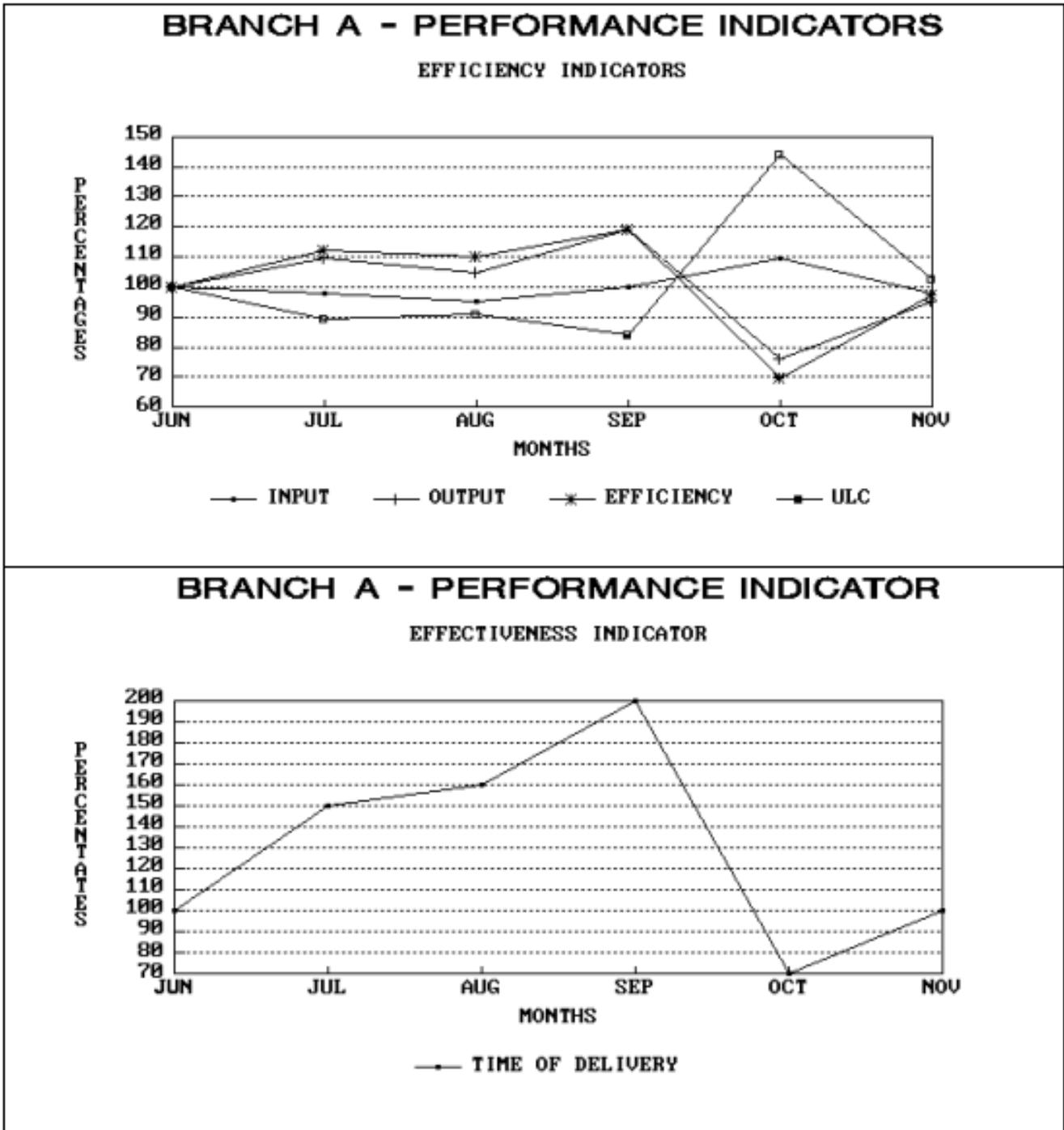
10.9.3. An example is shown here of how the minimum feedback data could be presented for the Base Supply Parts Issue Section at a base, a command, and Air Staff. The only limits on the approaches to present the data are your creativity and the available computer hardware and software.

10.9.3.1. Base Level. Furnish a monthly count of the work center's available man-hours and output to find the efficiency and unit man-hour cost indicators. Supply data for effectiveness indicators to identify how well the work center is meeting established standards or goals or performing in comparison to a baseline period. **Figure 10.12.** shows six months of data for a branch. Two effectiveness counts are included, one for the number of rejects and the other for delivery time. The first four report entries (that is, input, output, efficiency, and unit man-hour cost), use the month of June as the baseline month. The last two entries; issue rate quality and delivery time are effectiveness entries and are compared to an established goal or a baseline month. **Figure 10.13.** shows a graphic presentation of these indicators. Several indicators may be displayed together (input, output, efficiency, and unit man-hour cost indicators) as shown in the top graph of **Figure 10.13.**, or each indicator can be displayed by itself (time of delivery) as shown in the lower graph of **Figure 10.13.** Use the method that gets the information across to management most effectively. **NOTE:** All lines in **Figure 10.13.** begin at the baseline level of 100 in the baseline month of June. The value of each indicator in June establishes the baseline and later month indicator values are compared to the baseline month and percentage changes noted on the graph. If mission effectiveness charts are used, the effectiveness points earned each month are compared to the baseline month point values and the changes plotted. Remember that while graphically portrayed increases are usually associated with improvement, an increase for indicators such as cost or time might signal that action is needed. Although only data for Branch A is shown, all branches being monitored would have similar presentations each month for the base functional OPR.

Figure 10.12. Performance Data.

a. Tabulated Raw Data.						
	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
PERFORMANCE	840	820	800	840	920	820
MAN-HOURS AVAILABLE	21000	23000	22000	25000	16000	20000
ITEMS ISSUED	75	115	125	200	50	70
NUMBER OF REJECTS	10	15	16	20	7	10
DELIVERY TIME						
b. Transformed Data Using June as the Base Month.						
	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
INPUT	100	97.61904	95.23809	100	109.5238	97.61904
OUTPUT	100	109.5238	104.7619	119.047619	76.19047	95.23809
EFFICIENCY	100	112.1951	110	119.047619	69.56521	97.56097
UNIT LABOR COST	100	89.13043	90.90909	84	143.75	102.5
ISSUE RATE QUALITY	99.64285	99.5	90.43181	99.2	99.6875	99.65
DELIVERY TIME	100	150	160	200	70	100

Figure 10.13. Graphic Presentation of Performance Data.



10.9.3.2. Major Command Level. Every quarter the command OPR can view the functional measures indicators for functions at each base in the command. One approach of rolling up the data to the mid-level OPR is to sum the data for each indicator every month and take an average for the quarter. The first quarter of data becomes the baseline quarter. Each later quarter is shown as a percentage deviation from the baseline quarter. As in the base-level presentations, one efficiency and

one effectiveness indicator is used to show the overall performance of each command organization in graphic form.

10.9.3.3. Air Staff Level. The same process can be used semiannually (or annually) to roll up the performance of the MAJCOMs to develop a composite count and presentation for the Air Staff OPR. If semiannual reporting is desired, the data (using the two most current quarters) for each indicator is summed, averaged, and presented. The Air Staff OPR views the baseline deviations for the 6-month period for each indicator.

10.10. Implementing and Using the Feedback System for Continuous Improvement.

10.10.1. The complete system of KRAs, indicators, and charts is briefed to higher management. Because this process maintains and supports the prerogatives of traditional management, the facilitator should make sure that some cautions are observed in this approval process.

10.10.2. The facilitator should prebrief the manager to reaffirm the basic philosophy of the process. A key point of implementation is that the greatest gain in organizational performance comes from increasing worker motivation and restoring or increasing workers' pride in their work and sense of craftsmanship. These factors are especially important in a resource-constrained environment. In any case, management should be reminded that workers must feel a sense of ownership of their functional measures feedback system if its feedback component is to be motivational. Workers "buy into the feedback system" by creating the system themselves. Thus, management must appreciate that the central issue is not whether the system measures with great precision, but that it furnishes a platform or vehicle for continual improvement. Although overall accuracy is important, management should resist fine-tuning.

10.10.3. The essence of good management is continual improvement. So, it really does not matter if a feasible best is 65 or 70 or that a normal performance point is 25 or 30. What is important, however, is that workers accept feedback from the mission effectiveness charts and are willing to use them to identify better ways of doing business. It's reasonable for management to disagree with and ask questions about the system so long as workers maintain a feeling of ownership. In fact, management interest is stimulating to workers.

10.10.4. Certainly, management must be assured that the system is measuring the important components of the mission. If the system does not capture the important components of the mission, then time and resources could be improperly diverted by the system into less important areas of work. However, if management changes the system unnecessarily—perhaps merely to show who is "boss"—workers will lose their sense of ownership and become resigned to "business as usual." They'll do only what they are told and without much enthusiasm. They will once again be unwilling to make suggestions about improvement. This, of course, would mean that the main purpose of the feedback system has been defeated. Another way for the feedback system to be defeated is for management to be unresponsive to worker suggestions about how to improve the processes. Rather than being rule-bound and rigid, managers must play a supportive role and be willing to endorse improvement.

10.10.5. A second concern of the facilitator should be to convince the higher-level managers not to expect to routinely monitor work center mission effectiveness charts. Mission effectiveness charts are not part of any reporting requirement to higher management. Instead, management will receive aggregated or "rolled-up" results of work center performance, as discussed in the previous section. Manag-

ers need to appreciate that the mission effectiveness charts are intended for use only by the work center supervisor and workers as tools to improve work center performance.

10.10.6. The facilitator should also make it clear to personnel involved in implementation that they need not fear management disapproval of the feedback system sent for review. In fact, such disapproval, if handled correctly, can prove to be one of the most valuable facets of implementing the feedback system. Initial disapproval requires that managers and workers engage in a dialogue to seek agreement on the details of the system. After reflection, most workers welcome this dialogue because management is expressing an interest in their work. The workers now have an opportunity to present their viewpoint to management. Managers also welcome such dialogue because its underlying purpose is improving organizational performance that is of vital importance to them. In such discussions, both sides usually make concessions to some degree and consensus is soon reached on the final system to use.

10.10.7. As mentioned earlier, higher-level management has the right to approve or change the feedback system. Therefore, the facilitator should present the feedback system to workers realistically and in this light. The facilitator should stress that the feedback system represents an opportunity for workers to make suggestions to management about the best way to measure and improve organizational performance. The facilitator should create a positive outlook, with the expectation that most suggestions will likely be accepted by management. This is especially so since management took part in developing the feedback system. Workers are encouraged to develop a sense of ownership of the feedback system. However, the facilitator must also make sure they are fully aware of management prerogatives. They shouldn't naively believe that management will automatically accept everything they suggest. If the facilitator allows workers to believe that acceptance of their suggestions will be automatic, changes that result from management review are likely to surprise and disillusion workers. Then, instead of having workers who are interested and motivated, the opposite may occur.

10.11. Documentation Requirements. If the functional measures study is part of another study development effort (i.e., Manpower Standards Development Study, Consultant Study, or MEO Study) then the study contract and final report for that particular study would apply. Otherwise:

10.11.1. Study Contract. See [Figure 10.14](#). for minimum contract requirements and format.

Figure 10.14. Example Functional Measures Development Study Contract.

FUNCTIONAL MEASURES DEVELOPMENT STUDY CONTRACT	
FOR	
(TITLE OF FUNCTIONAL AREA)	
1. FUNCTIONAL AREA:	
1.1. (Title and functional account code)	
1.2. Applicability of the Study: The results of the functional measures study will apply to (locations where measures are expected to apply).	
2. STUDY OBJECTIVES:	
2.1. Evaluate and document existing functional measures systems.	
2.2. Develop new functional measures as needed.	
3. STUDY METHODOLOGY. Describe the research techniques and methodologies planned for the study. Include a list of data input and on-site visit locations.	
4. RESPONSIBILITIES. State “who will do what” to meet study objectives.	
5. STUDY TEAM. Give the name, rank, organization, and DSN number of each team member.	
6. STAFFING, APPROVAL, AND IMPLEMENTATION. Detail procedures.	
7. MILESTONES. List study milestones.	
8. AUTHORITY. Provide signature blocks for parent headquarters manpower and functional approval authorities.	
MANPOWER APPROVAL AUTHORITY	FUNCTIONAL APPROVAL AUTHORITY

10.11.2. Study Report. See [Figure 10.15](#) for minimum study report requirements and format.

Figure 10.15. Example Functional Measures Report Table of Contents.

TABLE OF CONTENTS	
PART ONE - INTRODUCTION. (Include the original study contract and documentation supporting the changes. Also include any decisions needed for follow-on implementation or other actions.).....	1-1
PART TWO - FUNCTIONAL MEASURES: (If more than one work center, separate by section number 2-A-1, 2-B-2, etc.)	
Efficiency Indication..... (continued on next page)	2-1
Effectiveness Indication.....	2-
Functional Measures Trend Analysis.....	2-
(Include charts which reflect efficiency and effectiveness performance. Use the minimum number of months to provide the customer an idea of what the feedback charts show and explain why changes have occurred in the charts.)	
PART THREE - DESCRIPTION OF FUNCTIONAL MEASURES FEEDBACK SYSTEM. 3- (Discuss the operation of the existing/proposed feedback system.) Ensure you identify:	
a. Personnel Involved.	
b. Procedures used.	
c. How frequently feedback occurs.	
d. How the feedback system provides a mechanism for customer improvement.	

Chapter 11

RATIO UNIT TIMES STANDARDS

11.1. General Concepts. Ratio unit times for development of manpower standards have been expanded to include large populations, as well as single location and small population standards. The decision to use ratio unit times for large populations should be based on analysis of workload count variations. If the workload counts do not vary widely from one location to another, ratio unit times are appropriate. If there is a wide variation, consider breaking the large population into smaller ones (e.g., small workload count, medium workload count, large workload count). If this is not feasible or desirable, then use regression analysis as outlined in [Chapter 2](#). This chapter addresses development procedures to be followed when using ratio unit times.

11.2. Population Definition.

11.2.1. Single location is applicable when the function under study is peculiar to one location or the service furnished (mode of operation) is very different from other locations.

11.2.2. Small population is defined as a population consisting of two, three, or four locations.

11.2.3. Large population is defined as a population of five or more locations. (**NOTE:** it is possible that large populations can be broken down to smaller populations based on analysis of workload data)

11.3. Input Data.

11.3.1. The quality of the input data is important in any study. However, it becomes increasingly important for small populations and single location studies because of the limited amount of data available. Accuracy is of great importance when limited measurement is possible. Since it is the only information available, it is essential to get the best estimate(s) possible.

11.3.2. When using Operational Audit (OA) as the primary measurement method, get multiple time estimates to find the best representation of the per accomplishment times. Procedures for handling multiple readings are in [Chapter 9](#). Evaluate these measurements carefully, using available statistical analysis techniques.

11.3.3. Accuracy is also critical when work sampling (WS) is selected as the prime measurement method. Do WS as prescribed in [Chapter 15](#).

11.4. Ratio Unit Times.

11.4.1. The ratio (b-value) is the result of measured direct man-hours divided by the associated workload. It represents the direct man-hours needed to produce one unit of work. The ratio development process is similar for both OA and WS except for one distinct difference: SIAMs are not used in WS; therefore, the final equation developed using WS doesn't need adjustment.

11.4.2. Equations developed by ratio unit times takes one of two forms, depending on whether or not the fixed man-hours are separated from the variable man-hours (see [Table 11.1](#)).

11.4.2.1. The first equation form is: $Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n$ where the a-value represents the sum of the fixed man-hours and the b-values represent the ratios of the variable man-hours to their respective WLFs.

11.4.2.2. The second equation form is $Y = b_1X_1 + b_2X_2 + \dots + b_nX_n$ and is the same as the first equation except there is no a-value. Use of the second equation is optional.

11.4.2.3. Associate variable man-hours with processes or steps that are expected to show a relationship with the selected WLF.

11.4.3. An example of using ratio unit times for a single location standard with the first equation form is shown in [Table 11.1.](#)

Table 11.1. Instructions for The Single Location Ratio Unit Times.

S T E P	A	B																								
	Action	Example																								
1	SELECT THE MAN-HOUR MODEL	$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3$																								
2	CLASSIFY MEASURED DIRECT MAN-HOURS AS FIXED OR VARIABLE	<table style="margin-left: auto; margin-right: auto; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: center;">AVG WLF</th> <th colspan="2" style="text-align: center;">MAN-HOURS</th> </tr> <tr> <th style="text-align: center;">WLF</th> <th style="text-align: center;">COUNT</th> <th style="text-align: center;">FIXED</th> <th style="text-align: center;">VARIABLE</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">10.20</td> <td></td> <td style="text-align: center;">65.07</td> </tr> <tr> <td style="text-align: center;">2</td> <td style="text-align: center;">15.50</td> <td></td> <td style="text-align: center;">199.00</td> </tr> <tr> <td style="text-align: center;">3</td> <td style="text-align: center;">5.00</td> <td></td> <td style="text-align: center;">134.65</td> </tr> <tr> <td colspan="2" style="text-align: center;">TOTAL MAN-HOURS</td> <td style="text-align: center;">47.00</td> <td style="text-align: center;">398.72</td> </tr> </tbody> </table>	AVG WLF		MAN-HOURS		WLF	COUNT	FIXED	VARIABLE	1	10.20		65.07	2	15.50		199.00	3	5.00		134.65	TOTAL MAN-HOURS		47.00	398.72
AVG WLF		MAN-HOURS																								
WLF	COUNT	FIXED	VARIABLE																							
1	10.20		65.07																							
2	15.50		199.00																							
3	5.00		134.65																							
TOTAL MAN-HOURS		47.00	398.72																							
3	DIVIDE THE VARIABLE MAN-HOURS (V_i) BY THEIR ASSOCIATED WLF COUNT (X_i) TO DETERMINE A RATIO (b_i) FOR EACH WLF $b_i = \frac{V_i}{X_i}$	$b_1 = \frac{V_1}{X_1} = \frac{65.07}{10.20} = 6.379$ $b_2 = \frac{V_2}{X_2} = \frac{199.00}{15.50} = 12.839$ $b_3 = \frac{V_3}{X_3} = \frac{134.65}{5.00} = 26.93$																								
4	COMBINE VALUES INTO THE APPROPRIATE EQUATION AND ADD SIAMs.	$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + \text{SIAMs}$ $Y = 47.00 + 6.379X_1 + 12.84X_2 + 26.93X_3 + \text{SIAMs}$																								

11.4.4. The ratio unit times procedure can be extended to develop small population and large population standards. To do so:

11.4.4.1. When only one WLF is used, sum the variable man-hours for that WLF for each location. Divide this sum by the sum of WLF values to form a ratio. (see [Table 11.2.](#))

Table 11.2. Instructions For Small & Large Population Ratio Unit Times - Single WLF.

S T E P	ACTION	EXAMPLE																								
1	SELECT THE MAN-HOUR MODEL	$Y = a + b_1X_1$																								
2	CLASSIFY MEASURED MAN-HOURS AS FIXED OR VARIABLE	<table style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th></th> <th style="text-align: center;">AVG WLF <u>COUNT</u></th> <th colspan="2" style="text-align: center;">MAN-HOURS <u>FIXED</u> <u>VARIABLE</u></th> </tr> </thead> <tbody> <tr> <td>Base A</td> <td style="text-align: center;">20</td> <td style="text-align: center;">120.50</td> <td style="text-align: center;">350.75</td> </tr> <tr> <td>Base B</td> <td style="text-align: center;">15</td> <td style="text-align: center;">95.60</td> <td style="text-align: center;">275.90</td> </tr> <tr> <td>Base C</td> <td style="text-align: center;">25</td> <td style="text-align: center;">130.70</td> <td style="text-align: center;">395.65</td> </tr> <tr> <td>Base D</td> <td style="text-align: center;"><u>29</u></td> <td style="text-align: center;"><u>125.60</u></td> <td style="text-align: center;"><u>397.35</u></td> </tr> <tr> <td>TOTAL</td> <td style="text-align: center;">89</td> <td style="text-align: center;">472.40</td> <td style="text-align: center;">1,419.65</td> </tr> </tbody> </table>		AVG WLF <u>COUNT</u>	MAN-HOURS <u>FIXED</u> <u>VARIABLE</u>		Base A	20	120.50	350.75	Base B	15	95.60	275.90	Base C	25	130.70	395.65	Base D	<u>29</u>	<u>125.60</u>	<u>397.35</u>	TOTAL	89	472.40	1,419.65
	AVG WLF <u>COUNT</u>	MAN-HOURS <u>FIXED</u> <u>VARIABLE</u>																								
Base A	20	120.50	350.75																							
Base B	15	95.60	275.90																							
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Base D	<u>29</u>	<u>125.60</u>	<u>397.35</u>																							
TOTAL	89	472.40	1,419.65																							
3	COMPUTE THE VARIABLE MAN-HOURS RATIO $b_1 = \frac{v_i}{x_i}$	$b_1 = \frac{V_1}{X_1} = 1,419.65 \div 89 = 15.951$																								
4	COMPUTE THE A-VALUE $A = \frac{\text{FIXED MAN-HOURS}}{\text{NUMBER OF LOCATIONS}}$	$a = 472.40 \div 4 = 118.10$																								
5	COMBINE VALUES INTO THE APPROPRIATE EQUATION AND ADD SIAMs	$Y = 118.10 + 15.951X_1 + \text{SIAMs}$																								

11.4.4.2. When more than one WLF is used, develop a ratio for each WLF (see [Table 11.3.](#))

Table 11.3. Instructions For Small & Large Population Ratio Unit Times - Multiple WLF

STEP	ACTION	EXAMPLE																																																				
1	SELECT THE MAN-HOUR MODEL	$Y = b_1X_1 + b_2X_2 + b_3X_3$																																																				
2	CLASSIFY MEASURED MAN-HOURS AS FIXED OR VARIABLE	<table border="1"> <thead> <tr> <th></th> <th>AVG WLF COUNT</th> <th>MAN-HOURS FIXED</th> <th>VARIABLE</th> </tr> </thead> <tbody> <tr> <td>Base A</td> <td>$X_1=50$</td> <td>197.65</td> <td></td> </tr> <tr> <td></td> <td>$X_2=15$</td> <td>254.85</td> <td></td> </tr> <tr> <td></td> <td>$X_3=300$</td> <td>650.35</td> <td></td> </tr> <tr> <td>Base B</td> <td>$X_1=55$</td> <td>205.20</td> <td></td> </tr> <tr> <td></td> <td>$X_2=22$</td> <td>260.70</td> <td></td> </tr> <tr> <td></td> <td>$X_3=295$</td> <td>635.75</td> <td></td> </tr> <tr> <td>Base C</td> <td>$X_1=43$</td> <td>190.45</td> <td></td> </tr> <tr> <td></td> <td>$X_2=20$</td> <td>254.65</td> <td></td> </tr> <tr> <td></td> <td>$X_3=305$</td> <td>670.50</td> <td></td> </tr> <tr> <td>Base D</td> <td>$X_1=51$</td> <td>195.90</td> <td></td> </tr> <tr> <td></td> <td>$X_2=17$</td> <td>259.25</td> <td></td> </tr> <tr> <td></td> <td>$X_3=285$</td> <td>615.75</td> <td></td> </tr> </tbody> </table>		AVG WLF COUNT	MAN-HOURS FIXED	VARIABLE	Base A	$X_1=50$	197.65			$X_2=15$	254.85			$X_3=300$	650.35		Base B	$X_1=55$	205.20			$X_2=22$	260.70			$X_3=295$	635.75		Base C	$X_1=43$	190.45			$X_2=20$	254.65			$X_3=305$	670.50		Base D	$X_1=51$	195.90			$X_2=17$	259.25			$X_3=285$	615.75	
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	$X_2=17$	259.25																																																				
	$X_3=285$	615.75																																																				
3	TOTAL THE WORKLOAD VALUES AND ASSOCIATED VARIABLE MAN-HOURS	<table border="1"> <thead> <tr> <th>WLF</th> <th>TOTAL(X)</th> <th>MAN-HOURS (V)</th> </tr> </thead> <tbody> <tr> <td>X_1</td> <td>199</td> <td>789.20</td> </tr> <tr> <td>X_2</td> <td>74</td> <td>1,029.45</td> </tr> <tr> <td>X_3</td> <td>1,185</td> <td>2,572.35</td> </tr> </tbody> </table>	WLF	TOTAL(X)	MAN-HOURS (V)	X_1	199	789.20	X_2	74	1,029.45	X_3	1,185	2,572.35																																								
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X_3	1,185	2,572.35																																																				
4	COMPUTE THE VARIABLE MAN-HOURS RATIO $b_i = \frac{v_i}{x_i}$	$b_1 = \frac{v_1}{x_1} = 789.20 \div 199 = 3.966$ $b_2 = \frac{v_2}{x_2} = 1029.45 \div 74 = 13.911$ $b_3 = \frac{v_3}{x_3} = 2572.35 \div 1185 = 2.171$																																																				
5	COMPUTE THE A-VALUE $A = \frac{\text{FIXED MAN-HOURS}}{\text{NUMBER OF LOCATIONS}}$	Not applicable for the man-hour model selected																																																				
6	COMBINE VALUES INTO THE APPROPRIATE EQUATION AND ADD SIAMs	$Y = 3.966X_1 + 13.911X_2 + 2.171X_3 + \text{SIAMs}$																																																				

11.5. Extrapolation Limits. Procedures for computing extrapolation limits are in [Chapter 2](#).

Chapter 12

STAFFING PATTERN

12.1. General Concepts. Certain work centers do not require work measurement to develop all or part of a standard. In these work centers, the objective of determining the manpower requirement can be met at less cost with acceptable validity by using functional models (**Chapter 6**), minimum manpower situation (**Chapter 7**), staffing pattern (including directed organizational positions), and SIAMs (**Chapter 13**). Use these methods in combination with measured data.

12.2. Staffing Pattern.

12.2.1. A staffing pattern recognizes long-standing use of manpower and standard operating procedures in a work center responsible for subordinate organizational elements. A directed organization position (for example, a commander) and the associated direct support position (for example, vice commander and secretary) are examples of a staffing pattern. The study team decides if a workload factor is relevant when using a staffing pattern. The size of the organization, in terms of manpower requirements or the number of subordinate elements, may drive the size of the work center. Explain pattern variations between locations in terms of workload or conditional factors. A staffing pattern, used as the basis for a standard, may result in a quantitative expression that is variable in terms of workload or may result in a constant manpower requirement for all applicable locations. The staffing pattern is normally used in work centers that command or manage two or more subordinate elements. Use the staffing pattern when these apply.

12.2.1.1. The work center is a specified element of a formal organizational structure approved by HQ USAF/XPM

12.2.1.2. The work center is reasonably stable as shown by consistent use of manpower in terms of the number, AFSCs, and grades of personnel over at least a 2-year period.

12.2.2. Directed organization position specifies a fixed manpower requirement to fill a particular named assignment (that is, wing commander, installation commander, etc.). This requirement is essential to the existence of a work center and will not change regardless of increases or decreases in workload or changes in the MAF. The directed organization position is usually the result of a staffing pattern or operational audit study. The directed organization position requirement is dictated by the need for one to be on duty in a given office of responsibility even though the individual may not be continuously productive. The man-hours that the given office must be manned are required man-hours. If a policy calls for several assistant personnel in a given office at a particular time, measure the assistants to validate the need. Do not conduct a measurement in the case of a stated two-man policy that is driven by security or safety reasons.

Chapter 13

STANDARD INDIRECT ALLOWED MAN-HOURS (SIAM)

13.1. General Concepts. To meet the needs for flexibility and accuracy, each functional OPR needs a Standard Indirect Description (SID) that fits their function. There are eleven categories of indirect work: Administers Civilian Employee, Administers Officer, Administers Enlisted Personnel, Directs Work Center Activity, Provides Administrative Support, Prepares for and Conducts/Attends Meeting, Administers Training, Manages Supplies, Maintains Equipment (Non Aircraft Maintenance Function), Maintains Equipment (Aircraft Maintenance Function), and Performs Cleanup. A "shopping list" method allows the functional and manpower communities to decide which SID tasks apply. Each SID task has an associated predetermined man-hour value. These predetermined man-hours are referred to as Standard Indirect Allowed Man-hours (SIAM) values. They were developed as a nonmeasurement method for determining a work center's indirect man-hour requirements. This concept uses standardized (core) indirect tasks that are common to most Air Force work centers. Indirect tasks are published in AFMS 00AA, *Standard Indirect Allowed Man-hours*. (**NOTE:** AFMIA is currently conducting an in-depth review of the SIAM. Once this review has been completed, updated guidance will be forthcoming. Until this review is complete, the instructions in this chapter should be followed.)

13.2. Classifying Work as Direct or Indirect.

13.2.1. When developing a Process Oriented Description (POD), all of the allowed productive work done by the work center is documented. This process describes the work in enough detail to allow for accurate measurement of the work center manpower requirements. All work needed to produce an end item (work unit) is grouped together as a process. Each process is represented by a work unit. Set up processes for all productive work, then classify the processes of work as either direct or indirect. This is often where problems begin.

13.2.2. Direct work defines productive work that directly relates to the work center producing an end product. It also defines work that is in direct support of the mission. Indirect work defines productive work that must be done, but does not directly relate to the work center producing an end product. Unlike direct work, it does not directly support the mission, e.g., preparing an enlisted performance report.

13.2.3. The SID defines all allowed core indirect work. This work is classified as indirect only when it's in support of the work center where it's done. Classify work done in support of subordinate work centers as direct work. In the latter case, these work centers are called "overhead" functions. These functions have direct management responsibility for one or more subordinate work centers.

13.2.4. Classify most tasks in the categories of Administers Civilian, Administers Officer, Administers Enlisted Personnel, Directs Work Center Activity, and Provides Administrative Support as indirect or direct. Classify tasks performed for subordinate work centers as direct work. This means that it is possible to have the same activities in both direct processes and indirect categories of work. AFMAN 38-208, Volume 1, **Table 3.2**, is a decision logic table for identifying tasks in the SID as either direct or indirect.

13.3. SIAM Task Data Sheets. SIAM Task Data Sheets have been developed for each task in the SID. These task data sheets were designed for determining which SID tasks apply to the function to be measured, and how the task is classified. Task data sheets are located in AFMS 00AA.

13.3.1. Task Title. Shows the task number and title as documented in AFMS 00AA. Task numbers will always remain unchanged.

13.3.2. Definition. Shows the task definition as documented in AFMS 00AA. Exercise caution to make sure the complete definition applies. If any portion does not apply, do not use the SIAM man-hour equation. Measure the task using the measurement instructions shown on the task sheets.

13.3.3. Applicability. The applicability statement defines those circumstances that could preclude the use of the SIAM man-hour equation. Some examples are:

13.3.3.1. The activity frequency used to develop the SIAM man-hour equation may differ from the natural rate of occurrence in the work center being measured.

13.3.3.2. When the work being performed is done by an overhead or another work center. The SIAMs may be applicable as a direct task rather than indirect, e.g., processing mail. Processing mail is normally credited in the indirect tasks, Processes Unclassified Incoming Distribution and Processes Unclassified Outgoing Distribution. A work center with a large volume of mail to process might have a full-time mail clerk. In this case, the work is classified as direct. No additional credit should be given for this workload through SIAMs.

13.3.4. Task Classification. The "shopping list" approach credits the work center with indirect man-hours. Man-hours associated with these tasks are identified as either fixed, variable, or personnel-generated.

13.3.4.1. Fixed Task Man-Hours. Fixed task man-hours do not vary with selected workload factor and are independent of the work center size.

13.3.4.2. Variable Task Man-Hours. Variable task man-hours have a direct relationship to the selected work units produced or selected workload factor. There are only a few indirect tasks that have been identified as variable, all in categories 9 and 10, Maintains Equipment.

13.3.4.3. Personnel-Generated Task Man-Hours. Personnel-generated task man-hours vary with the number of personnel assigned to the work center. They are not expected to show a direct relationship to the selected workload factor or remain constant. They are expected to relate to the total (direct and indirect) fixed and variable man-hours expended by the personnel in the work center. Personnel-generated task man-hours will be credited to the work center based on the average assigned strength of the work center. However, there are exceptions. For example, a work center has two officers assigned, and one officer is the work center supervisor or officer in charge (OIC). Only credit indirect man-hours for preparing Officer Performance Reports (OPRs) for one officer. Credit the preparation of the OIC's OPR as direct work to the overhead work center. PAT remeasurement for this task as direct work is not needed. Use the standard indirect task time (b value) and determine the activity frequency from the measurement instructions of the pertinent SIAMs Task Data Sheet. The same logic and rationale applies to every personnel-generated task in the SID.

13.3.5. Man-hour Equation. For some tasks, the allowed monthly man-hours have been converted to a per accomplishment time to help the craftsman and OPR in analyzing the task time for applicability. For example, task I3.3. Types Enlisted Evaluation, has a monthly man-hour value of 0.06193 per enlisted person assigned (less one if the work center supervisor is enlisted). In most instances, this

block also gives a per-unit accomplishment time. For example, task I3.3 allows 0.93 man-hours per enlisted evaluation typed. This information can be helpful when telling how much time is being credited to a work center for a certain task.

13.3.6. Measurement Instructions. This section shows the full instructions for determining the activity frequency and per accomplishment time when measurement is used in lieu of SIAMs. Follow these instructions explicitly, since they were used to develop the SIAMs. AF Form 1040 is completed IAW the chapter on operational audit.

13.4. Using SIAMs.

13.4.1. Selecting the SIAM Task. There is more to selecting a SIAM task than merely looking at the task title. There are four important steps that **MUST** be followed when selecting a SIAM task.

13.4.1.1. Step 1. Using the task title as a point of departure, find out whether or not the task is done in the work center being measured.

13.4.1.2. Step 2. Read the task definition. If **ALL** of the task definition elements apply to the work center being measured, then proceed to the next step. If **ANY** of the task definition elements are not done, or additional elements are done, the SIAM task man-hours **CANNOT** be used. You must measure this task using the task measurement instructions.

13.4.1.3. Step 3. Read the applicability statement. If the work center being measured satisfies all of the applicability criteria, proceed to the next step. If **ANY** of the applicability criteria **ARE NOT** satisfied, the SIAM task man-hours **CANNOT** be used. You must measure this task using the task measurement instructions.

13.4.1.4. Step 4. The last check is for logic. Is the SIAM allowed time representative of what normally occurs in this work center? If it's too high or too low, you must measure this task using the task measurement instructions.

13.4.2. SIAM Measurement. With these modifications, AF Forms 1040 will be completed IAW the chapter on operational audit (see [Chapter 9](#)).

13.4.2.1. Fixed Tasks. The fixed task allowed monthly man-hours (a value) will be entered in column 5F, Per Month, of the AF Form 1040. An activity frequency code of "S" and a per accomplishment code of "F" will be entered in column 5H, Type Data, of the AF Form 1040.

13.4.2.2. Variable Tasks. The variable task activity frequency will be entered in column 5B, Activity Frequency, and a frequency conversion code of "7" will be entered in column 5C, Freq. Code, of the AF Form 1040. An activity frequency code of "S" will be entered in column 5H, Type Data, of the AF Form 1040. The per accomplishment time, Column 5E, will be the "b value" from the SIAMs equation. A per accomplishment code of "V" will be entered in column 5H, Type Data, of the AF Form 1040.

13.4.2.3. Personnel-Generated Tasks. Enter the personnel-generated task activity frequency (number of the assigned personnel for the pertinent task) in column 5B, Activity Frequency, and a frequency conversion code of "7" in column 5C, Freq. Code, of the AF Form 1040. Enter an activity frequency code of "S" in column 5H, Type Data, of the AF Form 1040. Enter the per accomplishment time, the "b value" from the SIAM equation, in column 5E. Enter a per accomplishment code of "P" in column 5H, Type Data, of the AF Form 1040.

13.5. Alternate Indirect Man-Hour Measurement Methods:

13.5.1. In addition to the SIAM, several other standard indirect measurement methods are available to provide flexibility in responding to the dynamic expeditionary nature of our aerospace forces. These tools include the Standard Indirect Allowed Man-Hour Equation (SIAME), Direct and Indirect Manpower Equation (DIME) and the Capabilities Based Manpower Determinant (CBMD) Standard Indirect Allowance Factor (SIAF).

13.5.1.1. The Air Force is transforming to a capabilities-focused Expeditionary Air and Space Force. In doing so, our goal is to make warfighting effects, and the capabilities we need to achieve them, the drivers for everything we do. In addressing this Air Force goal, we define manpower requirements in an environment of global engagement with expeditionary forces performing capabilities. We call this manpower quantification the CBMD.

13.5.1.2. The CBMD SIAF is designed to address indirect man-hours or indirect fractional manning when computing a CBMD manpower requirement. The DIME is designed to address indirect man-hours or fractional manning when combining all CBMDs for a determination of manpower requirements at the organizational level or function.

13.5.2. Each tool is discussed in detail in the following paragraphs. [Table 13.1](#), Standard Indirect Measurement Tools Decision Logic Table, describes the advantages and disadvantages of each tool and when they are recommended for use.

Table 13.1. Standard Indirect Measurement Tools Decision Logic Table

Method	Recommended Employment	Advantage	Disadvantage
SIAM	To measure indirect man-hours for traditional peacetime manpower standards.	Most Accurate for non-CBMD manpower studies.	Slightly time consuming. Not designed for CBMD studies.
SIAME	Same as SIAM.	Quicker than SIAM.	Not designed for CBMD studies. Not as accurate as SIAM.
DIME	To quantify total CBMD manpower for a function. Since DIME was developed as a relationship of indirect requirement to direct requirement (while the SIAM and SIAME based on current assigned personnel), a recommended tool for computing indirect requirements for Most Efficient Organization (MEO). Also recommended for “to be” organizational models especially when significantly different from the “as is” POD.	Quick method to determine total CBMD FTEs for a function.	Not intended for application until completion of all associated CBMD studies.
CBMD SIAF	To quantify CBMD indirect man-hours or indirect fractional manpower. Also, a recommended tool for computing indirect requirements once direct requirements have been determined for relatively small mission changes or efficiencies.	Quick method to determine incremental indirect man-hours for a single CBMD.	Not as accurate as total measurement or SIAM.

13.6. Standard Indirect Allowed Man-Hour Equation (SIAME)

13.6.1. The SIAME is an alternate method of crediting indirect man-hours for Operational Audit and Time Study standards. Direct and SIAME man-hours are added to determine total monthly man-hours for work centers of five or more assigned personnel.

13.6.2. The SIAME was developed using the FAC family approach. Functional areas were analyzed by reviewing the primary mission, types of specialties used, and organizational levels within the function. Associated FACs were then grouped into SIAME families using the following definitions:

13.6.2.1. Management and Administration Work Centers. These work centers have the primary function of managing subordinate organizational elements and providing unit administrative support. Examples include the medical support squadron’s personnel and administration flight, the civil engineer unit administration and the operations squadron’s operations officer and the maintenance officer.

13.6.2.2. Production and Staff Support Work Centers. These work centers have the primary function of supporting the production area of an organization and researching, evaluating, reporting, coordinating, and advising. Examples include the wing manpower and organization office, the comptroller squadron financial analysis flight, the civil engineering or services squadron's resource management flights and the medical support squadron's medical information services flight.

13.6.2.3. Customer Service Work Centers. These work centers have the primary function of providing specific services to customers. Examples include the military and civilian personnel flights, base billeting, military pay and travel.

13.6.2.4. Medical Work Centers. These work centers include medical facilities and dental services.

13.6.2.5. Warehouse, Storage, and Issue. These work centers have the primary function of receiving, storing, or issuing material. Examples include the supply squadron material storage and distribution flight and fuels management flight.

13.6.2.6. Industrial Shop. These work centers have the primary function of testing, overhauling, repairing, or manufacturing specific products. Examples include aerospace ground equipment and vehicle maintenance.

13.6.2.7. **Table 13.2.**, Air Force Peacetime SIAME Families reflects the SIAME for each of the FAC family.

Table 13.2. AIR FORCE PEACETIME SIAME FAMILIES

SIAME FAMILY	SIAME
MANAGEMENT & ADMIN	$Y_{(SIAME)} = 148.03 + 9.6973X$
PRODUCTION & STAFF SUPPORT	$Y_{(SIAME)} = 176.90 + 10.4032X$
CUSTOMER SERVICE	$Y_{(SIAME)} = 183.43 + 8.3195X$
MEDICAL	$Y_{(SIAME)} = 170.84 + 9.1903X$
WAREHOUSE, STORAGE & ISSUE	$Y_{(SIAME)} = 221.31 + 8.8398X$
INDUSTRIAL SHOP	$Y_{(SIAME)} = 270.13 + 9.3033X$

NOTES:

1. $Y_{(SIAME)}$ results in total indirect man-hours.
2. X = Average Number of Assigned Work Center Personnel
3. Recommended for work centers of five or more assigned personnel.

13.6.2.8. **Table 13.3.** complements **Table 13.2.**, **Table 13.4.** and **Table 13.5.** It reflects the SIAME, DIME and SIAF Family for each specific FAC. **Table 13.2.**, **Table 13.4.** and **Table 13.5.** are summaries of SIAME, DIME and SIAF models by general FAC family. The study team identifies the family on **Table 13.3.** and uses the indicated equation or factor specified on **Table 13.2.**, **Table 13.3.** or **Table 13.5.** For example, **Table 13.3.** reflects Production and Staff Support for the

Manpower function. **Table 13.2.** states the SIAME model to use is $Y(\text{SIAME}) = 176.90 + 10.4032X$, **Table 13.4.** states the DIME model to use is $Y(\text{DIME}) = 1.88 + 1.0785X$, and **Table 13.5.** states the SIAF factor to use is 1.0785.

Table 13.3. SIAME, DIME & SIAF Listing by FAC

FAC	TITLE	SIAME, DIME, SIAF Family
1011	Protocol	Management & Administration
1012	Gp Sq Command Unit	Management & Administration
1015	History/Staff	Production & Staff Support
101A	History	Production & Staff Support
101D	Dormitory Management	Management & Administration
1022	Area Defense Counsel	Customer Service
1025	Contract Law Counsel	Production & Staff Support
102A	Judge Advocate	Production & Staff Support
104A	Public Affairs	Production & Staff Support
1050	Chaplain Staff	Management & Administration
105A	Chaplain	Management & Administration
106A	Safety	Production & Staff Support
1080	Manpower & Innovation	Production & Staff Support
1080A	Wing/Center Manpower	Production & Staff Support
10A0	Wing Commander	Management & Administration
10B0	Logistics Group	Management & Administration
10C0	Support Group	Management & Administration
10D0	Operations Group	Management & Administration
1100	Information Mgmt Staff	Management & Administration
1101	Administrative Systems Mgmt	Production & Staff Support
1107	Plans & Programs - Staff	Management & Administration
1122	Micrographics Mgmt	Warehouse, Storage & Issue
1123	Engineering Data Service Center	Customer Service
1136	Postal Finance Office	Production & Staff Support
1150	Printing Mgmt	Management & Administration
1151	Printing	Industrial Shop
1153	Microform Production	Customer Service
1160	Publishing	Management & Administration
1170	Information Mgmt Center	Management & Administration
1171	Word Processing Center	Management & Administration
1172	Information Mgmt Support Cntr	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
1200	Logistics Staff	Management & Administration
1205	Logistics Quality Assurance Staff	Management & Administration
1210	Logistics Plans Staff	Management & Administration
1220	Supply Staff	Management & Administration
1230	Maintenance Staff	Management & Administration
1231	Aircraft Maintenance Staff	Management & Administration
1232	Munitions Maintenance Staff	Management & Administration
1233	Missile Maintenance Staff	Management & Administration
1234	Ground Com Elec Maint Staff	Production & Staff Support
1235	Maintenance Stand & Eval Teams	Management & Administration
1240	Transportation Staff	Management & Administration
1250	Contracting & Acquisition	Production & Staff Support
12A0	Operational Contracting	Production & Staff Support
12A1	Acquisition Flight	Production & Staff Support
12B1	Performance Management Flt	Production & Staff Support
12C1	Plans & Programs	Production & Staff Support
12D1	Contingency Support	Industrial Shop
12E1	Specialized Contracting	Production & Staff Support
1300	Operations Staff	Management & Administration
1301	TAC Unit Operations Center	Production & Staff Support
1310	Operational Plans	Production & Staff Support
131A	Wing Plans	Management & Administration
1320	Operational Requirements	Production & Staff Support
1340	Standardization & Evaluation	Production & Staff Support
135A	Command Post	Production & Staff Support
13A0	Operations Support Squadron	Management & Administration
13A1	Standardization & Evaluation	Production & Staff Support
13B1	Weapon/Tactics Flight	Production & Staff Support
13C1	Current Operations Flight	Management & Administration
13E1	Airfield Operations Flight	Management & Administration
1400	Plans & Programming	Production & Staff Support
1410	Policy	Production & Staff Support
1430	Programming Staff	Management & Administration
151A	Financial Management	Production & Staff Support
1517	Cost	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
1530	Budget Staff	Management & Administration
1540	Data Automation/Operational	Production & Staff Support
1541	Systems Analysis	Production & Staff Support
1542	ADP Equipment Mgmt	Production & Staff Support
1543	Data Proc Equip Operations	Production & Staff Support
1544	Computer Programming	Management & Administration
1546	Data Automation Staff	Production & Staff Support
1550	Audit Staff	Production & Staff Support
1551	Audit Operations	Customer Service
16B1	Military Personnel Flight	Customer Service
16C1	Civilian Personnel Flight	Customer Service
16D1	Social Actions Flight	Management & Administration
16E1	Education Services Flight	Customer Service
16F1	Family Support Center	Customer Service
16G1	Info Management Flight	Management & Administration
16W1	Equal Empl Optn Cnslr	Production & Staff Support
21A0	Logistics Support Squadron	Management & Administration
21A1	Quality Assurance	Production & Staff Support
21B1	Quality Assurance	Industrial Shop
21C1	Maintenance Training Flt	Management & Administration
21D1	Logistics Plans Flt	Management & Administration
21E1	Current Ops - Maintenance	Industrial Shop
22A0	Aircraft Generation Squadron	Industrial Shop
22A1	Maintenance Officer	Management & Administration
22B1	Sortie Generation Flight	Industrial Shop
22C1	Sortie Support Flight	Industrial Shop
23A0	Maintenance Squadron	Management & Administration
23A1	Maintenance Supervisor	Management & Administration
23B1	Fabrication Flight	Industrial Shop
23C1	Propulsion Flight	Industrial Shop
23D1	Accessories Flight	Industrial Shop
23E1	Avionics Flight	Industrial Shop
23F1	Aerospace Ground Equip Flt	Industrial Shop
23G1	Armament Systems Flight	Industrial Shop
23H1	Munitions Flight	Industrial Shop

FAC	TITLE	SIAME, DIME, SIAF Family
23I1	Test Meas & Diagnostic Equip Flt	Industrial Shop
23J1	Maintenance Flight	Industrial Shop
23K1	Combat Munitions Flight	Industrial Shop
24L1	Munitions Depot Flight	Industrial Shop
2400	Avionics Maintenance	Management & Administration
2401	Avionics Maintenance Unit Admin	Management & Administration
2402	Avionics Maintenance Training	Production & Staff Support
2403	Avionics Maintenance Mobility	Customer Service
2404	Avionics Maintenance Supervision	Management & Administration
2405	Avionics Analysis	Production & Staff Support
2500	Munitions Maintenance Mgmt	Management & Administration
2501	Munitions Maint Unit Admin	Management & Administration
2502	Munitions Maintenance Training	Production & Staff Support
2503	Munitions Maintenance Mobility	Customer Service
2504	Munitions Maint Supervision	Management & Administration
2505	Munitions Supply	Customer Service
2507	Munitions Control	Production & Staff Support
2508	Munitions Analysis	Production & Staff Support
2510	Munitions Services	Management & Administration
2511	Weapons Loading	Industrial Shop
2520	Munitions Maintenance/Storage	Management & Administration
2521	Nuclear Maintenance	Industrial Shop
2522	Storage/Handling	Warehouse, Storage & Issue
25A1	Weapons Standards	Production & Staff Support
2800	Ground Launch Missile Maint	Industrial Shop
2910	Ground Support Equip Maint Mgt	Management & Administration
2A01	Unit Admin	Management & Administration
2A02	Training Admin	Management & Administration
2A03	Maintenance Supervision	Management & Administration
2A20	Conventional Avionics	Industrial Shop
2A30	Offensive/Defensive Avionics	Industrial Shop
2A42	B-2 Avionics Test Station	Industrial Shop
2E01	Equip Maintenance Unit Admin	Management & Administration
2E02	Equip Maintenance Training	Management & Administration
2E04	Equip Maintenance Supervision	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
2E13	AGE Pickup/Delivery	Warehouse, Storage & Issue
2E20	Maintenance	Management & Administration
2E30	Munitions	Management & Administration
2E31	Munitions Control	Industrial Shop
2E37	Munitions Supply (FK Account)	Warehouse, Storage & Issue
2E38	Explosive Ordnance Disposal	Industrial Shop
2E39	Munitions Inspection	Industrial Shop
2E3B	Line Delivery	Warehouse, Storage & Issue
2E3C	Material - Production	Management & Administration
2G00	Aircraft Generation	Management & Administration
2G01	Aircraft Generation Unit Admin	Management & Administration
2G02	Aircraft Generation Training	Management & Administration
2G03	Aircraft Generation Mobility	Management & Administration
2G04	Aircraft Gen Maint Supervision	Management & Administration
2G10	Aircraft Maintenance	Management & Administration
2G30	Support	Warehouse, Storage & Issue
2G40	Alert	Industrial Shop
2R00	Component Repair	Management & Administration
2R01	Component Repair Unit Admin	Management & Administration
2R02	Component Repair Training	Management & Administration
2R03	Component Repair Mobility	Management & Administration
2R10	Conventional Avionics	Management & Administration
2R20	Propulsion	Management & Administration
2R30	Accessory Maintenance	Management & Administration
2R90	Aircrew Training Devices	Industrial Shop
3100	Operations	Management & Administration
3101	Operations Unit Admin	Management & Administration
3102	Unit Aircrew Life Support	Industrial Shop
3112	Air Liaison Officer	Management & Administration
31A0	Operations Sq	Management & Administration
31B1	Flight Crews	Industrial Shop
31D1	Operations Data Management	Management & Administration
3201	Visual Info Activity Admin	Management & Administration
3270	Base Level Visual Info Support	Management & Administration
3271	Base Level Visual Info Library	Customer Service

FAC	TITLE	SIAME, DIME, SIAF Family
3272	Base Level Photographic Lab	Customer Service
3274	Base Level Graphic Arts	Customer Service
3275	Visual Info Training Aids	Customer Service
3280	Armament Delivery Recording	Industrial Shop
34A1	Weather Flight	Production & Staff Support
3500	Intelligence Management	Management & Administration
3501	Unit Administration	Management & Administration
3510	Intelligence Operations	Production & Staff Support
3511	Technical Intelligence	Management & Administration
3512	Transmission Activities	Production & Staff Support
3513	Emission Activities	Production & Staff Support
3514	Crypto Activities	Production & Staff Support
3515	Communications Activities	Production & Staff Support
3516	Electronics Activities	Production & Staff Support
3517	Radiation Activities	Production & Staff Support
3518	Electronic Warfare Activities	Production & Staff Support
3519	Radar Activities	Production & Staff Support
3520	Intelligence Collection Mgmt	Management & Administration
3521	COMINT Collection	Production & Staff Support
3522	Electronic Intelligence Collection	Production & Staff Support
3523	Imagery Intelligence Collection	Production & Staff Support
3524	FISINT Collection	Production & Staff Support
3525	Human Intelligence Collection	Production & Staff Support
3530	Intell Proc & Prod Mgmt	Management & Administration
3531	COMINT Processing & Production	Production & Staff Support
3532	ELINT Processing & Production	Production & Staff Support
3533	Imagery Intelligence Production	Production & Staff Support
3534	Frgn Instrumtion SIG INTEL Pro	Production & Staff Support
3535	HUMINT Processing & Production	Production & Staff Support
3536	Intell Library & Doc Repository	Production & Staff Support
3537	IDHS Development	Production & Staff Support
3540	All Source Intell Data Analysis	Production & Staff Support
3541	Intelligence Estimates	Production & Staff Support
3542	Target Intelligence Analysis	Production & Staff Support
3543	Scientific & Technological Analy	Production & Staff Support

FAC	TITLE	SIAME, DIME, SIAF Family
3560	Special Intelligence Operations	Production & Staff Support
3561	Communications Security	Production & Staff Support
3562	Comm Unit Administration	Management & Administration
3563	Precision Photographic Lab	Production & Staff Support
3564	Intelligence Graphics Services	Industrial Shop
35A1	Intelligence Flight	Production & Staff Support
3800	Ground Comm - Elect Activities	Management & Administration
3801	Ground Comm - Electronics Admin	Management & Administration
3802	Comm & Elect Programs Mgmt	Production & Staff Support
3803	Technical Control	Production & Staff Support
3812	Approach Control Tower	Production & Staff Support
3813	Ground Control Approach	Production & Staff Support
3820	Comm - Electronic Operations	Management & Administration
3821	Comm-Electronic Operation	Management & Administration
3854	Teletype/Crypto Terminal Center	Production & Staff Support
3861	Sec Digtl Op Autom Digtl Rly Ctr	Production & Staff Support
3863	Sec Digtl Op Termls - Terml Cntrs	Production & Staff Support
3872	Telephone Operations - TAC PBX	Customer Service
38A0	Communications Squadron	Management & Administration
38A1	Systems Flight	Industrial Shop
38AA	METNAVE Maintenance	Industrial Shop
38AB	ATCALs Maintenance	Industrial Shop
38AC	Ground Radio Maintenance	Industrial Shop
38AG	Secure Comm Maintenance	Industrial Shop
38AH	Telephone Operations	Industrial Shop
38AI	Telephone Outside Maintenance	Industrial Shop
38AJ	Telephone Inside Maintenance	Industrial Shop
38AK	Non-Hard Cable Maintenance	Industrial Shop
38AL	Land Mobile Radio	Industrial Shop
38AM	Systems Support	Industrial Shop
38AS	BISS Maintenance	Industrial Shop
38B1	Support Flt	Management & Administration
38BA	Visual Information	Industrial Shop
38BG	Publishing	Management & Administration
38BH	Reprographics	Production & Staff Support

FAC	TITLE	SIAME, DIME, SIAF Family
38C1	Plan/Implement Flt	Management & Administration
38D1	Information Systems Flight	Management & Administration
38DA	Base Network Cntrl Cntr (BNCC)	Production & Staff Support
38DB	Information Protection	Production & Staff Support
38DC	Administrative Communcations	Management & Administration
38DD	Records Management	Management & Administration
38DE	Customer Training	Customer Service
38DF	Maintenance Control	Management & Administration
38DI	Data Processing Systems	Production & Staff Support
38DJ	Small Computer Sys Element	Production & Staff Support
38DK	Telecomm Center	Production & Staff Support
41A0	Supply Squadron	Management & Administration
41A1	Regional Supply Sq	Production & Staff Support
41B1	MAT STOR/DST FLT (Historical)	Warehouse, Storage & Issue
41C1	MAT MGT FLT (Historical)	Warehouse, Storage & Issue
41D1	Fuels Management Flt	Warehouse, Storage & Issue
41E1	Combat Operations Flt (Historical)	Warehouse, Storage & Issue
41F1	Forward Supply Locations	Warehouse, Storage & Issue
42A0	Transportation Squadron	Management & Administration
42A1	Vehicle Operations Flight	Management & Administration
42A2	Vehicle Operations	Industrial Shop
42B0	Aerial Port Squadron	Management & Administration
42B1	Vehicle Maint Flt	Industrial Shop
42C1	Traffic Mgt Flt	Management & Administration
42D1	Combat Readiness Flight	Production & Staff Support
42D2	Combat Readiness Resources	Production & Staff Support
42E1	Air Passenger Flight	Customer Service
42F1	Fleet Services Flight	Industrial Shop
42G1	Combat Readiness/Resources Flt	Production & Staff Support
42H1	Air Term Ops Ctr	Production & Staff Support
42I1	Air Delivery Flight	Industrial Shop
42J1	Air Freight Flight	Industrial Shop
43A0	Security Police Squadron	Management & Administration
43A1	Stan/Eval	Production & Staff Support
43B1	Admin/Reports Flt	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
43C1	Operations Flt	Industrial Shop
43D1	Training/Resources Flight	Production & Staff Support
43E1	Acquisition Security	Production & Staff Support
44CE	Base Civil Engineer	Management & Administration
44EB	READINESS	Industrial Shop
44EC	Engineering	Production & Staff Support
44ED	Explosive Ordnance Disposal	Industrial Shop
44EF	Fire Protection	Industrial Shop
44EH	Housing	Industrial Shop
44EI	Sci Facil CE Supt	Management & Administration
44EN	Nonstd Unit CE Support	Industrial Shop
44EO	Operations	Industrial Shop
44EP	Acquisition & Liaison CE	Production & Staff Support
44EQ	Contracted CE Support	Industrial Shop
44ER	Resources	Production & Staff Support
44ES	Site/Radar CE Support	Industrial Shop
44ET	Site/Range CE Support	Industrial Shop
44EV	Environmental	Industrial Shop
45A0	MWRS Overhead	Management & Administration
45AA	Staff	Management & Administration
45B0	Resource Management	Production & Staff Support
45C0	Force Management	Production & Staff Support
45D0	Military Support	Management & Administration
45D1	Food Service	Customer Service
45D2	Contract Food	Management & Administration
45D5	Billeting	Customer Service
45D8	Physical Fitness	Customer Service
45D9	Recreation Center	Customer Service
45F0	Youth Programs	Customer Service
45F2	Child Development	Customer Service
45G1	General Libraries	Customer Service
45G4	Arts & Crafts	Customer Service
5100	Medical Command	Management & Administration
5112	Linen Supply	Management & Administration
5130	Medical Personnel	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
5140	Patient Administration	Management & Administration
5141	Inpatient Admin Services	Management & Administration
5142	Ambulatory Care Admin Svcs	Management & Administration
5143	Patient Admin (Clinics)	Customer Service
5144	Central Appointments	Production & Staff Support
5150	Facilities Management	Management & Administration
5200	Clinical Medicine	Medical
5205	Nursing Services	Medical
5206	Medical Surgical Nursing Units	Medical
5207	Obstetrical Nursing Units	Medical
5210	Medical Services	Medical
5211	Internal Medicine	Medical
5212	Respiratory Care	Medical
5214	Neurology	Medical
5215	Dermatology	Medical
5216	Mental Health Services	Medical
5217	Occupational Therapy	Medical
5220	Emergency Services	Medical
5221	Primary Care Clinic	Medical
5222	Emergency Room	Medical
5223	Family Practice	Medical
5224	Primary Care Teams	Medical
5230	Surgery Services	Medical
5231	Neurological Surgery	Medical
5232	Thoracic Surgery	Medical
5233	Urology	Medical
5234	General Surgery	Medical
5235	Ophthalmology	Medical
5236	Otorhinoloryngology	Medical
5237	Plastic Surgery	Medical
5239	Orthopedics	Medical
5240	Surgical Suite	Medical
5242	Anesthesia	Medical
5250	Maternal/Child Care	Medical
5251	Pediatrics	Medical

FAC	TITLE	SIAME, DIME, SIAF Family
5252	Medically Related Services	Medical
5254	Obstetrics and GYN	Medical
5260	Special Care/ICU	Medical
5261	Emergency Svc (Med Cen Only)	Medical
5262	Ambulance Svc (Med Cen Only)	Medical
5270	Physical Exams	Medical
5310	Flight/Missile Medicine	Medical
5311	Bioenvironmental Engineering	Medical
5313	Public Health	Medical
5318	Physical Medicine	Medical
5410	Environmental Health	Medical
5421	Dental Residency	Medical
5422	Dental Lab	Medical
5423	Area Dental Lab	Medical
542X	Dental Services	Medical
5440	Occ & Envmt Hlth Lab	Medical
5511	Histopathology	Medical
5512	Clinical Lab	Medical
5513	Pharmacy	Medical
5514	Radiology	Medical
5515	Nuclear Medicine	Medical
5530	Medical Logistics	Management & Administration
5540	Personnel & Administration	Management & Administration
5560	TRICARE	Management & Administration
5561	Business Ops & Bene Support	Management & Administration
5570	Medical Info Systems	Management & Administration
5610	Aeromed Evacuation Mgmt	Medical
5620	Aeromedical Evacuation Materiel	Medical
5630	Aeromed Evacuation Operations	Medical
5640	Inflight Medical Care	Medical
5660	Aeromed Staging Flt (Mobile)	Medical

13.6.3. Terms and Symbols:

13.6.3.1. The study team must use caution when selecting the DIME. Review the FAC family definitions in paragraphs [13.6.2.1.](#) through [13.6.2.6.](#) and select the DIME that best fits the work center or function being studied. Ensure the standard indirect description reflected in AFMS 00AA

applies. If ANY of the indirect task definition elements are not done, or additional elements are done, a variance must be developed to supplement the DIME. In this case, you must measure this task using the SIAM Task Measurement Instructions reflected on the SIAM Task Data Sheet. These measured man-hours are then added or subtracted, as appropriate, from the results of the DIME application.

13.6.3.2. $Y_{(SIAME)}$ = Indirect man-hours from application of the applicable SIAME.

13.6.3.3. $Y_{(Tot)}$ = Total direct and indirect man-hours. $Y_{(Tot)} = Y_{(Dir)} + Y_{(SIAME)}$

13.6.3.4. Application. The standards development team develops a direct manpower equation, $Y_{(Dir)}$, using measured direct time and an indirect equation, $Y_{(SIAME)}$, using the selected SIAME and the average number of assigned work center personnel as the workload factor. The direct equation results are added to the SIAME results to derive the total monthly man-hours.

13.6.3.4.1. Application Example: Using a notional $Y_{(Dir)} = 300 + 5.6555X$ equation,

$Y_{(Dir)} = 300 + 5.6555X$ (Where $X_{(Dir)}$ = Workload Factor = 250 Vehicles Assigned).

$Y_{(Dir)} = 300 + 5.6555(250) = 1713.88$.

$Y_{(SIAME)} = 270.13 + 9.3033X$ ($X_{(SIAME)}$ = 12 Average Assigned Personnel).

$Y_{(SIAME)} = 270.13 + 9.3033(12) = 381.77$ Indirect Man-Hours

$Y_{(Tot)} = Y_{(Dir)} + Y_{(SIAME)} = Y_{(Tot)}$

$Y_{(Tot)} = 1713.88 + 381.77 = 2095.65$ Total Man-Hours

13.6.4. Using SIAME:

13.6.4.1. The study team must use caution when selecting the SIAME. Review the FAC family definitions in paragraphs 13.6.2.1. through 13.6.2.6. and select the SIAME that best fits the work center or function being studied. Ensure the standard indirect description reflected in AFMS00AA applies. If ANY of the indirect task definition elements are not done, or additional elements are done, a variance must be developed to supplement the SIAME. In this case, you must measure this task using the SIAM task measurement instructions reflected on the SIAM task data sheet. These measured man-hours are then added or subtracted, as appropriate, from the results of the SIAME application.

13.6.4.2. Use logic. If the SIAME allowed time is not representative of what normally occurs in the work center the study team should measure the task using the SIAM task data sheet measurement instructions.

13.7. Direct & Indirect Manpower Equation (DIME)

13.7.1. The DIME is an alternate method of crediting indirect manpower for functions of five or more assigned personnel that has quantified total direct manpower requirements.

13.7.1.1. **Table 13.4.**, Air Force DIME Families, reflects the DIME model for each FAC family.

Table 13.4. AIR FORCE DIME FAMILIES

AIR FORCE DIME FAMILY	DIME
MANAGEMENT & ADMIN	$Y_{(DIME)} = 0.99 + 1.0753X$
PRODUCTION & STAFF SUPPORT	$Y_{(DIME)} = 1.88 + 1.0785X$
CUSTOMER SERVICE	$Y_{(DIME)} = 1.23 + 1.0610X$
MEDICAL	$Y_{(DIME)} = 1.14 + 1.0699X$
WAREHOUSE, STORAGE & ISSUE	$Y_{(DIME)} = 1.48 + 1.0650X$
INDUSTRIAL SHOP	$Y_{(DIME)} = 1.81 + 1.0681X$
NOTES:	
1. $Y_{(DIME)}$ results in total (direct & indirect) manpower.	
2. X = Direct Manpower	
3. Recommended for work centers of five or more assigned personnel.	

13.7.1.2. **Table 13.3.**, SIAME, DIME, & SIAF Listing by FAC, reflects the DIME for each individual FAC.

13.7.2. Terms and Symbols

13.7.2.1. $Y_{(Dir)}$ = Direct manpower from application of a manpower equation and subsequent conversion to a manpower requirement by applying the applicable MAF.

13.7.2.2. $Y_{(DIME)}$ = Total manpower requirement by applying the direct manpower ($Y_{(Dir)}$) in the applicable DIME.

13.7.2.3. Application. Prior to using the DIME model it is necessary to quantify the total functional direct manpower ($Y_{(DIR)}$). This is accomplished by determining the total direct required monthly man-hours for the function and dividing by the appropriate MAF. The study team selects the appropriate DIME ($Y_{(DIME)}$) model (See **Table 13.3.**) and applies direct manpower as the independent variable. The DIME produces the total direct and indirect manpower.

13.7.2.4. Application Example: Using a notional $Y_{(Dir)} = 300 + 5.6555X$ equation,

$$Y_{(Dir)} = 300 + 5.6555X \text{ (Where } X_{(Dir)} = \text{Workload Factor} = 250 \text{ Vehicles Assigned).}$$

$$Y_{(Dir)} = 300 + 5.6555(250) = 1713.88 \text{ Direct Man-Hours.}$$

$$1713.88/149.6 = 11.46 \text{ Direct Manpower}$$

$$Y_{(DIME)} = 1.81 + 1.0681X \text{ (Where } X = \text{Direct Manpower).}$$

$$Y_{(DIME)} = 1.81 + 1.0681(11.46) = 14.05 \text{ Total Functional Manpower Requirement.}$$

13.7.3. Using DIME:

13.8. Capability Based Manpower Determinant (CBMD) Standard Indirect Allowance Factor (SIAF).

13.8.1. The CBMD SIAF is a simple tool that quantifies the incremental indirect man-hours required for each CBMD resource (i.e., Security Forces, Personnel, Medical, etc.).

13.8.2. **Table 13.5.**, Air Force CBMD SIAF Families, reflects the SIAF for each FAC family.

Table 13.5. AIR FORCE CBMD SIAF FAMILIES

CBMD SIAF FAMILY	SIAF
MANAGEMENT & ADMIN	1.0753
PRODUCTION & STAFF SUPPORT	1.0785
CUSTOMER SERVICE	1.0610
MEDICAL	1.0699
WAREHOUSE, STORAGE & ISSUE	1.0650
INDUSTRIAL SHOP	1.0681

NOTES:

1. Multiply the SIAF by the CBMD Direct Man-hours and divide by the applicable MAF to compute the CBMD FTEs.

OR
2. Multiply the CBMD Direct FTE by the SIAF to compute the total CBMD FTE.

OR
3. Multiply the SIAF by the regression coefficients of the CBMD $Y_{(CBMD\ DIR)}$ equation (if available). For example: $Y_{(CBMD\ DIR)} = a + bX$, $Y_{(CBMD\ Total)} = a(SIAF) + b(SIAF)X$. $X =$ CBMD specific workload factor.

13.8.3. **Table 13.3.**, SIAME, DIME, & SIAF Listing by FAC, reflects the SIAF for each individual FAC.

13.8.4. Terms and Symbols

13.8.4.1. CBMD Direct Man-hours = Direct man-hours for each CBMD.

13.8.4.2. SIAF = Standard Indirect Allowance Factor.

13.8.4.3. Application. Application of the SIAF results in the total monthly man-hour requirement which may be converted to a full time equivalent (FTE) by dividing the man-hours by the applicable man-hour availability factor (MAF). The study team selects the appropriate SIAF and applies it to the respective direct man-hours.

13.8.4.4. Application Example: The study team selects the appropriate CBMD SIAF (i.e. Security Forces = SIAF 1.0785, Military Personnel Flight = 1.0610, Emergency Room = SIAF 1.0699) and multiplies it times the CBMD Direct Man-hours, if available. This value is divided by the appropriate MAF to determine the FTE. Sum all FTEs to determine the CBMD total FTE requirement. If the CBMD Direct FTE has been defined, the study team multiplies this value by the respective

SIAF to determine the total CBMD FTE. If a CBMD Direct man-hour equation has been developed, apply the SIAF as reflected in [Table 13.6.](#), CBMD SIAF Application.

Table 13.6. CBMD SIAF Application Example.

A. Multiply the SIAF by the CBMD Direct Man-hours and divide by the applicable MAF to compute the CBMD FTEs.					
CBMD Resources	Direct Monthly Man-hours	SIAF	Total Monthly Man-hours	MAF	CBMD FTEs
Security Forces	1496.00	1.0785	1613.44	149.6	10.79
Civil Engineer	598.40	1.0681	639.15	149.6	4.27
Vehicle Maint	600.50	1.0681	641.39	149.6	4.29
Admin	149.60	1.0753	160.86	149.6	1.08
Storage/Issue	500.60	1.0650	533.14	149.6	3.56
Total CBMD Requirement					23.99
B. Multiply the CBMD Direct FTE by the SIAF to compute the total CBMD FTE.					
CBMD Resources	Direct CBMD FTEs	SIAF			Total CBMD FTEs
Security Forces	10	1.0785			10.79
Civil Engineer	4	1.0681			4.27
Vehicle Maint	4	1.0681			4.27
Admin	1	1.0753			1.08
Storage/Issue	3.35	1.0650			3.57
Total CBMD Requirement					23.98
C. Multiply the SIAF by the regression coefficients of the CBMD $Y_{(CBMD\ DIR)}$ equation (if available). For example: $Y_{(CBMD\ DIR)} = a + bX$, $Y_{(Total)} = a(SIAF) + b(SIAF)$.					
$Y_{(CBMD\ DIR)} = 309.12 + 5.6555X$, $Y_{(Total)} = 309.12(1.0785) + 5.6555(1.0785)X$, $Y_{(Total)} = 333.39 + 6.099X$, Where $X = 210$ widgets, $Y_{(Total)} = 333.39 + 6.099(210)$, $Y_{(Total)} = 1614.18$, CBMD FTE = $1614.18/\text{Applicable MAF} = 1614.18/149.6 = 10.79$ FTE					

13.8.5. Using the CBMD SIAF:

13.8.5.1. The study team must use caution when selecting the CBMD SIAF. Review the FAC family definitions in paragraphs [13.6.2.1.](#) through [13.6.2.6.](#) and select the SIAF that best fits the work center or function being studied. Ensure the standard indirect description reflected in AFMS 00AA applies. If ANY of the indirect task definition elements are not done, or additional elements are done, the SIAF CANNOT be used. You must measure the indirect workload using the SIAM task measurement instructions reflected on the SIAM task data sheet.

13.8.5.2. Use logic. If the SIAF allowed time is not representative of what normally occurs in the CBMD defined environment the study team should measure the task using the SIAM task data sheet measurement instructions.

Chapter 14

TIME STUDY

14.1. General Concepts.

14.1.1. Time study is a work measurement method that records the time a worker takes to do each element of an operation in a specified way. A pace rating factor is applied to the recorded times to adjust them according to the pace of an average worker. The total of the elemental allowed times then gives the standard for the operation.

14.1.2. Time study is used primarily to measure operations that are repetitive, of short duration, and done at one work station.

14.1.3. The purposes of time study are:

14.1.3.1. To analyze the operations and job conditions to improve existing methods.

14.1.3.2. To increase the effectiveness of effort by using only necessary motions.

14.1.3.3. To establish standard conditions for an efficient operation.

14.1.3.4. To set up consistent and fair standards of performance.

14.1.3.5. To furnish reliable data for use in constructing equations and charts.

14.1.4. In addition, use time study to develop elemental standards to synthesize time standards for operations that have the same elements in different combinations. This eliminates the need for remeasurement.

14.1.5. Although few situations meet the time study prerequisites of being both highly standardized and repetitive, the broad use and acceptance of the method, coupled with its accuracy advantages, warrants its consideration. However, if the prerequisites are not met, do not use the method.

14.2. Verification of the Process Oriented Description (POD). The time study method is generally used for some portions of the POD. To do this:

14.2.1. Verify that the portion of the POD to be time-studied is properly designed. Make sure each step describes the operations in the proper sequence with definite beginning and ending points.

14.2.2. Ensure the POD agrees with governing directives and local performance procedures. Significant differences from location to location may cause variances in timing and result in inaccurate values. Resolve any differences before timing operations.

14.3. Wartime Operation Measurement. Time study is not applicable for functions where wartime and peacetime operations differ. Since this technique needs step repetition, the OPR must apply a great amount of effort and expense to duplicate the wartime situation for measurement. Thus, the amount of effort involved may not justify the practicality of this measurement method.

14.4. How to do Time Study.

14.4.1. Set up a system to record daily work counts. If the work center activities do not allow this to be done, record the work unit count as the work is finished. Use production reports, but get enough data to verify them, make valid comparisons, and set an average workload level.

14.4.2. Find the time study method that best fits the work situation to accurately measure the various steps. Two basic ways of reading a watch when doing a time study are the snapback method and continuous method.

14.4.2.1. In the snapback (repetitive) method, record a reading after timing each element, and then reset the watch back to zero.

14.4.2.1.1. Advantages of this method are that it eliminates the need for making subtractions to find element time and that it also facilitates rapid analysis of variations in readings for each element per cycle.

14.4.2.1.2. Disadvantages of this method are that it does not present a clear picture of the sequence in which the elements were done and that the extent and nature of foreign elements as they occur are not always recorded. In addition, unavoidable errors occur due to the time needed to snap the watch back to zero.

14.4.2.2. In the continuous method, the watch runs continuously from the beginning to the end of the study. Record the time at the end of each element.

14.4.2.2.1. An advantage of this method is that every event that occurs is recorded and is traceable back to the actual sequence of occurrence. This makes it easy to handle elements that occur out of normal sequence.

14.4.2.2.2. The disadvantage of this method is that additional time is needed to develop the elemental time.

14.4.2.3. The use of either the snapback or continuous method is at the discretion of the craftsman. However, **Figure 14.1.** displays the various characteristics that contribute to the use of each method and should be taken into account when selecting a particular timing method. For example, when checking a job situation to be timed, use **Figure 14.1.** to select a timing method. If at least six job situation attributes are identified in a timing method, then that method should be favorably considered for use.

Figure 14.1. Timing Methods Attributes.

The suggested timing method to be used is	When the available time study equipment is	and the elements to be timed are	and the study environment
Snapback (Repetitive) Method	- Easy to use - Decimal minute watch	- few in number - long in duration - easy to time - relatively constant occurrence	- is semi-quiet - has good lighting - elements are performed in usually one location - is climate controlled - allows for normal wearing apparel
Continuous Method	- difficult or cumbersome - decimal hour watch	- many in number - short in duration - hard to time - somewhat variable with only minor interruptions	- is crowded or noisy - has uneven lighting or dark areas - elements are performed in several locations in sequence - has a climate variable in nature - requires the wearing of safety equipment

14.4.3. When conducting the study:

14.4.3.1. Identify elements to be timed to make sure that they are recognizable and have obvious beginning and ending points before starting the study. Audible beginning and ending points makes the process easier.

14.4.3.2. Make a sketch showing the equipment used, flow of work, significant distances traveled by the operator, and unusual working conditions.

14.4.3.3. Record stopwatch readings on DD Forms 2042, **Work Measurement Time Study Worksheet (snapback)**; DD Form 2042-1, **Work Measurement Time Study Worksheet (Continuous Method)**; or DD Form 2043, **Work Measurement Project Non-Repetitive Time Study**. The Industrial Engineering Handbook and the commercial texts on motion and time study discuss the various timing techniques that may be used.

14.4.3.4. Take readings for 5 to 20 cycles to find the number of good readings needed.

14.4.3.5. Circle and do not use those readings that are obviously inaccurate because of fumbles, distractions, or changes in methods.

14.4.3.6. Pace rate each timed element. The technician compares the observed pace (speed) of work done to a predetermined normal pace (see paragraph [15.17.2.](#)).

14.5. Determining Sample Size.

14.5.1. Find the number of readings needed after measuring a relatively small number of cycles. Include the first cycle readings as part of the total needed. Observe complete cycles of an operation and take readings on all elements of the cycle. The number of cycle readings needed is the highest number needed for any one element.

14.5.2. [Table 14.1](#). gives instructions to compute the number of samples needed.

Table 14.1. Validating Time Study Samples.

S T	A	B	C
E P	Action	Needed Equation	Example
1	Take readings for five to twenty cycles.	n = number of readings for an element in the cycle.	n = 10
2	Compute summary statistics.	ΣX and ΣX^2	$\Sigma X=1.29$ $\Sigma X^2=0.1673$
3	Compute mean (\bar{X}).	$\bar{X} = \frac{\Sigma X}{n}$	$\bar{X} = \frac{1.29}{10} = 0.129$
4	Compute standard deviation (s^x).	$S_x = \sqrt{\frac{n\Sigma X^2 - [\Sigma X]^2}{n(n-1)}}$	$s_x = \frac{(10)(.1673) - (1.29)^2}{(10)(9)} = 0.00994$
5	Calculate desired accuracy (d).	$d = \pm .10\bar{X}$	$d = 0.10(.129) = 0.0129$
6	Determine confidence factor (z^*) using a t-Table and the number of readings (n).	$z^* = t_{(.975,n-1)}$	$z^* = t_{(.975,9)} = 2.262$
7	Compute the precision (E) obtained with this sample.	$E = \frac{Z^* S^x}{\sqrt{n}}$	$E = \frac{(2.262)(.00994)}{\sqrt{10}}$
8	Make decision: If the precision obtained (E) is less than or equal to the desired accuracy (d), then this sample is good and you can stop here. If not, additional samples are needed. Go to step 9.	none	0.0071 < 0.0129 Therefore, no additional samples are required.
9	Calculate new sample size using values just calculated (z^* , s^x , & d). Obtain additional samples to meet this new size. Repeat the procedures in this Table.	$E = n = \frac{[z^* s_x]^2}{d}$	

14.6. Recording the Study Data.

14.6.1. The DD Form 2042 is designed for using the snapback method of stopwatch time study. This method is normally applied for long-cycle elements or where irregular elements or cycles are prevalent. Use the instructions in [Table 14.2.](#) to complete this form.

Table 14.2. Preparation Instructions For DD Form 2042, Work Measurement Time Study Worksheet (Snapback).

L I N E	A	B	C
	TO COMPLETE		ENTER
	BLOCK	TITLE	
1	1	Drawing Number	Referenced drawing number if applicable, otherwise, N/A.
2	2	Date	Date of study.
3	3	Reference/File/Study Nr	Study file number being referenced, otherwise, N/A.
4	4	Operation	Brief description of operation.
5	5	Organization/Work Center	Name of organization and location. Appropriate work center title and number.
6	6	Work Unit	Unit of count.
7	7	Observer	Grade and name of technician performing study.
8 9	8	Name of Operator/ Operator Number	Name of operator performing operation, if applicable. Employee number, if applicable.
10	9	Machine No./Stock Nr.	Number of machine being studied, if applicable.
11	10	Material	Type of material being used in operation being studied, if applicable.
12	11	Weight	Weight of material used in operation being studied as it affects handling. If weight is negligible, enter N/A.
13	12	Quantity	Quantity of work units completed during study.
14	13	Stop Time	Reading on clock when study is completed.
15	14	Start Time	Reading on clock at start of study.
16	15	Elapsed Time	Block 13 minus Block 14.
17	16	Type of Timing Device	Decimal minute stopwatch.
18	17a	No.	Number of each element in sequential order. Continue on additional forms, if needed.
19	17b	Element Description	Brief description in terms that are indicative of work being performed. Elements represent logical increments of an operation.

L I N E	A	B	C
	TO COMPLETE		ENTER
	BLOCK	TITLE	
20	17c	Readings	Elapsed time per element. Enter leveling factor in block below each reading. Circle disallowed element and show reason in Remarks.
21	17d	Total	Sum of acceptable element readings.
22	17e	Cycle	Number of acceptable readings.
23	17f	AVG or SEL	Average or selected time. Normally Block 17d (total) divided by Block 17e (cycle).
24	17g	Level Factor	Percentage value of leveling factor. Factor equals number of times element occurs divided by number of cycles observed.
25	17h	NOR Time	Block 17f multiplied by Block 17g.
26	17i	Occ	Occurrence factor of the element per operation. Factor equals number of times element occurs divided by number of cycles observed.
27	17j	Base Time	Block 17h multiplied by Block 17i.
28	18	Remarks	Comments to explain special information relating to study.
29	19	Total Base Time	Sum of element base times (Block 17j).
30	20	PF&D Allowance (PR&D is the acronym used in the MEP)	Computed percentage allowance.
31			Time value PR&D percentage factor represents Block 19 multiplied by PR&D allowance factor.
32	21	Standard Time for Minutes	Sum of Block 19 and PR&D time value.
33		Hours	Value in "Minutes Block" divided by 60 (three significant digits).
34		Units	Number of work units standard time per hour represents, 60 mins/hr divided by 0.427 = 140.515
<p>NOTE: An example of a completed DD Form 2042 is located on the AFMIA home page, https://www.afmia.randolph.af.mil. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples.</p>			

14.6.2. The DD Form 2042-1 is designed for using the continuous method of stopwatch time study. Use this method for short-element, short-cycle operations, and for multiperson activities. Run the

stopwatch continuously, recording readings in the R block and the calculated time in the T block. **Table 14.3.** gives instructions for completing a DD Form 2042-1.

Table 14.3. Preparation Instructions For DD Form 2042-1, Work Measurement Time Study Worksheet (Continuous Method).

L I N E	A	B	C
	TO COMPLETE		ENTER
	BLOCK	TITLE	
1	1	Operator Name or Number	Location.
2	2	Element Description	Brief description of each element (continue on additional forms if needed).
3	3	Reference Number	Study number, e.g., work center title and code.
4	4	Date of Study	Date started and completed.
5	5	Name of Analyst	Grade and name of technician performing study.
6	6	Approved (initials and date)	Initials or name of technician's approving supervisor or team chief and date.
7	7	Number	N/A. Indicated number of readings (continue on additional forms if needed).
8		R	Clock time (continuously running). Beginning or ending time of element being timed.
9		T	Element time (calculated after study).
10		P	Pace rating.
11	8	Foreign Elements	
12		S	Reading on clock at start of foreign element.
13		F	Reading on clock at finish of foreign element.
14		T	Element time (F minus S).
15		Description	Brief description of foreign element.
16	9	Total Time	Sum of element times.
17	10	Number of Observations	Number of acceptable readings.
18	11	Avg/Sel	Average or selected time. Normally, Block 9 divided by Block 10.
19	12	Leveling Factor	Percentage value of leveling factor. Factor equals sum of individual element ratings divided by Block 10.
20	13	Normal Time (Leveled Time)	Product of Block 11 (average or selected time) multiplied by Block 12 (leveling factor).
21	14	Occurrence	Occurrence per work unit (number of times element occurs divided by the number of cycles observed).

L I N E	A	B	C
	TO COMPLETE		ENTER
	BLOCK	TITLE	
22	15	Base Time	Product of Block 13 (normal time) multiplied by Block 14 (occurrence per work unit).
23	16	Total Base Time	Sum of element base time (Block 15).
24	17	PF&D Allowance %	Computed allowance.
25		Time	Product of Block 16 multiplied by Block 17 (%).
26	18	Standard Time (minutes)	Sum of Block 16 (total base time) and Block 17 PF&D allowance time).
27	19	Standard Time (Hours) (Allowed Time)	Quotient of Block 18 divided by 60 (three significant digits).
28	20	Work Units	Unit of count.
29	21	Units per Hour (continued on next page)	Quotient of one hour divided by Block 19.
30	22	Start Time	Reading on clock at start of study.
31	23	Stop Time	Reading on clock at completion of study.
32	24	Elapsed Time	Difference of Block 23 minus Block 22.
33	25	Type of Timing Device	Type of watch (decimal minute or decimal hour watch).
34	26	Remarks	Comments to explain abnormalities of study.
<p>NOTE: An example of a completed DD Form 2042-1 is located on the AFMIA home page, https://www.afmia.randolph.af.mil. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples.</p>			

14.6.3. Use the DD Form 2043 for irregular cycle work. The craftsman records the methods description by listing each element as it occurs and uses the continuous watch reading method. Use the form for developing good operator per accomplishment times and for supplementing time study and work sampling measurement methods. Report the derived times on an AF Form 313, **Time Study Record**, or an AF Form 1040. Use the instructions in **Table 14.4.** to complete the DD Form 2043.

Table 14.4. Preparation Instructions For DD Form 2043, Work Measurement Project Non-Repetitive Time Study.

L I N E	A	B	C
	TO COMPLETE		ENTER
	BLOCK	TITLE	
1	1	Study Number	Consecutive number of type of study; or functional account code.
2	2	Operation	Title of operation of task.
3	3	Organization	Code of organization where study of operation is performed or unit designation.
4	4	Part Name and Type	Self-explanatory.
5	5	Stock Number	Federal Stock Number (FSN) of part studied.
6	6	Location	Specific location and installation where study was conducted.
7	7	Machine Number	Number of machine involved in study.
8	8	Control Station Number	Number assigned to station where completed item is checked.
9	9	Operator's Name/Number	Name of employee performing operation, if required.
10	10	Tech Ord/Qual Spec No.	Technical order modification work order, or quality control specifications number.
11	11	Drawing Number	Number assigned to drawing/blueprint, etc.
12	12	Observer	Name of consultant conducting study.
13	13	Material	Material used in making part.
14	14	Weight	Weight of material as it affects handling process.
15	15	Date	Date study completed.
16	16	Type of Timing Device	Self-explanatory.
17	17	Start Time	Clock reading at beginning of study.
18	18	Stop Time	Clock reading at completion of study.
19	19	Elapsed Time	Difference (Block 17 minus Block 18).
20	20a	No.	Consecutive numbers of elements.
21	21b	Element Description	Brief description of element.
22	21c	Readings	Clock time (continuous running).
23	21d	Time	After study, element time. This is the time difference between present element reading and previous reading.
24	21e	Level Factor	Pace rating of the worker as the element is performed.

LINE	A	B	C
	TO COMPLETE		ENTER
	BLOCK	TITLE	
25	21f	Normal Time	Computed time (Column 21d multiplied by column 21e).
26	21g	OCCR Factor	Occurrence(OCCR) factor of the element per operation.
27	21h	Base Time	Column 21f multiplied by column 21g. (continued on next page)
28	22	Remarks	Comments to explain abnormalities of study.
29	23	Total Base Time	Sum of Block 21h.
30	24	PF&D Allowance %	Computed Personal, Rest and Delay Allowance. Time value PR&D percentage factor represents. Block 19 multiplied by PR&D allowance factor.
32	25	Standard Time for Minutes Hours	Sum of Block 23 and PR&D time value. Value in “Minutes Block” divided by 60 (three significant digits).
34	26	Approval	Signature of approving official.
35	27	Date	Date of signature.
NOTE: An example of a completed DD Form 2043 is located on the AFMIA home page, https://www.afmia.randolph.af.mil. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples.			

14.6.4. Use an AF Form 313 to compute and summarize average allowed monthly man-hours for activities measured by time study techniques. Use this form as the sole man-hour reporting document, when time study is the only measurement method used. It is also sent as backup man-hour documentation for time study man-hours reported on the AF Form 308 when time study is a supplemental measurement technique to the primary measurement method. See instructions in **Table 14.5.** for completing the AF Form 313.

Table 14.5. Preparation Instructions For AF Form 313, Time Study Record.

L I N E	A	B	C
	TO COMPLETE		ENTER
	BLOCK	TITLE	
1		Command, Location, Organization Level	Command, location, organization level (base, etc.).
2		Dates	Date the measurement was started and date completed.
3		Function	Appropriate title from AF Data Dictionary.
4		Subfunction/Code	Appropriate title and functional account code (FAC) from AF Data Dictionary
5		Work Center	Appropriate title from AF Data Dictionary. If FAC title does not specifically identify work center, enter a unique descriptive title.
6	A	Category	In ascending order, the numbers of tasks or operation which were time studied.
7	B	Work Unit or Activity	Task or operation description.
8	C	Allowed Unit Time	Total work unit allowed time from DD Forms 2042, 2042-1, or 2043.
9	D	Monthly Production or Frequency	Average production or frequency of occurrence for the task or operation.
10	E	Monthly Allowed Time	Product of Columns C and D.
11	F	Category totals	Total of Column E task entries for a given category.
12		Total Allowed Man-Hours	Sum of all values of Column F.

NOTE: An example of a completed AF Form 313 is located on the AFMIA home page, <https://www.afmia.randolph.af.mil>. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples.

Chapter 15

WORK SAMPLING (WS)

15.1. General Concepts.

15.1.1. WS is a measurement method based on the principle that random samples taken from a large group tend to keep the same distribution characteristics as the group. Conclusions are drawn about the population based on the sample. The WS method relies heavily on input technicians to collect accurate samples and workload information.

15.1.2. The method defines processes, makes observations, computes percentage of occurrence for each process, and applies these percentages to man-hours sampled.

15.2. Wartime Operation Measurement. The WS method has limited application for a wartime environment because of the time needed to successfully do a measurement of this type. Another drawback is that if peacetime data, measured by WS, is converted to wartime values, consistency between peacetime and wartime policy and procedures must be assumed. Conversion in this instance is limited to workload and the MAF only. The most likely arena for WS in a wartime operation is a realistic and representative exercise or operational readiness inspection.

15.3. Applying WS.

15.3.1. WS is commonly used to determine equipment utilization; analyze work distribution; conduct methods improvement studies; and compute and verify personal, rest, and delay (PR&D) allowances. WS is most effective when work centers have:

15.3.1.1. Nonrepetitive or irregular work.

15.3.1.2. Many different processes of work.

15.3.1.3. Many workers in a relatively small area.

15.3.2. Take care when identifying work centers to be sampled. Historically, work centers requiring product analysis, closed-session counseling, or creative thinking have been difficult to sample. For these work centers, consider using productive and nonproductive sampling (see paragraph 15.21.1.). Some office work is difficult to quantify by WS because the work is not cyclical or is completed over a long period of time. Also, work cycles may be variable because of the many different products.

15.4. Economic Desirability of WS.

15.4.1. The economic desirability of WS increases with the number of people being sampled. Each measurement technician should measure a minimum of five workers where possible; however, those being sampled may be assigned to more than one work center, for example, family of standards. Generally, measure a work center with two or less people by OA unless it is necessary to observe standby time or the need for an assistant. When several input points have four or less people to be measured, it is not economical to conduct a WS study.

15.4.2. The measurement work force should consist of personnel who spend most of their available time in a place that allows for observation of work. Account for work done away from the immediate work center for extended periods of time as follows:

15.4.2.1. Arrange for a measurement technician to observe the worker at the out-of-area location.

15.4.2.2. Sample this time as out-of-area and OA this time if it is not feasible to observe the worker. Account for out-of-area samples by applicable process on the daily observation sheet. However, do not transfer these samples to the AF Form 1111, **Work Sampling Record**. Merge out-of-area time later with WS time on the AF Form 308. For multipoint standards, study teams furnish guidance in the measurement plan for treatment of these samples.

15.4.2.3. Do not plan for more observations than a technician can do in a reasonable period. Giving the measuring technician too many personnel or too many work centers may not allow timely observations and may bias the sampling data. Conversely, giving the measuring technician too few personnel is not economically feasible.

15.5. Briefings for WS.

15.5.1. Study Inbriefing. Make sure the work center supervisor and workers fully understand the principle of WS during the inbriefing. Because its statistical basis makes WS difficult to understand, use illustrations without technical terms. Use simple explanations to eliminate confusion and allow work center personnel to understand the WS principle. Some examples of situations similar in principle to WS are: testing antifreeze in a car radiator, taking blood samples, or trying one package of cigarettes before buying a carton. Since all of these actions represent the source from which they come, the opinions formed from the samples are valid for the whole product. Explain during inbriefing that WS daily observation sheets are to be treated confidentially and not shown to supervisors or managers. Sampling data must never be used by superiors to evaluate individuals.

15.5.2. Study Outbriefing. Summarize process percentages of occurrence for presentation during out-briefings. A pie chart is a convenient way to graphically present this information. Brief local OPRs on measured man-hours and workload factor values. Cover the treatment of assumed and inferred work. Tell local OPRs measurement results do not represent the final standard. The study team does C&R analysis and computes the final standard using data from measurement points.

15.6. WS Process Development.

15.6.1. Write the Process Oriented Description (POD) for WS at the same level as for OA, or write it at the broader process level. Study teams may derive step times by using the percentage estimates described in paragraph 15.21. In either case, write the POD to facilitate observation during sampling. Make sure processes in the POD cover all required work, and are clearly distinctive, yet mutually exclusive.

15.6.2. Select processes for both direct and indirect work. Further define the process by using steps. Each step must be discrete and understandable to the observer. Failure to clearly define processes distorts process percentages and later makes analysis and standard maintenance difficult.

15.6.3. WS studies identify time spent in available and nonavailable activities. Available time is broadly classified as productive (direct and indirect) and nonproductive. Examples of nonavailable activities are: leave, medical absences, TDY for training, and additional duties. Additional processes for management information such as additional duties may be described and measured during WS.

15.6.4. Nonproductive categories, for sampling purposes, are personal and rest, idle (extended lunch) and unavoidable delay. Other nonproductive categories may be added when needed, for example, assumed and inferred. Do not use other and miscellaneous for nonproductive category titles as they

become catchalls during WS studies. Usually, productive indirect and nonproductive activities are sampled at the category level. Data collected for these categories is useful when outbriefing WS results. Treatment of lunch and unscheduled time is described in these paragraphs.

15.6.4.1. Sample lunch to account for productive time expended during the lunch period and to account for nonproductive time taken for an extended lunch. Sampling of lunch eases the accounting of samples at the end of each sampling day. Be cautious when selecting random times and making observations during the lunch period. Incorrect accounting of lunch samples affects other process percentages. Study teams give specific guidance on treatment of lunch observations in the measurement plan. This example illustrates the need for caution: Assume three observations per hour are being taken and the lunch period for half the work center is 1100 to 1200. Assume the other half takes lunch from 1200 to 1300. Select random times so that three observations occur between 1100 and 1200 and three occur between 1200 and 1300. The sampling technician normally records three samples for lunch for each worker. However, if worker A (from the first group) was working at 1145 (observation time) and did not take his or her full lunch hour, then one productive sample and two lunch samples would be recorded. On the other hand, if worker B (from the second group) left for lunch at his or her regular time and was still on lunch break at 1310 (observation time), then three lunch samples and one idle or extended lunch sample would be recorded for worker B. If lunch periods are staggered or workers do not take scheduled lunch breaks, this example is inappropriate. In this case, sample lunch cautiously and check the percentage of lunch samples daily and at the end of the study to verify representativeness.

15.6.4.2. An unscheduled (U) category is useful for keeping accountability of samples. Use this category when:

15.6.4.2.1. Shift changes are staggered during a multi-shift operation.

15.6.4.2.2. Workers are doing required work before the beginning or after the end of a scheduled shift.

15.7. POD Verification. As part of the verification process, accomplish the following:

15.7.1. Investigate the operation of the work center thoroughly before beginning the study. Check organizational structure, mission requirements, directives, and other pertinent factors such as backlogs, work cycles, and historical production.

15.7.2. Review the POD. Contact the study team for guidance if steps are found that are not in the approved POD. Measure such steps separately. The study team, in cooperation with the OPR during data analysis, makes the final decision to include or disallow these steps in the manpower standard. If the study team determines the added steps apply to all work centers, the POD is changed.

15.8. Work Counts (Work Units and Potential WLFs). Man-hours collected during WS studies represent only one part of the data needed to compute an equation. The other part is work counts. Set up a work count system to record workload on a daily basis. If work counts are not completed daily, then record them as frequently as the work is completed. Use a production report if it is available, but make periodic checks to make sure of its accuracy. Make sure the period of the production report corresponds with the study period. Pay particular attention to recording correct values for work started before the study and work continuing after the study. Do not include work unit counts for days sampled but dropped from computations for nonrepresentativeness. Adjust the average daily work counts to an average monthly figure.

Use this figure as the independent variable for the standard man-hour equation. Use total monthly-allowed man-hours as the dependent variable. An exception to this procedure is allowed when the potential WLF is nonproduction oriented. For example, population serviced may be relatively constant on a daily, weekly, or monthly basis. In this case, use population serviced as reported for the time frame closest to the WS period for the dependent variable.

15.9. Determining Sampling Period.

15.9.1. Sample at least one complete cycle during the measurement period. The normal sampling period is 21 days (minimum of 15 usable days). When necessary, extend the sampling period to make sure it covers a complete cycle.

15.9.2. Conduct WS over a representative period or work cycle. Ideally, use WS when a normal period of productivity is to be measured and when reliable work units are available. When a work cycle is longer than a month, the study team decides the feasibility of using WS. Also, if several individuals in a small work center are on leave during the sampling period, this may affect representativeness. In a 7-day work center, be sure to keep a representative proportion between weekend days and weekdays during the sampling period. For example, when 21 usable days are needed, six of those days should be weekend days.

15.9.3. Use the experience of work center personnel to set up an average work cycle to pinpoint recurring periods of heavy productivity. Plotting these cycles against a time scale may reveal a pattern and its composite effect on the work center.

15.10. Supplementing WS with OA.

15.10.1. During a WS study, take samples for a process previously identified for measurement by OA. When this occurs, keep sample accountability on the AF Form 1152, **Daily Work Sampling Observation**, but do not record samples on the AF Form 1111. Measure the process by OA on AF Form 1040 and transfer this time to the AF Form 308 along with the monthly-allowed man-hours from WS.

15.10.2. The study team evaluates the supplemental OA for nonroutine work based on total review of OA work. No adjustment is needed for nonroutine work if the sampling period is considered representative. Study teams give special instructions to identify and report cyclical work that occurs less frequently than monthly (for example, quarterly or annually). A representative sample period reduces the need for OA.

15.10.3. Input team members must be cautious and realize that there is a difference between work not occurring during the sampling period and work not observed. If a particular step was done but was not observed due to the randomness of the observation schedule, do not add OA time for the step. OA only those nonroutine required steps that occur less frequently than monthly. Be particularly careful when supplementing WS data for indirect tasks. For example, preparing annual reports may be a wash item since daily or monthly reports normally feed into annual reports and the samples may have captured a normal amount of time for report preparations. Study teams identify reports and meetings along with sampling instructions in the measurement plan. When level I sampling is being used (productive and nonproductive), a supplemental OA for indirect tasks is not needed.

15.11. Man-Hour Population. The man-hour population (sampled man-hours) for accounting purposes consists of man-hours for available, nonavailable, borrowed, lunch, and overtime. It excludes loaned man-hours. For computational purposes, the man-hour population excludes nonavailable time. This allows for the complete accounting of time with no degradation of accuracy and percentage of occurrences.

15.12. Observation Schedule Development.

15.12.1. The purpose of sampling is to supply information about the population. Characteristics discovered in the sample are expected to exist in the population from which the sample is taken. The key to unbiased sampling is randomness of the sample. Several methods are available to ensure randomness. Two are discussed here.

15.12.1.1. Random numbers tables. Randomly pick a starting point in a random numbers table. Proceed horizontally, diagonally, or vertically and record the one-digit, two-digit, or three-digit numbers as they appear. Disregard numbers outside the needed range. For example, if you need two-digit random numbers ranging from 00 through 59, then disregard the two-digit numbers greater than 59. If a number appears again after it has previously been recorded for use within a particular strata (hour or day), ignore its later appearance. This ensures consistency with sampling without replacement. If it takes five minutes to make an observation round, disregard numbers within five-minute increments of each other. Continue selecting numbers until you reach the desired sample size.

15.12.1.2. Random numbers from computers. When a computer is available, get a series of numbers with the needed number of digits. Treat this series the same as with the random numbers table.

15.12.2. Sampling period, work center operating hours and locations, desired accuracy, and number of people assigned determine the number of observation rounds needed for each work center during a WS study. A sample is a single recorded status of one person during an observation of a work center. An observation yields a number of samples equal to the number of people observed. For example, an observation made at 1015 in a seven-man work center yields seven samples. Set up the observation schedule to get no fewer than 1111 available samples (excluding lunch) in each work center. This number ensures accuracy in all available processes and eliminates the need to estimate the number of samples needed when conducting a mini-study. Before sampling, consult the work center supervisor regarding scheduled nonavailable activities such as leave, medical absences, or TDY.

15.12.3. Input teams determine the observation schedule. Study teams determine the cycle, the days to sample, and the strata to use (for example, stratified hourly or stratified daily random sampling). Take care when setting up the observation schedule. Taking less than 1111 samples might cause the study to fail statistical accuracy. If this happens, extend the measurement period through the next cycle. Taking too many samples may cause an excessive number of technicians to be used for measurement, thereby increasing the cost of the study.

15.12.4. Input teams select observation times so that the number of samples taken per individual per day remains constant. An exception to this rule may occur when an individual is borrowed or loaned, works overtime, is newly assigned, or departs the work center for PCS during the duty day.

15.12.5. When an observation schedule cannot be met because locations are widely dispersed, set up a randomized location schedule. A randomized location schedule is similar to a randomized time

schedule, however, instead of listing observation times on tickets or cards, write the title of each location on tickets or cards. Draw cards randomly from a hat or box, record locations in the order drawn, replace the cards in the box, and then repeat the draw a second, third time, etc. Next, visit each location in the order recorded. Begin sampling at the start of the normal duty day and continue until the end of the normal duty day. Move from one location to another in the order previously recorded, but on no prescribed schedule. Sample the location on arrival. Follow the recorded order until you have enough samples to achieve accuracy, a complete cycle is sampled, and the minimum sampling period is covered. Operationally audit overtime when this method is used.

15.12.6. Often it is desirable to make sure each hour of the day has equal representation in the sample. In work centers where activity fluctuates hourly, use stratified sampling. In this procedure, determine the number of observations needed per hour and randomly select observations within the hour. Once sampling begins, input technicians must consistently follow the predetermined schedule per hour until completion of the sampling period. Make sure that the number of observation times for lunch are representative before sampling. This example illustrates how to determine the number of observations needed per hour.

15.12.6.1. Assume a work center size of seven people and a sampling period of 21 work days.

15.12.6.2. One observation of seven people per hour, assigned for an 8-hour day over a 21-day period, yields 1176 samples ($1 \times 7 \times 8 \times 21 = 1176$). This meets the minimum requirement of 1111 available samples. However, if normal nonavailability (13.5%) occurs during the study, then only 86.5% of 1176 (or 1017 available samples) would be obtained. Therefore, increase the minimum number of observations per hour to two. Increasing the number of observations per hour above the minimum improves study accuracy and reduces the technicians' slack time. Make allowances for loaned time when setting up observation schedules.

15.13. Man-Hour Shift Profile Sampling.

15.13.1. The purpose of the man-hour shift profile chart is to reduce standby. When minimum manpower is not clearly defined and it is not possible to accurately sample standby, construct a present and proposed man-hour shift profile chart. Use the proposed chart to support the standby time allowed in the standard. Also, use the chart to graphically support reduced standby to the OPR.

15.13.2. When collecting WS data to build the man-hour shift profile chart:

15.13.2.1. Use stratified hourly sampling.

15.13.2.2. Designate each productive process as transferable or nontransferable.

15.13.2.3. Construct the present man-hour shift profile chart directly from information on the daily observation and recapitulation sheets.

15.13.2.4. Construct the proposed chart by analyzing and improving the present chart (**Chapter 7** tells how to construct man-hour shift profile charts).

15.14. WS Procedures.

15.14.1. Make observations at scheduled times without distracting workers. Enter the work center as inconspicuously as possible. Sometimes it is best to remain in the work center between closely spaced observations because distractions caused by entering could bias samples.

15.14.2. Classify the sample instantaneously so that each sample is the result of an immediate observation. When it is not possible to identify the proper process, classify the sample as productive or non-productive and reconcile it later. The workers' activity immediately before or after the scheduled observation may give a clue to proper classification.

15.14.3. Conduct familiarization or trial sampling to reduce the number of questions during observation rounds. When possible, wear apparel similar to that of personnel in the work center being sampled. Likeness in clothing causes the sampling technician to blend with work center personnel and helps reduce apprehension due to the study. Avoid unnecessary conversation, but be friendly and answer questions regarding the study.

15.14.4. Properly classify personal, rest, unavoidable delay, standby, and idle time. Accurate identification gives rationale for using the fixed allowance factor or for proving a larger factor that includes additional rest or delay. The technician should also be alert to assumed work (make work) or inferred work during sampling. Although the measurement plan should identify potential areas for assumed and inferred work, the key to proper identification is the technician's familiarity with the work center. Identify inferred and assumed work separately on the AF Form 1152. Later, credit inferred work to the proper work center or remove it from allowed man-hours. Always remove assumed work from allowed man-hours.

15.14.5. Sample pre-duty and post-duty periods. The measurement technician should be in the work center when the first worker arrives and stay until the last worker departs. When a worker is present during pre-duty or post-duty periods, but is not productive, sample the worker as unscheduled (U) and exclude from sample man-hour computation. A productive sample during this period increases the number of samples per person per day and is equivalent to sampled overtime.

15.14.6. Follow the same measurement technique for all standard input locations. For example, when WS is the primary measurement method, all inputs use WS. An exception is allowed when the work center has two or less people (see paragraph 15.4.1.). When OA is specified for one process, all inputs OA that process. Also, when stratified sampling is specified, all inputs stratify. When work center personnel stagger lunch periods, use stratified, hourly sampling to make sure lunch samples are representative.

15.14.7. Avoid sampling at the lower task levels unless these tasks are easily identifiable by observation. Sampling a large number of steps increases the time needed to make an observation round and results in a need for more sampling technicians. Sampling at the step level disrupts work center personnel because questions need to be asked to properly classify samples.

15.14.8. Between samples, study technicians accomplish daily accumulations, compute control chart limits, collect work units or potential WLFs, conduct OAs, observe personnel who might be working out-of-area, and investigate process improvement opportunities.

15.14.9. Treat standby time during sampling according to [Chapter 7](#).

15.14.10. Study technicians should be able to recognize all the workers, their duty schedule and lunch period, and the work they do. Study technicians should also be familiar with the layout and boundaries of the work center.

15.14.11. Record irregularities during WS in the remarks block or on the reverse side of the AF Form 1152. These comments may explain variations that occur during measurement. List irregularities as

soon as practical after their occurrence. Devise coding systems to expedite sampling and facilitate recall. Use mutually agreed-on codes when more than one technician is involved in the study.

15.15. Daily Work Sampling Observation Form and Recapitulation Form Development.

15.15.1. Use AF Form 1152 to record samples during observation rounds. Prepare enough forms in advance to accommodate the entire sampling period. Completed AF Forms 1152 and AF Forms 1157 will be furnished to the study team if requested in the measurement plan.

15.15.2. Procedures for preparing and completing the AF Form 1152 are standardized. The format allows flexibility for tailoring observations to specific work centers. For example, columns are furnished to record observation times and rows are furnished to record names or codes, ratings, and daily process totals. When additional columns or rows are needed, input teams may use a general-purpose form for recording observations. [Table 15.1](#) tells how to prepare and complete the AF Form 1152.

Table 15.1. How to Prepare AF Form 1152, Daily Work Sampling Observation (See Notes).

Box	Enter
1	Sampling date (day, month, and year).
2	Sampling day.
3	Work center title and functional account code.
4	Observer's name.
5	Normal hours of operation of the work center.
6	Names or codes for work center personnel. Enter the sample process number (letters for indirect tasks) opposite the worker's name and in the column corresponding to the observation time. When rating observations, enter the word "Rating" below each person's name or code. Enter specific ratings (minimum of 25% of the observations for each ratable process) below the sample and on the line titled "Rating."
7	Scheduled, random observation times
8	Each worker's daily total number of samples. This total should be the same for each worker unless the worker is: (a) On loan to another work center. (b) Borrowed from another work center. (c) Working overtime. (d) Departing the work center PCS. (e) Reporting to the work center for assignment. NOTE: Sub-paragraphs (d) and (e) refer to time an individual is carried in the transient account. They do not refer to nonavailable time for in- or out-processing.
9	Total number of samples of each observation time.
10	Grand total. The sum of the totals in column 8 and the sum of the totals on line 9 must be equal.
NOTES:	
<ol style="list-style-type: none"> Sample indirect, nonproductive, and nonavailable categories by using alpha codes. These codes are easily memorized and need not be recorded on the observation sheet until category accumulation is done at the end of the sampling day or the following day. Sample direct processes by number. Place the direct process title and number (if needed) on the observation sheet for reference during the sampling period. An example of a completed AF Form 1152 is located on the AFMIA home page, https://www.afmia.randolph.af.mil. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples. 	

15.15.3. Use the AF Form 1157 to recap daily observations so:

15.15.3.1. An orderly transition to the AF Form 1111 can be made.

15.15.3.2. A man-hour shift profile chart can be constructed when needed.

15.15.3.3. WS data can be control charted.

15.15.4. **Table 15.2.** tells how to transfer data from the AF Form 1152 and complete the AF Form 1157. Use four forms to accumulate 21 days of WS data.

Table 15.2. How to Prepare AF Form 1157, Work Sampling Recapitulation.

Box	Enter
1	Work center title and functional account code.
2	Command and base name.
3	Direct process titles or number.
3A	Sampling day "1" on the first page of the recapitulation. Four pages are required to accumulate 21 days of WS data. Enter "6 CUM" on page two, "11 CUM" on page three, and "16 CUM" on page four. For page one, enter the number of direct process samples in column 3A. For pages two, three, and four, respectively, transfer the number of samples (column 3K) for 6 CUM, 11 CUM, and 16 CUM, to column 3A.
3B	Sampling day "2, 7, 12, and 17" respectively, on pages one through four. In column 3B, enter the number of direct process samples.
3C	Cumulative totals in this column.
3D	Sampling day "3, 8, 13, and 18" respectively, for pages one through four. In column 3D, enter the number of direct process samples.
3E	Cumulative totals in this column.
3F	Sampling day "4, 9, 14, and 19" respectively, for pages One through four. In column 3F, enter the number of direct process samples.
3G	Cumulative totals in this column.
3H	Sampling day "5, 10, 15, and 20" respectively, for pages one through four. In column 3H, enter the number of direct process samples.
3I	Cumulative totals in this column.
3J	Sampling day "6, 11, 16, and 21" respectively, for pages one through four. In columns 3J, enter the number of direct process samples.
3K	Cumulative totals in this column. These totals can be transferred directly from the last recapitulation page to the AF Form 1111.
4	Totals for columns 3A through 3K.
5	Direct category percentages for blocks A (first page only), B, D, F, H, and J. These percentages are computed by dividing productive direct samples by available samples for each sampling day. Productive direct process percentages may be used for daily control charting. Enter indirect category samples and cumulative samples in columns 5A through 5K in a similar manner as was done for columns 3A through 3K.
6	Totals for columns 5A through 5K.

Box	Enter
7	Indirect category percentages for blocks A (first page only), B, D, F, H, and J. These percentages are computed by dividing productive indirect samples by available samples for each sampling day.
8	Sum of the direct and indirect samples and sum of the direct and indirect, cumulative samples in blocks A through K.
9	Productive percentages in blocks A (first page only) B, D, F, H, and J. These percentages are computed by dividing total productive samples by available samples for each sampling day. These percentages may be transferred directly to the front side of the AF Form 1111.
10-13	Nonproductive samples in blocks A (first page only), B, D, F, H, and J. Enter cumulative nonproductive samples in blocks A (pages two, three, and four), C, E, G, I, and K.
14	Total nonproductive samples in blocks A (first page only), B, D, F, H, and J. Enter cumulative nonproductive samples in blocks A (pages two, three, and four), C, E, G, I, and K.
15	Total available samples in blocks A (first page only), B, D, F, H, and J. Enter cumulative available samples in blocks A (pages two, three and four), C, E, G, I, and K.
16	Total lunch samples in blocks A (first page only), B, D, F, H, and J. Enter cumulative lunch samples for each sampling day in blocks A (pages two, three, and four), C, E, G, I, and K.
1	Work center title and functional account code.
2	Command and base name.
3	Direct process titles or number.
17	Total nonavailable samples in blocks A (first page only), B, D, F, H, and J. Enter cumulative nonavailable samples in blocks A (pages two, three, and four) C, E, G, I, and K.
18	Total samples in blocks A (first page only), B, D, F, H, and J. Enter cumulative samples in blocks A (pages two, three, and four), C, E, G, I, and K. The total samples should equal or exceed the assigned man-hours (Box 19) multiplied by the number of samples taken per hour (sampling rate).
19	Assigned man-hours in blocks A (first page only), B, D, F, H, and J. Compute assigned man-hours by multiplying the number of hours in the normal duty day by the number of personnel sampled. For example, if the duty day is 8 hours plus 45 minutes for lunch, then multiply the number of personnel sampled by 8.75 hours.
20	Sampled time in blocks A (first page only), B, D, F, H, and J. Enter cumulative sampled time in blocks A (pages two, three, and four), C, E, G, I, and K. Compute sampled time by multiplying available samples (line 15) by the relative weight of each sample. The relative weight is obtained for: <ul style="list-style-type: none"> a. Stratified hourly sampling: Divide "one" by the number of observation rounds per hour. b. Stratified daily sampling and random location sampling. Divide "eight" by the number of observation rounds per day.
<p>NOTE: An example of a completed AF Form 1157 is located on the AFMIA home page, https://www.afmia.randolph.af.mil. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples.</p>	

15.16. Confidentiality of WS Data. Daily WS observation data is considered sensitive information and is not releasable by name. These practices may be followed to maintain confidentiality.

15.16.1. Cut out personnel names and identification on the AF Form 1152 after the samples have been totaled. As an alternative, black out names and make a copy.

15.16.2. Use codes for identification in lieu of names.

15.16.3. Devise a code for idle and sensitive processes. Use codes familiar to other technicians. Memorize codes for productive indirect and nonproductive categories and omit the legend on the form.

15.16.4. Place a sheet of bond paper over the form while sampling.

15.17. WS Data Leveling.

15.17.1. Pace rating is used to determine a leveling factor. The leveling factor is used to adjust productive time to a norm. Many processes do not lend themselves to rating, for example, supervision and mental work. Also, the technician must be proficient with rating and familiar with the job to rate effectively. The nature of selecting inputs from a cross section of installations, coupled with the standard development process of using least squares regression, helps ensure the norm. Pace rating for WS studies is a study team option. If pace rating is used, the study team specifies the pace rating range in the measurement plan. Rate at least 25 percent of the process observations for ratable processes. If pace rating is not used, the leveling factor is 1.00. Procedures described in these paragraphs may be amplified in the measurement plan.

15.17.2. In pace rating, the technician compares the observed pace (speed) of work done to a predetermined normal pace. He or she then considers the difficulty of each step and mentally adjusts to allow for inherent job difficulties. Use unity (1.00) as the numerical value for the normal pace, and give all ratings a value in relation to 1. For example, the technician may give a rating of .95 to a certain observation. This rating shows that, at the time the worker was observed, he or she was doing at a speed five percent SLOWER than normal for the observed activity. Conversely, a rating of 1.05 shows the worker was doing at a speed five percent FASTER than normal.

15.17.3. The terms pace rating and performance rating are used interchangeably in the MEP. Averaging these ratings for individual workers results in a leveling factor that is applied to productive time. Leveling is limited to the observed activity. In the MEP, it is used only in WS and time study.

15.17.4. To be pace rated, the job must be repetitive and production oriented (producing an end product). The concept of normal pace can then be compared to a greater or lesser pace.

15.17.5. Pace rating results in a number of separate ratings. At the end of the study, find the average of these ratings (leveling factor) and use this average to figure leveled time. This example shows the computation of a leveling factor from six separate pace rating values.

Leveling Factor Computation

Rating No. Pace Rating (R)

1	.95
2	.90
3	.95
4	1.05
5	.90
6	<u>.95</u>
ΣR	= 5.70

$$\bar{R} = \Sigma R \div N = 5.70 \div 6 = .95$$

15.18. Allowance Factor Computation.

15.18.1. Allowances are computed to recognize personal, rest, and unavoidable delay (PR&D). Use a fixed allowance factor when PR&D do not vary considerably between processes of work. A standard fixed allowance factor for personal and rest based on two 15-minute breaks per day is considered realistic and liberal for most work centers. The standard fixed allowance factor is 1.067 when computed per paragraph 15.18.3. Additional allowance is authorized for work centers that justify additional rest or unavoidable delay. Furnish full justification and computation in the final report when the allowance factor exceeds the standard fixed allowance.

15.18.2. Allowances are applied at the process level for WS studies. When the fixed allowance factor is used for the work center, apply it to all productive, leveled processes. When a larger allowance factor is computed, apply it only to the affected process. Use the fixed allowance factor for the remaining productive processes. Following are two ways for determining allowance factors (in priority order):

15.18.2.1. The study team determines whether the fixed factor is pertinent. If it isn't, the study team computes the allowance factor according to paragraph 15.18.3.. The allowance factor, fixed or computed, is evaluated during test measurement and then coordinated with the OPR. The coordinated allowance factor is then put in the measurement plan for all input locations to use. Input locations that do not use the allowance factor supplied by the study team must furnish full justification and computation for the factor used in their measurement reports.

15.18.2.2. Input locations determine their own allowance factor and furnish rationale and computation in their measurement reports.

15.18.3. Compute the allowance factor for PR&D with the equation:

$$AF = \frac{100\%}{100\% - PR\&D\%}, \text{ where percentages are expressed in terms of the total workday.}$$

Example 1. Compute the fixed allowance factor for 30 minutes personal and rest (P&R) as follows:

$$P\&R = \frac{30 \text{ min}}{480 \text{ min}} = 6.25\%, \text{ where 480 equals the number of minutes in an 8-hour duty day, and the}$$

$$\text{Allowance Factor} = \frac{100}{100 - 6.25} = 1.067.$$

Example 2. Compute an allowance factor when 20 additional minutes of delay per day is justified for one process.

$$PR\&D = \frac{30 + 20}{480} = 10.42\%,$$

$$\text{Allowance Factor} = \frac{100}{100 - 10.42} = 1.116.$$

15.19. How to Complete AF Form 1111. Transfer WS results from the AF Form 1157 to the AF Form 1111. **Table 15.3.** has instructions on how to fill out an AF Form 1111. AF Forms 1111 sent with measurement reports can be computerized, typed, or handwritten. Use continuous calculations when manually completing the AF Form 1111. Make sure handwritten forms are neat and legible when sent in with measurement reports. Study teams and input teams should always give read permissions when using computerized data.

Table 15.3. How To Prepare AF Form 1111, Work Sampling Record.

Box	Enter
1	Work center title and functional account code.
2	Command and name of installation.
3B	The calendar day, month, and year for each sampling day, for example, 18 Jun 88.
3C	Man-hours sampled for each sampling day, from line 20 of the WS recapitulation sheets.
3D	Available samples for each sampling day, from line 15 of the WS recapitulation sheets.
3E	Productive samples for each sampling day, from line 8 of the WS recapitulation sheets.
3F	Percent of occurrence for each sampling day, from line 9 of the WS recapitulation sheets.
3G	Average daily leveling factor for each sampling day, when rating is done. Otherwise enter "1.00."
4C	Sum of column C. This sum should agree with line 20 of the last WS recapitulation sheet.
4D	Sum of column D. This sum should agree with line 15 of the last WS recapitulation sheet.
4E	Sum of column E. This sum should agree with line 8 of the last WS recapitulation sheet.
4F	Lower and upper control limits. Compute these limits according to Table 15.5 . Circle percentages in column F which lie outside the control limits. If the sampling day outside the control limits is not used in the AF Form 1111 computations, line through that day (all columns) and leave it on the form. Explain in the measurement report why days outside the control limits are considered representative or nonrepresentative.
4G	Sum of column G.
5C	Average man-hours sampled by dividing block 4C by the number of sampling days in the study.
5D	Average available samples by dividing block 4D by the number of sampling days in the study.
5F	Average percentage of occurrence in three decimal places by dividing block 4E by block 4D.
5G	Average leveling factor by dividing block 4G by the number of sampling days.
6A	Productive direct and indirect category titles.
6B	Total samples recorded for each productive category from the last page of the recapitulation sheet. Exclude samples for days not used in the study.
7B	Total productive samples (sum of column 6B). This sum should agree with line 8 on the last recapitulation sheet.
8B	Total samples recorded for each nonproductive category from the recapitulation sheet. Enter nonavailable and lunch samples in parenthesis.
9B	The sum of total available samples (7B plus column 8B). Do not add samples in parentheses in this total. (continued on next page)

Box	Enter
6C 7C & 8C	<p>Percents of occurrences to three decimal places. Compute each percentage as the quotient of the number of samples in a given category divided by the total available samples (box 9B).</p> <p>Compute the percentage of nonavailable using the following relationship.</p> $P = \frac{\text{nonavailable}}{\text{Nonavailable} + \text{available}} = \frac{310}{310 + 2814} = .099.$ <p>Compute the percentages for lunch in the same manner, as follows:</p> $\frac{360}{360 + 2814} = .113.$ <p>Lunch and nonavailable percentages are used for comparison only.</p>
9C	Total of all percentages in column C. except lunch and nonavailable.
6D 7D & 8D.	Measured man-hours for all processes except lunch and nonavailable. Compute measured man-hours by multiplying samples in each process by the relative weight of each sample for example, measured man-hours for process one is $(409)(.2500000) = 102.25$ (refer to Table 15.2. , Box 20 for relative weight computation).
9D.	Total measured man-hours by adding man-hours in column D.
6E.	Leveled man-hours. Multiply the leveling factor in block 5G times the measured man-hours.
7E.	Total of column E.
6F	Allowance factor used for each process.
6G	Allowed man-hours for each process by multiplying the unrounded number in 6E by the allowance factor 6F. (These numbers are shown at two decimal places for display purposes only.)
7G	Total of column G.
6H	Adjusted man-hours by multiplying the number in block 11 by the unrounded number in 6G.
7H	Total of column H.
10	<p>Accuracy for largest productive process (column 6C). Compute accuracy with the following equation:</p> $A = 1.96 \sqrt{P(1 - P) / n}$ <p>where A = accuracy, P = largest percentage of occurrence for a productive category, and n = total number of available samples (block 9b).</p>
11	<p>Adjustment Factor. Compute the monthly adjustment factor by dividing the average number of work center work days per month by the number of days included in the study. Example: For a five day work week and 15 usable sample days, the computation is: $\frac{20.91}{15} = 1.3940000$</p> <p>(Use all significant digits when using calculators.)</p>
<p>NOTE: An example of a completed AF Form 1111 is located on the AFMIA home page, https://www.afmia.randolph.af.mil. Go to MO Library>Manpower Standards>Tech Guidance & Forms>MEP Form Examples.</p>	

15.20. WS Data Control Charting.

15.20.1. Types of Control Charts. The two types of control charts used with WS data are productivity charts and workload factor control charts.

15.20.2. Productivity Charting.

15.20.2.1. AF Form 1111, block 4F, shows the lower and upper control limits for the study. Visual inspection of this form will show days outside these limits. However, it is difficult to furnish rationale later for a day out of control when charts are not kept on a daily basis. Recompute control charts after each five days and at the end of the measurement period. Plot control charts daily to identify days needing explanation at the end of the measurement.

15.20.2.2. Exercise caution in discarding data. Do not declare data unusable simply because a point falls beyond established limits. Clearly state a reason for not using each day's data. Investigate and explain all points circled on the AF Form 1111, column 3F.

15.20.2.3. Frequently, in the first few days (possibly a week) of sampling, a greater percentage of productivity is observed than in the remaining days of the study. This situation is usually caused by the craftsman's presence in the work center. After personnel in the work center become accustomed to the craftsman, the data is usually more representative of the normal situation. When this situation causes high productivity followed by low productivity, include both in the study.

15.20.2.4. Consider alternating craftsmen daily and compare odd and even days. This will identify any observer bias.

15.20.2.5. Productivity charts are effective for determining representativeness of daily productivity. By comparing productivity control charts with the workload factor control chart more information is apparent to the craftsman.

15.20.2.6. A productivity chart is a graph that has a center line, upper and lower control limits (LCL), and the daily productivity to be analyzed.

15.20.2.6.1. Center line. The center line is the average productivity for the period the chart represents.

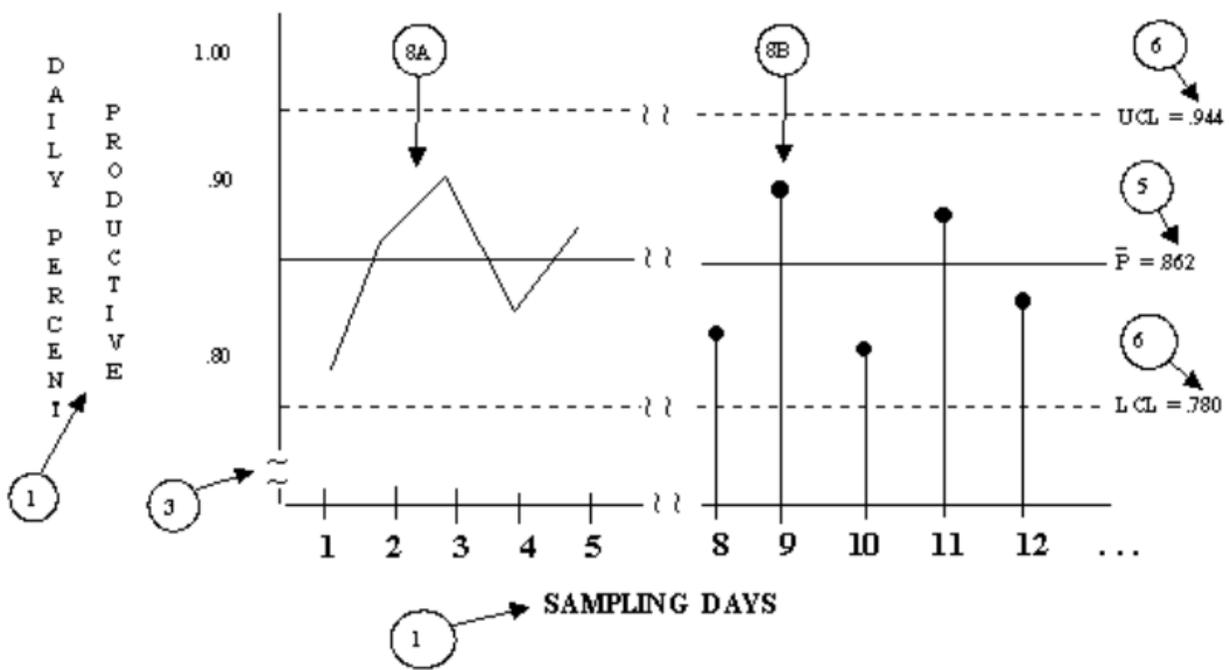
15.20.2.6.2. Control limits. Set upper and lower control limits by adding and subtracting three standard errors of proportion from the center line.

15.20.2.7. The same general procedures for preparing control charts ([Table 15.4.](#)) apply to all types of control charts. However, the computations of the needed values differ for variable data (measurements of time, length, etc.) and attribute data (percents or proportions). WS uses attribute data.

Table 15.4. Preparation Of A Control Chart.

Step	Action
1	Clearly label both vertical and horizontal axes to indicate what is being charted.
2	Scale the vertical axis to include the range of values to be charted.
3	Indicate with a broken line when an axis does not go all the way to zero.
4	Extend the horizontal axis to allow all of the data to be charted (both current data and data to be obtained in the future).
5	Draw a solid line to indicate the center line. Identify the value.
6	Place dotted lines for the upper (UCL) and lower (LCL) control limits. Indicate the value of each.
7	Plot the points to be evaluated on the control chart.
8	Connect all of the points to aid the visual analysis by using a solid line between each of the points or by using a vertical line between each point on the X-axis.

Example:



15.20.2.8. Attribute data is suitable for a P-chart that evaluates changes in the percent or proportion. The P-chart is based on the binomial distribution. This distribution uses the average quantity in computing its variation. The instructions for the needed values are in [Table 15.5.](#)

Table 15.5. Preparation Of A P-Chart For Attribute Data.

S T	A	B																																
E P	ACTION	EXAMPLE																																
1	List total number of available samples and the number of samples that were productive (direct, indirect, or total) by the consecutive days sampled.	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;"></th> <th style="width: 30%; text-align: center;">Daily Available Samples (n)</th> <th style="width: 20%; text-align: center;">Productive Samples (X)</th> <th style="width: 40%; text-align: center;">Percent Productive (P)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">Day</td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">162</td> <td style="text-align: center;">137</td> <td style="text-align: center;">.8457</td> </tr> <tr> <td style="text-align: center;">2</td> <td style="text-align: center;">180</td> <td style="text-align: center;">158</td> <td style="text-align: center;">.8778</td> </tr> <tr> <td style="text-align: center;">3</td> <td style="text-align: center;">184</td> <td style="text-align: center;">157</td> <td style="text-align: center;">.8533</td> </tr> <tr> <td style="text-align: center;">4</td> <td style="text-align: center;">188</td> <td style="text-align: center;">159</td> <td style="text-align: center;">.8457</td> </tr> <tr> <td style="text-align: center;">5</td> <td style="text-align: center;"><u>190</u></td> <td style="text-align: center;"><u>156</u></td> <td style="text-align: center;">.8211</td> </tr> <tr> <td></td> <td style="text-align: center;">Σn = 904</td> <td style="text-align: center;">Σx = 767</td> <td></td> </tr> </tbody> </table>		Daily Available Samples (n)	Productive Samples (X)	Percent Productive (P)	Day				1	162	137	.8457	2	180	158	.8778	3	184	157	.8533	4	188	159	.8457	5	<u>190</u>	<u>156</u>	.8211		Σn = 904	Σx = 767	
	Daily Available Samples (n)	Productive Samples (X)	Percent Productive (P)																															
Day																																		
1	162	137	.8457																															
2	180	158	.8778																															
3	184	157	.8533																															
4	188	159	.8457																															
5	<u>190</u>	<u>156</u>	.8211																															
	Σn = 904	Σx = 767																																
2	Compute the percent productive for each day: $P = \frac{X}{n}$ Carry one or two extra decimal places during computations.																																	
3	Calculate the average value, where: $P = \frac{\sum X}{\sum n}$ $n = \frac{\sum n}{\sum K}$ K=number of days	$\bar{P} = \frac{767}{904} = 0.8485$ $\bar{n} = \frac{904}{5} = 180.8$																																
4	Compute the standard error of proportion $\sigma_p = \sqrt{\frac{\bar{P}(1 - \bar{P})}{\bar{n}}}$	$\sigma_p = \sqrt{\frac{(0.8485)(0.1515)}{180.8}}$ $\sigma_p = 0.0267$																																
5	Determine control limits $UCL = \bar{P} + 3\sigma_p$ $LCL = \bar{P} - 3\sigma_p$	$UCL = 0.8485 + 3(0.0267)$ $UCL = 0.929$ <hr/> $LCL = 0.8485 - 3(0.0267)$ $LCL = 0.768$																																
6	Prepare a P-Chart on graph paper using these values. Label all values and each axis clearly.																																	

15.20.3. Workload Factor Control Charting.

15.20.3.1. The workload factor control chart is used in combination with productivity charts. Make a workload factor control chart when the workload factor count is available on a daily basis.

15.20.3.2. A workload factor control chart often helps determine the representativeness of the study period, verify the accuracy of the work count, and identify normal workloads. Development of a work center standard during other than normal workload periods might result in a distortion of the standard. Prepare the chart as follows:

15.20.3.2.1. Get the historical workload (6 to 12 months). Then compute the average daily historical workload by dividing the total workload for the period by the number of months included and then dividing the quotient by the average number of days the work center works each month.

15.20.3.2.2. Draw the chart on standard graph paper with days as the horizontal axis and workload as the vertical axis. The range of days will be determined by the number of days you wish to analyze (usually the entire study period). The range of workload will be from zero to the maximum total workload expected (add 10% for error).

15.20.3.2.3. Multiply the average daily historical workload by the number of study days intended, then plot the product on the vertical axis. The corresponding horizontal coordinate is the last date to be studied. Connect this point and the origin with a solid straight line. This line is the historical average workload line.

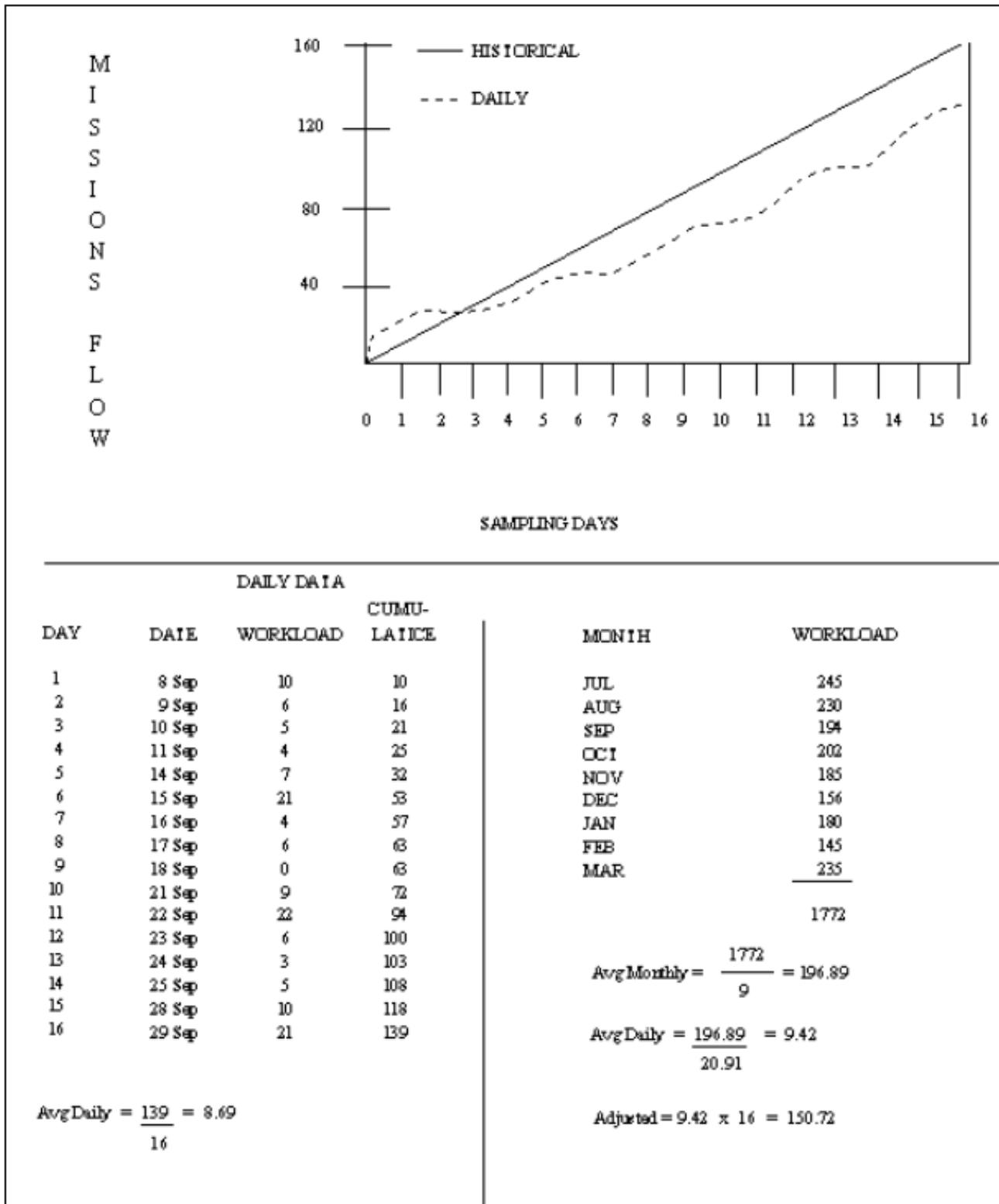
15.20.3.2.4. As the study develops, plot each day's workload factor count cumulatively.

15.20.3.2.5. The shape of the daily plot shows the work pattern. When cycles end near the historical average workload line, the work center is working at the average workload volume.

15.20.3.2.6. Valuable questions in analyzing points that deviate from the historical line include: Are the daily and historical counts based on the same workload factor? Check the definition of the workload factor. Is a regular cycle appearing? Plan to stop sampling as close as possible to the completion of a cycle. Is productivity commensurate with high or low current workload compared to historical workload? Check rating factors for indications of high or low ratings. Is the unit experiencing an activity (exercise or operational test) that affects the workload count? Is it affecting productivity? Check the P-chart to determine whether days should be excluded from the study.

15.20.3.2.7. **Figure 15.1.** shows an example of a workload factor control chart and the data used to prepare it.

Figure 15.1. Workload Factor Control Chart.



15.20.4. Interpretation of Control Charts.

15.20.4.1. Control charts are used in the MEP to determine whether or not a single population is represented.

15.20.4.2. If a control chart is stable, the measurements are considered to be from the same population. Then use the average value to describe this population. A control chart is considered stable if these conditions exist:

15.20.4.2.1. All points are scattered evenly on both sides of the center line and no points are outside the three standard deviation control limits.

15.20.4.2.2. Most points tend to cluster around the center line.

15.20.4.2.3. Relatively few points are near the control limits.

15.20.4.2.4. There are no runs of seven or more consecutive points on the same side of the center line.

15.20.4.3. When any of the rules for stability are violated, further investigation is needed. Suitable responses are needed for the instability. The value can be used, omitted, or corrected. Document all decisions of this type. Some possible reasons for instability are:

15.20.4.3.1. An error in the data.

15.20.4.3.2. A different situation or population was measured.

15.20.4.3.3. Additional work was included or excluded in the data.

15.20.4.3.4. High or low productivity.

15.21. Types of WS Studies.

15.21.1. Level of Studies. Design WS studies to measure work as productive and nonproductive (level I) or at the process level (level II).

15.21.2. Level I Studies.

15.21.2.1. In Level I studies, samples are broadly classified as productive, nonproductive, non-available, and lunch. Sample nonproductive categories such as personal, rest, delay, and idle at the category level since they are easily discernible. This supplies information to support the allowance factor and to brief the OPR.

15.21.2.2. Use percentage estimates to distribute productive time (direct and indirect) into processes. Derive these percentage estimates through consultation with key personnel and the work center supervisor. Get estimates from several work center personnel to improve the reliability of process distribution. Percentage estimates must equal 100%. **Figure 15.2.** shows an example of estimated process distribution percentages. It assumes that estimates were obtained from the work center supervisor (estimate A) and the foreman (estimate B). The "percent of total" column (column five) is used to distribute the productive direct time into processes.

Figure 15.2. Percentage Distribution of Productive Processes.

(1) Process Number	(2) Percent Estimate by A	(3) Percent Estimate by B	(4) Total of (2) + (3)	(5) Percent of Total (4)/200%
1	9%	7%	16%	.08
2	30%	26%	56%	.28
3	15%	13%	28%	.14
4	8%	8%	16%	.08
5	25%	21%	46%	.23
I1	8%	4%	12%	.06
I2	4%	4%	8%	.04
I3	4%	2%	6%	.03
I4	3%	3%	6%	.03
I5	1%	1%	2%	.01
I6	1%	1%	2%	.01
I7	1%	1%	2%	.01
			200%	1.00

15.21.3. Level II Studies.

15.21.3.1. Level II studies are measured at the process level. In most WS studies, it is easy to distinguish between productive and nonproductive samples. The distinction between productive direct and productive indirect is more difficult. For example, the productive direct process of management is similar to the productive indirect processes of supervision and administration when observed at the task level of accomplishment. If a sample is misclassified as direct when it is really indirect, there is no change to total productive time.

15.21.3.2. Because measured indirect time is based on observations, do not use SIAMs with WS studies. Do not compromise standard studies based on observation by comparing their economics with the economics for standard studies based on nonmeasurement methods.

15.21.3.2.1. Productive direct time is sampled at Level I and prorated by percentages to get direct process and indirect category time, and

15.21.3.2.2. Productive indirect time is sampled at Level II (category level).

Chapter 16

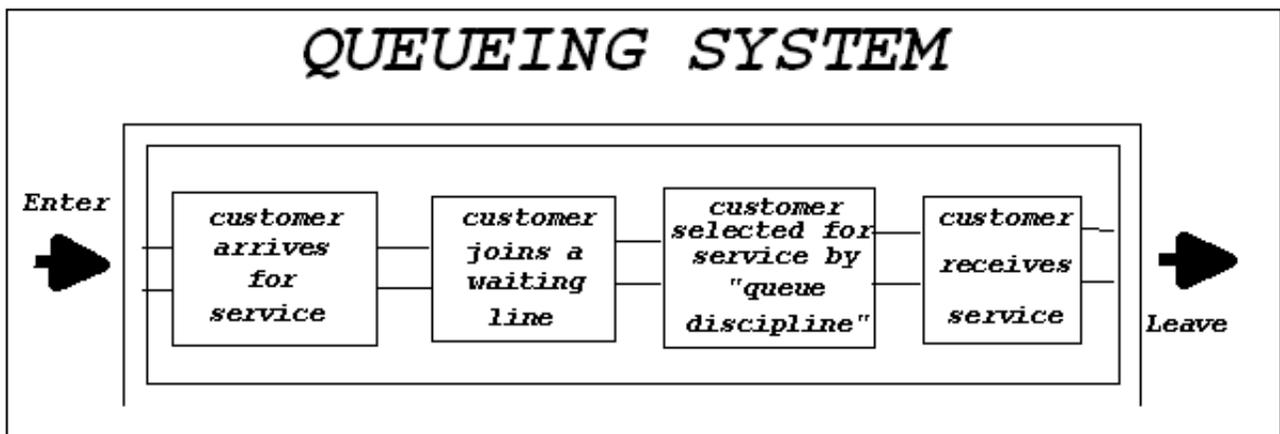
QUEUEING

16.1. General Concepts.

16.1.1. A queue is defined as a waiting line. Queue analysis involves a mathematical study of waiting lines.

16.1.2. A queueing system refers to the entire process of a customer arriving, being served, and leaving. **Figure 16.1.** illustrates the basic steps of a queueing system.

Figure 16.1. General Flow of a Queueing System.



16.1.3. A specific definition is needed to understand the term customer. It is used in a general sense and does not necessarily refer to a human customer. A customer could be:

- 16.1.3.1. An airplane waiting to be refueled.
- 16.1.3.2. A computer program waiting to be run.
- 16.1.3.3. A ball bearing waiting to be inspected.

16.1.4. Traditional work measurement techniques apply to a situation where the next item to be processed is available when the worker is ready to start. In situations where workload develops randomly, queueing theory applies. Examples of such areas are:

- 16.1.4.1. Checkout cashiers in the commissary.
- 16.1.4.2. Forklift truck operators.
- 16.1.4.3. Personnel who check out records such as in a hospital or Military Personnel Flight (MPF)
- 16.1.4.4. Tool crib attendants.
- 16.1.4.5. Clerks who set up telephone appointments.
- 16.1.4.6. Drivers for the base taxi service.
- 16.1.4.7. Inventory items in a warehouse.

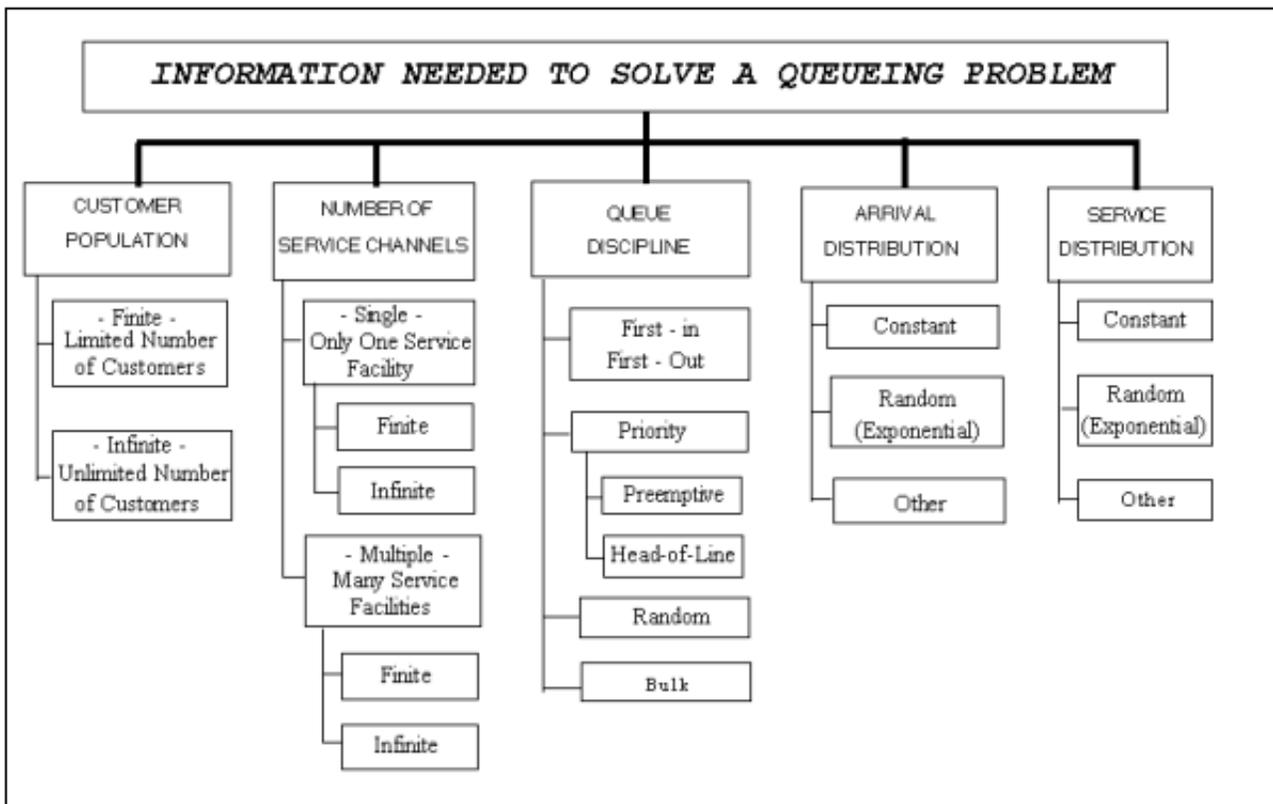
16.1.5. A queueing model does not make decisions. It provides information to base decisions on. It can tell you the probability of waiting or not waiting. It can also determine the average number of units to be served and the average time spent in the queue. Given any of these as the selection criteria, you can decide what level of performance is acceptable. For example, you can determine the number of cashiers needed to make sure a desired average waiting time. On the other hand, you can measure an arrival rate to setup an appointment system.

16.1.6. The primary intent of this chapter is to relate queueing analysis to the MEP. General procedures are presented to give direction to the analysis and a feel for queueing situations. Due to the complexity of the subject matter, the specific details are omitted and textbooks are referenced at the end of this chapter. A team desiring to use this method should either have a person on the team who knows queueing theory or seek advice from such a person.

16.2. Information Needed.

16.2.1. Queueing Analysis. Before doing any queueing analysis carefully study the entire queueing system. **Figure 16.2.** presents the type of information needed to do a queueing study.

Figure 16.2. Types of Information Needed in Queueing.



16.2.2. Customer Population. The size of the customer population (either finite or infinite) is basically a count of the actual population. A customer population that is fixed in size is finite. However, when a finite population is large enough not to be affected by the service capacity of the system, then the population is essentially infinite. Most queueing systems have finite customer populations and are

correctly assumed to be infinite. Unless the population is infinite (or can be assumed to be infinite), the probability of a customer arriving for service changes is based on the number of customers already in the system. For example:

16.2.2.1. Consider repairing lathes. The machine shop has five lathes (customer population equals five). These machines break down occasionally (arrive for service). Two repairmen (servers) are assigned to that shop. The down machine will be repaired and put back in service. This is considered a finite source. While one machine is down, the customer population is not the same (only four remain in service).

16.2.2.2. A Similar Machine. Now assume a similar machine shop has included a sufficient number of spare machines. When one machine is down, a spare is immediately substituted. Hence, the customer population is constant at five, even if one is down.

16.2.2.3. Next, consider a commissary. The customer population is finite because only people with commissary privileges are customers. However, this population is large when compared to the service capacity of the commissary. In effect, it is inexhaustible (infinitely large).

16.2.3. Number of Service Channels.

16.2.3.1. Service channels are concerned not only with the number of service facilities but also with the associated queues. A queue is characterized by the maximum number of customers it can hold. When a given number of customers are waiting in a queue, future customers are denied entry into the queue until others are served. This is a finite queue. An infinite queue does not have such restrictions.

16.2.3.2. A single service channel usually has only one queue or waiting line.

16.2.3.3. Multiple service channels can have one queue, such as a barbershop with multiple barbers and a general waiting area where customers are served on a first-come, first-served basis.

16.2.3.4. Multiple service channels can also each be served by a different queue, such as a supermarket with several checkers.

16.2.4. Queue Discipline.

16.2.4.1. This refers to the method that customers are selected from the queue to be served. Some of the common disciplines are:

16.2.4.1.1. First-come, first-served. The next available server services the first customer in the queue line.

16.2.4.1.2. Priority. A customer is given some sort of priority on entering the queue. Those with higher priorities are served before those with lower priorities. Two types of priority are preemptive and head-of-line. Preemptive priority is when a customer with high priority is allowed to enter the service channel immediately even if a customer with a lower priority is being serviced. Head-of-line priority puts a higher priority customer at the head of the line, but does not preempt any ongoing service.

16.2.4.1.3. Random selection. Selection is independent of arrival time.

16.2.4.1.4. Bulk selection. A group of customers are selected at one time.

16.2.4.2. Queue disciplines alter when customers do not behave as expected. Two examples are when a customer jumps from one channel to another and when a customer balks (turns around and leaves instead of waiting in line for service).

16.2.5. Arrival and Service Patterns.

16.2.5.1. The arrival pattern of customers to a queueing system can be described by one of these.

16.2.5.1.1. The average number of arrivals to the system per some unit of time (mean arrival rate).

16.2.5.1.2. The average time between successive arrivals (mean interarrival time).

16.2.5.2. The service pattern of customers within a nonempty queueing system can be described by:

16.2.5.2.1. The average number of customers served per some unit of time (mean service rate).

16.2.5.2.2. The average time to service a customer (mean service time).

16.2.5.3. Similarities and relationships exist between these two types of distinct patterns. Study both patterns in depth to adequately describe a queueing system.

16.2.5.4. The random occurrences within each of these patterns will follow a particular statistical distribution. The identification of the distribution may or may not be straightforward. In favorable situations, when the arrival rates follow a Poisson distribution and the service time follows an exponential distribution, straightforward queueing formulas can be used. Knowing, recognizing, and using these distributions involve mathematical sophistication that is beyond the scope of this chapter. A general example is provided in the remainder of this chapter to illustrate the flow of one queueing analysis without detailing all of the mathematical steps.

16.3. Collecting Information.

16.3.1. In queueing analysis, the information collected can be categorized in two broad categories - general information and numerical information.

16.3.2. General information comes from an in-depth look at the queueing system that includes evaluating the customer population limit, the queue discipline used, and the number of parallel service channels. This type of information appears easy to obtain, but a careful study of the situation may uncover some subtle differences embedded in the system. For example, recall the comments in the previous paragraph about infinite versus finite customer populations.

16.3.3. Numerical information is a general grouping that includes collecting and analyzing the distribution of service times, arrivals, and times between arrivals. Needed numerical data are the exact times that customers arrive at a system for service and the actual service times. The method of collecting this data (either through measurement or from historical files) depends on the availability of data and the type of standard to be built.

16.3.3.1. Historical data, such as dispatch logs and job-supervisors records, may provide the needed information. Verify the data for accuracy and representativeness. For example, does the service time include standby time?

16.3.3.2. Measurement is the most common source of data. Design a procedure for gathering this data for both the service time and the arrival rate (or interarrival time) for the particular work center being studied. One of several methods or a combination of methods may be used.

16.3.3.2.1. Use a stopwatch to measure the amount of time needed to give service. Time only the actual time spent giving service, from the second it starts to the second it finishes.

16.3.3.2.2. Use a log to show the exact time a customer arrives for service. Compute the arrival rates from such a log by counting how many customers arrived in a given block of time (e.g., per each 10 minutes).

16.3.3.2.3. Use a log to record when service begins and ends. An example could be a dispatching log used at a base taxi service.

16.3.3.2.4. There are many other methods that may be more suitable for the situation being studied. Remember, the quality of this input data is extremely important because it will form the basis for analysis.

16.3.4. Consider a tool crib as the setting of a queueing analysis. It is decided to obtain information about the arrivals of mechanics at the tool crib by using a log to account for the number of arrivals per each 10 minutes. Information about the time it takes an attendant to wait on a mechanic is obtained with actual timings.

16.4. Evaluating Data.

16.4.1. Analyze information about arrival and service data separately, but the procedures are the same in both cases.

16.4.2. Arrange and organize the data in a frequency table. This will prepare the data for the chi square goodness-of-fit test. Make sure the number of categories in the frequency table reflect the situation (for example, when talking about the number of arrivals per block of time, begin with 0 arrivals, 1 arrival, etc.). Usually between 8 and 20 categories are sufficient.

16.4.3. Construct a histogram of the data to provide a visual method for estimating how well this data is exhibiting the properties of the desired distribution.

16.4.4. Do the chi square goodness-of-fit test to determine whether the data can be considered from the desired probability distribution. Group some of the categories together to make sure the expected frequency in each cell is at least 5. Find the details of this test in the references listed at the end of this chapter.

16.4.4.1. If the data passes the goodness-of-fit test, use the mean time from this data in further analysis.

16.4.4.2. If the data does not pass this test, do one of the following steps:

16.4.4.2.1. Reevaluate the data (collection method, accuracy, and representativeness of the data) to discover possible errors.

16.4.4.2.2. Resort to more complex modeling of this queueing system. This may require both more theoretical knowledge and extensive computer support for simulation of the problem.

16.4.5. The arrival rates for our tool crib example have been gathered by counting the number of arrivals per ten minutes. One hundred observations were made. The data is tested to see if these arrival

rates follow a Poisson distribution (**Figure 16.3**). The data passes the test and we conclude that the arrival distribution is Poisson. The average value for the arrival rate (λ) can then be used in further analysis:

$\lambda = 16.04$ arrivals per ten minutes or

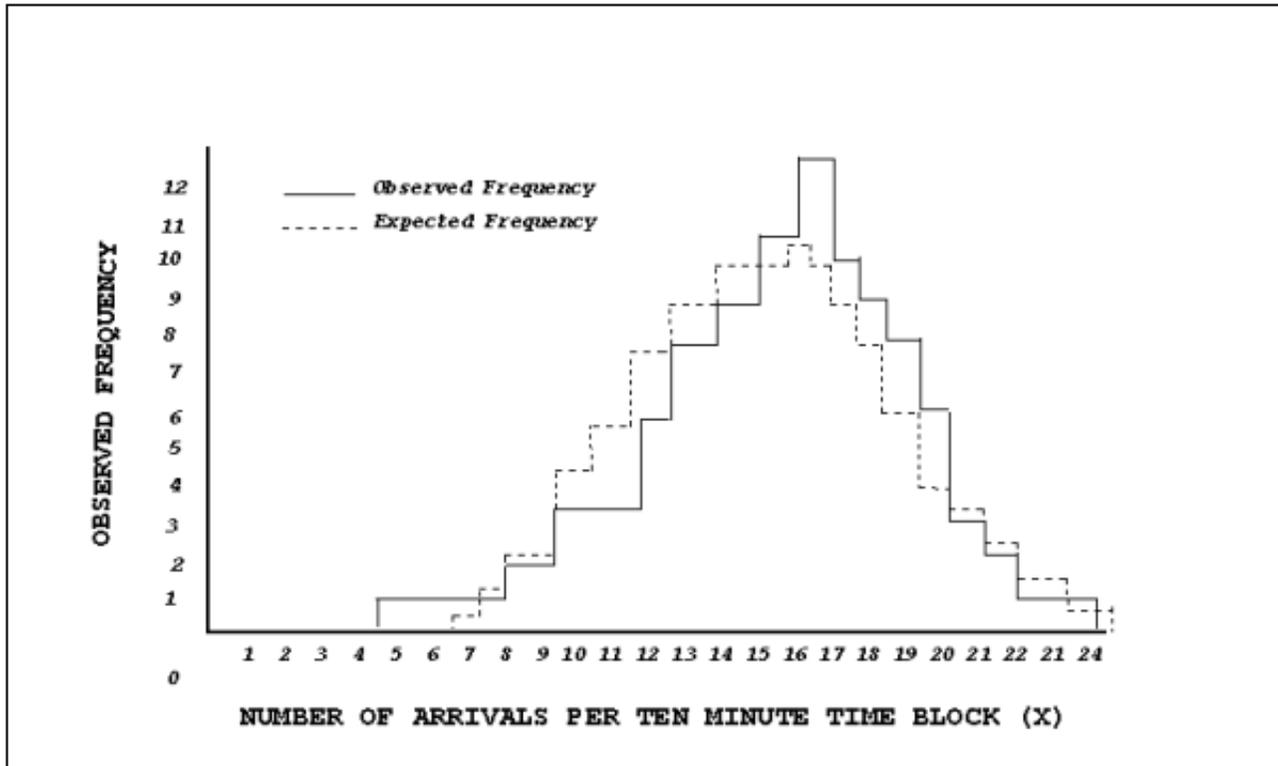
$\lambda = 96.24$ arrivals per hour

Figure 16.3. Evaluation of Sample Queueing Data.

NUMBER OF ARRIVALS PER TEN MINUTES	OBSERVED FREQUENCY	EXPECTED FREQUENCY		(OBSERVED-EXPECTED) ² / EXPECTED		COMPUTATION SUMMARY:	
		(f _o)X	(f _e)	(f _o - f _e) ² / f _e	(grouped values)		
(X)	(f _o)	(f _o)X	(f _e)	(f _o - f _e) ² / f _e	(grouped values)	<p>$\lambda = \text{mean} = \frac{\sum f_o X}{\sum f_o} = \frac{1604}{100} = 16.04$</p> <p>The expected frequency was derived from:</p> $f_e = \frac{(n)(e^{-16.04})(16.04)^x}{x!}$ <p>where n = $\sum f_o$ for x = 0, 1, 2, ∞ For Example: The expected frequency of fifteen arrivals in a ten minute block of time (x = 15) is:</p> $f_e = \frac{(100)(e^{-16.04})(16.04)^{15}}{15!} = 9.8965$ <p>For any set of 100 observations, it is expected that approximately 10% of the 10 minute time blocks will contain 15 arrivals. This statement is based on the arrivals (per 10 minutes) having a mean of 16.04 and following a Poisson distribution.</p> <p>CHI SQUARE (X²) TEST:</p> <p style="text-align: center;">K</p> $X^2 \text{ Test Statistic} = \sum_{i=1}^k (f_{oi} - f_{ei})^2 / f_{ei} = 3.5361$ <p>where k = 12 (the number of groupings)</p> <p>Critical X² Value = X²_(.95,10) = 18.31</p> <p>The test statistic is less than the critical value (3.5361 < 18.31). Therefore, it passes the CHI SQUARE test. This data can be represented by a Poisson distribution with a mean of 16.04.</p>	
0			0.00001				
1			0.00017				
2			0.00139				
3			0.00744				
4			0.0298				
5	1	-	5	0.0957			
6	1		6	0.2557			
7	1		7	0.5860			
8	1	- 9	8	1.175	- 7.604		0.2563
9	2		18	2.094			
10	3		30	3.359			
11	3	-	33	4.898	- 11.445		1.0370
12	5		60	6.547			
13	7		91	8.078			0.1439
14	8		112	9.255			0.1702
15	10		150	9.897			0.0011
16	10		160	9.921			0.0006
17	12		204	9.361			0.7440
18	9		162	8.342			0.0519
19	8		152	7.042			0.1303
20	7		140	5.648			0.3236
21	5	-	105	4.314	- 7.459		0.0392
22	3		66	3.145			
23	2		46	2.193			
24	1	-	24	1.466	- 5.948	0.6380	
25	1		25	0.941			
> 25				1.348			

16.4.6. Figure 16.4. presents a histogram of this example data and the data represented by the expected frequency.

Figure 16.4. Histogram of Example Data.



16.4.7. The service times for this example are tested to determine if they follow an exponential distribution. The details of this analysis are not presented in this chapter. For this example, assume it passes the test for an exponential distribution. Since the average service time is determined to be .7496 minutes per customer, the average service rate is the reciprocal of .7496 or:

$$\mu = 1.334 \text{ customers per minute}$$

$$\mu = 80.04 \text{ customers per hour}$$

16.4.8. The utilization factor (ρ) for a queueing system is defined as the mean arrival rate (λ) divided by the service capacity of the system. The service capacity of the system is the mean service rate (μ) times the number of service channels (c) in the system. Hence, $\rho = \lambda / c\mu$. The utilization factor represents the proportion of the total service capacity needed to service the customers. If $\rho \geq 1$, then the customers are arriving at a faster rate than they can be served, and queues will build indefinitely. In such a situation, either λ , c , or μ must be changed to get $\rho < 1$. For example, more servers (increase c) can be added to meet the needs of the system, or labor-efficient equipment can be incorporated to serve more per unit time (increase μ).

16.4.9. The utilization factor for the tool crib when it is operated with only one attendant ($c = 1$) is greater than one:

$$(\rho = \frac{\lambda}{c\mu} = \frac{96.24}{80.04} = 1.2024).$$

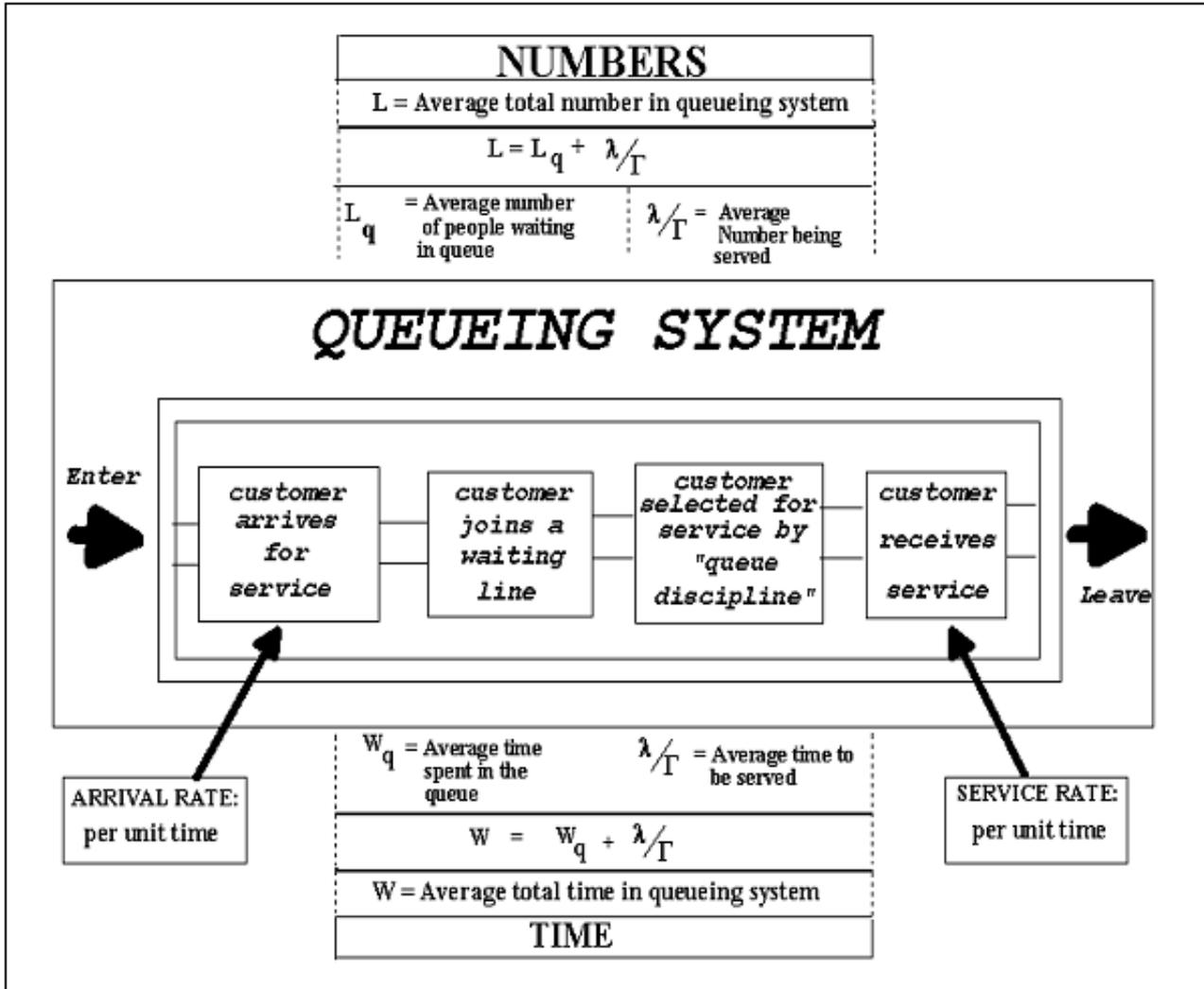
Therefore, the mechanics will always have to wait since one attendant is not able to wait on them fast enough. Hence, more than one attendant is needed.

16.5. Combining Information.

16.5.1. After the service times and arrival rates have been identified as coming from a relevant distribution, this numerical information can be joined with the general information already obtained.

16.5.2. See [Figure 16.5](#) for a simplistic picture that relates common queueing terms to the general queueing system.

Figure 16.5. Simplified Relationship Between Queuing System and Definitions.



16.5.3. When the most favorable situations exist (identified under Major Assumptions in [Figure 16.6.](#)), the formulas in that figure apply.

Figure 16.6. Queueing Formulas.

MAJOR ASSUMPTIONS:

1. The arrival rate follows a Poisson distribution.
2. The service time follows an exponential distribution.
3. The system is considered to be a "steady state" system. This is an ongoing system instead of one that is just starting up (in transition).
4. The queue discipline used is "first-come-first-served."

DEFINITIONS:

- λ (Lamda) Average rate per unit of time at which customers arrive at the queueing system (e.g., 6 per hour).*
- μ (Mu) Average rate per unit of time at which each service channel provided service (e.g., 1 per minute or 60 per hour).*
- χ Number of service channels in the queueing system.
- ρ (Rho) Utilization factor defined as: $\rho = \frac{\lambda}{c\mu}$

W Mean time in system; average amount of time one customer spends in the queueing system (waiting and being served).

W_q Mean time in queue; average amount of time one customer spends in the queue (waiting only).

L Mean line length; average number of customers in the queueing system (waiting and being served).

L_q Mean queue length; average number of customers in the queue (waiting only).

P_0 Probability of no one being in the queueing system at a given point in time (to be used in computations).

* Remember: Units of time must be the same for all computations.

FORMULA (for use when the above assumptions are met):

$$P_0 = \left[\sum_{n=0}^{c-1} \frac{1}{n!} \left(\frac{\lambda}{\mu}\right)^n + \frac{1}{c!} \left(\frac{\lambda}{\mu}\right)^c \left(\frac{c\mu}{c\mu - \lambda}\right) \right]^{-1} \quad W = W_q + 1/\mu$$

$$L_q = W_q \lambda$$

$$W_q = \left[\frac{(\lambda/\mu)^c \mu}{(c-1)!(c\mu - \lambda)^2} \right] P_0 \quad L = W\lambda$$

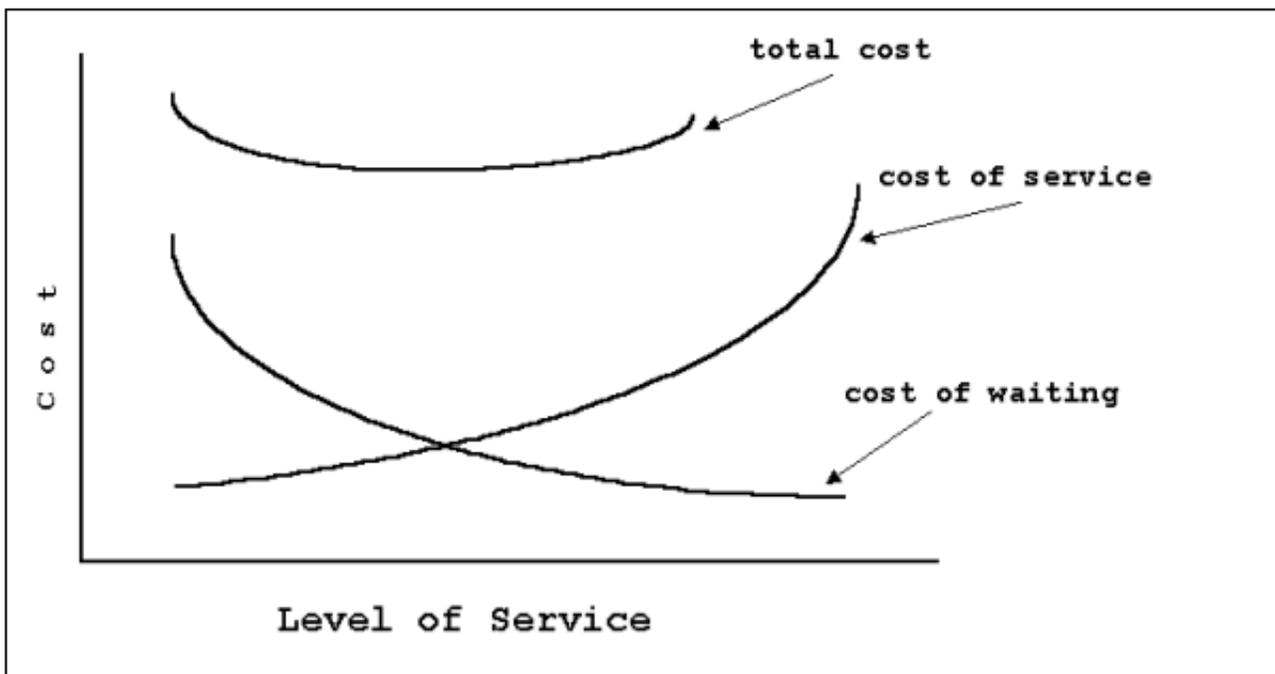
16.5.4. When different queueing systems are identified, obtain the needed formulas from a queueing textbook.

16.6. Average Costs of Various Systems.

16.6.1. A queue will form any time a customer arrives for service and all of the servers are busy. More servers can be added to eliminate the queueing problem. Since customers arrive at random times, each additional server will also result in an increase in idle time. This will increase the operational costs.

16.6.2. The total cost of a system can be viewed as the cost of service and the cost of waiting. **Figure 16.7.** shows that as the level of service is increased (for example, adding more service channels), the cost of providing the service also increases. However, as the level of service is increased, customers do not have to wait as long for service and the cost of waiting decreases. The curve of the total cost starts out decreasing. This shows that adding more servers cuts waiting time enough to lower the total cost. However, the total cost curve reaches its minimum and then increases. This shows additional servers after that point are a waste of money. Note that the minimum total cost does not have to occur at the intersection of waiting and service costs.

Figure 16.7. Cost Model.



16.6.2.1. The cost of service is normally found by multiplying the number of servers by their salary rate. For example, if three servers are needed and each is paid \$3.50 per hour, the cost of service is 3 times \$3.50 or \$10.50 per hour.

16.6.2.2. The cost of waiting may often be difficult to compute. We must recognize that there are different types of costs involved in waiting.

16.6.2.2.1. For example, what is the cost of an aircraft waiting to be loaded during an emergency? While we may not be able to quantify this type of cost, other costs of waiting can be quantified.

16.6.2.2.2. There is the obvious cost of the salary paid to the person standing in line, waiting for service. This person is idle (not being productive), thus creating a waiting cost.

16.6.2.2.3. Similarly, an aircraft in a holding pattern is using extra fuel while waiting to land. Also, if several people work with a machine that breaks down, they are idle until the machine is repaired.

16.6.2.2.4. Finally, there are intangible costs such as decreased morale because a person had to wait too long for service at the Military Personnel Flight (MPF) or gymnasium. A customer may refuse to wait and leave the system.

16.6.3. When arrival and service rates can be held constant, the number of service channels can be varied to see their effect on the number of customers waiting for service and on the average waiting time. In this situation, the total cost of alternate systems can be compared.

16.6.4. Because the major assumptions have been met for our tool crib example, use the straightforward formulas in [Figure 16.6](#). It has already been determined that one attendant at the tool crib cannot meet the needs of the mechanics. Would two attendants be enough? Three? Four?

16.6.4.1. In our example, to compute the cost of waiting, we need two additional values: the average number of mechanics waiting and the average amount of time each waits. ("In the system" refers to both waiting in the queue and being served.) Calculate these two values separately for situations where there are two, three, and four servers. [Figure 16.8](#) shows step-by-step calculations for three servers. It also shows the average times for two, three, and four servers.

Figure 16.8. Computation of Average Waiting Time and Average Number of Customers.

TWO TOOL CRIB ATTENDANTS C = 2	THREE TOOL CRIB ATTENDANTS C = 3	FOUR TOOL CRIB ATTENDANTS C = 4
$P_0 = \left[1 + \left(\frac{\lambda}{\mu}\right) + \frac{1}{2} \left(\frac{\lambda}{\mu}\right)^2 \left(\frac{2\mu}{2\mu - \lambda}\right) \right]^{-1}$ $P_0 = \left[1 + 1.2024 + \frac{1}{2} (1.2024)^2 \left(\frac{2(80.04)}{2(80.04) - 94.24}\right) \right]^{-1}$ $P_0 = 0.248063$	$P_0 = \left[1 + \left(\frac{\lambda}{\mu}\right) + \frac{1}{2} \left(\frac{\lambda}{\mu}\right)^2 + \frac{1}{6} \left(\frac{\lambda}{\mu}\right)^3 \left(\frac{3\mu}{3\mu - \lambda}\right) \right]^{-1}$ $P_0 = \left[1 + 1.2024 + \frac{1}{2} (1.2024)^2 + \frac{1}{6} (1.2024)^3 \left(\frac{3(80.04)}{3(80.04) - 94.24}\right) \right]^{-1}$ $P_0 = 0.228357$	$P_0 = \left[1 + \left(\frac{\lambda}{\mu}\right) + \frac{1}{2} \left(\frac{\lambda}{\mu}\right)^2 + \frac{1}{6} \left(\frac{\lambda}{\mu}\right)^3 + \frac{1}{24} \left(\frac{\lambda}{\mu}\right)^4 \left(\frac{4\mu}{4\mu - \lambda}\right) \right]^{-1}$ $P_0 = \left[1 + 1.2024 + \frac{1}{2} (1.2024)^2 + \frac{1}{6} (1.2024)^3 + \frac{1}{24} (1.2024)^4 \left(\frac{4(80.04)}{4(80.04) - 94.24}\right) \right]^{-1}$ $P_0 = 0.209442$
W_q = THE AVERAGE TIME (PER HOUR) A MECHANIC IS SPENDING WAITING TO BE SERVED AT THE TOOL CRIB.		
$W_q = \left(\frac{(\lambda / \mu)^2}{2\mu - \lambda} \right) P_0$ $W_q = \left(\frac{(1.2024)^2 (80.04)}{2 [2(80.04) - 94.24]} \right) 0.248063$ $W_q = 0.007072$	$W_q = \left(\frac{(\lambda / \mu)^3}{2 [3\mu - \lambda]} \right) P_0$ $W_q = \left(\frac{(1.2024)^3 (80.04)}{2 [3(80.04) - 94.24]} \right) 0.228357$ $W_q = 0.005839$	$W_q = \left(\frac{(\lambda / \mu)^4}{6 [4\mu - \lambda]} \right) P_0$ $W_q = \left(\frac{(1.2024)^4 (80.04)}{6 [4(80.04) - 94.24]} \right) 0.209442$ $W_q = 0.003145$
W = THE AVERAGE TIME (PER HOUR) A MECHANIC IS SPENDING AT THE TOOL CRIB, BOTH WAITING AND BEING SERVED.		
$W = W_q + 1/\mu$ $W = 0.007072 + 1/80.04$ $W = 0.019986$	$W = W_q + 1/\mu$ $W = 0.005839 + 1/80.04$ $W = 0.013480$	$W = W_q + 1/\mu$ $W = 0.003145 + 1/80.04$ $W = 0.012960$
L = THE AVERAGE NUMBER (PER HOUR) OF MECHANICS ARE IN THE TOOL CRIB, BOTH WAITING AND BEING SERVED.		
$L = W \lambda$ $L = (0.019986)(94.24)$ $L = 1.8820$	$L = W \lambda$ $L = (0.013480)(94.24)$ $L = 1.2720$	$L = W \lambda$ $L = (0.012960)(94.24)$ $L = 1.2220$

16.6.4.2. When this information is combined, make an economical decision about the number of attendants (or servers) to use, given that the service rate and arrival rate do not change. See [Figure 16.9](#) for this comparison. This figure shows that three attendants provide the most efficient operation.

Figure 16.9. Average Total Costs of Operation for Tool Crib Example.

	2 ATTENDANTS	Cost per Hour	3 ATTENDANTS	Cost per Hour	4 ATTENDANTS	Cost per Hour
CALCULATED VALUES:						
Average rate of arrival for each customer	96.24 mechanics arrive per hour		96.24 mechanics arrive per hour		96.24 mechanics arrive per hour	
Average rate of service for each attendant	80.04 mechanics served per hour		80.04 mechanics served per hour		80.04 mechanics served per hour	
Average time a mechanic spends waiting in system	0.019566 hours		0.013480 hours		0.012660 hours	
Average number of mechanics waiting in system	1.8830 mechanics		1.2973 mechanics		1.2184 mechanics	
COST OF WAITING:						
Pay rate for the mechanics	\$7.00 per hour		\$7.00 per hour		\$7.00 per hour	
Total cost for the mechanics waiting (pay rate times the number waiting)	(\$7.00)(1.8830)	\$13.18	(\$7.00)(1.2973)	\$ 9.08	(\$7.00)(1.2184)	\$ 8.53
COST OF SERVICE:						
Pay rate for the attendants	\$3.00 per hour		\$3.00 per hour		\$3.00 per hour	
Total cost to pay this many attendants (pay rate times the number of attendants)	(\$3.00)(2)	\$ 6.00	(\$3.00)(3)	\$ 9.00	(\$3.00)(4)	\$12.00
TOTAL COST FOR ONE HOUR OF OPERATING THE TOOL CRIB		<u>\$19.18</u>		<u>\$18.08</u>		<u>\$20.53</u>

16.7. Uses of Queueing Analysis.

16.7.1. Manpower Standards. Use queueing analysis to determine the number of requirements allowed by a manpower standard when the acceptable level of service is known.

16.7.2. Management Consultant Studies. In management consultant studies, the main thrust of a queueing study is directed more toward improving the productivity rather than determining manpower requirements. Queueing analysis can provide the potential improvement results of changing the average service times or the number of servers.

16.8. Queueing Analysis References. Queueing analysis is covered in various textbooks for operations research, management, and simulation. References include: Gross, Donald and Harris, Carl A., Fundamentals of Queueing Theory, John Wiley & Sons, 1974. Hillier, Frederick S., and Lieberman, Gerald J., Introduction to Operations Research, Holden-Day, Inc., 1972, pp. 285-356. Levin, Richard I., and Kirkpatrick, Charles A., Quantitative Approaches to Management, 2d ed., McGraw-Hill, Inc., 1971, pp. 368-391. Schmidt, J. W., and Taylor, R. E., Simulation and Analysis of Industrial Systems, Richard D. Irvin, Inc., 1970, **Chapters 3 and 8.**

16.9. Forms Prescribed. The following forms are prescribed by this volume: **NOTE: SOME OF THE FORMS REFERRED TO IN THIS VOLUME ARE NOT PUBLISHED ELECTRONICALLY BUT ARE CURRENT. YOU MUST REFER TO THE MASTER CATALOG ON AIR FORCE PUBLISHING WEBSITE TO DETERMINE THE CURRENCY AND PUBLISHING METHOD.**

Figure 16.10. Forms Prescribed.

FORM NO.	TITLE
AF 308	Standard Input Data Computation
AF 313	Time Study Record
AF 1040	Operational Audit Data
AF 1111	Work Sampling Record
AF 1113	Standard Applicability Man-Hour Range
AF 1152	Daily Work Sampling Observation
AF 1157	Work Sampling Recapitulation
AF 3576	Flow/Procedures Chart
DD 1723	Flow Process Chart
DD 1724	Work Distribution Chart
DD 2030	Activity/Task List
DD 2042	Work Measurement Time Study Worksheet (Snapback)
DD 2042-1	Work Measurement Time Study Worksheet (Continuous Method)
DD 2043	Work Measurement Project Non-Repetitive Time Study
DD 2050	Procedures Chart

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DCS/Plans and Programs

Attachment 1**GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION*****References***

NOTE: The user of this instruction is responsible for verifying the currency of the cited documents.

AFI 36-502, *Operating a Position Management Program*

AFI 36-2611, *Officer Professional Development Guide* (formerly AFR 36-23)

AFI 36-2618, *Enlisted Force Structure* (Formerly AFR 39-6)

AFI 38-201, *Determining Manpower Requirements* (formerly AFRs 25-5 and 26-1, Volume 3)

AFI 90-1102, *Performance Management*

AFMAN 36-2105, *Officer Classification* (formerly AFR 36-1)

AFMAN 36-2108, *Airman Classification* (formerly AFR 39-1)

AFMS 00AA, *Standard Indirect Allowed Man-hours*

Abbreviations and Acronyms

AFMS—Air Force Manpower Standard

AFS—Air Force specialty

AFSC—Air Force Specialty Code

MDS—Manpower Data System

C&R—correlation and regression

CEM—chief enlisted manager

CME—contract manpower equivalent

CPG—career progression group

DRF—directed requirement factor

FAC—functional account code

FASCAP—Fast Payback Capital Investment

FEE—functional estimating equation

FOA—Field Operating Agency

FP—flow procedures

FYDP—Future Years Defense Program

KRA—key result area

LCL—lower control limit

LCOM—Logistics Composite Model

M&O—Manpower and Organization
MAF—man-hour availability factor
MEO—most efficient organization
MEP—Management Engineering Program
MFP—Major Force Program
MET—mission-essential tasks
MMF—minimum manpower factor
MPF—Military Personnel Flight
MSDS—Manpower Standards Development System
OA—Operational Audit
OPR—Office of Primary Responsibility
PAT—per accomplishment time
PEC—program element code
PEF—program estimating factor
POD—process oriented description
POR—process oriented review
P&R—personal and rest
PR&D—personal, rest, and delay
PWLF—potential workload factor
PWS—Performance Work Statement
RNLTD—report not later than date
SIAM—standard indirect allowed man-hours
SID—standard indirect description
SOC—Statement of Conditions
UCL—upper control limit
UMD—Unit Manpower Document
WLF—workload factor
WS—work sampling

Terms

Absolute Accuracy—Desired accuracy defined by a set interval not specifically related to another process parameter.

Accountable Time—Total man-hours that the work center supervisor is held accountable in determining productivity or operational efficiency. Accountable time equates to assigned time plus borrowed time plus

overtime minus nonavailable time minus loaned time.

Adjustment Factor—A specific computed value used to adjust an individual process time or associated work unit count.

Aggregation—The procedure of summing fractional work center manpower requirements (generated by application of manpower standards) before applying rounding procedures. This definition is applicable only when the term is associated with fractional manpower.

Air Force Manpower Standard (AFMS)—A numbered, specialized publication that quantifies manpower requirements for a work center. Also includes approved Air Force variances. See AFI 38-201.

Allowance—A time increment included in the standard time for an operation to compensate the worker for production lost due to fatigue and normally expected interruptions, such as for personal, rest, and unavoidable delays (PR&D). It is usually applied as a percentage of the normal or leveled time to determine standard time.

Allowance Factor—A coefficient, based on authorized allowances, that is applied to productive time (leveled time, if appropriate), and results in the productive allowed time.

Allowed Time—The leveled time plus allowances for rest and delays. If leveling is neither required nor feasible, the allowed time is the actual productive time plus necessary allowances for PR&D as appropriate.

Ancillary Training—Training that contributes either directly or indirectly to mission accomplishment, but that is separate from requirements in an individual's primary Air Force specialty. Included are training subjects not identified in specific AFSSs contained in AFMANs 36-2105 or 36-2108 or appropriate civilian job qualifications and classification standards. Examples include standards of conduct, disaster preparedness, and drug and alcohol education. Also included are all non-AFS-related training conducted in conjunction with formal technical programs such as student leader training and study habits.

Assigned Time—The normal duty hours prescribed for an individual assigned to a military unit. Total assigned hours are computed by multiplying daily normal duty hours by the net assigned duty days (gain report not later than date (RNLTD) to loss RNLTD). Net assigned duty days exclude relief days (for example, weekends and holidays). **NOTE:** For purposes of this computation, borrowed personnel are not classified as assigned.

Assumed Work—Work being done that is not necessary to work center productivity. Assumed workloads are not compensated for in the standard.

Available Time—Man-hours dedicated to performance of primary duties.

Average Monthly Workdays—The average number of days a work center operates during a month to cover stated required weekly hours of operation.

Average Monthly Workload—The arithmetical average of the actual monthly workload volumes.

Avoidable Delay—Any unnecessary delay, regardless of source, that causes work stoppage. Time lost to avoidable delay is not included in the standard.

Backup Aerospace Vehicle Authorized (BAA)—Aircraft authorized over and above the Primary Aerospace Vehicle Authorized (PAA) to allow for scheduled and unscheduled depot level maintenance, modifications, inspections and reports, and certain other mitigating circumstances without reduction of aircraft available for the assigned mission.

Backup Aerospace Vehicle Inventory (BAI)—Aircraft assigned to meet the BAA.

Balking—A situation in queueing analysis where a member of the input population (a customer) arrives for service, but elects not to enter the queue (perhaps it was too full). This behavior alters the arrival pattern.

Base Population (assigned)—The summation of all categories of assigned personnel at an Air Force installation. This definition may be expanded to include assigned personnel not located on, but supported by, the installation. Base population may also be modified to exclude certain categories of assigned personnel.

Base Time—The time required for completion of a task under the circumstances defined as standard, except that it does not include any time for the operators' personal needs and time lost due to other miscellaneous causes.

Benchmark Time—Reasonably expected value for frequency, per accomplishment time, or workload values to be used as guides during work measurement.

Bivariate Equation—An equation that contains only two variables, such as X and Y.

Borrowed Time—Time on loan from another work center.

Common Cause—A cause of variation in a process that is random and uncontrollable.

Constraining—A process that an analyst incrementally changes the availability of resources used during simulation in order to determine mission requirements. Nonmanpower resources are constrained on a unit basis and manpower resources are constrained by specific shift authorizations.

Continuous Improvement—Using the combined knowledge of all workers associated with a process to identify small or large changes that will improve the product or service that results.

Contract Manpower Equivalent (CME)—The amount of manpower required if the contract workload were done in-house at the same workload and level of performance as the contractor. CMEs are in terms of civilian manpower requirements. During the application process, manpower standards are computed. CME values (representing workload included in the standard) are subtracted from the computed requirement to yield the in-service portion of the work center requirements.

Control Chart—A chart showing time-related performance of a process. It's used to determine when the process is operating in or out of statistical control, using control limits defined on the chart.

Control Limits—A statistically derived limit for a process that indicates the spread of variation attributable to chance variation in the process. Control limits are based on averages.

Delay Allowance—A time increment in a time standard used to compensate for unavoidable delay.

Desired Accuracy—The maximum amount of error acceptable in a sample. This is stated as absolute accuracy or relative accuracy.

Directed Organization Position—A position requirement established by HQ USAF to fill a particular named assignment (for example, Wing Commander, etc.).

Directed Requirement Factor (DRF)—A constant man-hour requirement directed by higher headquarters policy. It is used to determine the minimum-manpower factor.

Directed Requirement Technique—An operational audit technique that recognizes many activities and some positions as directed requirements. These requirements may apply to whole-man positions; to

directed frequencies, such as monthly inspections; or to directed time values, such as the periodic run up of a standby electrical power generator.

Direct Time—Productive time expenditure that can be identified with and assessed against a particular end product (work unit, workload factor, etc.) or group of products accurately and without undue effort and expense.

Element—A subdivision of the work cycle made up of a sequence of one or more fundamental motions and machine or process activities, that is distinct, describable, and measurable.

Equivalent Workload Factor—A single, constructed workload factor value derived by a weighting of multiple work units. The weighting process is done by selecting one unit as the prime work generator, assigning a value of 1.00 to it, and giving all other applicable work units a weighted value in relation to that prime factor.

Extrapolation—Extension of the regression line beyond the range of the input data to increase the standard's utility, to expand the manpower standard's applicability, and to prevent rapid obsolescence due to workload changes.

Facilitator—A person who functions as the coach/consultant to a group, team, or organization. The facilitator focuses on the techniques to generate ideas from the participants of the workshop or improvement team.

Family of Standards—A group of manpower standards, concurrently or separately developed, related by the characteristic that the entire group is common to the same functions or work centers.

Fast Payback Capital Investment (FASCAP) Program—A part of the Productivity Enhancing Capital Investment Program that uses capital investment funds for improved productivity according to AFI 38-301.

Flow Diagram—A representation of the location of activities or operations and the flow of materials between activities on a pictorial layout of a process. Usually used with a flow process chart.

Flow Process Chart—A graphic, symbolic representation of the work done or to be done to produce a product or service as it passes through some or all of the stages of a process.

Fractional Manpower—Manpower requirements to do a specific workload, expressed in fractional parts of whole persons.

Frequency—The number of times a specific value occurs within a sample of several measurements of the same dimension or characteristics on several similar terms. In work measurement, the number of times an element occurs during an operation cycle.

Functional Estimating Equation (FEE)—An estimating equation that is used to predict manpower requirements for a functional group. Each FEE has two parts: a mathematical equation and a series of percentage factors by program element code.

Functional Measures—Indicators of performance documented for feedback to all levels of management on productivity; a monitoring tool that is reactive to the needs of management in terms of input, output, efficiency, effectiveness, and unit labor cost indicators.

Functional Model—A mathematical representation of the relationship between the manpower in a specific function and relevant policy, program, or workload variable.

Good Operator Timing Technique—An operational audit technique that establishes time values by

measuring the time a qualified individual spends on a given activity.

Grade Structure.—Distribution of grades within an organizational entity.

Historical Records—Documented past work performances of the work center. Includes mistakes or inefficiencies of past operations. Syn: Historical Data.

Idle Time—Any time expended by the worker either in an avoidable delay status or in doing unnecessary work when work is available. It does not include time for personal, rest, and unavoidable delays (PR&D). Idle time is not included in a manpower standard. An individual who goes to the base exchange, commissary, barber shop, etc., and meets the above conditions, is classified as being on idle time.

Impact Application—The result of a newly-developed manpower standard that is applied to either the total or partial number of bases in the work center population to show the effect that the standard has on a work center's current manpower requirements.

Indirect Time—Time that does not add to the value of a product, but must be done to support the manufacture of the product. It may not be readily identifiable with a specific product or service.

Inferred Workload—Workload that is defined as the responsibility of another work center. It can be treated by transferring either the workload, prior to measurement, or the time expended on that workload (loaned time) to the appropriate work center, after measurement.

In-house Activities—Activities operated and managed by Air Force in-service personnel to provide products or services.

Input Population—Data that enters the queueing system, characterized by its size (that is, the total number of units that could require service at one time or another).

Internal Work—Manual work done by an operator while a machine or process is operating automatically.

Key Result Areas (KRA)—The most critical selected areas of a function's responsibilities that, when monitored, state how well the work center is performing its mission requirements.

Layout—The physical arrangement, either existing or on plans, of facilities or items necessary to do a work task.

Layout Analysis—Studies used to improve production, ease physical exertion, and shorten travel for material and personnel.

Leveled Time—Actual productive time adjusted to account for differences in pace of observed workers.

Leveling—Process whereby an analyst evaluates observed operator performance in terms of a concept of normal performance. Syn: Performance or Pace Rating.

Loaned Time—Time loaned to other work centers. This time is not accountable to the work center providing the loaned time.

Management Work Center—Set up to manage two or more subordinate work centers. Syn: Overhead Work Center.

Man-hour—A unit of measuring work. It is equivalent to one person working at a normal pace for 60 minutes, two people working at a normal pace for 30 minutes, or a similar combination of people working at a normal pace for a period of time equal to 60 minutes.

Man-hour Availability Factor (MAF)—This factor is the average number of man-hours per month an assigned individual is available to do primary duties. Required man-hours are divided by the MAF times the overload factor to determine the manpower requirements.

Man-hour Population—The total set of man-hours that a sample is drawn from reflecting the required man-hours for a work center. This set includes: man-hours for all personnel assigned, borrowed time, and overtime. It does not include loaned time.

Manpower Authorization—A funded manpower requirement.

Manpower Model—Mathematical equation that describes the relationship between independent variables (workload values) and manpower or man-hours.

Manpower Requirements—Human resources needed to accomplish specified workloads of organizations. There are two types of manpower requirements: funded and unfunded. Funded manpower requirements are those that have been validated and allocated. Unfunded requirements are validated manpower needs that have been deferred because of budgetary constraints.

Manpower Resources—Human resources available to the Air Force that can be applied against manpower requirements.

Manpower Standard—The basic tool used to determine the minimum level of manpower required to support a function. It is a quantitative expression that represents a work center's man-hour requirements in response to varying levels of workload.

Manpower Standards Study Final Report—Historical documentation consisting of the manpower standard, supporting comments and documents, and computational data.

Manpower Standards Study Measurement Plan—Document prepared addressing WHAT is to be measured and HOW it is to be measured.

Manpower Utilization—The manner that manpower resources are distributed in an organization to accomplish the assigned functional mission.

Methods Improvement—A systematic way of finding easier, faster, or more economical methods of doing work.

Minimum Manpower—A method of developing a standard that couples a functional OPR-approved requirement with a predetermined manpower factor.

Minimum Manpower Factor (MMF)—A fractional manpower computation that shows the manpower required to man a position. This factor is dictated by the need for one or more individuals to be on duty, although they may not be continuously productive.

Minimum Response Rates—A standard of operation specifying the reaction time to a situation that can affect the work center manpower requirements.

Mission Directive—Description of work that explains a work center's responsibility.

Mix—The combination of military, civilian, and contract resources used for mission accomplishment.

Modular Equations—A series of equations that represent one work center or family of standards. These equations are appropriate when all required man-hours for a work center or family of standards can be subdivided into separate independent modules.

Monthly Allowed Man-hour Adjustment—Adjustment of work sampling data to the work center's

average workdays per month to reflect a monthly man-hour requirement.

Monthly Workload Data Adjustment—Adjustment of the counts of production-type work units to an average monthly count, when work sampling is done for a period other than a normal work month.

Multilocation Standards—Standards that apply to more than one location that are developed from the data collected at two or more Air Force installations.

Multivariate Equation—An equation containing two or more independent variables.

Nonavailable Time—Assigned man-hours allowed for participation in those activities directed, recognized, and approved by the Air Force, that render the individual unavailable for assigned primary duties. For example:

1. **Leave.** Permission to be absent from work or duty in official status for a specified period of time to include passes and rest and recuperation.
2. **PCS Related.** The time workers are absent from duty for accomplishing tasks generated by a permanent change of duty station. This includes in and out processing, family settlement, and authorized shipment of privately owned vehicle.
3. **Medical.** Official permission to be absent from primary duty for medical reasons such as pregnancy, inpatient and quarters cases, outpatient visits, physicals, and dental visits.
4. **Organizational Duties.** Official release from primary duty to do aerobics, counseling, reviews boards and councils, Sponsor/INTRO Program, and additional duties.
5. **Education and Training.** Official release from duty to attend ancillary training, SOS, NCO Academy, TDY, and technical training. Also includes taking tests such as PFE, SKT, Air Force Supervisory Exam, and CLEP.

Nonmeasurement Approach—Measurement techniques that are used to validate the existing manpower requirements without actually doing a statistically controlled work measurement. The nonmeasurement approaches are staffing pattern, directed requirements, position manning and simulation.

Nonproductive Time—Accountable time expended in either PR&D, standby, on call, or idle (avoidable delay) status.

Nonprogrammable Workload Factor—If the selected WLF is not in programming documents or if the transition of a potential WLF to a programming variable cannot be made due to differences in definitions, then the WLF is nonprogrammable.

Nontransferable Work—Work essential to the work center that must be done at a specific time or period. It can be direct or indirect type work.

Observation—In work sampling, the act of noting what the people in a work center, or in a specified portion of a work center, are doing at a specific instant. Such an observation yields a number of samples equal to the number of people observed. See Sample.

Obsolete Standard—A manpower standard that has been rescinded or superseded by another standard and is no longer current. Also, a manpower standard that does not adequately portray the prescribed mission responsibilities of the function. Such standards are deleted from the manpower standards publication with the coordination of the appropriate functional OPR.

On Call Time—A nonproductive category of time when an off-duty worker can be contacted by

telephone or other means at a prearranged location other than the work station. Only the productive time spent by the worker in the work center or at the work location, including necessary associated travel, is to be credited to the work center. Examples are: a photographer needed to periodically take photos after duty hours or a maintenance specialist who is needed infrequently to repair or replace a critical item of equipment.

Operational Audit (OA)—A MEP work measurement method consisting of one or a combination of the following techniques: good operator timing, historical records, technical estimate, standard time, and directed requirement.

Outliers—A term used to describe those data points that do not conform to the general pattern or trend described by a data array or scattergram, (for example, data points that are beyond established control limits or that are significantly divergent from an otherwise apparent trend).

Overspecialization—Work centers that have become too specific in work description, thereby causing many small work centers to be established.

Overtime—Time expended in excess of regularly scheduled working hours.

Participating Base OPR—A base OPR whose activity serves as a data source for a participating input MO or lead team during a functional review manpower standards study.

Performance or Pace Rating—The act of comparing an actual performance by a worker against a defined concept of a normal performance. Various methods of performance rating are in use. These methods differ primarily as to the basis on which the comparisons are made. Pace rating is the method of performance rating prescribed for use in the MEP. See Leveling.

Performance Rating Factor—

1. A numerical index that relates an observed performance to a defined normal performance.
2. Any of the terms or elements used for the comparison of performance. Performance Sampling. A technique for deriving the performance rating factor to be applied to an operator or a group of operators determined by short, randomly spaced observations of the performance.

Personal Allowance—Time included in a standard to permit a worker to attend to personal necessities, such as obtaining drinks of water or making trips to the restroom (usually applied as a percentage of the leveled, normal or adjusted time).

Poisson Distribution—Independence of an occurrence in an interval and the proportionality of an occurrence to the size of the interval.

Predictability—A significant attribute that allows reliable predictions for future time periods to make a standard useful for programming future requirements.

Primary Aerospace Vehicle Authorized (PAA)—Aircraft authorized for performance of the unit's mission (e.g., Combat, Combat Support, Training, Test and Evaluation, etc). The PAA forms the basis for the allocation of operating resources to include manpower, support equipment, and flying hour funds. The operating command determines the PAA required to meet their assigned missions.

Primary Aerospace Vehicle Inventory (PAI)—Aircraft assigned to meet the PAA.

Procedure—A sequence of written operations established to get uniform processing by telling what actions are to be taken, who takes them, the sequence to be followed, and the tools to be used.

Procedure Chart—A graphical display showing the flow of material or information in an organization. It reflects the flow of information between work stations and between work centers, shows decisions made, and actions taken by individuals.

Process—A series of progressive and interdependent steps by which an end is attained.

Process Oriented Description (POD)—A format that shows work center responsibilities structured for easy measurement of process and steps.

Production Count—See Work Count.

Productive Time—Time spent doing work that is useful and essential to the mission of the work center. See Direct Time and Indirect Time.

Program Change—An approach used to determine programmed requirements. This could cause manpower changes.

Program Element Code (PEC)—An alphanumeric code assigned to each program element that is used to identify a Major Force Program.

Programmable Workload Factor (PWLF)—A workload factor (WLF) and definition that matches a program variable found in programming documents that allow the WLF to be programmable.

Programmability—A resource identified in a programming document.

Programming Document—An official programming document published by the Office of the Secretary of Defense or the Department of the Air Force. This document exhibits a program identifying the resources required, by time period, to provide defense capabilities necessary to support the national strategy, for example, the United States Air Force program bases, units, and priorities (PD).

Projected Workload—An amount of work proposed or anticipated to meet the requirements of a program over a specified period.

Quality Assurance—For purposes of an in-house manpower study, quality assurance is a planned and systematic pattern of all actions necessary to provide adequate confidence that adequate technical requirements are established; products and services conform to established technical requirements; and satisfactory performance is achieved. For commercial activities having undergone a cost comparison, quality assurance are those actions taken by the government to assure that services meet the requirements in the statement of work.

Rater Proficiency—Skill of a technician to gain a mental image of normal and to rate in a consistent manner.

Ratio Unit Time—A computational method using a ratio of man-hours required to workload accomplished to develop a standard. This method is generally used for single location standards.

Regression Analysis—A mathematical examination of relationships between two or more variables showing how useful these variables can be for prediction purposes.

Relatability—A characteristic relating to manpower requirements. A change in the value of the workload factor produces a corresponding change in the man-hours needed to do the task.

Relative Accuracy—Size of error allowed in the sample when accuracy is stated relative to the value of the mean. Relative accuracy is used primarily in time study. See Desired Accuracy.

Required Grade—The grade reflected in the required grade column (Data Element-RGR) of the UMD.

The grades in this data element represent unconstrained requirements needed to do the job and are, when applicable, determined by the management engineering process.

Resource Utilization—The application of resources (personnel, materials, and services) to accomplish missions, functions, and responsibilities.

Rest—An allowance made in a manpower standard to account for mental or physical weariness caused by job difficulty and environmental conditions.

Rounding—A process that terminates an endless string of decimal places.

Sample—A single recorded status of one person during an observation of a work center. Usually, more than one sample comes from one observation. The number of samples needed affects the number of observations required for each work center.

Sample Size—The number of samples taken usually for a desired level of accuracy.

Sample Subgroup—Size—For most AF MEP program applications, we assume a sample subgroup size of one; however, Manpower technicians should be aware that subgroup sizes can in fact be larger than one for given statistical applications.

Sampled Time—Computed man-hours from a work sampling study which are based on total available samples.

Scattergrams—A two-dimensional chart on which known values of two variables are plotted. Examination of the chart shows the form of relationship which exists between the variables - for example, straight line or curvilinear.

Simulation—A nonmeasurement method used to determine total work center manpower requirements. The most common technique is queueing.

Special Cause—A cause of variation in a process that is not a random or uncontrollable cause.

Special Study—A consultant service requested by a base-level work center supervisor or manager and generally applicable only to that base. Specific results are released with permission of the requesting OPR.

Staffing Patterns—Man-hours allowed, usually on a one-for-one basis, in work centers that are not governed by rate of production, but are established for management functions.

Standard—An exact value, physical entity, or abstract concept established and defined by authority, custom, or common consent to serve as a reference, model, or rule in measuring quantities or qualities, establishing practices or procedures, or evaluating results. A fixed quantity or quality.

Standard Indirect Allowed Man-Hours (SIAMs)—Predetermined times for standard indirect tasks (see AFMS 00AA).

Standard Time—

1. The time that is considered necessary for a qualified worker, working at a normal pace under capable supervision and experiencing normal rest and delays, to do a definite amount of work of specified quality when the prescribed method is followed.
2. Time measured by use of rigid statistical methods; for example, time study.
3. The normal or leveled time plus allowances for rest and unavoidable delays.

Standards Application—A systematic determination of required or allowed manpower authorizations for Air Force activities using manpower standards. The process consists of relating prescribed workload factor volumes to manpower models or tables resulting in a numerical identification of whole authorizations normally by Air Force specialty, skill level, and grade. Often referred to as “pricing out a standard.”

Standards Development—A study phase that designs, measures, analyzes, and determines a work center or function's manpower requirements.

Standby Time—When the worker is required to be present to do time-sensitive work, and is in a ready status to do this work, but is prevented from doing it because none is available. Time can be classified as standby only when it is essential to mission accomplishment and when no work can be done or made available during that period. Examples of standby time are: an emergency room medical technician awaiting patients; a commissary ID checker awaiting customers to enter the checkout line; a taxi driver awaiting passengers at a dispatch office; and a passenger processing specialist awaiting aircraft arrival.

Straightlining—A way to forecast future workload that assumes that there will be no change in workload from what has occurred in the past.

Stratified Random Times—Random times selected to provide equal number of observations for each specified time period, such as four random times per hour.

Systems Analysis—Investigating a system of operation in an organization from supplier to customer. Then developing a new system incorporating the viable ideas of all workers in the system with the intent of improving service to the customer.

Task List—A clear and complete description of the actions or duties of an individual.

Technical Estimate—A determination of the standard hours required for a given task, based on an estimate by individuals who are technically and professionally competent to judge the time required.

Time Study—A work measurement method consisting of careful time measurement of the task with a time measuring instrument. The study is adjusted for any observed variances from normal effort to pace. It allows adequate time for unavoidable or machine delays, rest to overcome fatigue, and personal needs. Learning or progress effects may also be considered. If the task is long, it is normally broken down into short, relatively homogeneous work elements, each of which is treated separately by, and in combination with, the rest.

Transferable Work—Work that is essential to the work center, but may be done at any time or during any period. It may be direct or indirect type of work.

Transient Time—Time associated with travel and leave in conjunction with a PCS move. Manpower authorizations to offset this loss are provided for in the transient or individual's account and are not contained in the MAJCOM UAF.

Unavoidable Delay—An occurrence that is essential and outside the worker's control or responsibility that prevents the accomplishment of productive work.

Unavoidable Delay Allowance—See Delay Allowance.

Unit Manpower Document (UMD)—A detailed manpower listing reflecting the distribution of manpower allocations into a finite structure of authorizations (by work center).

Variance—A condition that exists that either adds to or subtracts from the core workload, or impacts the

way the work is performed. A variance can be the result of environmental, mission or technological differences, and can be either negative or positive.

1. **Environmental Variance.** Accounts for different operating conditions from those used to develop the core manpower standard (e.g., snow, geographical separation, etc.). It can either increase (positive) or decrease (negative) requirements.
2. **Mission Variance.** Accounts for different operating processes from those used to develop the core manpower requirements. It can either increase (positive) or decrease (negative) requirements.
3. **Technological Variance.** Accounts for different operating equipment from those used to develop the core manpower requirements. It can either increase (positive) or decrease (negative) requirements.

Variation—A measure of the dispersion or scattering of values about the mean of a distribution.

Work Center—A group of personnel that use similar machines, processes, methods, and operations to do homogeneous work usually located in a centralized area. The term is used to identify a relatively small activity within a broad functional segment. Personnel within a work center do work that basically contributes to the same end product or result (duties are similar or closely related).

Work Count—The number of work units done during a specified time period.

Work Cycle—

1. A pattern or sequence of tasks, operations, or processes with a distinct beginning and ending point.
2. A pattern of manual motions, elements, activities, or operations that are repeated without significant variation each time a unit of work is completed.

Work Distribution Analysis—A technique to improve production that helps find out what work is being done, how much time is spent on it, and who is doing it.

Work Flow—The flow or movement of things being processed from one operation to another.

Work Measurement—Process to obtain data necessary to compute accurate manpower requirements. Techniques include work sampling, time study, and good operator timing and technical estimate. Usually results in a manpower standard or guide.

Work Sampling—The application of statistical sampling theory and techniques to the study of work systems. The characteristics of the sampled (observed) work done are used to produce estimates of the amounts of work and types of activity done. Work sampling data can be used in conjunction with associated work counts to compute standards.

Work Unit—The basic identification of work accomplished or services performed. Work units should be easy to identify; convenient for obtaining productive count; and usable for scheduling, planning, and costing. Syn: Workload Factor.

Workload—An expression of the amount of work, identified by the number of work units or volume of a workload factor, that a work center has on hand at any given time or is responsible for doing during a specified period of time.

Workload Factor (WLF)—

1. An index or unit of measure that is consistently expressive of, or relatable to, the manpower required to accomplish the quantitatively and qualitatively defined responsibilities of a work center.
2. An end product (or a combination of products) that represents the work done in the work center. It may be either something physically produced in the work center (referred to as a production-type WLF) or something that is external to, but served by, the work center (referred to as a work generator-type WLF).

Attachment 2

STATISTICAL TABLES

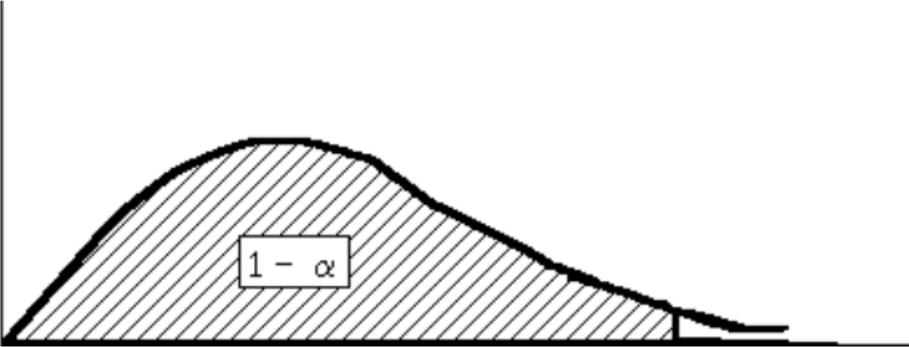
Critical Values (F^*) for the F-test

- Two Tables are contained here. One is for 90% confidence ([Table A2.1.](#)) and the other for 95% confidence ([Table A2.2.](#)).
- This test is primarily used for the MEP to decide if a regression equation explains a significant amount of the variation.

Critical Values (t^*) for the t-test.

- This test is used in regression analysis to determine if an individual variable contributes significantly to the overall equation.
- When the sample size (n) gets very large (∞), the values on the t-Table become the same as the values found on a normal Z-Table. Therefore, values in this t-Table corresponding with $df = \infty$ can be used for the Z values when $n > 30$.

Table A2.1. Critical Values For The F-Test.

<p>Definitions:</p> <ol style="list-style-type: none"> 1. $df_1 =$ degrees of freedom for the numerator ($m - 1$)* 2. $df_2 =$ degrees of freedom for the denominator ($n - m$)* 3. $(1 - \alpha)\%$ = per cent of confidence in the results of this test <p>* From regression analysis, m is the number of regression coefficients estimated and n is the number of data sets.</p>
<p>Diagram:</p>  <p style="text-align: center;">$F(1- , d/1, d/2)$</p>

Values for $F_{(.90, df_1, df_2)}$		90% Confidence									
		df ₁ = degrees of freedom for the numerator									
		1	2	3	4	5	6	7	8	9	10
1	1	39.86	49.50	53.59	55.83	57.24	58.20	58.91	59.44	59.86	60.19
2	2	8.53	9.00	9.16	9.24	9.29	9.33	9.35	9.37	9.38	9.39
3	3	5.54	5.46	5.39	5.34	5.31	5.28	5.27	5.25	5.24	5.23
4	4	4.54	4.32	4.19	4.11	4.05	4.01	3.98	3.95	3.94	3.92
5	5	4.06	3.78	3.62	3.52	3.45	3.40	3.37	3.34	3.32	3.30
6	6	3.78	3.46	3.29	3.18	3.11	3.05	3.01	2.98	2.96	2.94
7	7	3.59	3.26	3.07	2.96	2.88	2.83	2.78	2.75	2.72	2.70
8	8	3.46	3.11	2.92	2.81	2.73	2.67	2.62	2.59	2.56	2.50
9	9	3.36	3.01	2.81	2.69	2.61	2.55	2.51	2.47	2.44	2.42
10	10	3.29	2.92	2.73	2.61	2.52	2.46	2.41	2.38	2.35	2.32
11	11	3.23	2.86	2.66	2.54	2.45	2.39	2.34	2.30	2.27	2.25
12	12	3.18	2.81	2.61	2.48	2.39	2.33	2.28	2.24	2.21	2.19
13	13	3.14	2.76	2.56	2.43	2.35	2.28	2.23	2.20	2.16	2.14
14	14	3.10	2.73	2.52	2.39	2.31	2.24	2.19	2.15	2.12	2.10
15	15	3.07	2.70	2.49	2.36	2.27	2.21	2.16	2.12	2.09	2.06
16	16	3.05	2.67	2.46	2.33	2.24	2.18	2.13	2.09	2.06	2.03
17	17	3.03	2.64	2.44	2.31	2.22	2.15	2.10	2.06	2.03	2.00
18	18	3.01	2.62	2.42	2.29	2.20	2.13	2.08	2.04	2.00	1.98
19	19	2.99	2.61	2.40	2.27	2.18	2.11	2.06	2.02	1.98	1.96
20	20	2.97	2.59	2.38	2.25	2.16	2.09	2.04	2.00	1.96	1.94
21	21	2.96	2.57	2.36	2.23	2.14	2.08	2.02	1.98	1.95	1.92
22	22	2.95	2.56	2.35	2.22	2.13	2.06	2.01	1.97	1.93	1.90
23	23	2.94	2.55	2.34	2.21	2.11	2.05	1.99	1.95	1.92	1.89
24	24	2.93	2.54	2.33	2.19	2.10	2.04	1.98	1.94	1.91	1.88
25	25	2.92	2.53	2.32	2.18	2.09	2.02	1.97	1.93	1.89	1.87
26	26	2.91	2.52	2.31	2.17	2.08	2.01	1.96	1.92	1.88	1.86
27	27	2.90	2.51	2.30	2.17	2.07	2.00	1.95	1.92	1.87	1.85
28	28	2.89	2.50	2.29	2.16	2.06	2.00	1.94	1.90	1.87	1.84
29	29	2.89	2.50	2.28	2.15	2.06	1.99	1.93	1.89	1.86	1.83
30	30	2.88	2.49	2.28	2.14	2.05	1.98	1.93	1.88	1.85	1.82
40	40	2.84	2.44	2.23	2.09	2.00	1.93	1.87	1.83	1.79	1.76
60	60	2.79	2.39	2.18	2.04	1.95	1.87	1.82	1.77	1.74	1.71
120	120	2.75	2.35	2.13	1.99	1.90	1.82	1.77	1.72	1.68	1.65
α	α	2.71	2.30	2.08	1.94	1.85	1.77	1.72	1.67	1.63	1.60

Source: Pearson and Hartley, Biometrika Tables for Statisticians, Vol. I, (1958) pages 158-159.

Values for $F_{(.95, df_1, df_2)}$		95% Confidence									
		df ₁ = degrees of freedom for the numerator									
		1	2	3	4	5	6	7	8	9	10
1	1	161.40	199.50	215.70	224.60	230.20	234.00	236.80	238.90	240.50	241.90
2	2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40
3	3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79
4	4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96
5	5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74
6	6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06
7	7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64
8	8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35
9	9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14
10	10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98
11	11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85
12	12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75
13	13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67
14	14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60
15	15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54
16	16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49
17	17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45
18	18	4.41	3.53	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41
19	19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38
20	20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35
21	21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32
22	22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30
23	23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27
24	24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25
25	25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24
26	26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22
27	27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20
28	28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19
29	29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18
30	30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16
40	40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08
60	60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99
120	120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.91
α	α	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83

Source: Pearson and Hartley, Biometrika Tables for Statisticians, Vol. I, (1958) pages 158-159.

Table A2.2. Critical Values For The T-Test.

Definitions: 1. $df_1 = \text{degrees of freedom } (n - 1)$ 2. $1 - \alpha/2 = \text{probability associated with } (1 - \alpha) \% \text{ confidence when using a two-tailed test, i.e.,}$ $1 - \alpha/2 = .90 \text{ is used for } 80\% \text{ confidence}$ $1 - \alpha/2 = .95 \text{ is used for } 90\% \text{ confidence}$ $1 - \alpha/2 = .975 \text{ is used for } 95\% \text{ confidence}$							
Diagram: 							
Values of $t_{(1-\alpha/2, df)}$:							
df	$t_{.90}$	$t_{.95}$	$t_{.975}$	df	$t_{.90}$	$t_{.95}$	$t_{.975}$
1	3.078	6.314	12.706	16	1.337	1.746	2.120
2	1.886	2.920	4.303	17	1.333	1.740	2.110
3	1.638	2.353	3.182	18	1.330	1.734	2.101
4	1.533	2.132	2.776	19	1.328	1.729	2.093
5	1.476	2.015	2.571	20	1.325	1.725	2.086
6	1.440	1.943	2.447	21	1.323	1.721	2.080
7	1.415	1.895	2.365	22	1.321	1.717	2.074
8	1.397	1.860	2.306	23	1.319	1.714	2.069
9	1.383	1.833	2.262	24	1.318	1.711	2.064
10	1.372	1.812	2.228	25	1.316	1.708	2.060
11	1.363	1.796	2.201	26	1.315	1.706	2.056
12	1.356	1.782	2.179	27	1.314	1.703	2.052
13	1.350	1.771	2.160	28	1.313	1.701	2.048
14	1.345	1.761	2.145	29	1.311	1.699	2.045
15	1.341	1.753	2.131	30	1.310	1.697	2.042
				α	1.282	1.645	1.960

Source: Pearson and Hartley, Biometrika Tables for Statisticians, Vol I, (1958), page 138.

Table A2.3. Data Source And Statistical Analysis.

L I N E	A Standards based on work measurement method	B should meet	C and result in the following statistical parameters
1	Work Sampling	<ul style="list-style-type: none"> - 3% absolute accuracy - 95% confidence level - complete work cycle sampled - at least 15 usable sampling days 	<p>Regression analysis used to obtain equation and</p> <p>$R^2 \geq .750$ $V \leq .150$ $F_c \geq F_{.95, m-1, n-m}$ (not applicable if $n < 5$)</p> <p>or</p> <p>$V \leq .250$ $F_c \geq F_{.90, m-1, n-m}$ (not applicable if $n < 5$)</p> <p>and</p> <p>Equation meets realistic and economic criteria.</p>
2	Time Study	<ul style="list-style-type: none"> - 10% relative accuracy - 95% confidence level 	<p>Regression analysis used to obtain equation and</p> <p>$R^2 \geq .750$ $V \leq .150$</p> <p>For parabola $t_c \geq t_{.90, n-1}$</p> <p>For multivariate $t_c \geq t_{.90, n-1}$</p> <p>For parabola $t \geq t_{.90, n-1}$</p> <p>Equation meets realistic and economic criteria.</p>
3	Operational Audit		<p>Regression analysis used to obtain equation and</p> <p>$R^2 \geq .500$ $V \leq .250$</p> <p>For multivariate $t_{bi} \geq t_{.90, n-1}$</p> <p>Equation meets realistic and economic criteria.</p>

LINE	A	B	C
	Standards based on work measurement method	should meet	and result in the following statistical parameters
4	Staffing Pattern, Directed Requirement Minimum Manpower Factors, Functional Model, Historical Data, Simulation (excluding LCOM), Single Location and Small Population Standards	Based on logical rationale used to support the applicability of the development method as most appropriate for the work center. Should follow any other constraints outlined in this publication. Minimum number of input locations are not necessary. When using regression analysis for small population (three or four locations only) the R^2 must be $\geq .500$, the V must be $\leq .250$, and the economic and realistic criteria apply. When using regression analysis for single location (using historical data) the R^2 must be $\geq .500$, the V must be $\leq .250$, and $F_c \geq F$.	
5	Logical Computational Method	Based on logical rationale used to support the applicability of the development method as most appropriate for the work center. Minimum number of input locations is not necessary.	

Attachment 3**IC 2003-1 TO AFMAN 38-208, VOLUME 2, AIR FORCE MANAGEMENT ENGINEERING PROGRAM (MEP) - QUANTIFICATION TOOLS**

19 NOVEMBER 2003

SUMMARY OF REVISIONS

This change incorporates interim change (IC) 03-1, which operationalizes three new indirect man-hour measurement methods. Paragraphs 13.5 through 13.8.5.2 are all new paragraphs to Chapter 13, *STANDARD INDIRECT ALLOWED MAN-HOURS (SIAM)*.

13.5. Alternate Indirect Man-Hour Measurement Methods:

13.5.1. In addition to the SIAM, several other standard indirect measurement methods are available to provide flexibility in responding to the dynamic expeditionary nature of our aerospace forces. These tools include the Standard Indirect Allowed Man-Hour Equation (SIAME), Direct and Indirect Manpower Equation (DIME) and the Capabilities Based Manpower Determinant (CBMD) Standard Indirect Allowance Factor (SIAF).

13.5.1.1. The Air Force is transforming to a capabilities-focused Expeditionary Air and Space Force. In doing so, our goal is to make warfighting effects, and the capabilities we need to achieve them, the drivers for everything we do. In addressing this Air Force goal, we define manpower requirements in an environment of global engagement with expeditionary forces performing capabilities. We call this manpower quantification the CBMD.

13.5.1.2. The CBMD SIAF is designed to address indirect man-hours or indirect fractional manning when computing a CBMD manpower requirement. The DIME is designed to address indirect man-hours or fractional manning when combining all CBMDs for a determination of manpower requirements at the organizational level or function.

13.5.2. Each tool is discussed in detail in the following paragraphs. Table 13.1, Standard Indirect Measurement Tools Decision Logic Table, describes the advantages and disadvantages of each tool and when they are recommended for use.

TABLE 13.1. Standard Indirect Measurement Tools Decision Logic Table

Method	Recommended Employment	Advantage	Disadvantage
SIAM	To measure indirect man-hours for traditional peacetime manpower standards.	Most Accurate for non-CBMD manpower studies.	Slightly time consuming. Not designed for CBMD studies.
SIAME	Same as SIAM.	Quicker than SIAM.	Not designed for CBMD studies. Not as accurate as SIAM.
DIME	To quantify total CBMD manpower for a function. Since DIME was developed as a relationship of indirect requirement to direct requirement (while the SIAM and SIAME based on current assigned personnel), a recommended tool for computing indirect requirements for Most Efficient Organization (MEO). Also recommended for “to be” organizational models especially when significantly different from the “as is” POD.	Quick method to determine total CBMD FTEs for a function.	Not intended for application until completion of all associated CBMD studies.
CBMD SIAF	To quantify CBMD indirect man-hours or indirect fractional manpower. Also, a recommended tool for computing indirect requirements once direct requirements have been determined for relatively small mission changes or efficiencies.	Quick method to determine incremental indirect man-hours for a single CBMD.	Not as accurate as total measurement or SIAM.

13.6. Standard Indirect Allowed Man-Hour Equation (SIAME)

13.6.1. The SIAME is an alternate method of crediting indirect man-hours for Operational Audit and Time Study standards. Direct and SIAME man-hours are added to determine total monthly man-hours for work centers of five or more assigned personnel.

13.6.2. The SIAME was developed using the FAC family approach. Functional areas were analyzed by reviewing the primary mission, types of specialties used, and organizational levels within the function. Associated FACs were then grouped into SIAME families using the following definitions:

13.6.2.1. Management and Administration Work Centers. These work centers have the primary function of managing subordinate organizational elements and providing unit administrative support. Examples include the medical support squadron's personnel and administration flight, the civil engineer unit administration and the operations squadron's operations officer and the maintenance officer.

13.6.2.2. Production and Staff Support Work Centers. These work centers have the primary function of supporting the production area of an organization and researching, evaluating, reporting, coordinating, and advising. Examples include the wing manpower and organization office, the comptroller squadron financial analysis flight, the civil engineering or services squadron's resource management flights and the medical support squadron's medical information services flight.

13.6.2.3. Customer Service Work Centers. These work centers have the primary function of providing specific services to customers. Examples include the military and civilian personnel flights, base billeting, military pay and travel.

13.6.2.4. Medical Work Centers. These work centers include medical facilities and dental services.

13.6.2.5. Warehouse, Storage, and Issue. These work centers have the primary function of receiving, storing, or issuing material. Examples include the supply squadron material storage and distribution flight and fuels management flight.

13.6.2.6. Industrial Shop. These work centers have the primary function of testing, overhauling, repairing, or manufacturing specific products. Examples include aerospace ground equipment and vehicle maintenance.

13.6.2.7. Table 13.2, Air Force Peacetime SIAME Families reflects the SIAME for each of the FAC family.

TABLE 13.2. AIR FORCE PEACETIME SIAME FAMILIES

SIAME FAMILY	SIAME
MANAGEMENT & ADMIN	$Y_{(SIAME)} = 148.03 + 9.6973X$
PRODUCTION & STAFF SUPPORT	$Y_{(SIAME)} = 176.90 + 10.4032X$
CUSTOMER SERVICE	$Y_{(SIAME)} = 183.43 + 8.3195X$
MEDICAL	$Y_{(SIAME)} = 170.84 + 9.1903X$
WAREHOUSE, STORAGE & ISSUE	$Y_{(SIAME)} = 221.31 + 8.8398X$
INDUSTRIAL SHOP	$Y_{(SIAME)} = 270.13 + 9.3033X$
NOTES:	
1. $Y_{(SIAME)}$ results in total indirect man-hours.	
2. X = Average Number of Assigned Work Center Personnel	
3. Recommended for work centers of five or more assigned personnel.	

13.6.2.8. Table 13.3 complements Tables 13.2, 13.4 and 13.5. It reflects the SIAME, DIME and SIAF Family for each specific FAC. Tables 13.2, 13.4 and 13.5 are summaries of SIAME, DIME and SIAF models by general FAC family. The study team identifies the family on table 13.3 and uses the indicated equation or factor specified on Tables 13.2, 13.3 or 13.5. For example, Table 13.3 reflects Production and Staff Support for the Manpower function. Table 13.2 states the SIAME model to use is $Y_{(SIAME)} = 176.90 + 10.4032X$, Table 13.4 states the DIME model to use is $Y_{(DIME)} = 1.88 + 1.0785X$, and Table 13.5 states the SIAF factor to use is 1.0785.

Table 13.3. SIAME, DIME & SIAF Listing by FAC

FAC	TITLE	SIAME, DIME, SIAF Family
1011	Protocol	Management & Administration
1012	Gp Sq Command Unit	Management & Administration
1015	History/Staff	Production & Staff Support
101A	History	Production & Staff Support
101D	Dormitory Management	Management & Administration
1022	Area Defense Counsel	Customer Service
1025	Contract Law Counsel	Production & Staff Support
102A	Judge Advocate	Production & Staff Support
104A	Public Affairs	Production & Staff Support
1050	Chaplain Staff	Management & Administration
105A	Chaplain	Management & Administration
106A	Safety	Production & Staff Support
1080	Manpower & Innovation	Production & Staff Support
1080A	Wing/Center Manpower	Production & Staff Support
10A0	Wing Commander	Management & Administration
10B0	Logistics Group	Management & Administration
10C0	Support Group	Management & Administration
10D0	Operations Group	Management & Administration
1100	Information Mgmt Staff	Management & Administration
1101	Administrative Systems Mgmt	Production & Staff Support
1107	Plans & Programs - Staff	Management & Administration
1122	Micrographics Mgmt	Warehouse, Storage & Issue
1123	Engineering Data Service Center	Customer Service
1136	Postal Finance Office	Production & Staff Support
1150	Printing Mgmt	Management & Administration
1151	Printing	Industrial Shop
1153	Microform Production	Customer Service
1160	Publishing	Management & Administration
1170	Information Mgmt Center	Management & Administration
1171	Word Processing Center	Management & Administration
1172	Information Mgmt Support Cntr	Management & Administration
1200	Logistics Staff	Management & Administration
1205	Logistics Quality Assurance Staff	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
1210	Logistics Plans Staff	Management & Administration
1220	Supply Staff	Management & Administration
1230	Maintenance Staff	Management & Administration
1231	Aircraft Maintenance Staff	Management & Administration
1232	Munitions Maintenance Staff	Management & Administration
1233	Missile Maintenance Staff	Management & Administration
1234	Ground Com Elec Maint Staff	Production & Staff Support
1235	Maintenance Stand & Eval Teams	Management & Administration
1240	Transportation Staff	Management & Administration
1250	Contracting & Acquisition	Production & Staff Support
12A0	Operational Contracting	Production & Staff Support
12A1	Acquisition Flight	Production & Staff Support
12B1	Performance Management Flt	Production & Staff Support
12C1	Plans & Programs	Production & Staff Support
12D1	Contingency Support	Industrial Shop
12E1	Specialized Contracting	Production & Staff Support
1300	Operations Staff	Management & Administration
1301	TAC Unit Operations Center	Production & Staff Support
1310	Operational Plans	Production & Staff Support
131A	Wing Plans	Management & Administration
1320	Operational Requirements	Production & Staff Support
1340	Standardization & Evaluation	Production & Staff Support
135A	Command Post	Production & Staff Support
13A0	Operations Support Squadron	Management & Administration
13A1	Standardization & Evaluation	Production & Staff Support
13B1	Weapon/Tactics Flight	Production & Staff Support
13C1	Current Operations Flight	Management & Administration
13E1	Airfield Operations Flight	Management & Administration
1400	Plans & Programming	Production & Staff Support
1410	Policy	Production & Staff Support
1430	Programming Staff	Management & Administration
151A	Financial Management	Production & Staff Support
1517	Cost	Management & Administration
1530	Budget Staff	Management & Administration
1540	Data Automation/Operational	Production & Staff Support

FAC	TITLE	SIAME, DIME, SIAF Family
1541	Systems Analysis	Production & Staff Support
1542	ADP Equipment Mgmt	Production & Staff Support
1543	Data Proc Equip Operations	Production & Staff Support
1544	Computer Programming	Management & Administration
1546	Data Automation Staff	Production & Staff Support
1550	Audit Staff	Production & Staff Support
1551	Audit Operations	Customer Service
16B1	Military Personnel Flight	Customer Service
16C1	Civilian Personnel Flight	Customer Service
16D1	Social Actions Flight	Management & Administration
16E1	Education Services Flight	Customer Service
16F1	Family Support Center	Customer Service
16G1	Info Management Flight	Management & Administration
16W1	Equal Empl Optn Cnslr	Production & Staff Support
21A0	Logistics Support Squadron	Management & Administration
21A1	Quality Assurance	Production & Staff Support
21B1	Quality Assurance	Industrial Shop
21C1	Maintenance Training Flt	Management & Administration
21D1	Logistics Plans Flt	Management & Administration
21E1	Current Ops - Maintenance	Industrial Shop
22A0	Aircraft Generation Squadron	Industrial Shop
22A1	Maintenance Officer	Management & Administration
22B1	Sortie Generation Flight	Industrial Shop
22C1	Sortie Support Flight	Industrial Shop
23A0	Maintenance Squadron	Management & Administration
23A1	Maintenance Supervisor	Management & Administration
23B1	Fabrication Flight	Industrial Shop
23C1	Propulsion Flight	Industrial Shop
23D1	Accessories Flight	Industrial Shop
23E1	Avionics Flight	Industrial Shop
23F1	Aerospace Ground Equip Flt	Industrial Shop
23G1	Armament Systems Flight	Industrial Shop
23H1	Munitions Flight	Industrial Shop
23I1	Test Meas & Diagnostic Equip Flt	Industrial Shop
23J1	Maintenance Flight	Industrial Shop

FAC	TITLE	SIAME, DIME, SIAF Family
23K1	Combat Munitions Flight	Industrial Shop
24L1	Munitions Depot Flight	Industrial Shop
2400	Avionics Maintenance	Management & Administration
2401	Avionics Maintenance Unit Admin	Management & Administration
2402	Avionics Maintenance Training	Production & Staff Support
2403	Avionics Maintenance Mobility	Customer Service
2404	Avionics Maintenance Supervision	Management & Administration
2405	Avionics Analysis	Production & Staff Support
2500	Munitions Maintenance Mgmt	Management & Administration
2501	Munitions Maint Unit Admin	Management & Administration
2502	Munitions Maintenance Training	Production & Staff Support
2503	Munitions Maintenance Mobility	Customer Service
2504	Munitions Maint Supervision	Management & Administration
2505	Munitions Supply	Customer Service
2507	Munitions Control	Production & Staff Support
2508	Munitions Analysis	Production & Staff Support
2510	Munitions Services	Management & Administration
2511	Weapons Loading	Industrial Shop
2520	Munitions Maintenance/Storage	Management & Administration
2521	Nuclear Maintenance	Industrial Shop
2522	Storage/Handling	Warehouse, Storage & Issue
25A1	Weapons Standards	Production & Staff Support
2800	Ground Launch Missile Maint	Industrial Shop
2910	Ground Support Equip Maint Mgt	Management & Administration
2A01	Unit Admin	Management & Administration
2A02	Training Admin	Management & Administration
2A03	Maintenance Supervision	Management & Administration
2A20	Conventional Avionics	Industrial Shop
2A30	Offensive/Defensive Avionics	Industrial Shop
2A42	B-2 Avionics Test Station	Industrial Shop
2E01	Equip Maintenance Unit Admin	Management & Administration
2E02	Equip Maintenance Training	Management & Administration
2E04	Equip Maintenance Supervision	Management & Administration
2E13	AGE Pickup/Delivery	Warehouse, Storage & Issue
2E20	Maintenance	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
2E30	Munitions	Management & Administration
2E31	Munitions Control	Industrial Shop
2E37	Munitions Supply (FK Account)	Warehouse, Storage & Issue
2E38	Explosive Ordnance Disposal	Industrial Shop
2E39	Munitions Inspection	Industrial Shop
2E3B	Line Delivery	Warehouse, Storage & Issue
2E3C	Material - Production	Management & Administration
2G00	Aircraft Generation	Management & Administration
2G01	Aircraft Generation Unit Admin	Management & Administration
2G02	Aircraft Generation Training	Management & Administration
2G03	Aircraft Generation Mobility	Management & Administration
2G04	Aircraft Gen Maint Supervision	Management & Administration
2G10	Aircraft Maintenance	Management & Administration
2G30	Support	Warehouse, Storage & Issue
2G40	Alert	Industrial Shop
2R00	Component Repair	Management & Administration
2R01	Component Repair Unit Admin	Management & Administration
2R02	Component Repair Training	Management & Administration
2R03	Component Repair Mobility	Management & Administration
2R10	Conventional Avionics	Management & Administration
2R20	Propulsion	Management & Administration
2R30	Accessory Maintenance	Management & Administration
2R90	Aircrew Training Devices	Industrial Shop
3100	Operations	Management & Administration
3101	Operations Unit Admin	Management & Administration
3102	Unit Aircrew Life Support	Industrial Shop
3112	Air Liaison Officer	Management & Administration
31A0	Operations Sq	Management & Administration
31B1	Flight Crews	Industrial Shop
31D1	Operations Data Management	Management & Administration
3201	Visual Info Activity Admin	Management & Administration
3270	Base Level Visual Info Support	Management & Administration
3271	Base Level Visual Info Library	Customer Service
3272	Base Level Photographic Lab	Customer Service
3274	Base Level Graphic Arts	Customer Service

FAC	TITLE	SIAME, DIME, SIAF Family
3275	Visual Info Training Aids	Customer Service
3280	Armament Delivery Recording	Industrial Shop
34A1	Weather Flight	Production & Staff Support
3500	Intelligence Management	Management & Administration
3501	Unit Administration	Management & Administration
3510	Intelligence Operations	Production & Staff Support
3511	Technical Intelligence	Management & Administration
3512	Transmission Activities	Production & Staff Support
3513	Emission Activities	Production & Staff Support
3514	Crypto Activities	Production & Staff Support
3515	Communications Activities	Production & Staff Support
3516	Electronics Activities	Production & Staff Support
3517	Radiation Activities	Production & Staff Support
3518	Electronic Warfare Activities	Production & Staff Support
3519	Radar Activities	Production & Staff Support
3520	Intelligence Collection Mgmt	Management & Administration
3521	COMINT Collection	Production & Staff Support
3522	Electronic Intelligence Collection	Production & Staff Support
3523	Imagery Intelligence Collection	Production & Staff Support
3524	FISINT Collection	Production & Staff Support
3525	Human Intelligence Collection	Production & Staff Support
3530	Intell Proc & Prod Mgmt	Management & Administration
3531	COMINT Processing & Production	Production & Staff Support
3532	ELINT Processing & Production	Production & Staff Support
3533	Imagery Intelligence Production	Production & Staff Support
3534	Frgn Instrumtion SIG INTEL Pro	Production & Staff Support
3535	HUMINT Processing & Production	Production & Staff Support
3536	Intell Library & Doc Repository	Production & Staff Support
3537	IDHS Development	Production & Staff Support
3540	All Source Intell Data Analysis	Production & Staff Support
3541	Intelligence Estimates	Production & Staff Support
3542	Target Intelligence Analysis	Production & Staff Support
3543	Scientific & Technological Analy	Production & Staff Support
3560	Special Intelligence Operations	Production & Staff Support
3561	Communications Security	Production & Staff Support

FAC	TITLE	SIAME, DIME, SIAF Family
3562	Comm Unit Administration	Management & Administration
3563	Precision Photographic Lab	Production & Staff Support
3564	Intelligence Graphics Services	Industrial Shop
35A1	Intelligence Flight	Production & Staff Support
3800	Ground Comm - Elect Activities	Management & Administration
3801	Ground Comm - Electronics Admin	Management & Administration
3802	Comm & Elect Programs Mgmt	Production & Staff Support
3803	Technical Control	Production & Staff Support
3812	Approach Control Tower	Production & Staff Support
3813	Ground Control Approach	Production & Staff Support
3820	Comm - Electronic Operations	Management & Administration
3821	Comm-Electronic Operation	Management & Administration
3854	Teletype/Crypto Terminal Center	Production & Staff Support
3861	Sec Digtl Op Autom Digtl Rly Ctr	Production & Staff Support
3863	Sec Digtl Op Termls - Terml Cntrs	Production & Staff Support
3872	Telephone Operations - TAC PBX	Customer Service
38A0	Communications Squadron	Management & Administration
38A1	Systems Flight	Industrial Shop
38AA	METNAVE Maintenance	Industrial Shop
38AB	ATCALs Maintenance	Industrial Shop
38AC	Ground Radio Maintenance	Industrial Shop
38AG	Secure Comm Maintenance	Industrial Shop
38AH	Telephone Operations	Industrial Shop
38AI	Telephone Outside Maintenance	Industrial Shop
38AJ	Telephone Inside Maintenance	Industrial Shop
38AK	Non-Hard Cable Maintenance	Industrial Shop
38AL	Land Mobile Radio	Industrial Shop
38AM	Systems Support	Industrial Shop
38AS	BISS Maintenance	Industrial Shop
38B1	Support Flt	Management & Administration
38BA	Visual Information	Industrial Shop
38BG	Publishing	Management & Administration
38BH	Reprographics	Production & Staff Support
38C1	Plan/Implement Flt	Management & Administration
38D1	Information Systems Flight	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
38DA	Base Network Cntrl Cntr (BNCC)	Production & Staff Support
38DB	Information Protection	Production & Staff Support
38DC	Administrative Communcations	Management & Administration
38DD	Records Management	Management & Administration
38DE	Customer Training	Customer Service
38DF	Maintenance Control	Management & Administration
38DI	Data Processing Systems	Production & Staff Support
38DJ	Small Computer Sys Element	Production & Staff Support
38DK	Telecomm Center	Production & Staff Support
41A0	Supply Squadron	Management & Administration
41A1	Regional Supply Sq	Production & Staff Support
41B1	MAT STOR/DST FLT (Historical)	Warehouse, Storage & Issue
41C1	MAT MGT FLT (Historical)	Warehouse, Storage & Issue
41D1	Fuels Management Flt	Warehouse, Storage & Issue
41E1	Combat Operations Flt (Historical)	Warehouse, Storage & Issue
41F1	Forward Supply Locations	Warehouse, Storage & Issue
42A0	Transportation Squadron	Management & Administration
42A1	Vehicle Operations Flight	Management & Administration
42A2	Vehicle Operations	Industrial Shop
42B0	Aerial Port Squadron	Management & Administration
42B1	Vehicle Maint Flt	Industrial Shop
42C1	Traffic Mgt Flt	Management & Administration
42D1	Combat Readiness Flight	Production & Staff Support
42D2	Combat Readiness Resources	Production & Staff Support
42E1	Air Passenger Flight	Customer Service
42F1	Fleet Services Flight	Industrial Shop
42G1	Combat Readiness/Resources Flt	Production & Staff Support
42H1	Air Term Ops Ctr	Production & Staff Support
42I1	Air Delivery Flight	Industrial Shop
42J1	Air Freight Flight	Industrial Shop
43A0	Security Police Squadron	Management & Administration
43A1	Stan/Eval	Production & Staff Support
43B1	Admin/Reports Flt	Management & Administration
43C1	Operations Flt	Industrial Shop
43D1	Training/Resources Flight	Production & Staff Support

FAC	TITLE	SIAME, DIME, SIAF Family
43E1	Acquisition Security	Production & Staff Support
44CE	Base Civil Engineer	Management & Administration
44EB	READINESS	Industrial Shop
44EC	Engineering	Production & Staff Support
44ED	Explosive Ordnance Disposal	Industrial Shop
44EF	Fire Protection	Industrial Shop
44EH	Housing	Industrial Shop
44EI	Sci Facil CE Supt	Management & Administration
44EN	Nonstd Unit CE Support	Industrial Shop
44EO	Operations	Industrial Shop
44EP	Acquisition & Liaison CE	Production & Staff Support
44EQ	Contracted CE Support	Industrial Shop
44ER	Resources	Production & Staff Support
44ES	Site/Radar CE Support	Industrial Shop
44ET	Site/Range CE Support	Industrial Shop
44EV	Environmental	Industrial Shop
45A0	MWRS Overhead	Management & Administration
45AA	Staff	Management & Administration
45B0	Resource Management	Production & Staff Support
45C0	Force Management	Production & Staff Support
45D0	Military Support	Management & Administration
45D1	Food Service	Customer Service
45D2	Contract Food	Management & Administration
45D5	Billeting	Customer Service
45D8	Physical Fitness	Customer Service
45D9	Recreation Center	Customer Service
45F0	Youth Programs	Customer Service
45F2	Child Development	Customer Service
45G1	General Libraries	Customer Service
45G4	Arts & Crafts	Customer Service
5100	Medical Command	Management & Administration
5112	Linen Supply	Management & Administration
5130	Medical Personnel	Management & Administration
5140	Patient Administration	Management & Administration
5141	Inpatient Admin Services	Management & Administration

FAC	TITLE	SIAME, DIME, SIAF Family
5142	Ambulatory Care Admin Svcs	Management & Administration
5143	Patient Admin (Clinics)	Customer Service
5144	Central Appointments	Production & Staff Support
5150	Facilities Management	Management & Administration
5200	Clinical Medicine	Medical
5205	Nursing Services	Medical
5206	Medical Surgical Nursing Units	Medical
5207	Obstetrical Nursing Units	Medical
5210	Medical Services	Medical
5211	Internal Medicine	Medical
5212	Respiratory Care	Medical
5214	Neurology	Medical
5215	Dermatology	Medical
5216	Mental Health Services	Medical
5217	Occupational Therapy	Medical
5220	Emergency Services	Medical
5221	Primary Care Clinic	Medical
5222	Emergency Room	Medical
5223	Family Practice	Medical
5224	Primary Care Teams	Medical
5230	Surgery Services	Medical
5231	Neurological Surgery	Medical
5232	Thoracic Surgery	Medical
5233	Urology	Medical
5234	General Surgery	Medical
5235	Ophthalmology	Medical
5236	Otorhinoloryngology	Medical
5237	Plastic Surgery	Medical
5239	Orthopedics	Medical
5240	Surgical Suite	Medical
5242	Anesthesia	Medical
5250	Maternal/Child Care	Medical
5251	Pediatrics	Medical
5252	Medically Related Services	Medical
5254	Obstetrics and GYN	Medical

FAC	TITLE	SIAME, DIME, SIAF Family
5260	Special Care/ICU	Medical
5261	Emergency Svc (Med Cen Only)	Medical
5262	Ambulance Svc (Med Cen Only)	Medical
5270	Physical Exams	Medical
5310	Flight/Missile Medicine	Medical
5311	Bioenvironmental Engineering	Medical
5313	Public Health	Medical
5318	Physical Medicine	Medical
5410	Environmental Health	Medical
5421	Dental Residency	Medical
5422	Dental Lab	Medical
5423	Area Dental Lab	Medical
542X	Dental Services	Medical
5440	Occ & Envmt Hlth Lab	Medical
5511	Histopathology	Medical
5512	Clinical Lab	Medical
5513	Pharmacy	Medical
5514	Radiology	Medical
5515	Nuclear Medicine	Medical
5530	Medical Logistics	Management & Administration
5540	Personnel & Administration	Management & Administration
5560	TRICARE	Management & Administration
5561	Business Ops & Bene Support	Management & Administration
5570	Medical Info Systems	Management & Administration
5610	Aeromed Evacuation Mgmt	Medical
5620	Aeromedical Evacuation Materiel	Medical
5630	Aeromed Evacuation Operations	Medical
5640	Inflight Medical Care	Medical
5660	Aeromed Staging Flt (Mobile)	Medical

13.6.3. Terms and Symbols:

13.6.3.1. $Y_{(Dir)}$ = Direct man-hours from application of direct man-hour equation.

13.6.3.2. $Y_{(SIAME)}$ = Indirect man-hours from application of the applicable SIAME.

13.6.3.3. $Y_{(Tot)}$ = Total direct and indirect man-hours. $Y_{(Tot)} = Y_{(Dir)} + Y_{(SIAME)}$

13.6.3.4. Application. The standards development team develops a direct manpower equation, $Y_{(Dir)}$, using measured direct time and an indirect equation, $Y_{(SIAME)}$, using the selected SIAME and the average number of assigned work center personnel as the workload factor. The direct equation results are added to the SIAME results to derive the total monthly man-hours.

13.6.3.4.1. Application Example: Using a notional $Y_{(Dir)} = 300 + 5.6555X$ equation,

$$Y_{(Dir)} = 300 + 5.6555X \text{ (Where } X_{(Dir)} = \text{Workload Factor} = 250 \text{ Vehicles Assigned).}$$

$$Y_{(Dir)} = 300 + 5.6555(250) = 1713.88.$$

$$Y_{(SIAME)} = 270.13 + 9.3033X \text{ (} X_{(SIAME)} = 12 \text{ Average Assigned Personnel).}$$

$$Y_{(SIAME)} = 270.13 + 9.3033(12) = 381.77 \text{ Indirect Man-Hours}$$

$$Y_{(Tot)} = Y_{(Dir)} + Y_{(SIAME)} = Y_{(Tot)}$$

$$Y_{(Tot)} = 1713.88 + 381.77 = 2095.65 \text{ Total Man-Hours}$$

13.6.4. Using SIAME:

13.6.4.1. The study team must use caution when selecting the SIAME. Review the FAC family definitions in paragraphs 13.6.2.1 through 13.6.2.6 and select the SIAME that best fits the work center or function being studied. Ensure the standard indirect description reflected in AFMS00AA applies. If ANY of the indirect task definition elements are not done, or additional elements are done, a variance must be developed to supplement the SIAME. In this case, you must measure this task using the SIAM task measurement instructions reflected on the SIAM task data sheet. These measured man-hours are then added or subtracted, as appropriate, from the results of the SIAME application.

13.6.4.2. Use logic. If the SIAME allowed time is not representative of what normally occurs in the work center the study team should measure the task using the SIAM task data sheet measurement instructions.

13.7. Direct & Indirect Manpower Equation (DIME)

13.7.1. The DIME is an alternate method of crediting indirect manpower for functions of five or more assigned personnel that has quantified total direct manpower requirements.

13.7.2. Table 13.4, Air Force DIME Families, reflects the DIME model for each FAC family.

TABLE 13.4. AIR FORCE DIME FAMILIES

AIR FORCE DIME FAMILY	DIME
MANAGEMENT & ADMIN	$Y_{(DIME)} = 0.99 + 1.0753X$
PRODUCTION & STAFF SUPPORT	$Y_{(DIME)} = 1.88 + 1.0785X$
CUSTOMER SERVICE	$Y_{(DIME)} = 1.23 + 1.0610X$
MEDICAL	$Y_{(DIME)} = 1.14 + 1.0699X$
WAREHOUSE, STORAGE & ISSUE	$Y_{(DIME)} = 1.48 + 1.0650X$
INDUSTRIAL SHOP	$Y_{(DIME)} = 1.81 + 1.0681X$
NOTES:	
1. $Y_{(DIME)}$ results in total (direct & indirect) manpower.	
2. X = Direct Manpower	
3. Recommended for work centers of five or more assigned personnel.	

13.7.1.6. Table 13.3, SIAME, DIME, & SIAF Listing by FAC, reflects the DIME for each individual FAC.

13.7.2. Terms and Symbols

13.7.2.1. $Y_{(Dir)}$ = Direct manpower from application of a manpower equation and subsequent conversion to a manpower requirement by applying the applicable MAF.

13.7.2.2. $Y_{(DIME)}$ = Total manpower requirement by applying the direct manpower ($Y_{(Dir)}$) in the applicable DIME.

13.7.2.3. Application. Prior to using the DIME model it is necessary to quantify the total functional direct manpower ($Y_{(DIR)}$). This is accomplished by determining the total direct required monthly man-hours for the function and dividing by the appropriate MAF. The study team selects the appropriate DIME ($Y_{(DIME)}$) model (See Table 13.3) and applies direct manpower as the independent variable. The DIME produces the total direct and indirect manpower.

13.7.2.4. Application Example: Using a notional $Y_{(Dir)} = 300 + 5.6555X$ equation,

$$Y_{(Dir)} = 300 + 5.6555X \text{ (Where } X_{(Dir)} = \text{Workload Factor} = 250 \text{ Vehicles Assigned).}$$

$$Y_{(Dir)} = 300 + 5.6555(250) = 1713.88 \text{ Direct Man-Hours.}$$

$$1713.88/149.6 = 11.46 \text{ Direct Manpower}$$

$$Y_{(DIME)} = 1.81 + 1.0681X \text{ (Where } X = \text{Direct Manpower).}$$

$$Y_{(DIME)} = 1.81 + 1.0681(11.46) = 14.05 \text{ Total Functional Manpower Requirement.}$$

13.7.3. Using DIME:

13.6.3.1. The study team must use caution when selecting the DIME. Review the FAC family definitions in paragraphs 13.6.2.1 through 13.6.2.6 and select the DIME that best fits the work center or function being studied. Ensure the standard indirect description reflected in AFMS 00AA applies. If ANY of the indirect task definition elements are not done, or additional elements are done, a variance must be developed to supplement the DIME. In this case, you must measure this task using the SIAM Task Measurement Instructions reflected on the SIAM Task Data Sheet. These measured man-hours are then added or subtracted, as appropriate, from the results of the DIME application.

13.7.3.2. Use logic. If the DIME allowed manpower is not representative of what normally occurs in the function the study team should consider an alternate model.

13.8. Capability Based Manpower Determinant (CBMD) Standard Indirect Allowance Factor (SIAF).

13.8.1. The CBMD SIAF is a simple tool that quantifies the incremental indirect man-hours required for each CBMD resource (i.e., Security Forces, Personnel, Medical, etc.).

13.8.2. Table 13.5, Air Force CBMD SIAF Families, reflects the SIAF for each FAC family.

TABLE 13.5. AIR FORCE CBMD SIAF FAMILIES

CBMD SIAF FAMILY	SIAF
MANAGEMENT & ADMIN	1.0753
PRODUCTION & STAFF SUPPORT	1.0785
CUSTOMER SERVICE	1.0610
MEDICAL	1.0699
WAREHOUSE, STORAGE & ISSUE	1.0650
INDUSTRIAL SHOP	1.0681
NOTES:	
1. Multiply the SIAF by the CBMD Direct Man-hours and divide by the applicable MAF to compute the CBMD FTEs.	
OR	
2. Multiply the CBMD Direct FTE by the SIAF to compute the total CBMD FTE.	
OR	
3. Multiply the SIAF by the regression coefficients of the CBMD $Y_{(CBMD\ DIR)}$ equation (if available). For example: $Y_{(CBMD\ DIR)} = a + bX$, $Y_{(CBMD\ Total)} = a (SIAF) + b(SIAF)X$. X = CBMD specific workload factor.	

13.8.3. Table 13.3, SIAME, DIME, & SIAF Listing by FAC, reflects the SIAF for each individual FAC.

13.8.4. Terms and Symbols

13.8.4.1. CBMD Direct Man-hours = Direct man-hours for each CBMD.

13.8.4.2. SIAF = Standard Indirect Allowance Factor.

13.8.4.3. Application. Application of the SIAF results in the total monthly man-hour requirement which may be converted to a full time equivalent (FTE) by dividing the man-hours by the applicable man-hour availability factor (MAF). The study team selects the appropriate SIAF and applies it to the respective direct man-hours.

13.8.4.4. Application Example: The study team selects the appropriate CBMD SIAF (i.e. Security Forces = SIAF 1.0785, Military Personnel Flight = 1.0610, Emergency Room = SIAF 1.0699) and multiplies it times the CBMD Direct Man-hours, if available. This value is divided by the appropriate MAF to determine the FTE. Sum all FTEs to determine the CBMD total FTE requirement. If the CBMD Direct FTE has been defined, the study team multiplies this value by the respective SIAF to determine the total CBMD FTE. If a CBMD Direct man-hour equation has been developed, apply the SIAF as reflected in Table 13.6, CBMD SIAF Application.

Table 13. 6. CBMD SIAF Application Example.

A. Multiply the SIAF by the CBMD Direct Man-hours and divide by the applicable MAF to compute the CBMD FTEs.					
CBMD Resources	Direct Monthly Man-hours	SIAF	Total Monthly Man-hours	MAF	CBMD FTEs
Security Forces	1496.00	1.0785	1613.44	149.6	10.79
Civil Engineer	598.40	1.0681	639.15	149.6	4.27
Vehicle Maint	600.50	1.0681	641.39	149.6	4.29
Admin	149.60	1.0753	160.86	149.6	1.08
Storage/Issue	500.60	1.0650	533.14	149.6	3.56
Total CBMD Requirement					23.99
B. Multiply the CBMD Direct FTE by the SIAF to compute the total CBMD FTE.					
CBMD Resources	Direct CBMD FTEs	SIAF			Total CBMD FTEs
Security Forces	10	1.0785			10.79
Civil Engineer	4	1.0681			4.27
Vehicle Maint	4	1.0681			4.27
Admin	1	1.0753			1.08
Storage/Issue	3.35	1.0650			3.57
Total CBMD Requirement					23.98
C. Multiply the SIAF by the regression coefficients of the CBMD $Y_{(CBMD\ DIR)}$ equation (if available). For example: $Y_{(CBMD\ DIR)} = a + bX$, $Y_{(Total)} = a (SIAF) + b(SIAF)$.					
$Y_{(CBMD\ DIR)} = 309.12 + 5.6555X$, $Y_{(Total)} = 309.12 (1.0785) + 5.6555(1.0785)X$, $Y_{(Total)} = 333.39 + 6.099X$, Where $X = 210$ widgets, $Y_{(Total)} = 333.39 + 6.099(210)$, $Y_{(Total)} = 1614.18$, CBMD FTE = $1614.18/\text{Applicable MAF} = 1614.18/149.6 = 10.79$ FTE					

13.8.5. Using the CBMD SIAF:

13.8.5.1. The study team must use caution when selecting the CBMD SIAF. Review the FAC family definitions in paragraphs 13.6.2.1 through 13.6.2.6 and select the SIAF that best fits the work center or function being studied. Ensure the standard indirect description reflected in AFMS 00AA applies. If ANY of the indirect task definition elements are not done, or additional elements are done, the SIAF CANNOT be used. You must measure the indirect workload using the SIAM task measurement instructions reflected on the SIAM task data sheet.

13.8.5.2. Use logic. If the SIAF allowed time is not representative of what normally occurs in the CBMD defined environment the study team should measure the task using the SIAM task data sheet measurement instructions.