BY ORDER OF THE SECRETARY OF THE AIR FORCE

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Manpower and Organization

MANPOWER AND ORGANIZATION STANDARD WORK PROCESSES AND PROCEDURES

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SUMMARY OF CHANGES

This publication has been substantially revised and needs to be completely reviewed. Major changes are as follows: reorganizing manual into parts and rearranging chapter order; adding OMM and Wartime Determinant chapters; adding **Attachment 2**; updating the requirements determination process to current methodology; updating language to current terminology (e.g., post/position manpower, RPF, etc.); clarifying differences between PAT and SAT; and other administrative changes.

Part 1

STUDY MANAGEMENT

Chapter 1

OVERVIEW

1.1. Philosophy. The Manpower and Organization (M&O) function has four core competencies: (1) requirements determination, (2) manpower program allocation and control, (3) organization structure, and (4) performance management. These four competencies form the basis for all M&O activities. Specifics regarding the core competencies can be found in their applicable AFIs as referenced below.

1.1.1. Requirements Determination. Management Engineering Program (MEP) analysts assist senior leaders, commanders, and functional managers, at all levels, in mission accomplishment by objectively quantifying manpower requirements for the distribution of Air Force manpower resources. Key services of this competency include peacetime and wartime manpower requirements determination. Integral in any manpower requirements determination effort is ensuring quantified workload is required by MAJCOM or higher directives and balances efficiency and effectiveness. Guidance is provided in this AFMAN.

1.1.2. Manpower Program Allocation and Control. Results of requirements determination efforts are used to inform the Strategy, Planning, Programming, Budgeting, and Execution (SPPBE) system.

1.1.3. Organization Structure. Concepts and performance guidance are provided in Air Force Policy Directive (AFPD) 38-1, *Organization and Unit Designations*, and AFI 38-101, *Manpower and Organization*.

1.1.4. Performance Management. Performance management is the United States Air Force (USAF) construct for a continual performance improvement system that focuses on mission accomplishment. Guidance is provided in DAFI 38-401, *Continuous Process Improvement (CPI)*.

1.2. Purpose of the Management Engineering Program. The MEP provides the foundation for executing all M&O core competencies and helps senior leaders, commanders, and functional managers improve productivity using performance improvement techniques and procedures. The MEP provides the framework for requirements determination and other products and services.

1.2.1. Team Approach. MEP and functional personnel build cohesive teams to reach study objectives and achieve productivity improvement goals. Formal study charters outline specific study objectives and responsibilities for all team members to work together to meet those objectives.

1.2.2. MEP Methodology. MEP methodology is built utilizing performance improvement techniques.

1.2.2.1. Performance Improvement. A systematic look at a function to identify processes for potential improvement. Outcomes, outputs (products and services), processes, capital equipment, facility layout, customers, and suppliers are identified as part of a process improvement.

1.2.2.2. MEP Tools. The MEP develops tools and techniques to carry out policy and furnishes MEP customer-related technical support. Analysts at all levels will implement the MEP. **(T-2)**

1.3. General Roles and Responsibilities.

1.3.1. Air Force and MAJCOM OPR continually evaluate functions to determine the need to update or request development of a requirements determinant. This includes process changes, opportunities for process improvement, organization, and mission changes, as well as indicators from Air Force management information systems.

1.3.2. MEP analysts will lead and manage study efforts for requirements determinant development.

1.3.2.1. Complete preliminary research, select site visit locations, develop study plans, facilitate study workshops, develop Standard Work Documents (SWD), and develop and staff requirements determinants.

1.3.2.2. Staff results with appropriate functional office and affected MAJCOMs.

1.3.3. Functional personnel are the process owners of a function and make policy decisions. Functional personnel commit to study efforts for the duration and coordinate on study products.

1.3.3.1. Formally announce study efforts to the field and communicate senior leadership commitment.

1.3.3.2. Provide a dedicated functional lead to partner with MEP analysts during requirements determinant process.

1.3.3.2.1. Appoint subject matter experts (SME) to serve as study team members.

1.3.3.2.2. Ensure appointed team members and SMEs participate in all workshops facilitated by MEP analysts.

1.3.3.2.3. Assist in identifying the site visit location(s), coordinate on the study plan, and participate in study workshop(s) to develop the SWD.

1.3.3.2.4. Review and validate workload data as required.

1.3.3.2.5. Ensure all functional process outputs are identified and quantified.

1.3.3.2.6. Ensure process improvements are tested as needed.

1.3.3.2.7. Staff SWD through functional leadership for approval.

1.3.4. The Air Force Manpower Analysis Agency (AFMAA) will approve and post requirements determinants.

1.3.5. Air National Guard Directorate of Manpower Organization and Resources (ANG/A1M) and Air Force Reserve Command Manpower, Organization and Resources Division (AFRC/A1M) will approve requirements determinants affecting ANG and AFRC units, respectively.

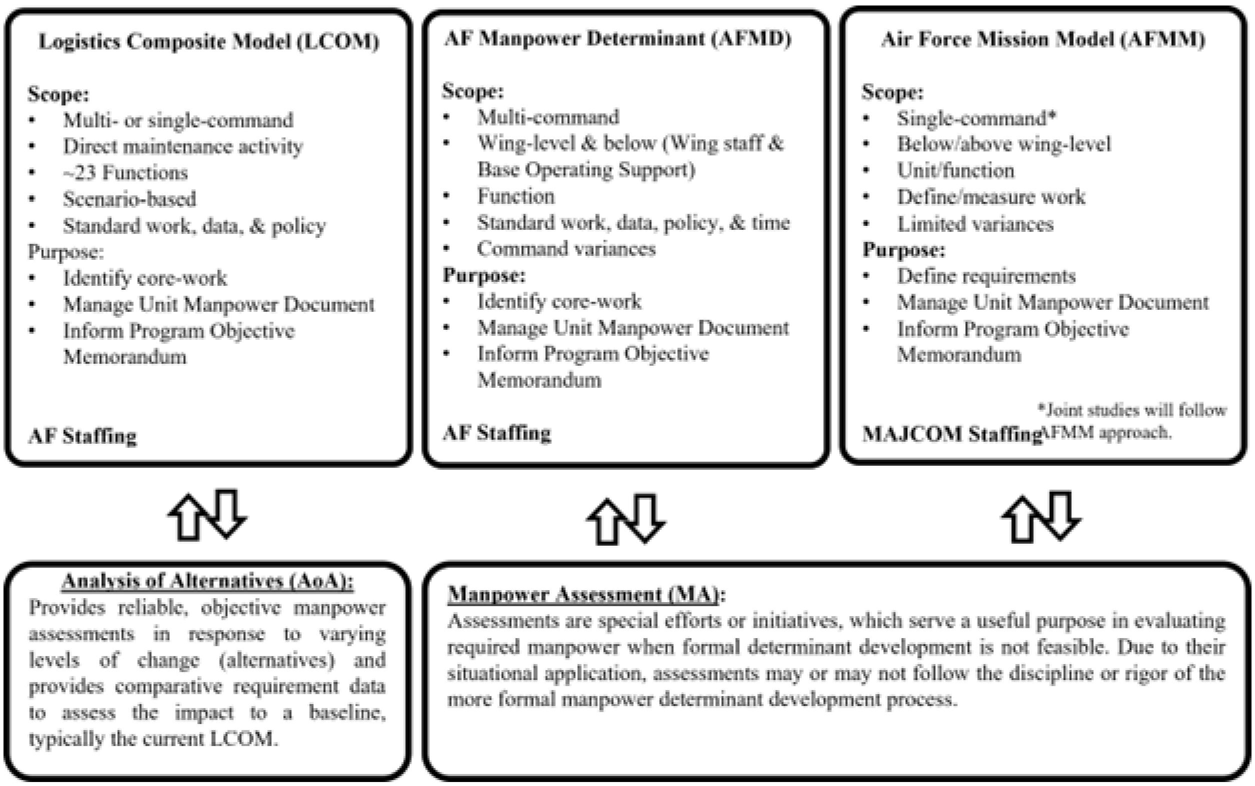
1.4. Documentation Requirements. This publication contains examples and formats of various documentation requirements.

Chapter 2

STUDY PROCESS

2.1. General Concepts. The goal of requirements determination is to develop a means of quantifying manpower requirements. There are a variety of study types to document manpower requirements. They include Air Force Manpower Determinant (AFMD), Air Force Mission Model (AFMM), Logistics Composite Model (LCOM), LCOM Analysis of Alternatives (AoA), and Manpower Assessment (MA). A Management Advisory Study (MAS) is another type of study; while it does not determine manpower requirements, it can provide a wide range of consultant services (see Chapters **26** and **27**).

Figure 2.1. Requirements Determination Study Types.



2.1.1. **Figure 2.1** shows the study type options depending on scope and purpose. The amount of time available is an important consideration in selecting the appropriate study type; AFMDs, AFMMs, and LCOMs generally take more time to complete than MAs or AoAs.

2.1.1.1. MAs are used to address a wide range of special situations and comprise varying levels of effort, depth, scope, and applicability. An MA has a charter and MA report.

2.1.1.1.1. Appropriate uses of an MA include:

2.1.1.1.1.1. When a lack of experience with new systems makes a formal manpower requirements determinant impractical.

2.1.1.1.1.2. When a determinant would be short-lived.

2.1.1.1.1.3. To determine the initial impact of emerging missions.

2.1.1.1.1.4. When leaders require assistance with rapidly evaluating manpower-related issues.

2.1.1.1.2. MA results are documented in a report addressing the specific situation and the needs of the requester. The report may define manpower or man-hour requirements as a "snapshot" in time, but not necessarily provide a mechanism to determine or predict future manpower needs.

2.1.1.2. LCOM and LCOM AoAs specifically determine aircraft maintenance requirements and are discussed further in **Chapter 20**.

2.1.2. A requirements determinant is a tool used to determine the minimum level of manpower required to support a function or organization based on a function's work as directed by MAJCOM or higher guidance. It is a quantitative expression representing a work center's requirements in response to varying levels of workload and serves to predict future manpower requirements. First steps in the AFMD and AFMM study process include reviewing posted requirements determinants.

2.1.2.1. Organization Maturity Model (OMM). If there is no posted requirements determinant for a function, an OMM should be completed prior to study start (see **Chapter 3**).

2.1.2.2. Currency Review (CR). If there is a posted requirement determinant, a CR should be completed prior to starting a new study. A CR determines if a determinant is accurate, in need of revision, or it is obsolete, and the function needs to be restudied (see **Chapter 18**).

2.1.3. Each study has deliverables. The purpose of these deliverables is to establish quality control points and to provide standardized products during the study process. The main deliverables are:

2.1.3.1. The study charter.

2.1.3.2. The study plan.

2.1.3.3. The SWD and SWD report.

2.1.3.4. The AFMD or AFMM and associated reports.

2.1.4. Requirements determination studies follow similar progression.

2.2. Preliminary Research. Prior to developing the charter, the study team will begin preliminary research. The primary goal of preliminary research is to understand the function or organization.

2.2.1. Considerations. The following should be considered, at a minimum:

2.2.1.1. The best proposed study approach.

2.2.1.2. The best proposed measurement method(s) and techniques.

2.2.1.3. Proper work classifications.

2.2.1.4. Special work requirements.

2.2.1.5. The minimum desired measurement locations.

2.2.1.6. Potential outputs (e.g., work unit (WU)).

2.2.1.7. Potential workload factors (WLF).

2.2.2. Documentation Sources. Document the information needed to design and conduct the study. Potential research sources are:

2.2.2.1. Air Force departmental publications.

2.2.2.2. Occupational Survey Report.

2.2.2.3. Organizational or functional websites.

2.2.2.4. Organizational policy and guidance.

2.2.2.5. Current and historical manpower documents.

2.2.2.6. Reports. Review productivity reports, DAF survey results, staff assistance visit reports, DAF and MAJCOM Inspector General reports, and Government Accountability Office reports concerning the function or work center under study.

2.2.2.7. Management Inspections. These reports may contain information concerning the drawbacks of present operations. These reports provide clues concerning manpower utilization, process bottlenecks, and present recommendations for improvement.

2.2.2.8. Specialty Training Material. Review Specialty Training Standards, on-the-job training (OJT) records, career development courses, and Air Force Specialty course charts and outlines.

2.2.2.9. Management Information Systems. Functional area system generated reports may aid in the development of historical frequencies of occurrence.

2.2.2.10. Equipment and/or Technology. Review equipment and/or technology (machinery or computer systems used, degree of standardization, etc.) listed on the automated data processing equipment account and custodian authorization/custody receipt listing.

2.2.3. Baseline Requirement. Pull a Unit Manpower Document (UMD) baseline for analysis. Query Business Objects from within Manpower Programming and Execution System (MPES) for total manpower requirements for the function or organization under study.

2.2.4. Assigned Strength. Collect assigned military and civilian strength information from the base-level Military Personnel Flight and Civilian Personnel Flight. Coordinate and validate this information with the work center supervisor. Also, request the supervisor provide information on other full-time and/or part-time over hires, contract manpower equivalents (CME), or borrowed/loaned personnel. Finally, obtain information regarding documented, uncompensated, or lost overtime or compensatory time.

2.3. Study Charter. The study charter is an agreement between the functional and manpower communities. It identifies all key members and establishes roles and responsibilities. It defines the scope of the study, sets the commitment level for leadership, and establishes the official start date. A well-defined scope clarifies the purpose and study parameters and prevents wasted effort. Note: As the complexity of the effort increases the communication, coordination, level of effort, time, and study costs also increase.

2.3.1. Study Participants.

2.3.1.1. Study Sponsor (SS). The SS is the owner of the process or function and can make policy decisions.

2.3.1.1.1. The SS represents the highest appropriate level in the functional organization for coordination and should be the individual who has authority to approve process improvement initiatives. The SS commits to the study and provides high-level leadership for the functional community for the duration of the study.

2.3.1.1.2. Typically, the SS does not participate in day-to-day study activities, but delegates this responsibility and authority to a Study Sponsor Representative (SSR). The SS signs the charter and reviews and coordinates on study products.

2.3.1.1.3. The SS for an AFMD is at the DAF level since these studies apply to multiple MAJCOMs. The SS for an AFMM is at the MAJCOM level since these apply to one specific MAJCOM.

2.3.1.2. Study Sponsor Representative (SSR). The SSR is the appointed functional focal point who works closely with the study lead to complete the study and ensures milestones are met. Since AFMDs apply to multiple MAJCOMs the SSR is at DAF level and the SSR for an AFMM is at MAJCOM level.

2.3.1.3. Study Lead. The study lead is responsible for the processes used to complete the study. The study lead also has management responsibilities for team members.

2.3.1.4. Study Team. The study team consists of the resources assigned to work on the study deliverables. They are responsible for completing assigned work within the budget, timeline, and quality expectations; informing the study lead of issues, scope changes, and risk and quality concerns; and proactively communicating status and managing expectations.

2.3.1.5. Additional Team Members. Depending on study type, additional functional and manpower points of contact (POC) are listed in the charter as necessary.

2.3.2. Strategic Communications Memorandums. After the AFMD charter is signed, a memo is released by AFMAA to the affected manpower community. A second memo is provided to the SSR for release to the functional community. The memos notify the affected functional and manpower communities of the intent to conduct an AFMD study and provide study POCs. **Note:** A memorandum is not needed for an AFMM because it applies to only one MAJCOM.

2.4. Site Visit. Site visits provide vital research to the study team to build on knowledge gained in preliminary research. Their purpose is to collect additional information to complete the study plan.

2.4.1. Site Visit Observations. The local work center is a prime source for initial information and a place to ask for work demonstration. Visit a representative cross-section of locations with the SSR. Discuss and verify findings with the SSR, local managers, and supervisors.

2.4.1.1. Use site visit observations to:

2.4.1.1.1. Identify processes and outputs for SWD development.

2.4.1.1.2. Identify data systems where work unit counts (WUC) are stored.

2.4.1.1.3. Collect WU data from identified systems, working relationships, and physical arrangements to increase understanding of procedures and data obtained.

2.4.1.1.4. Obtain information on work environment and worker productivity (e.g., idleness, work distribution, discipline, cleanliness, work layout, excessive standards of living, etc.).

2.4.1.2. Use operational audit (OA) good operator timing technique for high volume processes with short duration to assist in SWD development. With observation and understanding comes the enhanced ability to identify potential process improvements. See **Chapter 5** for OA details.

2.4.2. Questionnaires. A questionnaire is a quick and inexpensive tool to gather information. Design questionnaires to collect information not available from other sources and limit them to the specific data needed to meet the study objectives. Ensure the questionnaire serves a purpose, has clear objectives, and is formatted to achieve the objectives.

2.4.3. Interviews. The interview research method consists of four steps: planning, opening, controlling, and closing. Interviewing has two advantages, flexibility, and the ability to uncover information not documented elsewhere. Personal and group interviews may be used for gathering information. Both techniques provide valuable information, but each has advantages and disadvantages.

2.4.3.1. Personal Interviews. The primary objective of personal interviews is to collect information on what and how work is done, operating procedures, and workload volume.

2.4.3.1.1. Provide interviewees with an agenda (time, subject, and material).

2.4.3.1.2. Keep interviews informal but follow the organizational structure by starting at the top with commanders or flight chiefs. Different personnel levels provide different information and perspectives based on experiences in the organization. Personal interviews reveal management's general attitude and knowledge of the people who work for them. Interviews can also be used to gather customer requirements and obtain leadership perspectives for the future.

2.4.3.1.2.1. Chief enlisted managers and 9-skill level superintendents provide broad career field information and current career field issues; however, technical familiarity with lower-level tasks and procedures may not be current. In some fields, the superintendent manages several career groups and has no or very limited current lower-level work experience.

2.4.3.1.2.2. The 7-skill level provides the best technical information.

2.4.3.1.2.3. The 5-skill level provides the best information about processes and activities done within the work center.

2.4.3.1.2.4. The 3-skill level can often present an unbiased opinion from a fresh eyes perspective.

2.4.3.1.3. Individual interviews are more time-intensive but yield more data than a group interview. The analyst focuses questions to a specific individual without having other group members waiting. This allows each participant to provide a unique perspective without being overshadowed by other members of the group.

2.4.3.1.4. A disadvantage is personal interviews are not always complete, precise, or accurate. Sometimes personnel withhold valuable information, divulge inaccuracies, or simply give information that sounds good. When in doubt, verify the information with the source or a supervisor. Sources of information given in confidence should not be revealed unless required by competent authority.

2.4.3.2. Group Interviews. Group interviews are effective when time is limited and disagreement among personnel is strong. Group interviews normally result in consensus, eliminating major disagreements. Information provided by one participant often helps other participants recall details and requirements. A disadvantage is groupthink versus individual expertise.

2.4.4. Additional Research. The preceding paragraphs identify the best practices for site visits but are not all inclusive. The study lead should always be thinking of other ways to research and become familiar with the function. As the study lead progresses with the study, background knowledge of the function, and ability to think through potential issues will aid them in developing a comprehensive and successful study plan.

2.5. Study Plan. The study plan outlines the approach to completing the study by documenting methodology and scope, baseline, timelines, deliverables, POCs, and other pertinent information. It documents how the study team intends to accomplish the necessary actions, with completion dates, to complete study steps up to staffing (workshop, developing draft SWD and report, SWD approval, and requirements determinant development and report ready for staffing and approval).

2.5.1. One of the first decisions the study lead makes during study plan development is the general study approach. All study approaches require the study lead to evaluate current processes for potential improvement and ensure approved initiatives are implemented prior to determining man-hour or manpower requirements.

2.5.2. Depending on the nature of the work center under study, the following should be considered:

2.5.2.1. If detailed work measurement is deemed appropriate, consider:

2.5.2.1.1. What data is needed and how is the data to be collected? For example, is workshop measurement the primary means to gather per accomplishment times (PAT) and task frequency?

2.5.2.1.2. Which work measurement technique(s) or tools are to be employed to measure the work?

2.5.2.1.3. What other data (e.g., historical workload counts, authorized and assigned strength, etc.) is collected for follow-on analysis and requirements determinant development?

2.5.2.1.4. Which statistical tools are to be employed to determine data normalcy and man-hour model development?

2.5.2.1.5. Are there levels of service issues that need to be considered?

2.5.2.1.6. The selection of a particular approach and/or measurement technique should be fully justified and logical. If these criteria cannot be met with an initial approach, an alternative approach and/or work measurement method should be utilized.

2.5.2.2. If a detailed work measurement is not appropriate, consider if an accurate requirements determinant may be developed via other MEP techniques (i.e., functional model, directed requirement, staffing pattern, post/position requirement) not requiring detailed measurement. **Note:** Non-measurement methods are normally the most expensive methods, i.e., non-measurement methods are more likely to produce requirements results not as efficient as those produced via measurement methods.

2.6. Standard Work Document Development. The draft SWD is a description of the function's required work which is documented using process flowcharts, narrative descriptions, functional statements, or any combination of the three. SWD development is typically done through workshops. A workshop is defined as a scheduled meeting with a predefined agenda, facilitated by the study lead, and attended by functional SMEs and SSR. The SWD report documents how the SWD was developed to include a function's identification, mission, organization structure, study approach and scope, site visits, SWD development participants, Statement of Conditions (SOC), and potential process improvements. For specific workshop details refer to **Chapter 6**.

2.7. Standard Work Document Approval. Draft SWD and report are sent to SSR for approval. The SWD is the functional community's document reflecting required work. For AFMDs, the SSR works with MAJCOM functional managers (MFM) for their review. For AFMMs, the MAJCOM SSR works with base level functional managers. The SSR works with the study lead to adjudicate any comments and update the SWD as needed. SSR will brief SS before approving the SWD. The approved SWD is posted on the AFMAA SharePoint (or ANG/AFRC SharePoint equivalent). An AFMD or AFMM is developed after SWD approval.

2.8. Air Force Manpower Determinant/Air Force Mission Model Development.

2.8.1. The draft AFMD/AFMM determines a function's requirement based on varying levels of work. It normally contains standard data (approval date, applicability, equations, workload factors, and POCs), application instructions, SOC, and applicable attachments (glossary of references and supporting information, manpower tables, and variances, etc.).

2.8.2. The report documents how the AFMD/AFMM was developed and includes an executive summary, work center and measurement information, data collection and analysis, computations summary, manpower model selected, Air Force Specialty Code (AFSC) and grade determination, variance data analysis, workload factor (WLF) information, and internal model application.

2.9. Air Force Manpower Determinant/Air Force Mission Model Coordination. Draft AFMD/AFMM are sent to applicable MAJCOM Manpower, Organization and Resources Divisions (MAJCOM/A1M) for coordination and trial application. MAJCOM/A1Ms work with MFMs to review draft AFMD/AFMM, complete trial application and provide comments in a comment resolution matrix (CRM). The study lead adjudicates comments and updates draft AFMD/AFMM as needed. Since AFMDs apply to multiple MAJCOMs, the AFMD is also coordinated at DAF level with charter signatories after AFMAA leadership has been briefed on MAJCOM coordination.

2.10. Air Force Manpower Determinant/Air Force Mission Model Approval. AFMD/AFMM and report are approved by the AFMAA Commander (AFMAA/CC), or ANG/AFRC equivalent, and posted on the AFMAA SharePoint, or ANG/AFRC SharePoint equivalent. A posting notification is submitted to MAJCOM/A1Ms advising them that the study is completed and ready for implementation.

Chapter 3

ORGANIZATION MATURITY MODEL ASSESSMENT

3.1. Overview.

3.1.1. The OMM is a facilitated assessment of an organization's or functional's operations. The model utilizes 18 questions, aligned with AFI 1-2, *Commander's Responsibilities*, divided into four domains: Process Domain (seven questions), Data Domain (four questions), Resource Domain (four questions), and Organizational Domain (three questions). The OMM Tool can be accessed through the AFMAA SharePoint. See **Table 3.1** for a list of the questions categories within each domain. **Note:** The OMM is a tool specifically designed to help leaders improve operations and to help study teams scope measurement efforts. There are no repercussions associated with the scores.

3.1.2. Each question and domain are scored from 0 to 5. This score is associated with the following maturity levels: (0) Unaware, (1) Informal, (2) Documented, (3) Integrated, (4) Strategic, (5) Optimized. Assessed organizations that reach (3) Integrated are considered "mature." For more information on scores, see **paragraph 3.3.4**.

Table 3.1. OMM Domains and Question Categories.

Process Domain	Data Domain	Resource Domain	Organizational Domain
1. Policy and Guidance	8. Workload	12. Financial Management	16. Communication
2. Standard Work	9. Performance Metrics	13. Human Capital Allocation	17. Training Management
3. Process Documentation	10. Requirements Determinant	14. Equipment/Assets	18. Process Improvement Deployment Strategy
4. Voice of the Customer	11. Data Systems	15. Facilities	
5. Tracking Initiatives			
6. Capturing Lessons Learned			
7. Visual Controls			

3.1.3. An OMM is conducted by an analyst who operates the tool and facilitates a group of SMEs through the assessment questions. During the assessment, the analyst will document the maturity level assessed for each question, as well as evidence and observations to support the score. The score and associated notes are combined and provided to the assessed organization in the form of an Assessment Report.

3.1.4. The OMM is a scalable tool.

3.1.4.1. The tool can be applied at any level from a flight to a MAJCOM.

3.1.4.2. Multiple OMMs can be performed within the same organization and combine results to give leaders a more detailed picture of the organization's performance. The number of OMMs conducted will depend on the assessed organization's desired result.

3.1.4.3. For example, a single OMM performed for a Maintenance Group will result in vague observations and actions, as all subordinate units will be summarized in one report. Some best practices or high performing sections may be missed due to the OMM scoring process. A more detailed assessment could be achieved by performing OMMs on each subordinate squadron, then combining the results in a final report for the group leadership. To achieve the best result, the analyst should communicate with the organization's leadership, determine the level of depth and time commitment desired by the organization, and recommend the optimal number of OMMs required to achieve the desired result.

3.2. Organization Maturity Model Lenses of Application. There are two lenses of OMM implementation: Performance Management and Requirements Determinant.

3.2.1. Performance Management Lens. If the intent is to help an organization improve performance, the analyst(s) will perform the full 18 question assessment and provide targeted recommendations to the assessed organization's leaders based on the results and evidence identified during the assessment (see **Table 3.1**.). When utilizing the performance management approach, the action plan will be focused on improving operations through strategic planning, metrics development, process improvement, and other categories that can help an organization become more efficient and better utilize resources. When utilizing the OMM through this lens, consider the OMM as a method for scoping further consulting work that can be done within the assessed organization to help with performance improvement (see **Chapter 26**). It can also help identify areas to perform a Manpower Advisory Study (MAS) within an organization (see **Chapter 27**).

3.2.2. Requirements Determinant Lens. In addition to helping identifying improvement opportunities for an organization, the OMM can also be used during the preliminary research step of a requirements determinant study.

3.2.2.1. When performing the OMM, the analyst only utilizes eight study essential questions within the tool (see **Table 3.2**.).

3.2.2.2. The eight essential questions narrow the focus of the assessment on categories that will provide the study team knowledge on areas critical to the success of a study: policy, standard processes, outputs, and data. Identification of these items can help a study team scope the level of effort and plan the next steps within the study process.

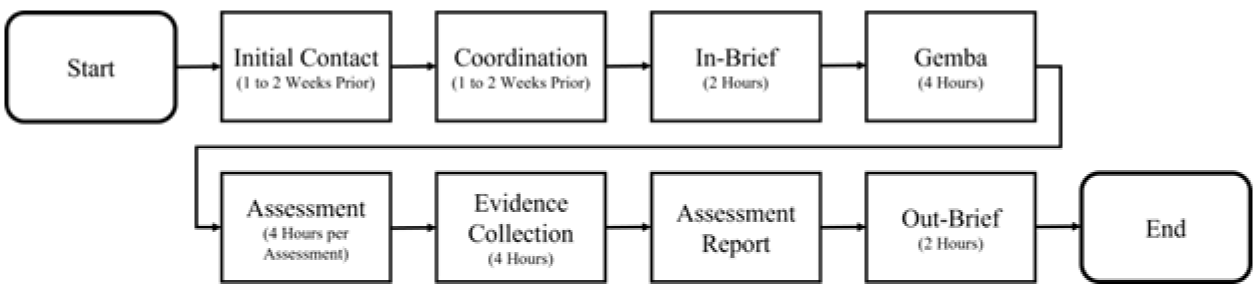
Table 3.2. Requirements Determinant Lens' Eight Essential Questions.

Process Domain	**Data Domain**	**Resource Domain**	**Organizational Domain**
1. Policy and Guidance	8. Workload	~~12. Financial Management~~	~~16. Communication~~
2. Standard Work	~~9. Performance Metrics~~	13. Human Capital Allocation	~~17. Training Management~~

3. Process Documentation	~~10. Requirements Determinant~~	~~14. Equipment/Assets~~	18. Process Improvement Deployment Strategy
4. Voice of the Customer	11. Data Systems	~~15. Facilities~~	
~~5. Tracking Initiatives~~			
~~6. Capturing Lessons Learned~~			
~~7. Visual Controls~~			

3.3. Organization Maturity Model Assessment Process Overview. Implementation of the OMM follows a standard process flow (see **Figure 3.1**), however, the analyst has flexibility to adjust or deviate from the process. Approximate timelines are provided, but these can be adjusted based on the needs of the analyst and organization being assessed. Note: Times given are approximations for use when developing an agenda and scoping the OMM. Times may vary depending on the number of OMMs required per organization or function. Additional OMM information and templates are available on the AFMAA SharePoint website.

Figure 3.1. OMM Standard Process Flow.



3.3.1. Initial Contact and Coordination (one to two weeks prior to assessment). Each OMM begins with identifying a representative within the organization being assessed. This representative will act as the main scheduling POC. Their responsibilities include identifying the SME group which will answer the OMM questions, scheduling the assessment, scheduling briefs with the assessed organization's leadership, guiding the analyst on the Gemba (go-and-see) walk, and assisting with evidence collection following the assessment.

3.3.2. In-brief (approximate time, two hours). During the in-brief, the analyst presents the schedule, presents basic facts and outcome of the OMM, and answers questions. This is also a time for the organization or function being assessed to present relevant mission information to the analyst.

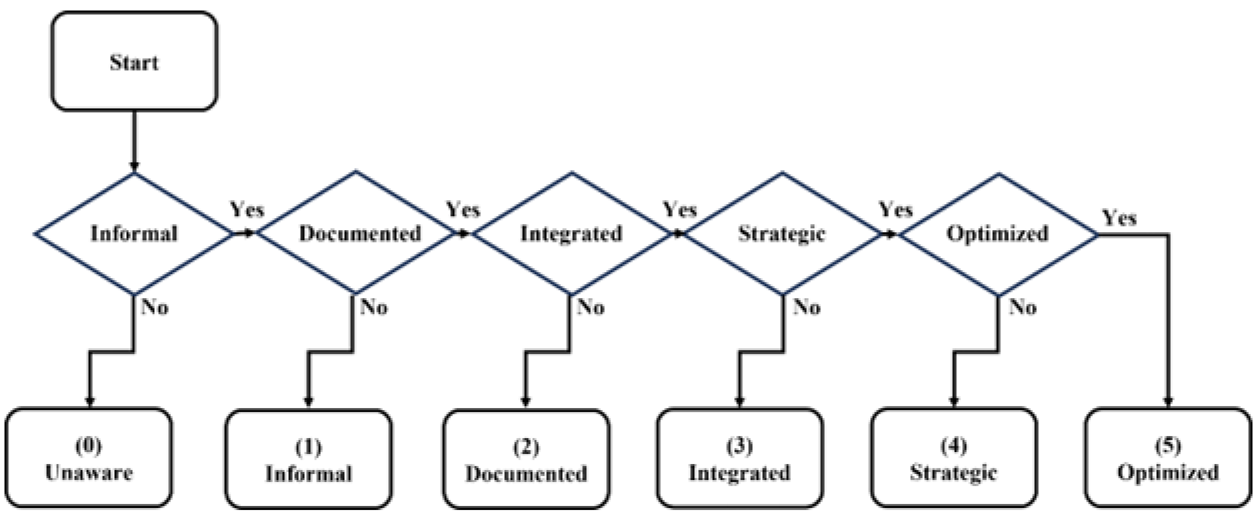
3.3.3. Gemba (Go-and-See) (approximate time, four hours). Conducted by the analyst prior to conducting the OMM workshop with the SME group. The analyst, accompanied by the POC, walks through the organization, and observes the processes as they happen in real time. The Gemba provides the analyst an opportunity to see how the work in the organization is conducted first-hand. The analyst should look for evidence that will support answers to the OMM questions and for facts about the organization that will help facilitate discussion.

3.3.4. Assessment and Scoring (approximate time, four hours).

3.3.4.1. Following the Gemba, the analyst will sit with a group of, ideally, six to eight SMEs from the organization being assessed. This working group should consist of a mix of workers and managers, who can speak to the work being done and the organization's strategy.

3.3.4.2. During the assessment, the analyst utilizes the OMM tool to facilitate the SME group through all questions and levels being assessed. The analyst begins with the first question at the informal level, presents the question and the informal level indicator, and then allows the group to respond. If the group agrees their organization meets the requirement, the analyst should ask for evidence to document and ask for additional information if necessary. If the criteria are met, the analyst will move the group to the documented level indicator. The analyst continues through the question levels in this way until the SME group agrees they do not meet the proposed level, or the SME group cannot find consensus. The SME group must be in complete agreement for the organization to meet the level proposed. Once the rating is determined, the analyst selects the score and continues to the next question. See **Figure 3.2** for the scoring logic map visual.

Figure 3.2. OMM Question Rating Logic Progression.



3.3.4.3. Each question, domain, and overall OMM is rated on a scale from (0) Unaware to (5) Optimized. The following provides a detailed explanation of each rating score:

3.3.4.3.1. Unaware (Rating Score: 0). An Unaware Function: unaware, unsure. At this level of maturity, the function does not have knowledge or evidence to support any questions within the OMM assessment.

3.3.4.3.2. Informal (Rating Score: 1). An Informal Function: initial, informal, inconsistent, limited, lacking structure, reactionary, ad-hoc, chaotic. At this level of maturity, the function is performing activities that satisfy the basic goals of the functional area. It produces work products; however, it does not have documented standard work processes. The activities being performed have not been documented and are person-dependent, and the sequence, timing, and results vary during repetition. There are no guarantees of either achieving the desired results or adhering to timelines.

Activities are ad hoc, with little communication. Knowledge transfer does not happen when there is a change in an activity. Results of process improvement initiatives are observed, but not quantified. Outputs are not widely understood or known.

3.3.4.3.3. Documented (Rating Score: 2). A Documented Function: initiating, documenting, emerging, updating, collecting, organizing, generating, managing. At this level of maturity, a documented function has the basic infrastructure in place to support the processes being performed; however, a standardized process has not been deployed at all locations. Strategy exists to establish standard work to effect best practices. Leading areas are implementing standard work and standard processes are being documented and/or updated to be implemented. Outputs are understood and known but are not being tracked for decision-making capabilities. Knowledge management or information sharing, and collaboration exist in some areas, but a functional-wide knowledge management strategy does not exist.

3.3.4.3.4. Integrated (Rating Score: 3). An Integrated Function: progressing, defined, structured, integrated, measured, competent. At this level of maturity, a function has managed activities in place. Best practice processes are documented, used, and instituted throughout the entire functional community. There is no inconsistency between the documented process and the deployed process. The policy is current and driving standard work. Outputs are standardized, defined, and measurable. Tracking systems are implemented for decision-making capabilities. A project management process is implemented to track progress or detailed process improvement projects against milestones, with feedback provided to leadership. An organizational-wide knowledge management strategy exists for information sharing, collaboration, decision-making, and content management. **Note:** An organization should strive to reach this level of maturity.

3.3.4.3.5. Strategic (Rating Score: 4). A Strategic Function: strategic, aligned, disciplined, predictable, quantitatively managed. At this level of maturity, a function is measured, has defined (documented) processes controlled using statistical and other quantitative techniques. Quantitative objectives for quality and process performance are used in managing the process. Processes are predictable and managed appropriately. The processes have set goals (adherence to timelines, customer satisfaction, cost, etc.) and are being measured against their goals. Standard work is continuously improved and driving achievement through performance goals. Leaders utilize process improvement, lessons learned, knowledge management, and performance measurements to continuously refine output data and align policy and guidance. The function has central, user-friendly knowledge management tools in place. Some automation has been deployed.

3.3.4.3.6. Optimized (Rating Score: 5). An Optimized Function: optimizing, innovative, adaptive, opportunistic, synthesized, proactive, agile. At this level of maturity, a function has strategic processes that are optimized and regularly improved based on the understanding of common causes in variation. The focus is on continually improving the range of process performance. Standard work is integrated with other functions to optimize the DAF enterprise performance and/or to deliver the highest customer value. Processes are continuously and systematically improved. Leaders have easy access to the information they need to make decisions. Leaders use knowledge management processes and lessons learned to inform the overall strategy and drive innovation. Automation systems are in place and provide near-real-time data for optimal decision-making capabilities.

3.3.5. Evidence Collection (approximate time, four hours). The analyst will document all potential evidence to support answers provided by SMEs during the working group. The analyst will work with the POC to view and collect (if necessary) evidence supporting the score. If the evidence does not support the level assessed, the analyst should adjust the score to an appropriate level.

3.3.6. Assessment Report.

3.3.6.1. The OMM tool generates a draft report compiling the results, recommendations, and score card in-line with AFI 1-2, *Commanders Responsibilities*. The analyst adapts the report to meet any additional needs and scope initially requested by the customer and presents the report to the organization's leadership.

3.3.6.2. The assessment report should provide the overall assessment score, the score for each question, and a recommendation summary. The analyst should explain what actions can be taken to improve the overall assessment score and explain how the manpower core competencies can be used to help the organization (see **Chapter 26**).

3.3.6.3. For requirements determination focused OMMs, the assessment report should indicate if the function is ready to be studied. If a function is ready, the assessment report should help scope the next steps. If the function is not ready, the report should provide recommendations.

3.3.7. Out-brief (approximate time, two hours). Following the assessment, the analyst should develop and present an out-brief to the organization's leadership team. This brief should provide an overview of the key findings and provide information on how to utilize the assessment results.

Part 2

DEFINING WORK

Chapter 4

DEFINING AND DOCUMENTING WORK

4.1. General Concepts. The foundation of any requirements determinant study is the ability to correctly define and document work in a SWD. This chapter provides an overview of how to define and document work. It also outlines policies and procedures for defining and documenting the work.

4.2. Defining Work. When developing the SWD, analyze the work center's activities to classify them as productive, nonavailable, or not allowed (e.g., assumed work or inferred work). Use Tables **4.1** and **4.2** to assist in conducting analysis. Proper accountability of special work requirements (flying requirements, travel, supervision, OJT, and cleanup) may be confusing or difficult. Refer to **Table 4.3** for rules on how to handle special circumstances.

Table 4.1. Classifying Direct Work.

RULE			and the work is		then classify the work as					
	If the work is required by a command or higher directive	and the directive identifies the work center to perform the work	performed at all locations where the work center exists	essential to the work center's mission	Productive (core for work center)	Productive (positive variance for work center)	NONAVAILABLE	NOT ALLOWED	ASSUMED WORK	and contact the responsible functional OPR to ensure the appropriate directive is changed to add or delete this requirement
1	Yes	Yes	Yes	Yes	X					
2				No					X	X
3			No	Yes		X				
4				No				X		X
5		No	Yes	Yes	X					X
6				No			X			
7			No	Yes		X				X
8	No							X		

Table 4.2. Classifying Indirect Work as Direct Work.

RULE	If the work is performed in support of the work center or personnel assigned to the work center being measured	If the work center is an overhead work center and the work performed is in support of a subordinate work center or personnel assigned to a subordinate work center	If the work center is an overhead work center and the work is performed in support of the work center or personnel assigned to the overhead work center being measured	Indirect (see **note 1**)	Direct (see **note 2**)
1	Yes			X	
2		Yes			X
3			Yes	X	

Notes:
1. Use appropriate indirect task description from Indirect Allowance Factor (IAF).
2. Use appropriate indirect task description from IAF as direct work. Management or overhead work can have direct processes which describe indirect work when it is performed in support of personnel in subordinate work centers. This is in addition to the standard indirect categories to support people inside the overhead work center. IN ALL CASES, ensure the "same" work is not counted twice.

Table 4.3. How to Treat Special Work Requirements.

RULE	If the work to be classified is	and includes	then
1	Flying Requirements	Flying to accomplish the work center's mission and to satisfy the requirements of Aircrew Position Identifier (API) 1, 2, 4, 5, or 8.	Identify steps related to conducting flying mission, training, or evaluation in a direct process titled "(type Aircraft) Flying Activities." Include steps required to satisfy all currency requirements.
2		Currency requirements associated with API 3 and 4 coded positions.	Consider the steps credited in the IAF and the Man-hour Availability Factor (MAF)
3	Travel	Travel between work centers, travel from the work center to the job site, or temporary duty (TDY) travel with the purpose of doing official mission-oriented direct process work.	If travel is required to accomplish a direct process, establish a step in the process for travel. If travel is required to do two or more steps in the same direct process, establish a separate step for each time travel is performed (see **note 1**).
4	Supervision (see **note 2**)	Managing two or more subordinate functions.	Establish a process called "Management" that contains those steps necessary to support subordinate work centers.
5		Supervising only internal work center personnel.	Consider tasks credited in the IAF for OA efforts.
6	On-the-Job Training	Accomplishing direct work while receiving OJT.	Credit this work to the direct process done.
7		Receiving in-house proficiency training or qualification training in a classroom environment in lieu of numerous individual OJT sessions on one subject.	Consider tasks credited in the IAF for OA efforts. In a post/position manning work center, where certification is maintained and personnel are attending training in addition to shift work, training would be considered direct work, and Post/Position Qualification Time (PQT) would be calculated to provide required man-hours.
8		Receiving Field or Mobile Training Detachment instructions when the training is of a recurring nature similar to, or in lieu of, normal OJT or proficiency training.	
9		Study of career development course and Weighted Airman Promotion System (WAPS) during normal duty hours.	Consider as nonproductive unless used in conjunction with rule 6 or 7.
10	Cleanup	Performing clean-up services not authorized for custodial service.	Consider tasks credited in the IAF for OA efforts.
11		Mowing grass (see **note 3**).	Considered assumed work.

Notes:
1. Ensure credit for travel is not double counted in the steps or processes identified.
2. Indirect tasks can be reflected as both direct and indirect in management or overhead work centers. However, when documented as direct work, the processes reflect steps to support personnel in subordinate work centers while the indirect categories reflect steps to support people inside the overhead work center. Ensure direct processes are written clearly and do not duplicate indirect work included in the IAF.
3. There may be other duties performed by the work center’s personnel (e.g., snow/ice removal) that may or may not be creditable to the work center. Use the decision logic in **Tables 4.1** and **4.2** to determine how this work should be classified.

4.2.1. Productive Work. There are two categories of productive work activities: direct work and indirect work. Direct work is documented in the SWD, while indirect work is normally addressed by application of an IAF.

4.2.1.1. Direct work activities are required by MAJCOM or higher directives, are essential to and directly support the work center's mission and can be identified with a particular service or end or final product accurately, logically, and without undue effort or expense.

4.2.1.2. Indirect work activities are considered productive work. However, indirect work is done in support of the function, does not add value to a product, and may not be readily identifiable with a specific output or service. It is not usually necessary to measure indirect work. Rather, application of an IAF is accomplished to credit a work center for standard indirect man-hour requirements. The IAF is discussed in more detail in **paragraph 4.3.10**.

4.2.2. Nonavailable Activities. There are activities directed, approved, or recognized by the Air Force making people unavailable to perform assigned primary duties. Therefore, this time should not be included in the SWD. For more information about nonavailable activities, refer to the military and civilian MAF reports located on the AFMAA SharePoint site.

4.2.3. Not Allowed. Inferred or assumed workloads are not included when developing a requirements determinant, so careful analysis of the work activity against Tables **4.1** and **4.2** is required.

4.2.3.1. Inferred Work. Workload defined as the responsibility of a function other than the one under development. When MAJCOM and higher headquarters guidance conflict, the higher headquarters guidance prevails.

4.2.3.2. Assumed Work. Work being done not necessary to accomplish the Air Force mission and is not required by MAJCOM or higher directive.

4.2.4. Infrequent Work. A tenet of requirement determinants development is to document the minimum number of man-hours needed to perform a given mission at various monthly average levels of workload (normally based on a 12-month period). Manpower or man-hours are not provided at peak workload nor reduced for sharp declines in workload levels that may be experienced by a work center. Rather, man-hours for peaks and valleys of workload are averaged throughout the year. Determinants attempting to set manpower at peak workload requirements inflate man-hour costs. The requirements determinant is set to the norm, and leadership manages to the exception (i.e., managing the peak workload when it happens).

4.2.4.1. Actions to reduce the impact of peak demand may include the transfer of work from one period to another or the revision of procedures to spread the workload over a longer cycle. The function may also opt to accommodate peak demand via management actions such as overtime or temporary over hire employment. Refer to **Chapter 8** for further details regarding Man-hour Shift-Profile Analysis.

4.2.4.2. Infrequent tasks (i.e., those occurring less than once per year) should not be ignored or dismissed without looking at the bigger picture. Independently, these taskings may seem to cause minor spikes in needed man-hours however, combined, these spikes may cause a higher and almost steady state of workload throughout the year. In conjunction with the functional manager, the analyst should analyze and address these peak demand situations.

4.2.4.3. The analysis results, decisions, and related actions concerning peak demands driven by infrequent work should be documented in the requirements determinant report.

4.3. Time Classification Considerations.

4.3.1. On-Call Time. On-call time is a period of time an off-duty worker is available at a prearranged off-duty location and can be reached by telephone or other means. When authorized work is required and cannot be held over to the next duty day, credit the work center with productive time expended and the travel time needed to get to the job site and return to the off-duty location. Off-duty time spent waiting for a call is not measured or included in requirements determinants.

4.3.2. Borrowed Time. Borrowed time is time provided by personnel authorized and assigned to another work center but used to do productive work within the work center that is part of the requirements determinant development.

4.3.3. Loaned Time. Loaned time is time expended by work center personnel to do work which is the responsibility of another work center.

4.3.4. Standby Time. This is time spent in a ready status awaiting work when work is unavailable (for example, the time a taxi driver waits to be dispatched). Include standby time only when it is essential to do the mission and when no other work (direct or indirect) can be accomplished.

4.3.5. Nonavailable Time (NAT). This is time work center personnel spend participating in activities directed, recognized, or approved by the Air Force which render them unavailable for assigned primary duties. Nonavailable time is accounted for through the MAF. The major groupings of nonavailable activities are leave, permanent change of station related, medical, organizational duties, education and training, transition assistance program, and miscellaneous. Refer to the military and civilian MAF reports on the AFMAA SharePoint site.

4.3.6. Overtime. Uncompensated overtime is the productive time spent in excess of regularly scheduled duty hours. This time is used to do productive work and cannot be caused by nonproductive activities or offset by compensatory time. For civilians, include only overtime documented according to AFI 36-128, *Pay Setting and Allowances*. For military personnel, document and thoroughly analyze the need for overtime. Ask the supervisor to validate overtime. If overtime is a normal occurrence, visit the work center during overtime periods and observe the work in progress. Identify the backlog driving the overtime work. Determine if the backlog is at unacceptable or growing levels.

4.3.7. Idle Time. This includes time spent by a worker in an avoidable delay status, doing unnecessary work, or doing work not job-related. Idle time is not included in a requirements determinant.

4.3.8. Avoidable Delay. Any unnecessary delay, regardless of source, that causes work stoppage. Time lost to avoidable delay is not included in the determinant. **Note:** When conducting simulation modeling, it may be necessary to measure and/or model avoidable delays to produce realistic scenario results; however, man-hours are still not provided in final requirements determinant.

4.3.9. Unavoidable Delay. An occurrence that is essential and outside the worker's control or responsibility preventing the accomplishment of productive work. Time lost to an unavoidable delay is included in the determinant as part of the Personal, Fatigue, and Delay (PF&D) allowance depending on the work measurement method used (see **Chapter 23**).

4.3.10. Quantifying Indirect Workload and the IAF General Concepts and Principles.

4.3.10.1. The IAF represents a portion of total productive work and is used to quantify productive, indirect work man-hours associated with the following nine standard indirect work activities: (1) civilian employee administration; (2) officer administration; (3) enlisted administration; (4) work center administration; (5) administrative support; (6) prepares for, conducts, or attends meeting; (7) training administration; (8) supply administration; (9) inspects and cleans work area.

4.3.10.2. The IAF is the monthly man-hour allowance factor to perform indirect duties. It is applied as a percentage of total monthly direct man-hours to determine the total monthly allowed man-hours required by the work center. Refer to the IAF report located on the AFMAA SharePoint site.

4.3.10.3. The IAF defines allowed indirect work. This work is classified as indirect only when it is in support of the work center where it is done. Work accomplished in support of subordinate work centers is classified as direct work. In the latter case, these work centers are called "overhead" functions because of direct management responsibility for two or more subordinate work centers. This means for overhead functions it is possible to have the same activity titles listed under both direct and indirect processes.

4.3.11. Application of the IAF. Indirect work is accounted for as a separate factor applied outside the model during the manpower requirements determination process. Directions are included in the requirements determinant application instructions, addressing the applicable IAF and how to apply it. The analyst should first determine total direct man-hours by adjusting the results of the basic manpower equation with applicable variances. The analyst selects the IAF, per application instructions, and multiply the sum of direct man-hours by the IAF. This product reflects the total monthly man-hours required by the work center. Conversion to full-time equivalents (FTE) is accomplished by dividing total monthly man-hours by the applicable MAF and uses the appropriate rounding rule to determine the FTE.

4.4. Documenting Work in the Standard Work Document. The SWD contains outputs and sources of count, process descriptions, standard activity descriptions, standard process times, and standard activity times (SAT). The SWD is a full description of the function's required work which can be defined using process flowchart, narrative description, a functional statement, directed requirement, staffing pattern, or post/position manning. The SWD is completed by compiling the individual processes plus any additional work not directly related to an output. SWD development is typically done through workshops. A workshop is defined as a scheduled meeting with a predefined agenda, facilitated by the study lead, and attended by functional SMEs. The functional representative selects SMEs based on experience and knowledge. For specific workshop details refer to **Chapter 6**.

4.4.1. Components of the SWD. The minimum components are the process number, process title, process time, standard activity description, SAT, and workload data definition and specific source of count. This information is required (1) to capture required work, and (2) for subsequent requirements determinant development. The SWD is the basic building block of the determinant and is written to facilitate work measurement and data analysis and computations. Functional characteristics, e.g., complexity, stability, and degree of standardization, influence the level of SWD detail, the selection of the measurement approach, and the ultimate maintenance of the determinant. **Note:** Ensure the SWD content reflects only mission-essential processes assigned to the work center being studied and governed by a MAJCOM or higher directive. Omit assumed or inferred workload. To build a good SWD, develop an accurate and understandable definition for each process step.

4.4.1.1. A process is a sequence of work activities with a definitive input and output. A process involves worker interaction with such things as equipment, material, other people, and information. Structure processes independently and mutually exclusive of each other.

4.4.1.2. Standard Activity Description. An activity description may only need a short phrase (e.g., repairs carburetor), or it may need a breakout of the process into several steps (e.g., disassembles carburetor, replaces part, reassembles carburetor, and inspects carburetor).

4.4.1.2.1. A detailed description is suitable when an operation is highly repetitive, and a specific sequence of steps are followed.

4.4.1.2.2. A less detailed description is suitable when a process can be done in a variety of ways. For example, management, research, and problem-solving activities may follow different steps each time completed; therefore, those activities can only be described in general terms.

4.4.1.3. The work measurement method selected:

4.4.1.3.1. A measurement method such as OA usually needs processes defined at the activity level to ensure accuracy of data.

4.4.1.3.2. For work sampling (WS), the sampling level dictates the degree of detail needed. If sampling is done at the process level, a listing of step titles or a grouping of the steps in sentence format may provide enough detail for measurement.

4.4.1.3.3. In all cases, clearly write descriptions in enough detail so the analyst can identify when an activity occurs during measurement.

4.4.1.3.4. Setting up the correct descriptions is a repetitive procedure requiring the analyst to use good judgment and common sense.

4.4.1.3.4.1. Steps made purposely broad to cover as much work as possible can increase interpretation problems, cause inaccurate measurement, and hinder data analysis.

4.4.1.3.4.2. Steps not accurately reflecting duties and responsibilities increase the chance for inaccurate measurement.

4.4.1.3.4.3. Steps too detailed may result in an unclear sequence of events.

4.4.2. Preparation of the SWD.

4.4.2.1. Clearly state process titles and accurately describe the steps that are grouped under each activity. Use a noun form or an adjective and a noun form (e.g., management, minor maintenance, officer classification, record processing). Make the process titles descriptive and easily identifiable.

4.4.2.2. State step titles in a single unit form with verbs in third person singular. Processes are described at the activity level only (e.g., 1.1., 1.2., 2.3., etc.). In WS measurement, processes are described to the level necessary for accurate measurement. In either case, each definitive step of the process, from the beginning (input) to the end (output), are described in the sequence as it occurs in the process. This increases the chances of getting accurate unit times and frequencies at the time of measurement. Titles that are vague or written in plural form increase the chance of error in the associated unit time values and may make later analysis of data harder. The same step title may be used in different processes. For example, "Reviews Unit Manpower Document" could be a step in processing a manpower authorization change request or in the process of applying a requirements determinant. See **Table 4.4** for examples of acceptable and unacceptable step titles.

Table 4.4. Examples of Acceptable and Unacceptable Step Titles.

Acceptable	Unacceptable
Types letter	Types letters
Inspects facility	Perform inspections
Attends meeting	Attend meetings
Prepares report	Prepare reports
Repairs pump	Repair pumps
Takes sample	Take samples

4.4.2.2.1. Including an indirect statement in the SWD is optional. If it is included, use the following statement:

INDIRECT: Indirect work involves those tasks which are not readily identifiable with the work center's specific product or service. The major categories of standard indirect work are: administers civilian, officer, and enlisted personnel; directs work center activity; provides administrative support; prepares for and conducts/attends meeting; administers training; manages supplies; maintains equipment; and performs cleanup.

4.4.2.2.2. Format the SWD using the template provided on the AFMAA SharePoint site.

4.4.3. SWD Approval. The SWD is sent to the SSR and MAJCOM/A1Ms.

4.4.3.1. The SSR will send to MFMs for coordination. The SSR compiles all CRMs (one per MAJCOM), adjudicates comments, and, with study lead assistance, updates SWD and SWD report with any adjustments. The SSR will brief the SS and approve the SWD. Once the SWD is approved, the functional community implements and owns the SWD. The SWD is posted on the AFMAA SharePoint.

4.4.3.2. The MAJCOM/A1Ms, with Installation Manpower Office (IMO) assistance, will review the SWD for missing core workload or MAJCOM unique workload (variance) and notify the command MFMs for submission back to the SSR.

4.5. Variances. A variance is a condition that either adds to or subtracts from the core workload identified in the SWD or impacts the way the work is performed and accounts for different operating conditions.

4.5.1. Types of Variances. **Note:** Each type of variance can have either a positive or negative effect on requirements.

4.5.1.1. Environmental. Accounts for different operating conditions from those used to develop the core manpower determinant (e.g., snow, geographical separation, etc.).

4.5.1.2. Mission. Accounts for different operating processes from those used to develop the core manpower requirements.

4.5.1.3. Technological. Accounts for different operating equipment from those used to develop the core manpower requirements.

4.5.2. Variance Development and Responsibilities.

4.5.2.1. MAJCOM/A1Ms. Forward draft SWD to IMO for review with the functional POC. Review variances received from IMOs with MFM. Submits validated or approved variances to study team. **Note:** MAJCOM/A1Ms may submit variances outside of requirements determinant development to AFMAA.

4.5.2.2. IMOs. Identify MAJCOM or installation unique mission, environmental, or technological variances using Work Center Analysis Record and provide calculated manpower estimates with the OA Workbook. Transactional work should be documented in a process flowchart and non-transactional work should be documented in a functional statement or narrative description. Both templates are provided on the AFMAA SharePoint. **Note:** Unless otherwise instructed, installation or command unique variances are the responsibility of applicable installation or MAJCOM to develop. If additional time is required, this does not stop the requirements determination study process.

4.5.3. Variance Approval.

4.5.3.1. A DAF variance, applicable to more than one MAJCOM, is approved by AFMAA with SSR coordination.

4.5.3.2. A MAJCOM variance, applicable to one MAJCOM, is approved by the MAJCOM/A1M with MFM coordination.

Part 3

MEASUREMENT TECHNIQUES

Chapter 5

OPERATIONAL AUDIT

5.1. General Concepts. The determination for using OA as the primary measurement technique is established early in the study process. The OA measurement methods encompass several non-engineering work measurement techniques using values at the process step level to determine the man-hours for a particular standard.

5.1.1. OA Versatility. OA is one of the Air Force MEP's most flexible and widely utilized work measurement methods. It is used for setting activity times and frequencies (FREQ) when alternate methods are not appropriate. This method can be used to measure workload in practically any type of work center (e.g., production, administration, supervision, etc.). OA can also be used to supplement time study (see **Chapter 21**) or WS (see **Chapter 24**).

5.1.2. Definitions.

5.1.2.1. Per Accomplishment Time (PAT). The time it takes to accomplish a single task one time.

5.1.2.2. Standard Activity Time (SAT). When a PAT is validated and included in a SWD it becomes a SAT.

5.1.2.3. Normal Time (NT). When a PAT is adjusted by the pace rating it becomes a NT. See **Chapter 22**.

5.1.2.4. Leveled Time. An average time adjusted to reflect differentiating factors in operator performance, such as effort, skill, and work conditions.

5.1.2.5. Standard Time (ST).

5.1.2.5.1. 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.

5.1.2.5.2. Time measured by use of rigid statistical methods, for example, time study.

5.1.2.5.3. The normal or leveled time plus allowances for rest and unavoidable delays.

5.2. Preparation. The analyst prepares in advance for OA to ensure the accuracy and validity of the data.

5.2.1. Check the SWD and functionally coordinated/defined SOC with work center personnel. A SOC identifies the environment and impact of conditional factors on the time needed to perform work center activities and identifies the basis for deviations and the projected impact, i.e., potential benefits from new equipment, automation, facilities, etc.

5.2.2. Ensure the work center supervisor and SMEs understand the work to be measured, SOC, and variations existing at the specific measurement sites. Keep in mind when the process is insufficiently defined, it may be difficult to estimate total process man-hours. In this case, break the process down into more detailed steps and sub-steps.

5.2.3. Make a concerted effort and attempt to obtain all workload values for the period specified. Work count procedures should call for a minimum of six months historical data, while 12 months of data are preferred. Data should be collected monthly, and not as an annual total, to assist with trend analysis. Obtain the number and skill level of people assigned to the work center for the same period. In conjunction with the functional OPR, establish data collection parameters to ensure complete work cycles are covered for all locations to use in measurement efforts.

5.2.4. Discuss the work situation with the supervisor to find out whether changes were made in methods, product, or type of services during the period covered by the records. Also, find out what effect any changes may have had on the data. In some cases, the effects of changes are not significant; in others, the records and data may no longer be valid and should not be used in the measurement. Use the average historical time based on all representative values.

5.2.5. Identify activities directly related to other activities. For example, if standard B is always done as follow-on to standard A, the FREQs should relate.

5.2.6. Identify activities indirectly related to other activities. For example, in a maintenance work center, part replaced might relate to part transaction processed in a materiel management work center.

5.2.7. Determine if the work center has borrowed or loaned manpower, scheduled or documented overtime, or has backlog.

5.3. Operational Audit Techniques. OA techniques are generally less accurate than engineered techniques, but document requirements for specific activities not appropriate for time study due to low frequency or long duration when time study is the primary measurement method.

5.3.1. Overview. OA integrates five primary techniques to obtain PATs and/or FREQs to systematically measure work: good operator timing, directed requirement, standard data, historical records, and, as a last resort, technical estimate. **Note:** It is not uncommon for analysts to use one technique to determine FREQs and another to determine PATs. Caution do not use personnel generated data sources to determine PATs. These sources are not reliable for manpower purposes because personnel generally only account for an 8-hour work day and not the time it takes to accomplish a task one time.

5.3.2. Good Operator Timing. A primary OA measurement technique used to determine PAT values through the measurement of the time a qualified individual expends on a given activity to a directed specified standard. Apply the PF&D allowance factor for values obtained with the good operator timing technique. **Note:** This technique is not used to determine FREQs.

5.3.2.1. Man-hours captured using the good operator technique are considered representative of the time that others need to do the same work.

5.3.2.1.1. Consult with the work center supervisor to jointly select a qualified person who does the process at an average pace.

5.3.2.1.2. If possible, measure several qualified individuals doing the same standard. Ensure sufficient samples or observations are taken to give accurate estimates of the ST. The number of observations taken should be comparable with the number of man-hours associated with the standard. The more samples used to determine average time increases the accuracy and credibility to the estimate. The significance of the standard man-hours to the total work center expenditure may determine how many sample estimates are needed. Time permitting, where two similar work centers exist at the same location in separate organizations, get estimates from both.

5.3.2.2. Where the activity is not accomplished frequently, or the PAT is relatively small, fewer observations may be appropriate. However, where the activity is accomplished often, or a large amount of the effort of the work center is spent in the standard, more observations are justified.

5.3.2.3. This technique instills confidence in the data since functional OPRs tend to trust the man-hours derived from actual timed observations more than those resulting from less objective means. This method is also useful for verifying suspect PATs collected via technical estimate.

5.3.2.4. This technique is similar to time study (see **Chapter 21**) but is not as stringent. Work does not need to be broken down into elements, nor does a specific number of samples have to be taken to meet statistical confidence and accuracy.

5.3.3. Directed Requirement. A technique used to determine FREQs and/or PATs based on DAF-approved guidance (e.g., AFIs, technical orders, etc.).

5.3.3.1. Examples of directed FREQs include monthly inspections or periodic maintenance of a standby electrical power generator. If the directed FREQ does not seem reasonable, research the mandate for the FREQ.

5.3.3.2. An example of a directed PAT is one included in an AFI or a contract Statement of Work.

5.3.4. Standard Data. Usually confined to maintenance and logistics functions. This technique uses a collection of standardized processes, step definitions, and associated time values to accurately reflect the FREQs and/or PAT for standardized units of work. One source for the creation of standard data is using pre-determined time systems standards. Another source would be data from previous requirements determination measurement. Use caution with these times since they are not considered as valid as current FREQs and PATs.

5.3.5. Historical Records. This technique draws on the work center's documented past performance to obtain historical FREQs and/or PATs. Research historical records such as functional workload, data systems, reports, letters, messages, rosters, etc. **Note:** Historical data reflects the mistakes and inefficiencies of past operations, and past performance. Do not use labor hour reporting data derived from timecard systems or other timekeeping documents to determine PATs.

5.3.5.1. Validate a reporting system by examining several recorded times for the same standard and comparing those to measured data, then verify data with work center personnel.

5.3.5.2. Historical workload data and associated man-hours may not show the work center's true requirements. FREQs and PATs determined with this technique often need to be validated, when possible, using good operator timing or technical estimate due to the lack of a clear understanding of what that time includes (e.g., delays, standby time, worst case scenario, etc.).

5.3.5.3. Over or under-manning impacts the level of effort and the historical workload production level. Contracted work, backlog, labor negotiations, or future production schedules might also be factors. Identify and document the impact of these conditions during measurement.

5.3.5.4. Do not to apply the PF&D allowance factor to historical PATs (see **Chapter 23**). An average PAT can be derived from estimates.

5.3.6. Weighted PATs. When the PAT is affected by varying levels of complexity, derive a weighted-average PAT based on percent of occurrence. In this approach, an optimistic, most likely, and pessimistic (OMP) time estimate is made.

5.3.6.1. The first time estimate, the optimistic time, is the shortest time in which the standard can be performed if everything goes very well.

5.3.6.2. The second time estimate, the most likely time, is the most realistic time it takes to perform the standard. The most likely time should occur more often than either the optimistic or pessimistic time estimate.

5.3.6.3. The third time estimate, the pessimistic time, is an estimate of the average time to perform the standard under adverse conditions (i.e., when things go wrong).

5.3.6.3.1. These three estimates are converted to a weighted PAT by a simple approximation formula. Functional SMEs can provide an estimate of the occurrence of each standard (as a percentage, with most likely being the highest percentage).

5.3.6.3.2. OMP is not intended to be used on every standard. Since all calculations are based on these estimates, PATs need to be as accurate as possible. Extreme values will need further analysis for validity.

5.3.7. Technical Estimate. This technique should be used as a last resort, when it is not practical or cost-effective to use historical records or good operator timing techniques.

5.3.7.1. The determination of the FREQ and/or PAT needed for a given process step is based on an estimate made by individuals technically and professionally competent to judge the FREQ and time needed to accomplish an activity.

5.3.7.2. Validate questionable technical estimates. Evaluate significantly divergent or extreme estimate values (outliers). Determine whether corrections are appropriate or if the values should be eliminated entirely.

5.3.7.3. Do not to apply the PF&D allowance factor to PATs determined by this technique.

5.4. Data Examination. Each input is analyzed and compared with all other input measurements. Forward comments to explain any questionable measurement data, even when verified with the work center.

5.4.1. Compute total measured manpower and compare to average assigned strength. If measured manpower is greater than average assigned strength, then the delta should be supported by borrowed time, overtime, unacceptable backlog, or a reason to explain how the measured work is being accomplished with existing resources. If measured manpower is less than assigned, ensure all valid work center workload has been documented and credited.

5.4.2. Document MFM concurrence or reasons for non-concurrence with the measurement data. Ultimately, the quality of the requirements determinant is dependent upon the quality of the measurement data submitted.

5.4.3. Document measurement results to report measurement data.

5.5. Data Reporting. For requirements determination, man-hours are typically converted to monthly man-hours. Conversion factors for each standard FREQ, and the related symbols are in **Table 5.1**. An overview of the key internal computations is described in **Table 5.2**.

Table 5.1. Activity Frequency Symbols and Conversion Factors.

Rule	Activity Frequency	Symbol	Code	Conversion Factor
1	Per day (5 workdays/wk exc. Hol.)	D1	1	20.82 *
2	Per day (5.5 workdays/wk exc. Hol.)	D2	2	23.00
3	Per day (6 workdays/wk exc. Hol.)	D3	3	25.17
4	Per day (6.5 workdays/wk exc. Hol.)	D4	4	27.35
5	Per day (7 workdays/wk exc. Hol.)	D5	5	29.52
6	Per day (5 workdays/wk inc. Hol.)	D6	6	21.74
7	Per day (5.5 workdays/wk inc. Hol.)	D7	7	23.92
8	Per day (6 workdays/wk inc. Hol.)	D8	8	26.09
9	Per day (6.5 workdays/wk inc. Hol.)	D9	9	28.26
10	Per day (7 workdays/wk inc. Hol.)	D10	10	30.44 *
11	Per week (5 workdays/wk exc. Hol.)	W1	11	4.164
12	Per week (5.5 workdays/wk exc. Hol.)	W2	12	4.182
13	Per week (6 workdays/wk exc. Hol.)	W3	13	4.195
14	Per week (6.5 workdays/wk exc. Hol.)	W4	14	4.208
15	Per week (7 workdays/wk exc. Hol.)	W5	15	4.217
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	0.3333 *
19	Per year	YR	19	0.08333 *

* Primary Factors to be used. All other are to be used with extreme caution to ensure correct application.
Note: Derivation of conversion factors based on other that 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 0.1111 and the activity frequency would read 1
ACADEMIC YEAR.

Table 5.2. Computing Monthly Man-hours and Examples.

Step	Data Elements Needed and Computation of Monthly Man-hours	Example
1	Number of Occurrences: Whole number occurrence per time period.	2
	Activity Frequency. Natural rate of occurrence.	Per Week
2	Conversion Factor: Converts the expected natural rate of occurrence to a monthly figure.	4.348

3	Unless specified by Air Force, MAJCOM, Department of Defense, Air Force Occupational Safety and Health, Occupational Safety and Health Administration, or other directive, crew size should always be quantified as "1"	1
4	PAT or Weighted PAT: The time required to complete one occurrence of the activity. Expressed in whole minutes and decimal points	40
5	Monthly Man-hour Calculation: Multiply each of the numbers in steps 1 through 4 and divide by 60. Monthly Man-hours = $\frac{2 \times 4.348 \times 1 \times 40}{60}$	5.80

5.6. Operational Audit Calculation. Total man-hours for a process are determined by the mathematical model $T = f_i\ t_i$, where T is the man-hours for one activity, f_i is the standard FREQ (converted to monthly), and t_i is the PAT.

5.6.1. PAT (t_i) Determination. Determine required standard man-hours using good operator timing, directed PAT, historical records, technical estimates, or standard data. The PAT is the time it takes to perform an activity for one occurrence.

5.6.2. ST Determination. To compute an average PAT, sum all observation times and divide by the number of observations. To determine the actual ST, multiply the average PAT by the base PF&D to determine the actual ST. This is the time recorded for the process measured. See **Table 5.3** for an example of deriving a ST using good operator timing. **Note:** The ST becomes the SAT when it is validated and included in the SWD.

Table 5.3. Deriving Standard Time Using Good Operator Timing.

Observation Number	Time (in min)
1	3.25
2	4.50
3	3.00
4	4.50
5	2.50
Avg. Observation Time	17.75 / 5 = 3.55
ST = Avg. Time x PF&D	3.55 x 1.067 = 3.79

5.6.3. Standard FREQ (f_i) Determination. Techniques used to establish standard FREQs are historical records, directed requirements, standard data, or, as a last resort, technical estimate. Make every effort to get accurate FREQs of occurrence. Generally, the best source of FREQ data can be captured using the historical record technique.

5.6.3.1. The standard FREQ is the naturally occurring FREQ that a work center performs an activity, e.g., once per day, three times per week, eight times per quarter. Standard FREQs are converted to monthly equivalents via conversion factors. Refer to **Table 5.1** for standard FREQ conversion factors.

5.6.3.2. Evaluate work counts and workload cycles associated with specific processes to determine the natural FREQ period (e.g., normally occurs on a daily, weekly, monthly, quarterly, or yearly basis), as well as the historical FREQ counts.

5.6.3.3. In some cases, it is possible to relate unknown FREQs to reliable recorded data to find more objective estimates. For example, if there is no record in a work center to show the FREQ with which a particular part is replaced on a piece of equipment, a check of supply issue records may verify the FREQ. Investigate inconsistencies between work counts and directly related standard FREQs.

5.6.3.4. When applicable, use benchmarks or expected FREQ values provided by the functional SME as a guide for evaluating work center estimates. Reasonable variations in values are expected; however, large variations generated by differences in conditions or levels of service warrant investigation.

5.6.3.5. Use technical estimates for standard FREQ only when no alternative data source is available. If the estimates are suspect (e.g., based on lack of experience or isolated situations), evaluate estimates when determining average FREQ. Attempt to verify the estimate by cross-referencing it with other relatable step FREQs. Do not adjust FREQs without justification or coordination from the work center supervisor.

5.6.3.6. 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.

5.6.4. Determining the Weighted PAT. When appropriate, (see **paragraph 5.3.6**) an analyst may be required to utilize OMP to derive weighted-average PAT. **Table 5.4** provides an example of calculating the weighted PAT. The calculation used is as follows:

Weighted PAT = (*Optimistic* % x PAT) + (*Most Likely* % x PAT) + (*Pessimistic* % x PAT)

Table 5.4. Weighted PAT Using OMP.

Complexity	Percent of Occurrence	PAT (min)	Product (min)
Optimistic	10%	20.00	2.00
Most Likely	70%	50.00	35.00
Pessimistic	20%	75.00	15.00
		Weighted PAT	52.00

5.7. Rounding Procedures. After completing calculations, round only the final result to the correct number of decimal places.

5.7.1. Identify the correct number of decimal places, using **Table 5.5** and use simple rounding rules. **Note:** **Table 5.5** should be used as a reference for rounding rules for all measurement and non-measurement techniques discussed in subsequent chapters through this manual.

Table 5.5. Rounding Rule Reference Table.

Rule	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 measures, including accuracy, mean and standard deviation, standard error of the estimate, coefficient of determination (R^2), coefficient of variation (*V*), or test statistics (F&t)	3 decimal places
5	Functional Estimating Equations (FEE), percentage factors	3 decimal places
6	fractional manpower values	3 decimal places
7	coefficients for manpower models (including regression equations, single location equations, or simulation equations)	At least 4 significant digits. For example, 5.332, 0.5332, or 0.05332

5.7.2. Examples of using simple rounding to three decimal places are shown in **Table 5.6**.

Table 5.6. Examples of Simple Rounding.

Example	Yields	Reason
27.16346	27.163	because 4 is less than 5.
31.39461	31.395	because 6 is greater than 5.
16.48450	16.485	because 5 is equal to 5.

Chapter 6

WORKSHOP MEASUREMENT AND FACILITATION

6.1. General Concepts. A workshop is an approach to develop and finalize process flowcharts, conduct man-hour measurement of processes and activities required to produce an output, and to develop level-of-service options.

6.1.1. Benefits of Workshop Measurement. The major benefit of using workshop measurement is it reduces the measurement staffing time. It also reduces the need for extensive data adjustments or corrections because they can be addressed and resolved during the workshop.

6.1.2. Drawbacks of Workshop Measurement. The major drawbacks are TDY costs and scheduling difficulties. This may impact the number of people available to attend. Analysts should maintain caution and ensure the participants are representative of the locations to which the subsequent determinant applies.

6.2. Workshop Procedures. When deemed necessary, the foundation for an effective workshop begins during preliminary research and site visits where key outputs and observation times are identified, validated, and recorded.

6.2.1. Define Purpose of the Workshop. Know the purpose or ultimate goal before conducting and planning a workshop. Develop the workshop's objectives (e.g., how many processes need to be measured; do FREQs and/or PATs need to be collected?).

6.2.2. Determine Location of the Workshop. When selecting the workshop location, consider cost, availability of facilities, and the participants' locations. Consider scheduling the workshop at a centralized location to reduce overall travel costs.

6.2.3. Determine Who Should Attend. Consider the purpose, scope, and objectives when deciding who should attend the workshop. The SS selects SMEs based on experience and knowledge. It is imperative the right people are selected to ensure that MAJCOM representation regarding the requirements determinant; selectees should reflect the different levels of work to be covered by the determinant and have recent hands-on experience in the work center. Senior managers and supervisors have previous experience, but the personnel currently performing the work are better able to identify ways to improve processes and to provide accurate technical estimates on the time and resources required to accomplish required activities. Identifying criteria for attendee selection reduces the risk of nonqualified participants attending based simply on availability. Balance complete representation while trying to minimize the number of participants.

6.2.4. Schedule the Workshop. Estimate how much time it should take to meet the objectives. Prepare a plan or schedule of those processes to flowchart and measure.

6.2.5. Prepare and Distribute Pre-workshop Information Package. Send an information package to each attendee. Include base and local area information, a workshop agenda, travel instructions (if appropriate), and any other information that will contribute to the success of the workshop. Identify information and/or data the participants are expected to bring to the workshop and provide information that can be read before the event, thus saving workshop time. If possible and appropriate, collect inputs from participants prior to the workshop on information to be addressed by the group.

6.2.6. Conduct the Workshop. There are many ways to conduct a measurement workshop. Refer to **Chapter 26** for additional information about facilitation.

Part 4

NON-MEASUREMENT TECHNIQUES

Certain work centers do not require work measurement to develop all or part of a determinant. In these work centers, the objective of determining the manpower requirement determinant can be met at less cost with acceptable validity by using functional models, post/position manpower situations, staffing pattern (including directed organizational positions), and IAF. Use these methods in combination with measured data.

Chapter 7

STAFFING PATTERN

7.1. General Concepts. 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 and the associated direct support position is an example of a staffing pattern. The study team decides if a WLF 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. It explains pattern variations between locations in terms of workload or conditional factors. A staffing pattern, used as the basis for a determinant, may result in a quantitative expression that is variable in terms of workload or may result in a fixed manpower requirement for all applicable locations.

7.2. Using a Staffing Pattern. The staffing pattern is normally used in work centers that command or manage two or more subordinate elements. Use the staffing pattern when the following conditions apply:

7.2.1. The work center is a specified element of a formal organizational structure.

7.2.2. 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 two-year period.

7.2.3. Directed organization position specifies a fixed manpower requirement to fill a particular named assignment. This requirement is essential to the existence of a work center and does not change regardless of increases or decreases in workload or changes in the MAF. The directed organization position requirement is dictated by the need for one to be in a given office of responsibility, even though the individual may not be continuously productive.

Chapter 8

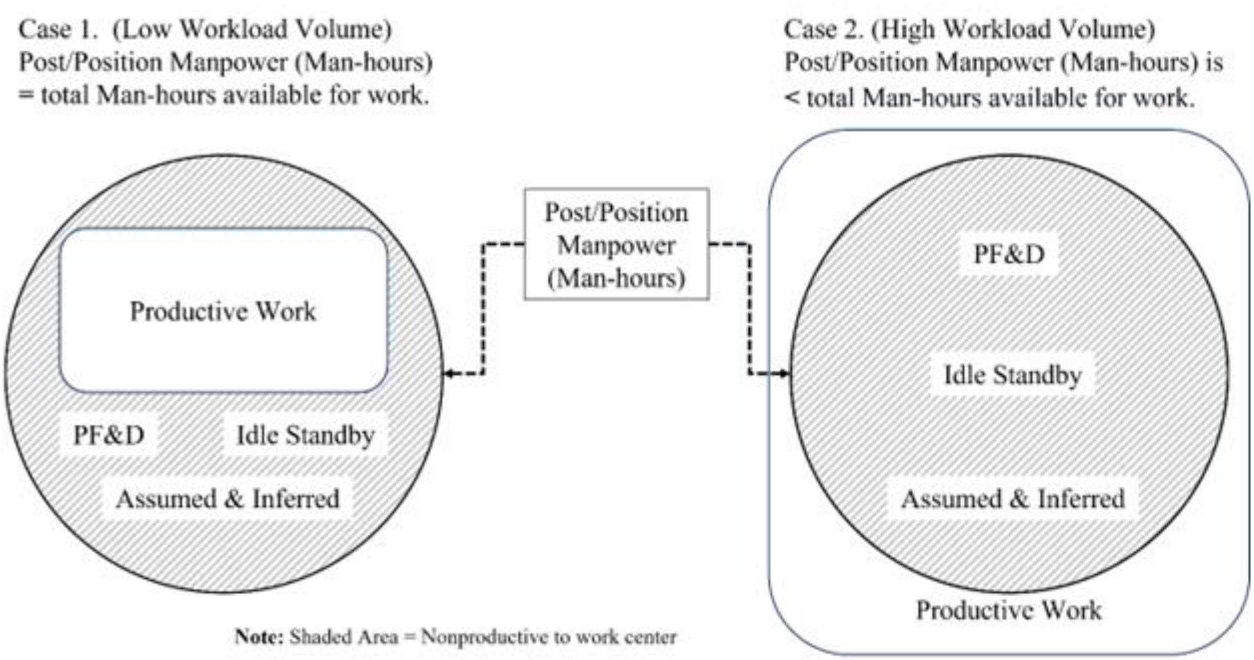
POST/POSITION MANPOWER REQUIREMENTS, STANDBY DETERMINATION, AND MAN-HOUR SHIFT PROFILE ANALYSIS

8.1. Post/Position Manpower.

8.1.1. General Concepts. Management decisions often produce manpower levels that drive standby time. Since all standby time is nonproductive and costly, it needs to 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 post/position manpower requirements and associated standby time.

8.1.1.1. **Figure 8.1** is a diagram depicting post/position manpower requirements at low (case 1) and high (case 2) workload volumes. In both cases, the post/position manpower requirements are considered constant and are represented by circles of the same size. In case 1, the post/position manpower requirement is equal to the total man-hours available to do work, that is, the universe is equal to man-hours required by manpower requirements. Standby is the difference between man-hours required by post/position manpower and man-hours required by productive work.

Figure 8.1. Post/Position Manpower Requirements at Low and High Workload Volumes.

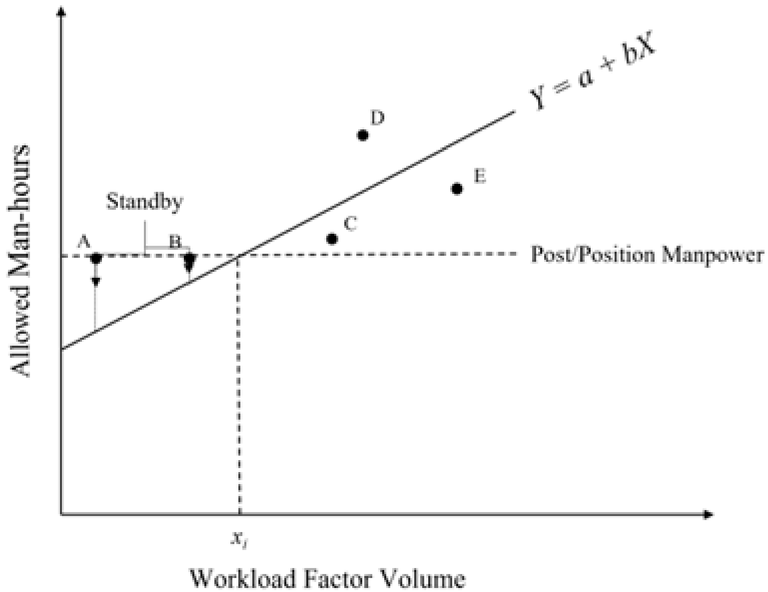


8.1.1.1.1. In case 2, on **Figure 8.1**, the post/position manpower requirement is less than total man-hours available for productive work. That is, the universe is equal to total hours available to do productive work. Derivation of standby in this case is more difficult.

8.1.1.1.2. **Figure 8.2** is a scattergram that shows a similar situation. Note that 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

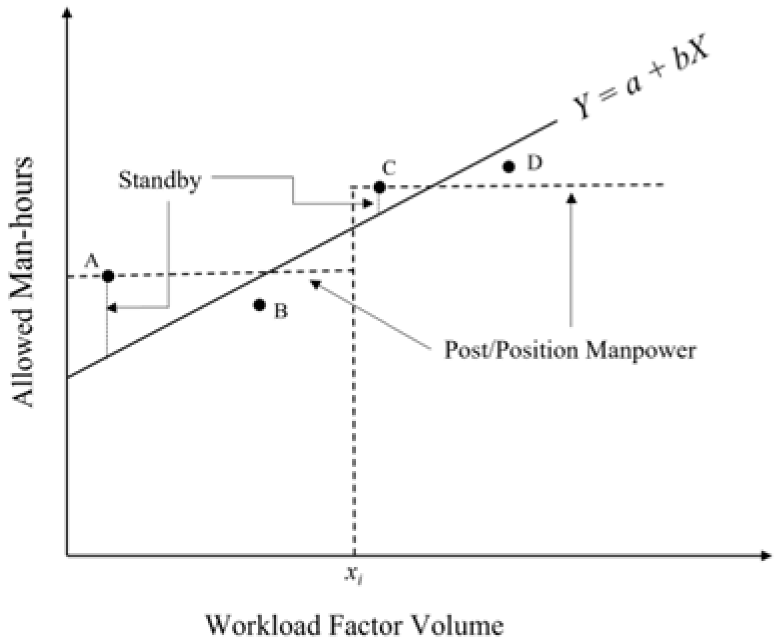
A and B), derive standby time. At bases C, D, and E, however, this procedure cannot be applied.

Figure 8.2. Workload Volume and Standby when Post/Position Manpower is Constant.



8.1.1.1.3. Post/position manpower requirements may be constant for each shift (Figures **8.1** and **8.2**, show this condition), or may vary with workload volume. **Figure 8.3** shows post/position 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 8.3** bases A and C 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.

Figure 8.3. Workload Volume and Standby when Post/Position Manpower is Variable.



8.1.1.2. When the 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 this condition in the application instructions in the requirements determinant.

8.1.2. Observations Regarding Standby Time.

8.1.2.1. Post/position manpower requirements may be the same at all locations or may change with workload volume.

8.1.2.2. Allow only standby necessary for mission accomplishment.

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

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

8.1.3. Rationale for Post/Position Manpower. Numerous factors contribute to establishing these requirements. Some of these factors, often a result of management decisions, are:

8.1.3.1. Mission needs.

8.1.3.2. Performance standards.

8.1.3.3. Machine design.

8.1.3.4. Facility limitations.

8.1.3.5. Hours of operation.

8.1.3.6. Shift size and necessity.

8.1.3.7. Crew size.

8.1.3.8. Post-manpower requirements.

8.1.3.9. Safety.

8.1.3.10. Security.

8.1.4. Evaluating Post/Position Manpower Requirements. Carefully check the need, question the basic need, and offer alternatives and clearly define the cost of such service. Study documentation contains rationale to justify these requirements. After the functional OPR confirms the management decision that results in post/position manpower requirements, quantifying standby time is generally straightforward. Reduce or minimize standby time through improved shift scheduling, reorganization, planning, and workload control techniques. Be ready to show the functional OPR how to meet the needed performance standards to reduce standby time. When standby time is minimized, the total manpower requirement is also minimized.

8.1.5. Requirements Position Formula (RPF) Computations. These are used to determine post/position manpower.

8.1.5.1. In situations which meet the criteria described in **paragraph 8.1.3**, use the RPF in model development. RPF method requires direct hours for each measurable variable in the equation to compute manpower requirements for an OPR-approved post/position. Compute the fractional manpower by dividing the man-hours for coverage by the applicable MAF, minus additional NAT not included in the MAF. NAT is lost man-hours due to decertification, disqualification, and/or suspension. Two programs that can decertify, disqualify, or suspend personnel from performing primary duties are Personnel Reliability Program (PRP) and Arming and Use of Force (AUoF).

8.1.5.2. In certain situations, additional man-hours associated with post/position coverage are needed. These situations fall into two categories.

8.1.5.2.1. Post/Position Related Time (PRT). PRT is constant man-hours required to be expended for processes accomplished either before and/or after post/position coverage ends. For example, Security Forces personnel are issued weapons and ammunition from the armory and guard mount attendance is mandatory before assuming the post. Likewise, at the end of the shift, weapons and ammunition are returned to the armory. The time associated with this work is in addition to the time needed for post duty and should be measured as PRT.

8.1.5.2.2. Post/Position Qualification Time (PQT). PQT is a constant man-hour requirement directed by higher headquarters policy in addition to duties. This includes recurring training hours that keep individuals qualified to fill the post/position which cannot be received while the individual performs their duties. An example of PQT is proficiency or refresher training needed by all Security Forces, such as weapons training. This is another example of NAT which must be subtracted from the MAF.

8.1.5.2.3. When additional allowances are given for these two types of post/position related manpower, derive the man-hours used in computing the allowances from work measurement. To compute required manpower, divide the coverage in man-hours by the MAF minus the NAT. **Note:** Standby time is normally an inherent part of post/position based on application, such as Security Forces assigned to a base access gate and firefighters.

8.1.5.3. Use the following RPF to compute fractional manpower. Use continuous calculations, i.e., round after all calculations are done.

$$RPF = \frac{D_w \times [H_d + (PRT \times S_d)] \times W_m \times C}{MAF - (NAT)}$$

8.1.5.4. In this equation, D_w represents the number of days per week the post/position operates, H_d represents the number of hours per day the post/position operates, *PRT* represents the number of constant man-hours required to perform tasks before and after one shift, S_d represents the number of shifts per day the post/position operates, W_m represents the number of weeks per month (conversion factor) the post/position operates, and *C* represents the size of the crew that is needed to man the post/position. Crew size is normally one, unless safety, security, mission, or regulatory guidance provides additional information. *MAF* represents the man-hour availability factor. Potential *NAT* to be subtracted from the *MAF* includes PQT, and PRP or AUoF. PQT represents the number of defined man-hours per month per person dedicated to post/position qualification time. PRP represents the number of measured man-hours per month per person associated with Personnel Reliability Program (use only with PRP units). AUoF represents the number of measured man-hours per month per person associated with arming and use of force (use only with Security Forces). PRP and AUoF are never used together in one equation. **Table 8.1** provides RPF variables and their descriptions.

$$RPF = \frac{D_w \times [H_d + (PRT \times S_d)] \times W_m \times C}{MAF - (PQT + AUoF)} \quad \text{or} \quad RPF = \frac{D_w \times [H_d + (PRT \times S_d)] \times W_m \times C}{MAF - (PQT + PRP)}$$

(Security Forces) (PRP Units)

Table 8.1. RPF Variables and Description.

RPF Variables	Description
D_w	Number of days per week the post/position operates.
H_d	Number of hours per day the post/position operates.
PRT	Number of constant man-hours required to perform post/position related tasks before and after one shift.
S_d	Number of shifts per day the post/position operates.
W_m	Number of weeks per month (conversion factor) the post/position operates.
C	Size of the crew that is needed to man the post/position. This normally equals 1, unless safety, security, mission, or some regulatory guidance provides additional information.
MAF	Average number of man-hours per month an assigned individual is available to do assigned duties.
PQT	Number of defined man-hours per month per person dedicated to PQT.
AUoF	Number of measured man-hours per month per person associated with AUoF.
PRP	Number of measured man-hours per month per person associated with PRP.

8.1.5.5. The following example calculates the fractional manpower for two hypothetical Security Forces posts at one location.

8.1.5.5.1. The first post is within the non-nuclear enterprise and operates 7 days a week, 24 hours a day, with 3 shifts per day. Each shift requires a 2-person crew. PRT was measured at 40 minutes per shift. PQT for this post is directed at 18 hours a month and AUoF is 7.30 hours per month for the non-nuclear enterprise. Post #1 fractional requirements are 12.886 (see below for calculation).

$$RPF = \frac{D_w \times [(H_d + (PRT \times S_d)] \times W_m \times C}{MAF - (\mathrm{PQT} + \mathrm{AUoF}))}$$

$$= \frac{7 \times \left(24 + \left[\left(\frac{40}{60}\right) \times 3\right]\right) \times 4.348 \times 2}{148.12 - (18.00 + 7.30)}$$

$$= 12.886$$

8.1.5.5.2. The second post is within the non-nuclear enterprise and operates 5 days a week excluding holidays, 24 hours a day, with 3 shifts per day. Each shift requires a 2-person crew. It is also open one weekend a month, 16 hours on Saturday (2 shifts) and one 8-hour shift on Sunday. Each shift requires a 2-person crew. PRT was measured at 40 minutes per shift. PQT for this post is directed at 18 hours a month and AUoF is 7.30 hours per month for the non-nuclear enterprise. Calculate the RPF for each shift. RPF for the post is calculated by adding together each shift RPF. Post #2 fractional requirements equal 9.238 (see below for calculations).

$$RPF = \frac{D_w \times [(H_d + (PRT \times S_d)] \times W_m \times C}{MAF - (\mathrm{PQT} + \mathrm{AUoF}))}$$

$$= \frac{5 \times \left(24 + \left[\left(\frac{40}{60}\right) \times 3\right]\right) \times 4.164 \times 2}{148.12 - (18.00 + 7.30)}$$

$$= 8.815$$

$$RPF = \frac{D_w \times [(H_d + (PRT \times S_d)] \times W_m \times C}{MAF - (\mathrm{PQT} + \mathrm{AUoF}))}$$

$$= \frac{1 \times \left(16 + \left[\left(\frac{40}{60}\right) \times 2\right]\right) \times 1 \times 2}{148.12 - (18.00 + 7.30)}$$

$$= 0.282$$

$$RPF = \frac{D_w \times [(H_d + (PRT \times S_d)] \times W_m \times C}{MAF - (\text{PQT} + \text{AUoF}))}$$

$$= \frac{1 \times \left(8 + \left[\left(\frac{40}{60}\right) \times 1\right]\right) \times 1 \times 2}{148.12 - (18.00 + 7.30)}$$

$$= 0.141$$

8.1.5.5.3. Add the fractional manpower for both posts to determine the fractional manpower requirement of 22.124.

8.1.5.6. When determining fractional manning for multiple posts of the same make-up in hours of operation, crew size, PQT, etc., use the RPF to determine fractional manpower for a single post and multiply the result by the number of posts authorized for the function under study.

8.1.5.7. If RPF is the sole measurement method, add all fractional requirements together and round once for like functions. For example, add all Security Forces post requirements before rounding.

8.1.5.8. IAF is not added to RPF since it is assumed that this work will be accomplished during standby time.

8.1.5.9. Document post/position manpower as follows:

8.1.5.9.1. When the post/position manpower computation is not the sole measurement method for the work center, compute the man-hours by multiplying the fractional manpower requirement by the applicable MAF.

8.1.5.9.2. When the post/position manpower computation is the sole measurement method for the work center, furnish only the RPF computation. There is no need to convert the rounded fractional manpower into man-hours.

8.2. Study Design.

8.2.1. A well-designed study accurately shows post/position manpower requirements and true standby time. Necessary standby man-hours cannot be identified during development, as they are grouped in with other nonproductive categories of time and when the post/position manpower requirements have not been accurately documented.

8.2.2. Clearly define the method for measuring standby when the possibility of standby time exists. Use standard data collection and work measurement procedures to identify standby; however, some innovation is needed with these methods. Do not simply state that queueing or shift profile analysis is used to quantify standby time; explain how inputs are utilized in these techniques. Standby time is discussed in conjunction with various data collection and analysis procedures in the paragraphs that follow.

8.2.3. Include standby time computed according to the procedures outlined in this section as input to regression analysis when developing the determinant man-hour equation. Build a variance for applicable locations if standby time does not exist at all locations.

8.3. Data Collection and Analysis Procedures.

8.3.1. Queueing Analysis. Queueing data does not directly identify allowed standby time. The percentage of server time in productive direct work may be determined with the queueing utilization factor after an acceptable level of service has been determined (e.g., the number of taxi drivers needed to give a four-minute response time). Queueing also shows when servers are not busy, including standby time. Design the study to collect queueing data on standby time if queueing is used. Details describing queueing techniques are in **Chapter 25.**

8.3.2. Work Sampling.

8.3.2.1. Identify standby time during WS observation rounds when post/position manpower requirements are previously defined. For example, suppose an office requires customers with inquiries be assisted within 30 min of customer arrival. It was predetermined that two technicians are necessary to give this level of service at the counter between 0900 and 1500.

8.3.2.2. 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 technicians were awaiting customers.

8.3.2.3. 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 (e.g., the time finance customers wait for service) may reveal the specified level of service has been exceeded or a second worker is needed only during peak periods, such as pay days.

8.3.2.4. Standby time collected in this manner represents adjusted or derived standby time required to support a predetermined level of service. 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.

8.3.2.5. Show the standby time derived through this procedure on the WS 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. WS techniques are described in **Chapter 24**.

8.3.3. Operational Audit.

8.3.3.1. Include enough rationale in the report to support the post/position manpower requirement when using OA as the primary work measurement method. It is not necessary to measure standby time if the post/position manpower requirement represents the total man-hour universe (see case 1, **Figure 8.1**.).

8.3.3.2. Minimize and fully explain all standby allowed in the study when the total man-hour universe is greater than the post/position manpower requirement (see case 2, **Figure 8.1**.). 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.

8.4. Man-hour Shift Profile Analysis.

8.4.1. Overview.

8.4.1.1. Use a man-hour shift profile chart to aid in analyzing standby time when WS or queueing is used, and standby time exists.

8.4.1.2. Man-hour shift profile charts are an effective way to identify and minimize standby time. The charts aid the analyst in defining the minimum essential manpower levels by:

8.4.1.2.1. Leveling workloads to economize on nonproductive standby periods.

8.4.1.2.2. Identifying minimum standby time based on the accepted level of service.

8.4.2. Use of the Man-hour Shift Profile Chart.

8.4.2.1. The man-hour shift profile chart helps functional managers realize economies of operation and helps analysts build accurate requirements determinants. Use this process as a data analysis technique during management consultant studies or with other data collection methods during a requirements determinants study.

8.4.2.2. The man-hour shift profile is used to justify standby requirements. Analysts use the chart to find the proper amounts of standby time to include in measurement reports when either:

8.4.2.2.1. Queueing analysis is the primary determinant development technique.

8.4.2.2.2. WS is the primary work measurement method and standby time cannot be distinguished from other nonproductive categories during the sampling period.

8.4.3. Development of the Present Man-hour Shift Profile Chart.

8.4.3.1. 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).

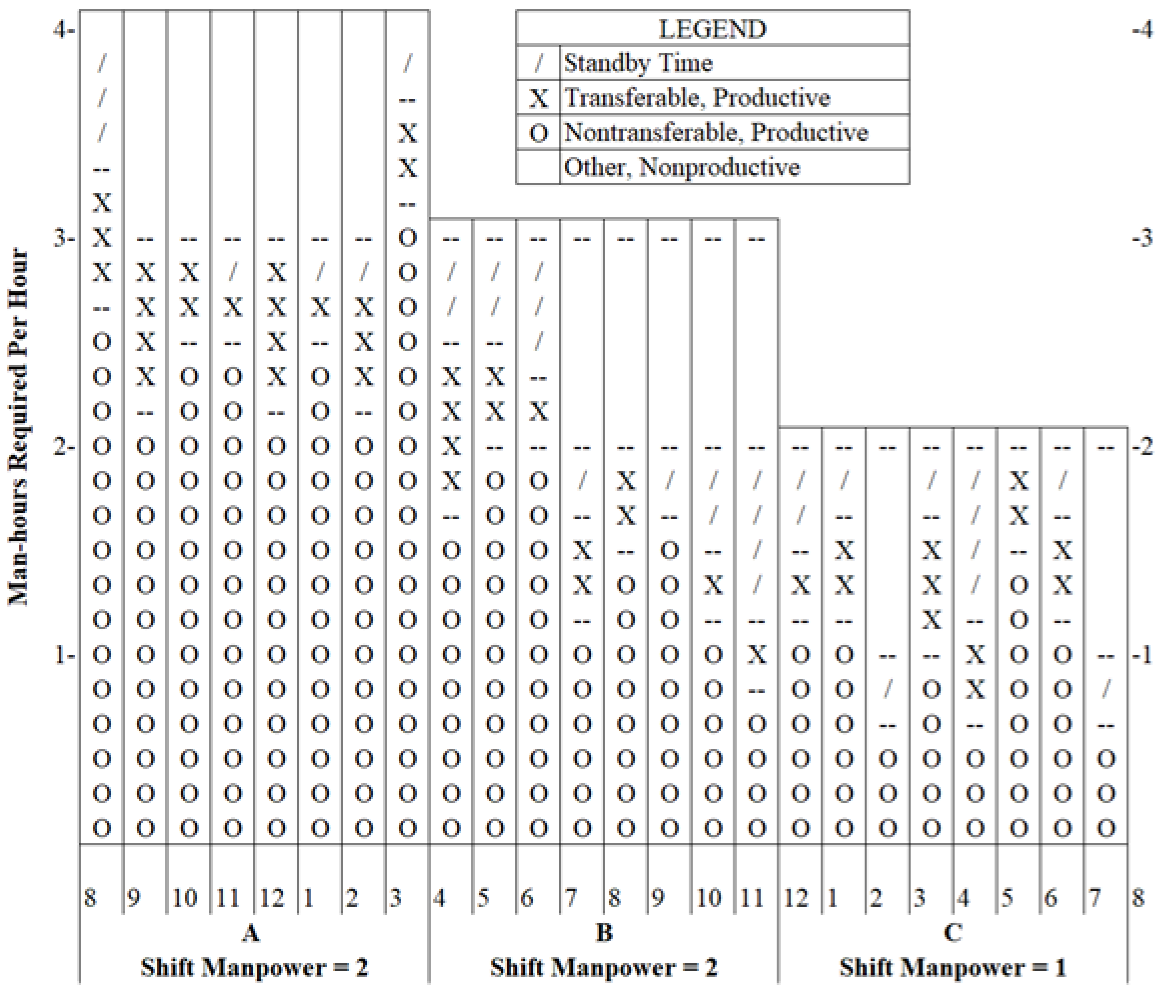
8.4.3.2. Identify work as transferable and nontransferable when a man-hour shift profile chart is needed. This helps in making the shift profile chart show productive work for the stratified time increments.

8.4.3.3. 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 queueing 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 recommendations based on the profile chart. The procedures for developing a shift profile chart using WS data follow:

8.4.3.3.1. 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 measurement data. 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 SWD has not been marked.

8.4.3.3.2. Construct the present man-hour shift profile (see **Figure 8.4**.).

Figure 8.4. Man-hour Shift Profile, Present.



8.4.3.3.2.1. Identify average man-hours per hour on the vertical axis.

8.4.3.3.2.2. Identify each stratified period for each shift (hour or half hour) on the horizontal axis.

8.4.3.3.2.3. Extend a vertical line downward from the duty hour corresponding to each shift change and state the post/position manpower requirement for that shift.

8.4.3.3.2.4. Plot, from bottom to top, the average nontransferable and transferable man-hours computed for each stratified period.

8.4.3.3.2.5. Identify the nontransferable and transferable time within each stratified period. **Note:** Color-coding is helpful in this identification.

8.4.3.3.2.6. 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.

8.4.3.3.2.7. 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.

8.4.3.3.2.8. Prepare a legend for the chart identifying nontransferable, transferable, standby time, and other nonproductive time.

8.4.4. Analysis of the Man-hour Shift Profile Chart. Shift profile analysis can point out deficiencies in scheduling practices, or it can point out excessive manpower levels. Further study of the actual shift profile chart may lead to additional benefits such as more efficient choices for shift hours.

8.4.4.1. 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, split shifts should be kept to a minimum. During analysis, remember:

8.4.4.1.1. An evenly spread workload often reduces manpower needs.

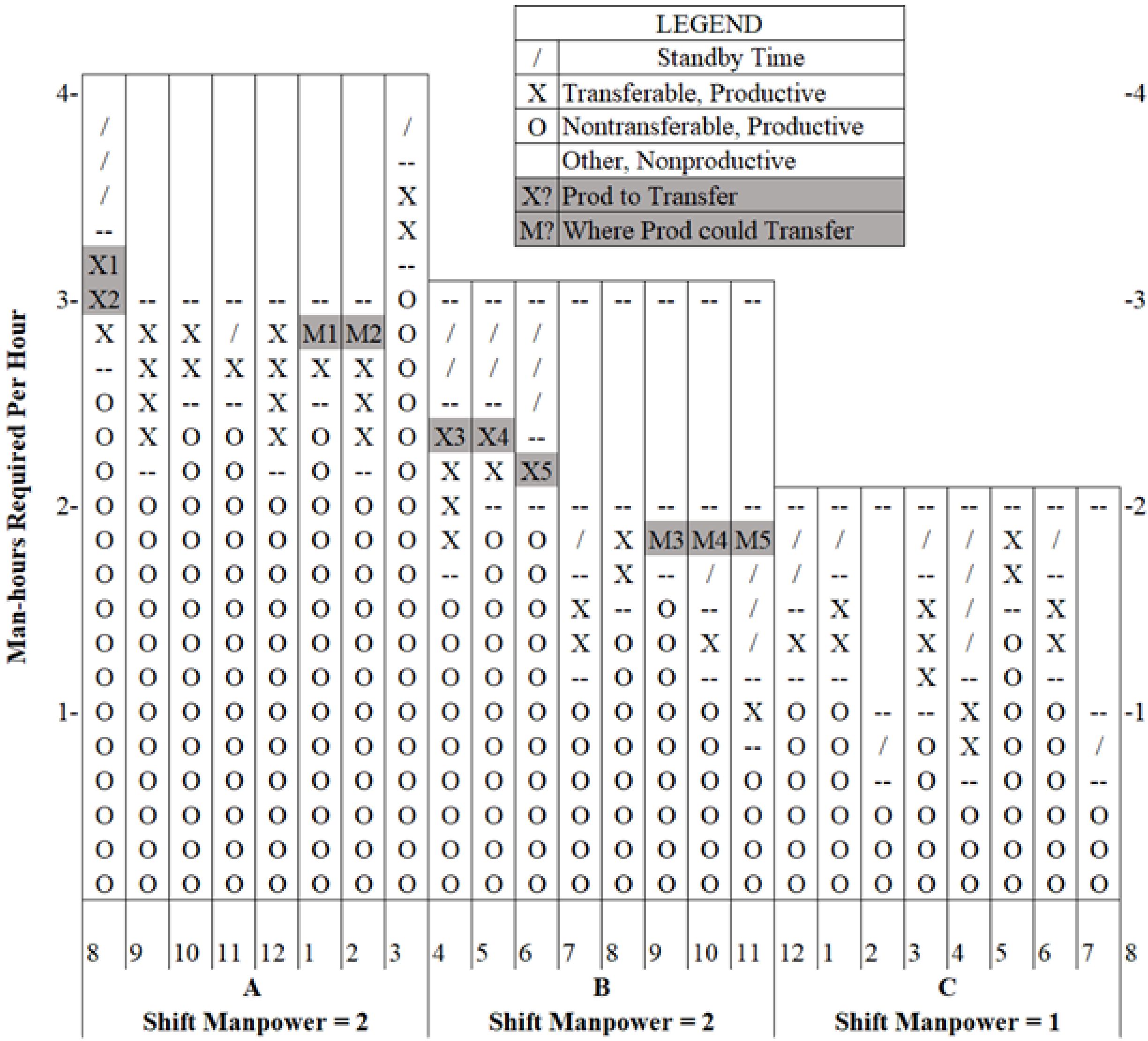
8.4.4.1.2. A related work center with standby man-hours may be able to accept some transferable work. This can take place only if the work can be done by the individuals receiving the work.

8.4.4.1.3. Adjustments to existing standby time should be coordinated with local OPRs. Adjustments are not to add man-hours that exceed the stated level of service.

8.4.4.2. A large amount of standby time at one location may mean a variance is needed for that location. On the other hand, it may mean that the analyst did not properly adjust the standby time. Do not average or prorate standby time during data analysis.

8.4.4.3. **Figure 8.5** shows a properly constructed man-hour shift profile chart that identifies recommended time movements.

Figure 8.5. Man-hour Shift Profile, Time Movements.



8.4.5. Development of 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. Follow the below steps:

8.4.5.1. Step 1. For purposes of this example, assume the pre-stated post/position manpower required for the A and B shift is two and the post/position manpower required for the C shift is one. The proposed chart accommodates this manpower requirement.

8.4.5.2. Step 2. Examine the present man-hour shift profile. In **Figure 8.4**, examination shows large standby and nonproductive time within shifts A and B. This is a logical place to look for improvements.

8.4.5.3. 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.

8.4.5.4. 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 8.6** shows where transferable man-hours were moved within the same shift. **Figure 8.7** shows how overlapping shifts were used to reduce man-hours required per shift.

8.4.5.5. Step 5. Compute the derived standby time from the proposed chart.

Figure 8.6. Man-hour Shift Profile, Proposed.

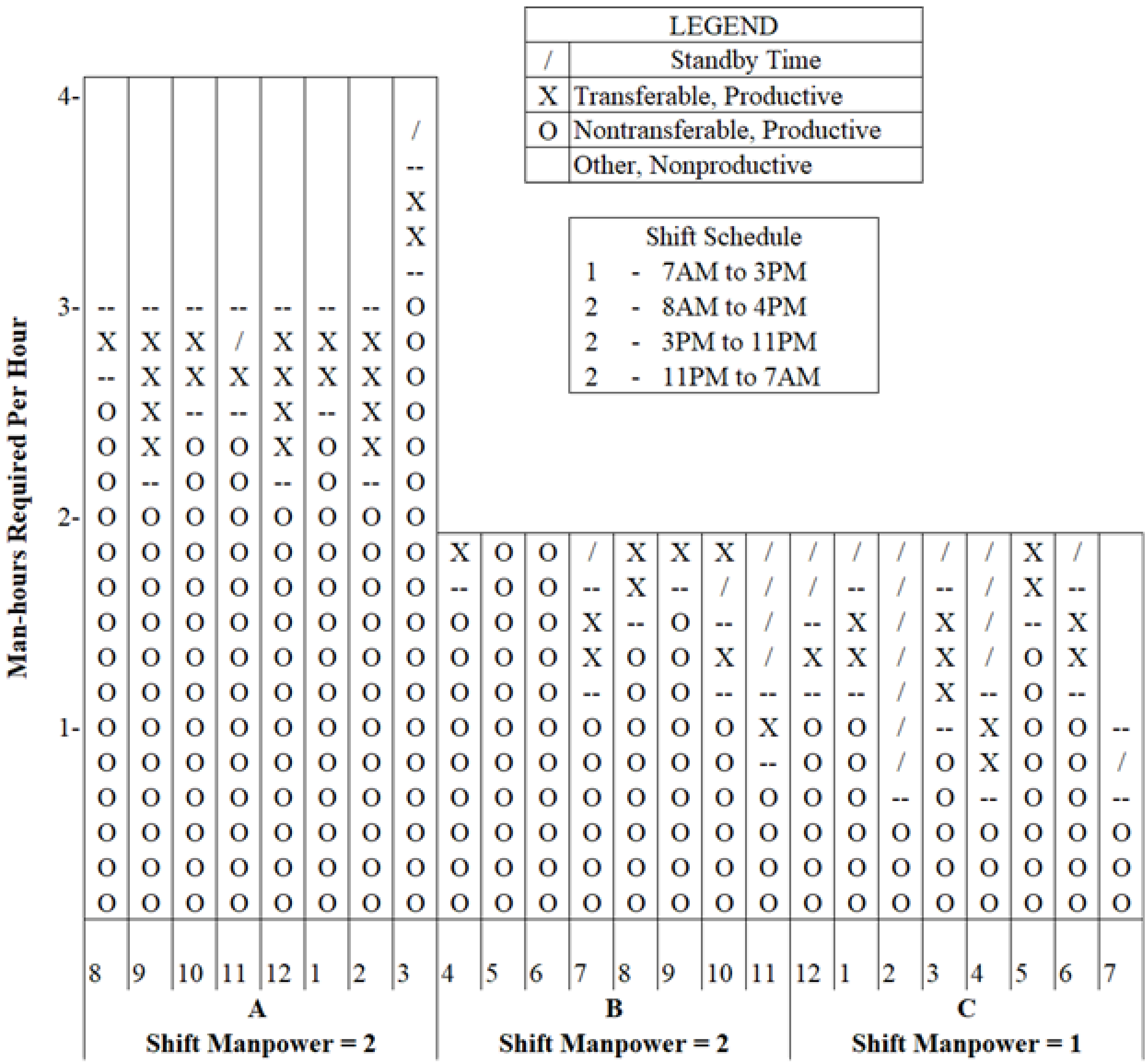
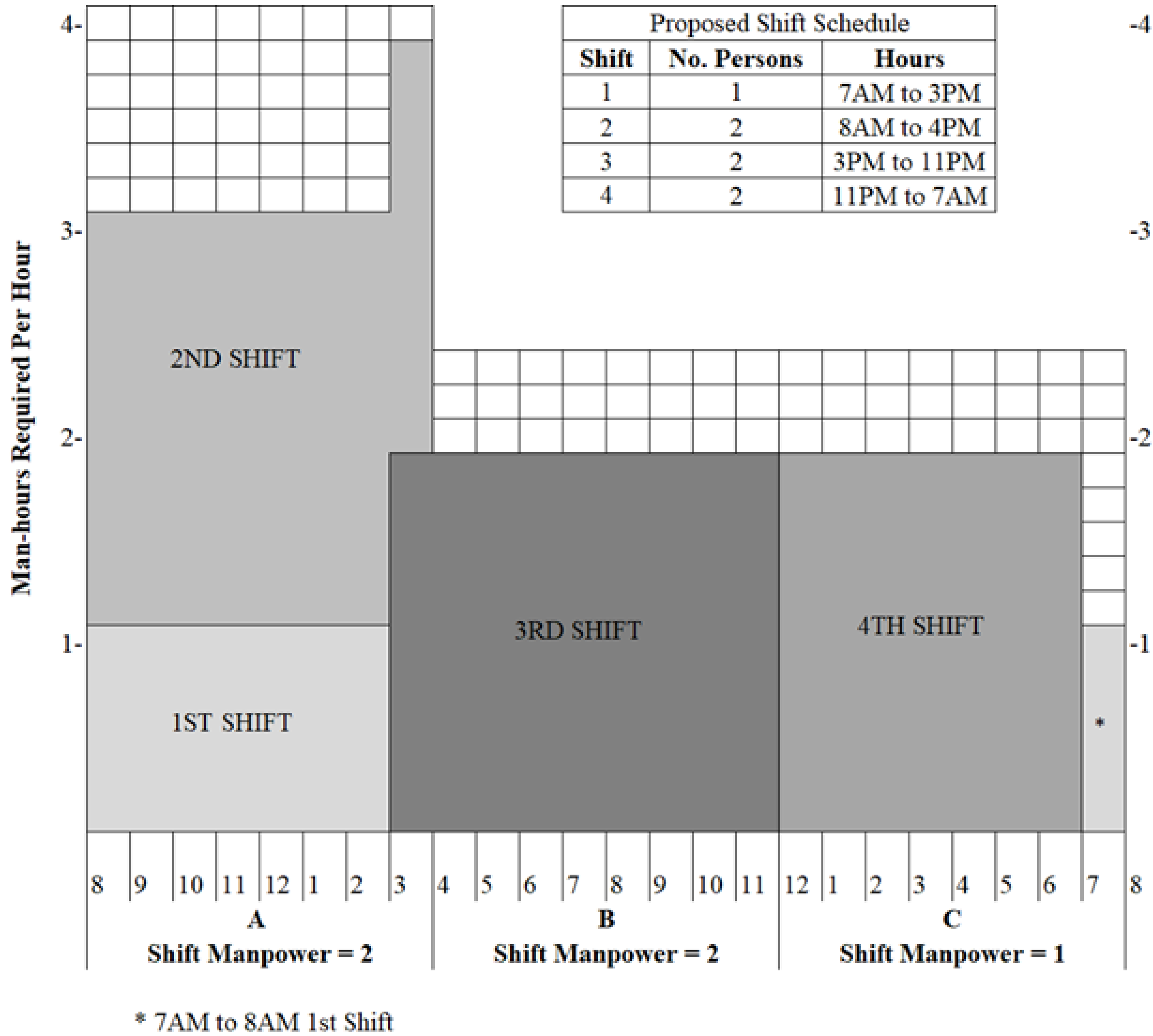


Figure 8.7. Proposed Shift Schedule.



Proposed Shift Schedule		
Shift	**No. Persons**	**Hours**
1	1	7AM to 3PM
2	2	8AM to 4PM
3	2	3PM to 11PM
4	2	11PM to 7AM

8.4.6. Man-hour Shift Profile Chart Comparison. Compare the present (**Figure 8.4**) and proposed (**Figure 8.7**) shift profile charts to determine:

8.4.6.1. If the proposed chart fully accounts for all transferable and nontransferable time.

8.4.6.2. If post/position manpower requirements have been satisfied for all shifts.

8.4.6.3. The extent of shift man-hour savings on the proposed chart.

8.4.6.4. A comparison of man-hour savings for the present and proposed charts is summarized in **Table 8.2**. This comparison shows a man-hour savings of 16 hours per day or 487.04 man-hours per month (16 x 30.44 = 487.04).

Table 8.2. Shift Comparison for Present and Proposed Charts.

	Present		**Proposed**		**Shift**
Shift	**Actual Personnel**	**Shift Hours**	**Proposed Personnel**	**Shift Hours**	**Hour 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

8.4.7. Utilizing the Man-hour Shift Profile Chart. Use the proposed man-hour shift profile chart to:

8.4.7.1. Support the standby time included in the measurement input.

8.4.7.2. Justify the derived (reduced) standby time to the functional OPR.

Chapter 9

FUNCTIONAL MODEL

9.1. General Concepts.

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

9.1.2. The functional model is a method used to develop equations and analyze potential workload factors.

9.2. Standards Development.

9.2.1. Before model construction, analyze and adjust authorized and assigned data to reflect approved initiatives.

9.2.2. The following steps are used for constructing a model and incorporating initiatives.

9.2.2.1. 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. Refer to **Table 9.1**. **Note:** For bases/work centers having seven or fewer authorizations/assigned, to convert manpower to man-hours, the analyst will use the current MAF times 1.070 to avoid under-manning small work centers. For bases/work centers of eight or more then the analyst will just use the current MAF. Current MAFs can be found on the AFMAA SharePoint.

Table 9.1. Functional Model Example, Step 1.

Base	Authorized	Y_1	Assigned	Y_2	WLF (X)
A	5	792.45	6	950.94	740
B	8	1184.96	7	1109.43	980
C	11	1629.32	11	1629.32	1270
D	9	1333.08	9	1333.08	1100
E	14	2073.68	13	1925.56	1560
F	7	1109.43	6	950.94	890
G	13	1925.56	13	1925.56	1500
H	10	1481.20	11	1629.32	1225
	77	11529.68	76	11454.15	
Authorized Man-hours:			Assigned Man-hours:		
$Y_1 = -275.60 + 1.482(X)$			$Y_1 = -164.76 + 1.379(X)$		
$R^2 = 0.991$			$R^2 = 0.961$		
$S_{yx} = 43.86$			$S_{yx} = 86.46$		
$V = 0.030$			$V = 0.060$		
Note: For bases/work centers of 7 or fewer: MAF x 1.070					
For bases/work centers of 8 or more: only use the current MAF					

9.2.2.2. Step 2. Equation Selection. Because the difference between authorized and assigned strength represents less than 10 percent of the total authorized, the authorized man-hour equation was selected as the functional model because of the better statistics.

9.2.2.3. 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. Refer to **Table 9.2**.

Table 9.2. Functional Model Example, Step 3.

Base	Y_1	WLF (X)	Calculated (Y_c)	Change (Y_c - Y_1)
A	792.45	740	821.08	28.63
B	1185	980	1176.76	-8.20
C	1629.3	1270	1606.54	-22.78
D	1333.1	1100	1354.6	21.52
E	2073.7	1560	2036.32	-37.36
F	1109.4	890	1043.38	-66.05
G	1925.6	1500	1947.4	21.84
H	1481.2	1225	1539.85	58.65
Use Authorized Equation to get Calculated Man-hours $Y_1 = -275.60 + 1.482(X)$				

9.2.2.4. Step 4. Determine man-hour adjustment for each initiative. When and if an initiative is identified, compute the change between derived man-hours for current operations and the enhanced operations. This information shows an average reduction of 97.50 man-hours per base. Refer to **Table 9.3** to see the effect of an initiative reflected in new monthly man-hours.

Table 9.3. Functional Model Example, Step 4.

Base	Current Monthly Man-hours	New Monthly Man-hours	Change
A	250.00	180.00	-70.00
B	300.00	210.00	-90.00
C	275.00	170.00	-105.00
D	410.00	280.00	-130.00
E	360.00	265.00	-95.00
F	380.00	270.00	-110.00
G	290.00	205.00	-85.00
H	335.00	240.00	-95.00
This information shows and average reduction of 97.50 man-hours per base.		TOTAL	-780.00
		AVERAGE	-97.50

9.2.2.5. Step 5. Calculate enhanced equation for the functional model. Regress revised total man-hours (reduced for change) against the selected workload factor. Refer to **Table 9.4**.

Table 9.4. Functional Model Example, Step 5.

Base	Authorized Man-hours	Change	Revised Man-hours	WLF (X)	Calculated
A	792.45	-70.00	722.45	740	725.89
B	1184.96	-90.00	1094.96	980	1080.37
C	1629.32	-105.00	1524.32	1270	1508.70
D	1333.08	-130.00	1203.08	1100	1257.61
E	2073.68	-95.00	1978.68	1560	1937.03
F	1109.43	-110.00	999.43	890	947.44
G	1925.56	-85.00	1840.56	1500	1848.41
H	1481.20	-95.00	1386.20	1225	1442.24
Enhanced Equation: $Y_c = -367.09 + 1.477(X)$ $R^2 = 0.099$ $S_{yx} = 42.975$ $V = 0.0320$					

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

9.2.3. Functional Model Selection.

9.2.3.1. Correlate the dependent variable with the independent workload variables.

9.2.3.2. 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.

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

9.2.3.4. 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.

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

9.3.1. During preliminary research, 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 relatability. Other means of evaluation such as activity analysis charts, discussions with the functional OPR, and logical analysis help refine the list of potential WLFs.

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

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

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

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

9.3.2.4. Step 4. Analyze data. See **Chapter 11** for analysis tools used to review and correct data submissions.

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

9.3.2.4.2. Plot the data pairs on a scatter diagram and analyze the relative position of each plot with respect to a trend or pattern of the overall display.

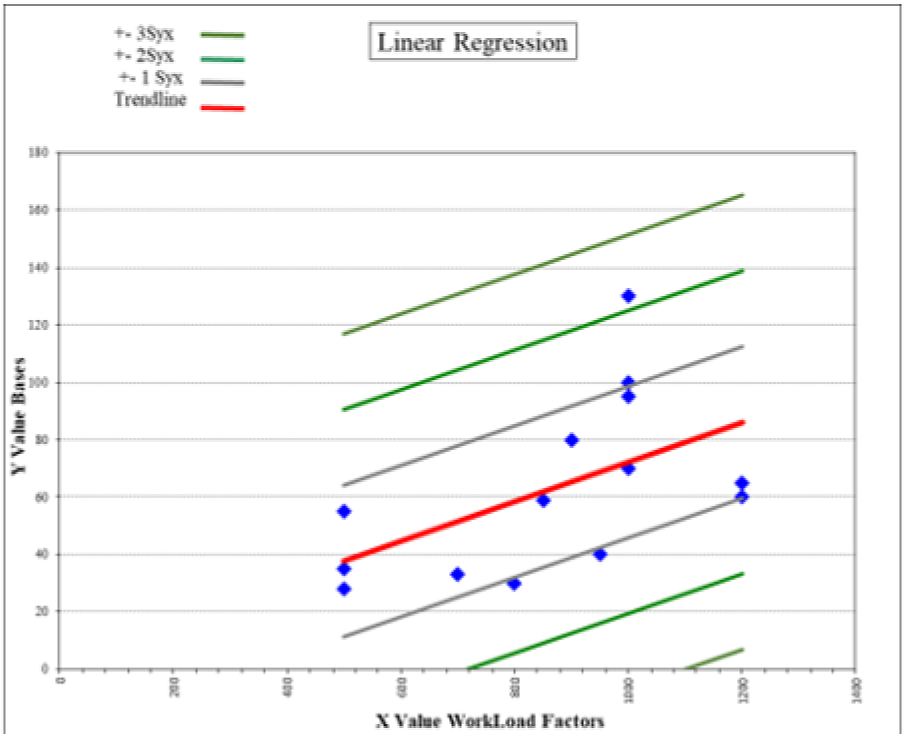
9.3.2.4.3. Do regression analysis to find the relationship between manpower authorizations and the candidate workload variables.

9.3.2.4.4. 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.

9.3.2.5. Step 5. Repeat steps 2 through 4 to evaluate alternative workload variables. Additional models using assigned strength 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.

9.3.3. An example of a functional model is depicted in **Figure 9.1**. Note that the equation and all data points are plotted for ease of analysis. The functional model shows the relationship between manpower and the tested workload variable. Although it does not require discarding the potential WLF, the model shows the absence of a strong relationship.

Figure 9.1. Functional Model Example.



Base	Assigned (Y)	WLF (X)
1	28	500
2	35	500
3	55	500
4	33	700
5	59	850
6	30	800
7	40	950
8	80	900
9	130	1000
10	100	1000
11	65	1200
12	60	1200
13	70	1000
14	95	1000

$Y = 3.44 + 0.06875(X)$

$R^2 = 0.294$

$S_{yx} = 26.387$

$V = 0.420$

Values above are represented as the trend line.

(Y) = Average Assigned Strength

(1 April 2021 - 31 March 2022)

Chapter 10

FUNCTIONAL ESTIMATING EQUATIONS

10.1. General Concepts. Functional Estimating Equations (FEE) are the Air Force manpower tools built specifically for use in SPPBE process. 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. These equations are used to predict future years manpower requirement forecasts for Air Force functional areas.

10.2. Building a Functional Estimating Equation.

10.2.1. Each FEE is made up of two major parts:

10.2.1.1. A mathematical equation that shows the relationship between a function's total manpower requirements and a selected program estimating factor (PEF).

10.2.1.2. Percentage factors that break a function's total manpower requirements into various Program Element Codes (PEC), Functional Account Codes (FAC), and manpower categories at MAJCOM, base, and work center levels.

10.2.2. At least one FEE is built for each functional area. Functional areas are defined by the first, second, third, and fourth digit of a FAC (e.g., the 5-series defines the medical functional area while the 42-series defines the logistics readiness functions). However, if manpower resources need to be programmed in the SPPBE at a lower functional level (e.g., 42M100, Materiel Management), then FEEs are built at these levels.

10.2.3. The mathematical equation of a FEE is normally built using regression analysis. This analysis uses the function's total required manpower and actual historical values for selected PEFs from each appropriate location (e.g., standard host wings).

10.2.3.1. All mathematical equations must be linear (i.e., bivariate or multivariate).

10.2.3.2. The function's required manpower total at each location is obtained by applying all requirements determinants that cover work centers in the function (the manpower values used are converted from man-hours to FTEs).

10.2.3.2.1. The workload factor values used in these applications are the result of analysis done on three years of historical data.

10.2.3.2.2. Included in the function's total manpower requirements are any CME that are appropriate. These numbers are tracked separately and will eventually be identified as a CME percentage factor.

10.2.3.3. PEFs are used in FEEs like WLFs are used in requirements determinants.

10.2.3.3.1. PEFs are identified as the following: base populations (military (includes sister services), civilian, and dependent), flying hours, number of aircraft, number of missiles, number of vehicles, and average daily student load.

10.2.3.3.2. PEF values used in building a FEE represent average values obtained from analysis of the PEF historical data for each location. This historical data is taken from the same time as the workload data used to apply the requirements determinants.

10.2.3.4. Specific instructions for building the mathematical equation of a FEE by using regression analysis are provided in **Table 10.1**. An example is shown in **Figure 10.1**.

Table 10.1. Construction of a Functional Estimating Equation.

STEP	Action	Example
1	Identify all work centers within a functional area.	Within functional area 81XXXX there are four work centers: 81A100, 81B100, 81C100, and 81D100.
2	Identify all locations in the MAJCOM which have work centers from this functional area.	There are 20 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 20 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 requirement determinant.	At base 1, the following requirements were obtained: WORK CENTER REQUIREMENTS 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 10.1**.

Figure 10.1. Example of Data Used to Build a FEE.

TITLE: FEE DATA PAIRS

MAJCOM: ABC

PEF AND WLF TIME FRAME: JANUARY 2021 - DECEMBER 2021

PEF SOURCE: PM (31 December 2021)

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:

$Y = 38.82 + 0.006482(X)$

$R^2 = 0.751$

$Syx = 8.505$

10.2.3.5. There are no classification categories for a FEE. However, a FEE built using regression analysis must satisfy the statistical criteria of at least a R^2 of 0.5. If it does not, then the equation, $Y = bX$ can be used. Where Y is the manpower requirements for a functional area; b is requirements determinant application requirements divided by historical monthly PEF value; and X is the programmed PEF value.

10.2.3.6. When an equation applies to four or fewer locations in a MAJCOM, build the mathematical equation for the FEE using single location and small population instructions for requirements determination development (see **Chapter 16**).

10.2.4. The factors of a FEE are built using information obtained from application of the requirements determinants, UMD data, and values resulting from the development of the FEE's mathematical equation.

10.2.4.1. The first factor computed is a FEE adjustment factor for each location in the command. This value identifies how much each location's manpower requirement total, obtained from application of the function's requirements determinant, is different from the manpower requirement total obtained from application of the FEE. The PEF data used to build the FEE is used to apply the FEE to get this factor.

10.2.4.1.1. This factor is rounded to three decimal places.

10.2.4.1.2. An example showing how this factor is computed is in **Table 10.2**.

Table 10.2. Computation of Base Adjustment Factors for a FEE.

Base	Requirement Determinants Application	minus	FEE Requirements	equals	FEE Adjustment Factor
1	65	-	55.212	=	9.788
2	47	-	52.897	=	-5.897
3	67	-	65.694	=	1.306
4	64	-	66.504	=	-2.504
5	39	-	47.640	=	-8.640
6	71	-	70.549	=	0.451
7	51	-	49.215	=	1.785
8	64	-	54.512	=	9.488
9	71	-	72.624	=	-1.624
10	49	-	50.817	=	-1.817
11	53	-	58.297	=	-5.297
12	106	-	107.220	=	-1.220
13	39	-	49.105	=	-10.105
14	72	-	61.500	=	10.500
15	62	-	66.154	=	-4.154
16	61	-	41.436	=	19.564
17	64	-	67.950	=	-3.950
18	82	-	70.128	=	11.872
19	37	-	46.804	=	-9.804
20	43	-	52.742	=	-9.742

10.2.4.2. The remaining FEE percentage factors show what percentage of the total functional area requirements are in different PECs and FACs, and within each, the various manpower categories. Different factors are determined for work center, base, and MAJCOM levels. There are three kinds of percentage factors required for each location in a MAJCOM.

10.2.4.2.1. The first are percentages of the total manpower requirements represented by each PEC and FAC. Percentages are needed for the overall function as well as for each work center in the function. Instructions for building these percentages are provided in **Table 10.3** with an example shown in **Table 10.4**.

Table 10.3. PEC Percentage Factor Calculation for Three Operational Levels.

<table>
<tr><th>STEP</th><th>Action</th><th>Example</th></tr>
<tr><td>1</td><td>Within each work center at a location, identify the PECs that cover the UMD requirements.</td><td>At base 16, all requirements fall into either PEC 91212A or PEC 27596A.</td></tr>
<tr><td>2</td><td>For the fiscal quarter in which the standard applications are done, identify the number of requirements in each PEC for each work center.</td><td>
<table>
<tr><td>WORK CENTER</td><td>PEC</td><td>REQUIREMENTS</td></tr>
<tr><td rowspan="2">A</td><td>27596A</td><td>4</td></tr>
<tr><td>91212A</td><td>16</td></tr>
<tr><td>B</td><td>91212A</td><td>12</td></tr>
<tr><td>C</td><td>91212A</td><td>17</td></tr>
<tr><td>D</td><td>91212A</td><td>12</td></tr>
</table>
</td></tr>
<tr><td>3</td><td>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 rounded to three decimal places.</td><td>
<table>
<tr><td>WORK CENTER</td><td>PEC</td><td>WORK CENTER (BASE LEVEL) PEC %</td></tr>
<tr><td rowspan="2">A</td><td>27596A</td><td>4/20 = 0.200</td></tr>
<tr><td>91212A</td><td>16/20 = 0.800</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>For each location, compute the function's total requirements by PEC by adding the work center results in step 2.</td><td>
<table>
<tr><td>WORK CENTER</td><td>27596A</td><td>91212A</td><td>TOTAL FUNCTIONAL REQUIREMENTS</td></tr>
<tr><td>A</td><td>4</td><td>16</td><td>20</td></tr>
<tr><td>B</td><td>--</td><td>12</td><td>12</td></tr>
<tr><td>C</td><td>--</td><td>17</td><td>17</td></tr>
<tr><td>D</td><td>--</td><td>12</td><td>12</td></tr>
<tr><td>TOTAL</td><td>4</td><td>57</td><td>61</td></tr>
</table>
</td></tr>
<tr><td>5</td><td>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 rounded to three decimal places.</td><td>
<table>
<tr><td>LOCATION</td><td>PEC</td><td>FUNCTIONAL (BASE LEVEL) PEC %</td></tr>
<tr><td rowspan="2">Base 16</td><td>27596A</td><td>4/16 = 0.066</td></tr>
<tr><td>91212A</td><td>57/61 = 0.934</td></tr>
</table>
</td></tr>
<tr><td>6</td><td>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 Table 10.4).</td><td>
<table>
<tr><td>PEC</td><td>FUNCTION'S TOTAL REQUIREMENT</td></tr>
<tr><td>27596A</td><td>1106</td></tr>
<tr><td>91212A</td><td>57</td></tr>
<tr><td>41896A</td><td>2</td></tr>
<tr><td>31196A</td><td>39</td></tr>
<tr><td>11896A</td><td>3</td></tr>
<tr><td>OVERALL TOTAL</td><td>1207</td></tr>
</table>
</td></tr>
<tr><td>7</td><td>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 rounded to three decimal places.</td><td>
<table>
<tr><td>MAJCOM</td><td>PEC</td><td>FUNCTIONAL (MAJCOM LEVEL) PEC %</td></tr>
<tr><td rowspan="4">ABC</td><td>27596A</td><td>1106/1207 = 0.916</td></tr>
<tr><td>91212A</td><td>57/1207 = 0.047</td></tr>
<tr><td>41896A</td><td>2/1207 = 0.002</td></tr>
<tr><td>31196A</td><td>39/1207 = 0.032</td></tr>
</table>
</td></tr>
</table>

STEP	Action	Example		
			11896A	3/1207 = 0.002

Table 10.4. Example of Base Level and 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	0.981	--	--	2	0.019	--	--	106
13	--	--			39	1.000	--	--	--	--	39
14	--	--	72	1.000	--	--	--	--	--	--	72
15	--	--	62	1.000	--	--	--	--	--	--	62
16	--	--	4	0.066	--	--	--	--	57	0.934	61
17	--	--	64	1.000	--	--	--	--	--	--	64
18	3	0.037	79	0.963	--	--	--	--	--	--	82
19	--	--	37	1.000	--	--	--	--	--	--	37
20	--	--	43	1.000	--	--	--	--	--	--	43
MAJCOM Functional Totals	3	0.002	1106	0.916	39	0.032	2	0.002	57	0.047	1207

10.2.4.2.2. The next percentages of the function's total manpower requirements represented by each work center. Instructions for building these percentages are provided in **Table 10.5**.

Table 10.5. Work Center Percentage Factor Calculation.

STEP	Action	Example	
1	Identify all work centers within a functional area.	Within functional area 81XXXX there are four work centers: 81A100, 81B100, 81C100, and 81D100.	
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 requirements determinants.	At base 1, the following requirements were obtained:	
		WORK CENTER	REQUIREMENTS
		A	22
		B	15
		C	10
		D	18

STEP	Action	Example	
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 rounded to three decimal places.	WORK CENTER	PERCENTAGE
		A	22/65 = 0.338
		B	15/65 = 0.231
		C	10/65 = 0.154
		D	18/65 = 0.277

10.2.4.2.3. The final ones are percentages of officers, airmen, United States direct hire (USDH) civilians, Foreign National direct hire (FNDH) civilians, Foreign National indirect hire (FNIH) civilians, and CMEs within each PEC and FAC at the overall functional level. For each PEC in each work center, percentages are developed for military (officers and airmen combined), USDH civilians, FNDH civilians, FNIH civilians, and CMEs. Instructions for building these percentages are provided in **Table 10.6** and an example is shown in **Table 10.7**.

10.2.4.2.4. The first and third kinds of factors are also required at the MAJCOM level (see **paragraph 10.2.4.2.1** and **paragraph 10.2.4.2.3**.). Percentages of the function's total MAJCOM manpower requirements are developed for each PEC and FAC. Within each PEC and FAC, MAJCOM percentages are developed for officers, airmen, USDH civilians, FNDH civilians, FNIH civilians, and CMEs. Instructions for building these percentages are provided in **Table 10.3** and **Table 10.6**.

Table 10.6. Manpower Category Percentage Factor Calculation.

STEP	Action	Example				
1	Identify the manpower categories that are present within each work center at a MAJCOM location. These categories include officers, airmen, USDH and FNDH civilians, and CMEs.	At base 12, in work center C, there are officers, airmen, and USDH civilians.				
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 requirements determinant.	BASE 12 WORK CENTER	OFF	ENL	CIV (USDH)	TOTAL
		C	1	21	1	23
3	Determine the PECs that are in the work center of interest. This is the same as the percentage calculation procedures determined in **Table 10.3.**	In this work center there are two PECs: 27596A and 41896A				
4	Multiply the total work center requirements found in step 2 by the	WORK CENTER (BASE LEVEL)				

<table>
<tr><th>STEP</th><th>Action</th><th>Example</th></tr>
<tr><td></td><td>work center (base level) PEC percentage calculation procedure found in Table 10.3, step 3, to obtain the requirement for each PEC in the work center.</td><td>
<table>
<tr><td>PEC</td><td>PEC %</td><td>WORK CENTER C TOTAL</td><td>RQMT PER PEC</td></tr>
<tr><td>27596A</td><td>0.913</td><td>23</td><td>21</td></tr>
<tr><td>41896A</td><td>0.087</td><td>23</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>5</td><td>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.</td><td>
The UMD shows all requirements in PEC 41896A are airmen. Maintaining this finding, the PEC split by manpower category becomes:
<table>
<tr><td colspan="5">MANPOWER CATEGORY TOTALS
(BY BASE BY WORK CENTER)</td></tr>
<tr><td>PEC</td><td>OFF</td><td>ENL</td><td>CIV (USDH)</td><td>TOTAL</td></tr>
<tr><td>27596A</td><td>1</td><td>19</td><td>1</td><td>21</td></tr>
<tr><td>41896A</td><td>--</td><td>2</td><td>--</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>6</td><td>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 rounded to three decimal places.</td><td>
<table>
<tr><td colspan="3">MANPOWER CATEGORY PERCENTAGES
(BY BASE BY WORK CENTER)</td></tr>
<tr><td>PEC</td><td>MILITARY</td><td>CIVILIAN (USDH)</td></tr>
<tr><td>27596A</td><td>$\frac{1 + 19}{21} = 0.952$</td><td>$\frac{1}{21} = 0.048$</td></tr>
<tr><td>41896A</td><td>$\frac{2}{2} = 1.000$</td><td>--</td></tr>
</table>
</td></tr>
<tr><td>7</td><td>For each MAJCOM location, compute the function's requirements by manpower category within each PEC by adding the work center totals obtained in step 3.</td><td>
<table>
<tr><td colspan="5">MANPOWER CATEGORY TOTALS
(BY BASE BY FUNCTION)</td></tr>
<tr><td>PEC</td><td>OFF</td><td>ENL</td><td>CIV (USDH)</td><td>TOTAL</td></tr>
<tr><td>27596A</td><td>6</td><td>96</td><td>2</td><td>104</td></tr>
<tr><td>41896A</td><td>--</td><td>2</td><td>--</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>8</td><td>Determine the PEC manpower category percentages for the function at each MAJCOM location. 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 rounded to three decimal places.</td><td>
<table>
<tr><td colspan="4">MANPOWER CATEGORY PERCENTAGES
(BY BASE BY FUNCTION)</td></tr>
<tr><td>PEC</td><td>OFF</td><td>ENL</td><td>CIV (USDH)</td></tr>
<tr><td>27596A</td><td>$\frac{6}{104} = 0.058$</td><td>$\frac{96}{104} = 0.923$</td><td>$\frac{2}{104} = 0.019$</td></tr>
<tr><td>41896A</td><td>--</td><td>$\frac{2}{2} = 1.000$</td><td>--</td></tr>
</table>
</td></tr>
<tr><td>9</td><td>For the overall command, compute the total manpower category requirements within each PEC by adding the functional totals obtained in step 5 for each location.</td><td>
<table>
<tr><td colspan="6">MANPOWER CATEGORY TOTALS
(BY BASE BY FUNCTION)</td></tr>
<tr><td>PEC</td><td>OFF</td><td>ENL</td><td>CIV (USDH)</td><td>CIV (FNDH)</td><td>TOTAL</td></tr>
<tr><td>11896A</td><td>--</td><td>3</td><td>--</td><td>--</td><td>3</td></tr>
<tr><td>27596A</td><td>82</td><td>993</td><td>30</td><td>1</td><td>1106</td></tr>
<tr><td>31196A</td><td>4</td><td>33</td><td>2</td><td>--</td><td>39</td></tr>
<tr><td>41896A</td><td>--</td><td>2</td><td>--</td><td>--</td><td>2</td></tr>
<tr><td>91212A</td><td>4</td><td>53</td><td>--</td><td>--</td><td>57</td></tr>
</table>
</td></tr>
</table>

STEP	Action	Example					
		TOTAL	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 rounded to three decimal places.	MANPOWER CATEGORY PERCENTAGES (BY MAJCOM BY FUNCTION)					
		PEC	OFF	ENL	CIV (USDH)	CIV (FNDH)	
		11896A	--	$\frac{3}{3}$ = 1.000	--	--	
		27596A	$\frac{82}{1106}$ = 0.074	$\frac{993}{1106}$ = 0.898	$\frac{30}{1106}$ = 0.027	$\frac{1}{1106}$ = 0.001	
		31196A	$\frac{4}{39}$ = 0.103	$\frac{33}{39}$ = 0.846	$\frac{2}{39}$ = 0.051	--	
		41896A	--	$\frac{2}{2}$ = 1.000	--	--	
		91212A	$\frac{4}{57}$ = 0.070	$\frac{53}{57}$ = 0.930	--	--	

Table 10.7. 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	0.077	56	0.862	4	0.062	--	--	65
2	4	0.085	42	0.894	--	--	1	0.021	47
3	5	0.075	61	0.910	1	0.015	--	--	67
4	5	0.078	57	0.891	2	0.031	--	--	64
5	3	0.077	35	0.897	1	0.026	--	--	39
6	5	0.070	65	0.915	1	0.014	--	--	71
7	4	0.078	45	0.882	2	0.039	--	--	51
8	5	0.078	58	0.906	1	0.016	--	--	64
9	5	0.070	64	0.901	2	0.028	--	--	71
10	4	0.082	43	0.878	2	0.041	--	--	49
11	4	0.075	45	0.849	4	0.075	--	--	53
12	6	0.058	96	0.923	2	0.019	--	--	104
13*									
14	5	0.069	65	0.903	2	0.028	--	--	72
15	5	0.081	56	0.903	1	0.016	--	--	62
16	--	--	4	1.000	--	--	--	--	4
17	5	0.078	58	0.906	1	0.016	--	--	64
18	6	0.076	71	0.899	2	0.025	--	--	79
19	2	0.054	34	0.919	1	0.027	--	--	37
20	4	0.093	38	0.884	1	0.023	--	--	43
MAJCOM Functional Totals	82	0.074	993	0.898	30	0.027	1	0.001	1106
* Data not available									

10.3. Using a Functional Estimating Equation.

10.3.1. FEEs are used to project manpower requirements for a function. They can be applied at either base or MAJCOM level.

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

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

10.3.3.1. If zero-based requirements are needed for each work center at a specific base, follow the instructions in **Table 10.8**.

10.3.3.2. If zero-based requirements are needed for the entire function at a specific base, follow the instructions in **Table 10.8** with the following modifications:

10.3.3.2.1. Delete steps 4 and 7.

10.3.3.2.2. Use the results of step 3 in step 5.

10.3.3.2.3. Use function (base level) PEC and manpower category percentages.

10.3.3.3. If incremental requirements are needed for each work center at a specific base, follow the instructions in **Table 10.5** with the following modifications:

10.3.3.3.1. In step 1, only change in PEF data at the location is obtained.

10.3.3.3.2. In step 2, only the *b*-coefficient of the FEE is applied. The *a*-value is not used.

Table 10.8. Application of FEE for Zero-Based Requirements of Work Centers at Base Level.

STEP	Action	Example
1	Obtain a location's total PEF value for the fourth quarter of the appropriate fiscal year.	For base 11, assume the PEF value is 3004.
2	Apply the FEE using the PEF total found in step 1. Round to three decimal places.	For a FEE of Y = 38.820 + 0.006482(X) Y = 38.820 + 0.006482 (3004) = 38.82 + 19.472 = 58.292
3	Adjust the application result of step 2 by adding the location's FEE adjustment factor. Round to a whole manpower number by simple rounding rules.	The base 11 adjustment factor is -5.297. The adjusted result = 58.292 + (-5.297) = 58.292 - 5.297 = 52.995 = 53
4	Multiply the result of step 3 by each of the work center percentage factors. Round to whole manpower numbers by using simple rounding rule. Make appropriate adjustments to each work center number to ensure the sum of all work center manpower values equals the functional value in step 3.	The percentages for each are Work Center A, 0.400, Work Center B, 0.205, Work Center C, 0.185, and Work Center D, 0.210. Therefore, the work center requirements are: Work Center A = (0.400)(53) = 21.200 = 21 Work Center B = (0.205)(53) = 10.865 = 11 Work Center C = (0.185)(53) = 9.805 = 10 Work Center D = (0.210)(53) = 11.130 = 11 TOTAL 53

STEP	Action	Example
5	Multiply each work center total found in step 4 by its applicable PEC percentage factors. Round to whole manpower numbers by using the simple rounding rule. Make appropriate adjustments to each PEC number to ensure the sum of all PEC manpower values equals the work center total found in step 4.	Base 11 only has PEC 27596A in this function. Therefore, the PEC percentage for each work center is 100% and the values are the same as those found in step 4.
6	Multiply each work center PEC value computed in step 5 by its applicable manpower category percentage factors. Round to whole manpower numbers by using the simple rounding rule. Make appropriate adjustments to each manpower category number to ensure the sum of all manpower category values equal the PEC total found in step 5.	In Work Center C at base 11, the manpower category percentages are military, 0.920, and USDH civilians, 0.080. Therefore, the manpower totals for Work Center C in PEC 27596A are: Military = (10) (0.920) = 9.20 = 9 USDH Civilians = (10) (0.080) = 0.80 = 1 TOTAL 10
7	Obtain the officer and airmen numbers, grades, and skills from the appropriate work center manpower table.	In Work Center C, the manpower table shows one officer for a manpower level of 10. Therefore, there are 8 airmen. Appropriate grades and skills are assigned based on the manpower table.

10.3.3.4. If zero-based requirements are needed for the entire function at MAJCOM level, follow the instructions in **Table 10.9**.

10.3.3.5. If incremental requirements are needed for the entire function at MAJCOM level, follow the instructions in **Table 10.9** with the following modifications.

10.3.3.5.1. In step 1, only the net change in PEF data for the entire MAJCOM is obtained.

10.3.3.5.2. Delete step 2.

10.3.3.5.3. In step 3, only the *b*-coefficient of the FEE is applied. The *a*-value is not used.

Table 10.9. Application of FEE for Zero-Based Requirements of Function at MAJCOM Level.

STEP	Action	Example
1	Sum the PEF data for all bases to which the FEE applies. This results in a MAJCOM PEF total for the fourth quarter of the appropriate fiscal year.	Assume MAJCOM ABC has the FEE Y = 38.820 + 0.006482 (X) that applies to 20 bases. By adding the PEF data for each of the 20 bases, the MAJCOM PEF total of 66413 is obtained.
2	Adjust the *a*-value of the FEE by multiplying it by the number of bases to which the FEE applies.	The *a*-value in the FEE for MAJCOM ABC is multiplied by 20 to get an adjusted *a*-value of 776.400.
3		Y = 776.400 + 0.006482 (66413)

	Apply the FEE using the PEF total found in step l and the adjusted *a*-value computed in step 2. Round to a whole manpower number by using the simple rounding rule.	= 776.4 + 430.489		
		= 1206.889 = 1207		
4	Multiply the result of step 3 by each of the MAJCOM's functional PEC percentage factors. Round to whole manpower numbers by using the simple rounding rule. Make appropriate adjustments to each PEC manpower number to ensure the sum of all PEC manpower values equals the functional value found in step 3.	PEC	% FACTOR x MANPOWER TOTAL	= PEC MANPOWER TOTAL
		11896A	0.002 x 1207	= 2.414 = 2
		27596A	0.916 x 1207	= 1105.612 = 1106
		31196A	0.032 x 1207	= 38.624 = 39
		41896A	0.002 x 1207	= 2.414 = 2
		91212A	0.047 x 1207	= 56.729 = 57
5	Multiply each MAJCOM PEC value computed in step 4 by its· applicable manpower category percentage factor. Round to whole manpower numbers by using the simple rounding rule. Make appropriate adjustments to each manpower category number to ensure the sum of all manpower category values equals the PEC total found in step 4.	PEC 27596A		
		MANPOWER CATEGORY	% FACTOR x PEC TOTAL	= MANPOWER CAT TOTAL
		OFF	0.074 x 1106	= 81.844 = 82
		ENL	0.898 x 1106	= 993.188 = 993
		USDH	0.027 x 1106	= 29.862 = 30
		FNDH	0.001 x 1106	= 1.106 = 1
		TOTAL		1106

Part 5

DATA ANALYSIS

Chapter 11

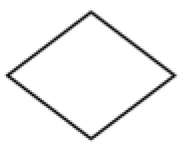
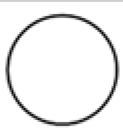
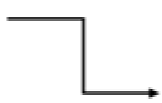
ANALYSIS TOOLS

11.1. Process Flowcharting.

11.1.1. General Concepts. This section discusses basic concepts for building a process flowchart to document a process and process improvement initiatives and how to analyze the physical layout where processes are performed.

11.1.2. Process Flowcharting. A process is a series of actions or continuous operations leading to a particular and desirable result or ending. In other words, the process produces a product or service for a customer. A diagram used to depict the step-by-step progression through a process is a flowchart. The process flowchart diagram is created by using connecting lines and a set of conventional symbols. Figure 11.1 provides a list of the most commonly used process flowchart symbols. Other symbols may be used but should be applied consistently. Provide a symbol key to identify the shapes used throughout the study.

Figure 11.1. Commonly Used Process Flowchart Symbols.

Symbol		Meaning	Examples
Elongated Circle		Start or Stop	Receives trouble report Machine Operable
Diamond		Decision point	Approve/disapprove Accept/decline Yes/no Pass/fail Percent of Split
Rectangle or Square		Activity (with an associated time)	Completes travel voucher Opens access panel
Circle		Connector (to another page or part of the diagram)	Process continues from page one
Arrow		Connects activities and indicates direction of process flow	From step one to step two

11.1.3. Techniques. There are numerous techniques used to create and document process flowcharts. Two variations are presented in **Figure 11.2** and **Figure 11.3**. Adding swim lanes to a process, (e.g., sales) in **Figure 11.3**, is an easy way to illustrate demarcation points for various offices, work centers, or work elements owning a piece of the process. Another variation is to arrange the process flowchart according to the physical layout of the function. The analyst is not limited to these formats when deciding which technique best documents the processes under review. However, regardless of the technique used, ensure the format is consistent in final study documents, i.e., do not use swim lanes on some processes and not on others.

Figure 11.2. Example of a Basic Process Flowchart.

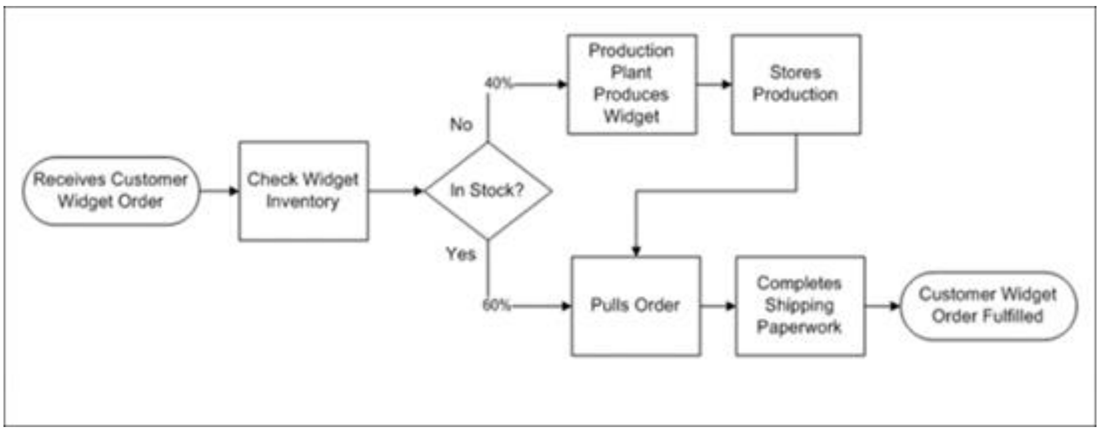
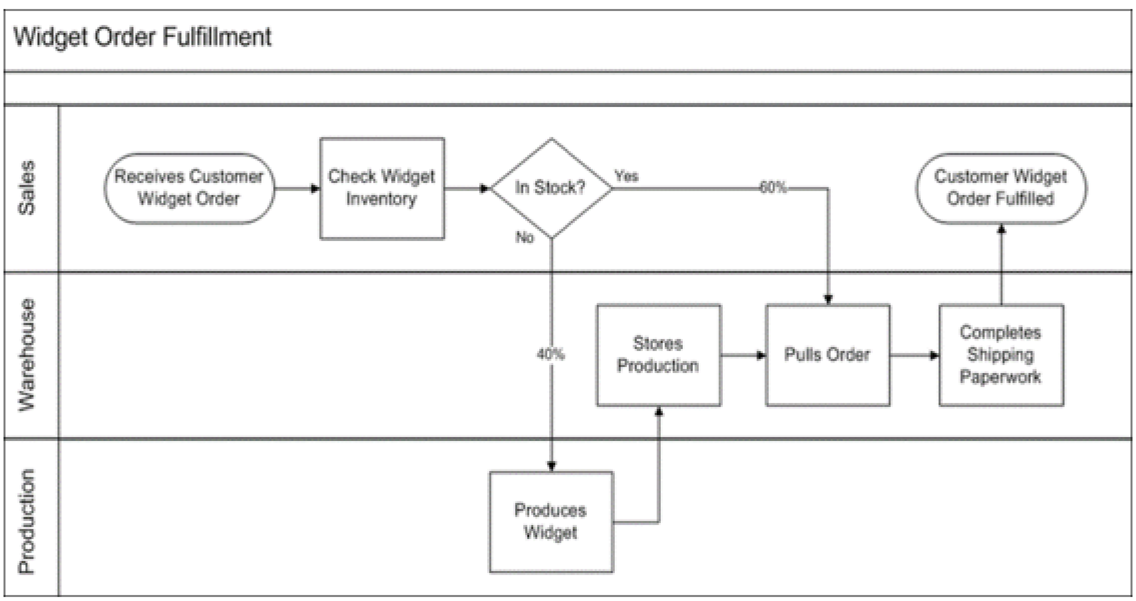


Figure 11.3. Example of a Process Flowchart Using Swim Lanes.



11.1.4. Guidelines for Developing Work Center Process Flowcharts. Since a process flowchart shows relationships between different steps and helps to locate or pinpoint problem areas, it is important to include key people in the process flowcharting activity, e.g., suppliers, customers, workers, and supervisors. Process flowcharts help the people involved with the process understand and communicate how the process is performed and then aid in process improvement efforts.

11.1.4.1. Break apart complex processes by creating sub-processes. Develop the sub-process process flowchart and use the sub-process title as the description for the activity within the higher-level process flowchart. Consider using a special formatting symbol on the primary process flowchart to make identification of sub-processes easier. However, remember to include a symbol key in the documents to identify all shapes used in the process flowchart.

11.1.4.2. Process flowcharting is partly an art and takes time to create a finished product ready for posting. Thoroughly inspect the chart for discrepancies.

11.1.4.3. Verify and validate the process flowchart. Ensure the technical experts agree with the process flow and clearly understand activity descriptions. Remember, include only MAJCOM or higher headquarters directed workload.

11.1.4.4. The steps to develop and analyze a process flowchart are described in **Table 11.1**.

Table 11.1. Steps to Develop and Analyze a Process Flowchart.

STEP	Action	Description
1	Identify and define the process.	Determine the title of the process. Where, when, and why does the process start and finish? What stimulus causes the process to start? What product or service is produced as a response? What is the output?
2	Describe the current process.	Determine the level of detail to be included on the chart. From the starting point, chart the entire process. Work slowly and include every step along the way, right through to the finish. If need be, brainstorm the activities that happen within the process without concern of the sequence, then place them in order later. When the analyst and/or SMEs agree the process is complete, connect the activities using the arrow connectors.
3	Chart the ideal process. (optional)	Try to identify the easiest and most efficient way to go from the "start" to the "finish." This makes it easier to find improvements.
4	Search for improvement opportunities.	Study the process flowchart. Find areas that hinder the process or add little to no value. If an ideal process was charted, compare and question any differences.
5	Update the chart with the improved process.	Build a new process flowchart that corrects the problems that were identified.

11.1.4.5. Some questions to address during process analysis:

11.1.4.5.1. What is produced by the process? Why is it needed? What Air Force requirement is satisfied as a result?

11.1.4.5.2. What is actually done? Are all steps included? Can the process or some steps be eliminated, combined, optimized, or automated?

11.1.4.5.3. Where should the process or steps be done? Are environmental conditions conducive to accomplishment of the process?

11.1.4.5.4. Are processes and/or steps in the right sequence? Can some be combined or simplified by moving them ahead or back?

11.1.4.5.5. Are the right people doing the work? Do the people have the right skills? Is the work being done at the most effective and efficient organizational level?

11.1.4.5.6. How are the process or steps being done? Can the process or steps be performed more efficiently or effectively with different equipment or work area layout?

11.1.4.5.7. Have proper administrative controls been set up? How often is work checked for accuracy? What inspections can be merged with operations?

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

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

11.1.4.5.10. When would an error be caught if present checks were left out? Are there fail-safe measures that can be put in place to eliminate the need for human detection, harm, or error? How serious is the result of errors not found? Is a sampling check for errors enough?

11.1.4.5.11. Is there duplication of effort, in whole or in part?

11.1.4.6. Identify process improvements during process flowcharting exercises prior to the measurement and development of manpower equations and determinants. The idea is to base the work center's manpower requirements on the most effective and efficient way to perform the work.

11.2. Systems and Procedures Analysis.

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

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

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

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

11.2.3.2. 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.

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

11.2.3.4. 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.

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

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

11.2.3.4.3. Organizational Elements. List all the elements responsible for doing the procedures action statement in enough detail for clarity.

11.2.3.4.4. Skills. List the AFSCs needed.

11.2.3.4.5. Equipment. List the equipment used.

11.2.3.4.6. 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.

11.2.3.4.7. Information Resources. List data sources such as reports, files, records, guides, and directives. Include information resources added to, or updated as part of, the action.

11.2.3.4.8. 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.

11.2.3.4.9. Objectives and Goals. Rank, for each procedure, the qualitative aspects of performance and the quantitative measures used.

11.3. Preparing a Procedure Chart.

11.3.1. A procedure chart is specifically designed to give, in symbol format, the type of work found in an administrative environment.

11.3.2. 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.

11.3.3. 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 mainstream of the procedure. If done well, the procedure chart shows the following information about a procedure:

11.3.3.1. The title, number of copies, and source of each document entering the procedure.

11.3.3.2. The method of preparation, organizational element, and person preparing each document originating in the procedure.

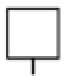
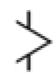
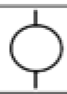
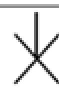
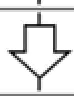
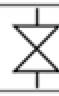
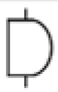
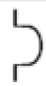
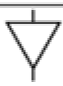
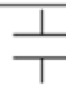
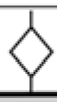
11.3.3.3. A symbol, with a short explanation to show each step in the procedure.

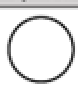
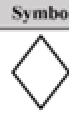
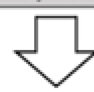
11.3.3.4. Processing times and movement distances (optional).

11.3.3.5. Final disposition of each copy of each document involved in the procedure.

11.3.3.6. Some common chart symbols and uses are found in **Figure 11.4**.

Figure 11.4. Common Procedure Chart Symbols and Usage.

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

For Personnel Activity					
Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
	Operation		Inspection		Move

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

11.3.4.1. Chart preparation begins with entering basic information on the chart such as procedure title, data, and analyst.

11.3.4.2. 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.

11.3.4.3. 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.

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

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

11.4. Layout Analysis.

11.4.1. General Concepts.

11.4.1.1. Layout analysis studies are used to improve production, ease physical exertion, and shorten distances of travel for material and personnel. These studies concentrate on the physical flow of work, 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 providing an optimum workable arrangement of personnel and equipment.

11.4.1.2. 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:

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

11.4.1.2.2. Providing each employee with enough space to work efficiently while, at the same time, minimizing total space. Air Force Office of Safety and Health/Occupational Safety and Health Administration standards specify minimum workspace requirements.

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

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

11.4.1.2.5. Eliminating furniture and equipment not needed in the work center operation.

11.4.1.3. Potential benefits of an effective layout are:

11.4.1.3.1. 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.

11.4.1.3.2. Increased Employee Comfort and Safety.

11.4.1.3.3. Reduced Labor Turnovers.

11.4.1.3.4. Improved Supervision. Careful layout planning makes controlling the workflow and inspecting easier for the supervisor.

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

11.4.1.3.6. Better Space Utilization.

11.4.1.3.7. Reduced Costs. Cost is the most important benefit. Accelerating production, controlling waste, and reducing labor expenses all save money.

11.4.2. Layout Analysis Applicability.

11.4.2.1. Steps necessary to conduct a layout study 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 key.

11.4.2.2. 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 creating a low productivity environment. Accurate and detailed definition of the problem is essential for problem solution.

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

11.4.2.4. Classify layout analysis studies according to the magnitude of the effort:

11.4.2.4.1. Minor change to present layout.

11.4.2.4.2. Major rearrangement of existing layout.

11.4.2.4.3. Relocating into other existing facilities.

11.4.3. Using Flow Diagrams for Layout Analysis.

11.4.3.1. Prepare a scaled layout chart of the area under study. Use a standard scale when preparing the chart.

11.4.3.2. 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 process flowchart.

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

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

11.4.3.5. When presenting two or more workflows, use a different color for each flow.

11.4.3.6. Study the flow diagram for improvement possibilities. Use the flow diagram checklist in **Figure 11.5**.

Figure 11.5. Flow Diagram Checklist.

1. Workflow □ Does workflow follow a relatively straight line with minimum backtracking and crossover? Where are the bottlenecks? □ Has each step been questioned and analyzed? □ Have other workflows been considered? □ Does furniture and equipment spacing consider at least minimum space requirements per worker as outlined in AFPD 32-10, *Installations and Facilities.* □ Does layout consider person-person and person-equipment workflow relationships? □ Is there excess furniture or equipment?

- ◻ Would movement of furniture or equipment reduce or eliminate the number of moves or distances?
- ◻ Does layout recognize nature of work such as privacy or security considerations?

2. Diagram

- ◻ Does diagram portray its story clearly?
- ◻ Is diagram too elaborate and/or cluttered?
- ◻ Is it easier to understand than a chart or narrative description? Is it more effective?
- ◻ Is the layout used current? To scale?

11.4.4. Layout Analysis Development.

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

11.4.4.1.1. Determine facility location.

11.4.4.1.2. Plan overall layout.

11.4.4.1.3. Plan detailed layouts.

11.4.4.1.4. Plan processes and machinery around material functions.

11.4.4.1.5. Plan the layout around processes and machinery.

11.4.4.2. Consider the following:

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

11.4.4.2.2. 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.

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

11.4.4.2.4. Set up a workflow following the simplest and shortest path.

11.4.4.3. Prepare proposed process flowchart and work distribution charts to optimize workflows and travel. Document the proposal on a revised flow diagram.

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

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

11.4.4.5.1. Produce a better product or increase production?

11.4.4.5.2. Smooth the flow of work or reduce effort?

11.4.4.5.3. Minimize material handling?

11.4.4.5.4. Reduce costs, waste, and scrap?

11.4.4.5.5. Release floor spaces or reduce wasted space?

11.4.4.5.6. Decrease maintenance?

11.4.4.5.7. Eliminate congestion or improve housekeeping?

11.4.4.5.8. Facilitate scheduling or reduce quality checks?

11.4.4.5.9. Make supervision easier?

11.4.4.5.10. Reduce accidents or improve morale?

11.4.4.5.11. Allow for future expansion?

11.4.4.6. Include a concise implementation plan with enough detail for systematic implementation.

11.4.5. Implementing the Proposed Plan.

11.4.5.1. Present all recommendations and the proposed implementation plan to the supervisor, then to other key senior leadership personnel. Recognize it is the unknown rather than the new that creates apprehension. Sell major ideas of the study in the order of 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 may often be readily accepted, thereby avoiding complete rejection of an idea or proposal.

11.4.5.2. On acceptance of final implementation plans, make sure all affected personnel are fully informed of the entire plan and 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 contrary to study objectives. Ensure all recommendations are instituted as planned.

11.5. Work Distribution Analysis.

11.5.1. General Concepts.

11.5.1.1. Division of work is a potential area for productivity enhancement and is an aspect of skill determination for requirements determination.

11.5.1.2. 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.

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

11.5.1.4. This technique is a good tool to check and compare present and proposed procedures during study preliminary research and consultant studies.

11.5.2. How to Prepare a Work Distribution Chart. There are three basic steps to prepare this chart.

11.5.2.1. Step 1. Have each person in the work center complete an activity task list. Use this to record each duty activity and type of work done and estimate the average number of hours spent on each.

11.5.2.1.1. The activity list 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.

11.5.2.1.2. Number tasks by activity to help in developing a work distribution chart. The WU volume aids in work distribution analysis.

11.5.2.2. Step 2. Complete a work center activity list. This list records the basic processes done by the work center. It includes all the major activities completed to meet assigned objectives.

11.5.2.3. Step 3. Prepare a work distribution chart. The activity list gives the information needed to do the chart.

11.5.2.3.1. List the activity of the work center in the left column of the chart, in order of relative importance. Leave space between lines.

11.5.2.3.2. Columns labeled “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.

11.5.2.3.3. For purposes of analysis, list individuals doing the activities in the first column by grade, beginning with the person in charge.

11.5.2.3.4. Record the hours per week spent by each person on each task in the proper column.

11.5.2.3.5. 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 work distribution chart. If a weekly count is not representative, enter the natural frequency of occurrence (e.g., /MO or /YR).

11.5.2.3.6. 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.

11.5.2.3.7. Total the hours for each person.

11.5.3. Analysis.

11.5.3.1. After completing an initial work distribution chart, do a systematic analysis of the recorded findings. Ask the following questions for a detailed examination:

11.5.3.1.1. 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.

11.5.3.1.2. 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 all work is done according to schedule.

11.5.3.1.3. 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.

11.5.3.1.4. Are individuals doing too many unrelated tasks? A large number of tasks in any one column may show the individual has too many different tasks. Greater efficiency results if workers are assigned related tasks.

11.5.3.1.5. 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.

11.5.3.1.6. Are there excessive supervision or consultation tasks? Resistance to delegation of authority can restrict creativity and cause unnecessary delays.

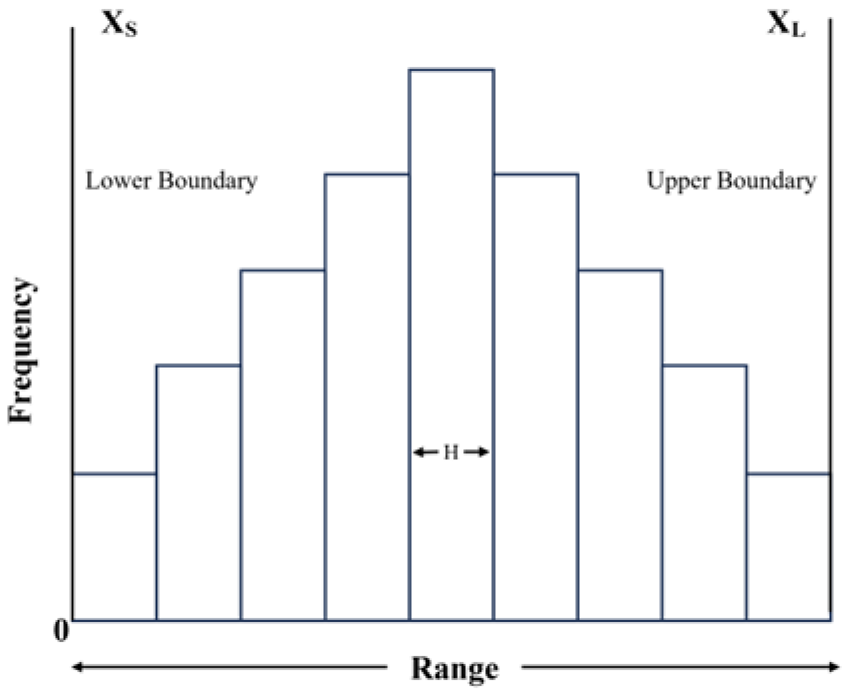
11.5.3.1.7. What activities take the most time? Are they the ones that should take the most time? Normally, the largest total time is spent on what is considered the major activity in the organization. If the activity is a continuing one with several steps, the analyst may make a more detailed analysis by preparing a work distribution chart. Identify such man-hour totals to mark them for future process analysis.

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

11.6. Histogram Chart.

11.6.1. 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 11.6**.

Figure 11.6. General View of a Histogram.



11.6.2. Procedures to Develop a Histogram.

11.6.2.1. Count the number of samples (n) for the process being analyzed and record the total counts, see **Table 11.2**.

Table 11.2. Histogram Example Data.

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

11.6.2.2. Identify the range (*R*) of data gathered. This number is the difference between the largest (X_L) and smallest (X_S) value in the data.

$$R = X_L - X_S \xrightarrow{yields} 8.7 - 7.0 = 1.7$$

11.6.2.2.1. Separate the data into classes (*K*). See **Table 11.3** below to identify the number of classes for different numbers of data points.

Table 11.3. Histogram Example Data, Sorted by Classes.

Points Counted	Classes (K) to Use
≤ 50	5 - 7
51 - 100	6 - 10
101 - 250	7 - 12
> 250	10 - 20

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.

11.6.2.2.2. 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, $H = 0.20$.

11.6.2.2.3. 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.

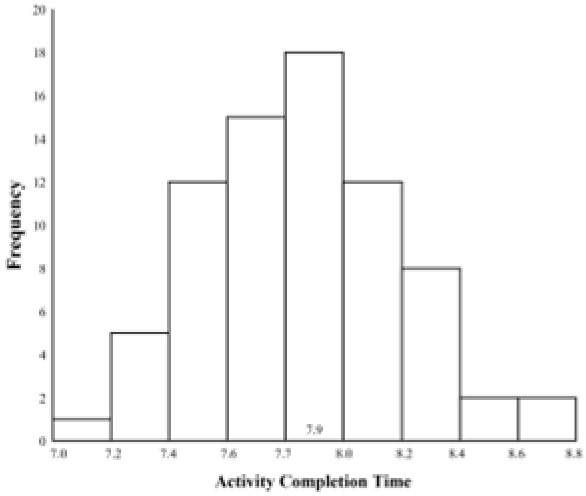
11.6.2.2.4. Identify the number of samples in each class to determine the frequency of occurrence and enable the construction of the histogram. These counts give a horizontal histogram (see **Table 11.4**.).

Table 11.4. Histogram Example, Horizontal Histogram.

Class (H)	Number of Counts	Total
7.00 - 7.19	I	1
7.20 - 7.39	~~IIII~~	5
7.40 - 7.59	~~IIII~~ ~~IIII~~ II	12
7.60 - 7.79	~~IIII~~ ~~IIII~~ ~~IIII~~	15
7.80 - 7.99	~~IIII~~ ~~IIII~~ ~~IIII~~ III	18
8.00 - 8.19	~~IIII~~ ~~IIII~~ II	12
8.20 - 8.39	~~IIII~~ III	8
8.40 - 8.59	II	2
8.60 - 8.79	II	2
		n = 75

11.6.2.2.5. Construct the histogram to show the samples in each class. In this example, the data is centered around a value of 7.90 and is very close to a bell-shaped curve. The histogram gives a view of where the counts are centered and the amount of dispersion of the data. See **Figure 11.7**.

Figure 11.7. Histogram of Example Data.

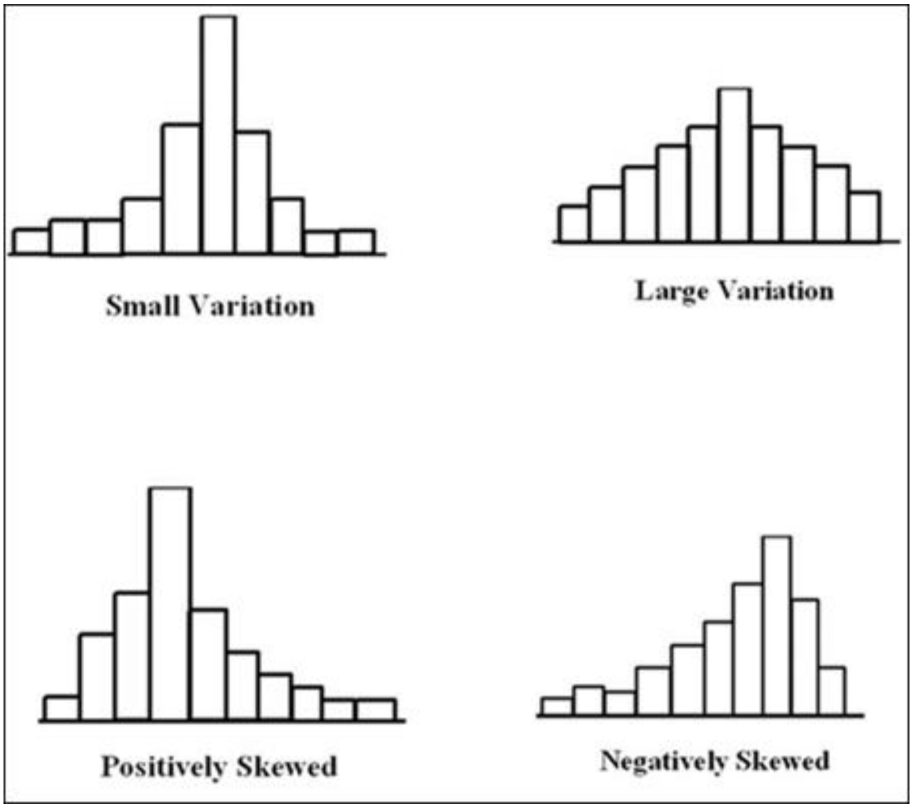


11.6.3. Histogram Shape. The data in a histogram may not always be symmetrical.

11.6.3.1. The data can be tightly centered around a point or greatly dispersed, or bimodal (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 11.8**.

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

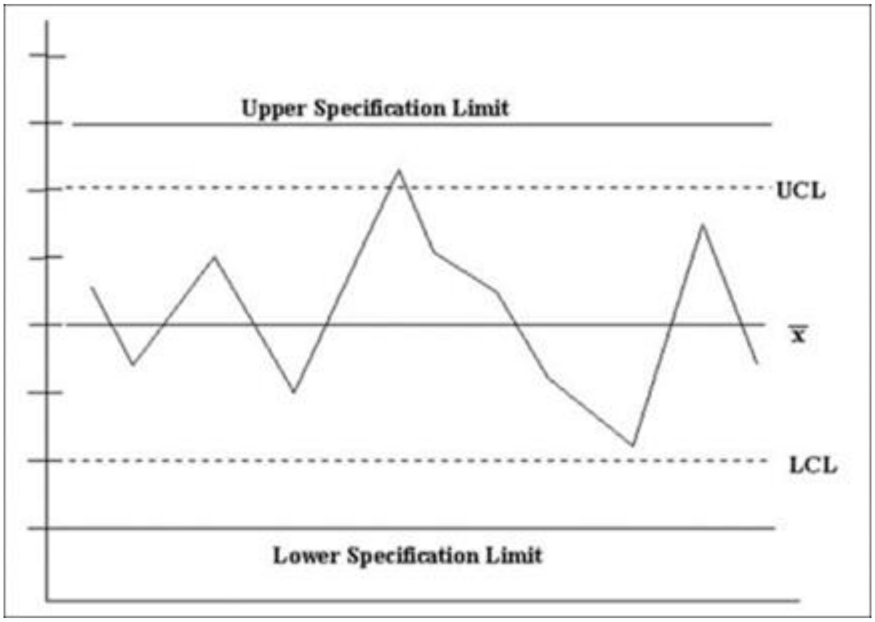
Figure 11.8. Four Histograms Displaying Potential Results.



11.7. Control Chart. 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.

11.7.1. General Concepts. Control charts give important graphical information to help determine where variation in a process might be normal or abnormal with the latter case requiring further analysis (see **Figure 11.9**.). By plotting the sample points in time order (in sequence of occurrence), control charts can identify unusual changes in the process indicating the need for further analysis.

Figure 11.9. Example of a Control Chart.



11.7.2. Types. There are two main types of control charts.

11.7.2.1. Attribute control charts are used to plot go or no-go factors such as an output being in or out of tolerance.

11.7.2.2. Variable control charts plot specific measurements of a variable characteristic such as size, time, or weight of an output.

11.7.3. Description of Terms.

11.7.3.1. Assignable Cause. Any force and/or situation, not deemed part of the defined population that causes a sample to deviate significantly (exceeding established control limits) from the mean. For example, a certain population of proportions may be defined 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, an analyst would know some force, not inherent to the defined population, was at work.

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

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

11.7.3.4. Population. Any set of objects. Each member of a population is called an element.

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

11.7.3.6. 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.

11.7.3.7. Sample Size (n). A sample may consist of one or more observations, i.e., 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).

11.7.4. Standard Deviation (s). The square root of the variation. The formula is:

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

11.7.5. Variation (s^2).

11.7.5.1. The average of the squared deviation from the mean. The formula is:

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

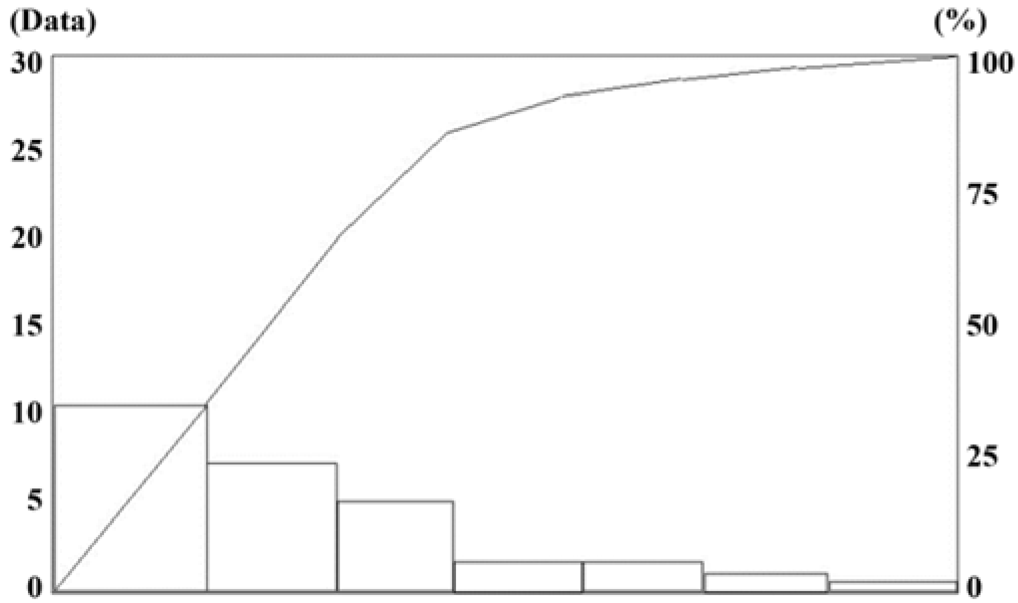
11.7.5.2. If the sample size is 30 or less, use the following formula for variation:

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

11.8. Pareto Chart.

11.8.1. General Concepts. The Pareto chart is useful because it shows the areas experiencing the most problems that should be addressed first for correction. Pareto analysis is a statistical technique in decision-making used for the selection of a limited number of tasks that produce a significant overall effect. Utilizing the Pareto principle, also known as the 80/20 rule, roughly 80 percent of a work centers processes come from 20 percent of the efforts. See **Figure 11.10** for an example of a Pareto chart.

Figure 11.10. Example of a Pareto Chart.



11.8.2. Procedures to Develop a Pareto Chart. Determine which variable (e.g., cost, defects, etc.) will be used to evaluate different processes. The samples are itemized into the processes that will be evaluated. For example, if errors are occurring in a supply organization, 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.

11.8.2.1. 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.

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

11.8.2.3. 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 have few samples, combine the samples and identify as other.

11.8.2.4. 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 percent point.

11.8.2.5. Usually, the tallest bars indicate the largest contributors to the overall problem. Dealing with these areas first is logical. However, most frequent does not necessarily equate to most important.

11.8.3. How to Use a Pareto Chart. Use care when selecting the variable 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.

11.9. Scatter Diagram.

11.9.1. General Concepts. The scatter diagram shows the relationship, or correlation, between two variables or the influence one variable has on the other. The variables could come from the potential WLFs of a requirement determinant 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.

11.9.2. Procedures to Develop a Scatter Diagram. 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.

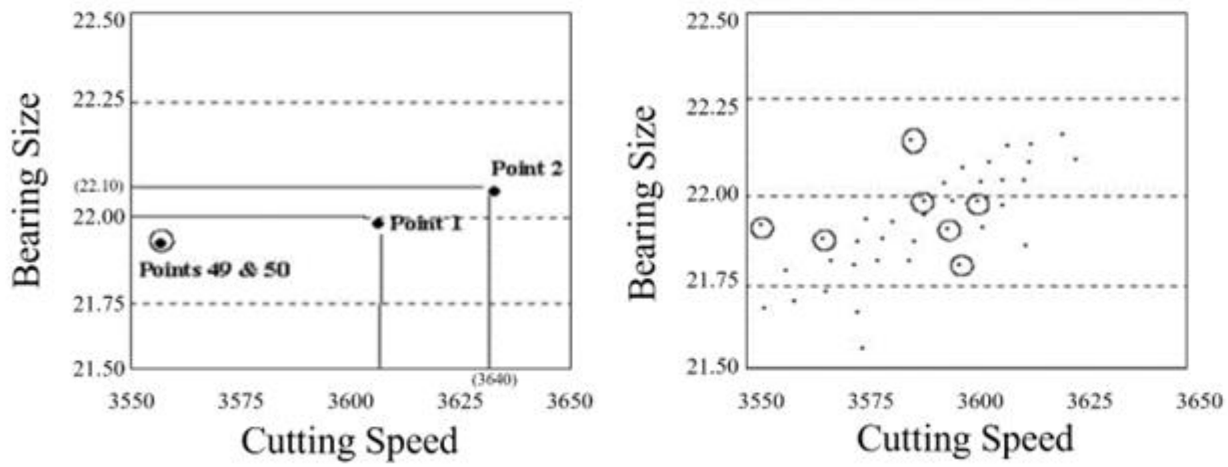
11.9.2.1. Collect 50 to 100 (x, y) data pairs that form the samples on the diagram. See **Table 11.5** for a partial listing of point pairs.

Table 11.5. Example of 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

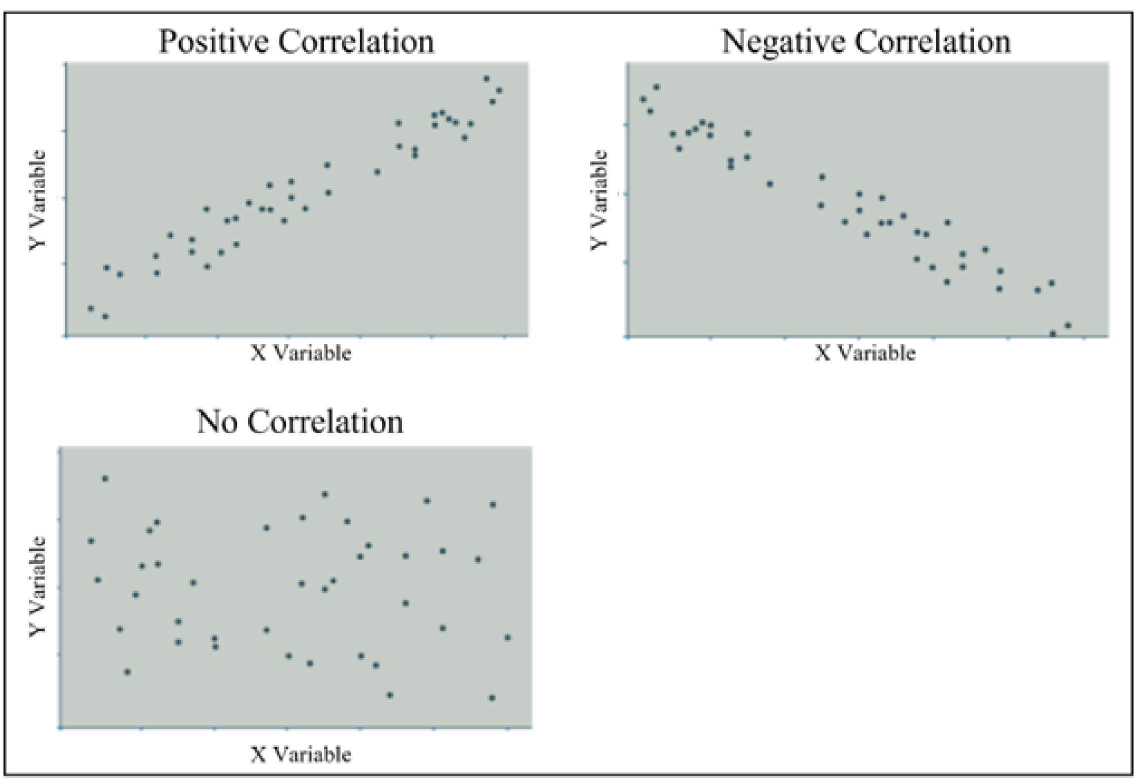
11.9.2.2. Draw and label the x-axis and y-axis. Plot the individual samples on the scatter diagram. If samples overlap, place concentric circles around the point, with a circle representing each additional point. See **Figure 11.11** for an example of how to plot the samples and a scatter diagram.

Figure 11.11. Example of Plotting a Scatter Diagram.



11.9.3. How to Interpret a Scatter Diagram. After the samples are plotted on the chart, observe if one variable affects the other. See **Figure 11.12** for a variety of possible results.

Figure 11.12. Scatter Diagram Outcomes.



11.9.3.1. 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.

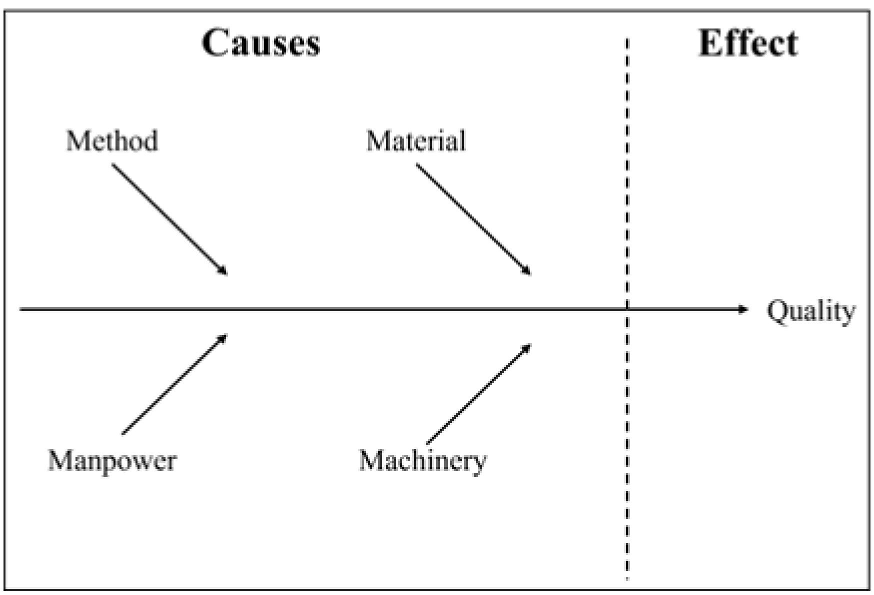
11.9.3.2. The diagram indicating "No Correlation" shows the data points scattered all over the diagram. There is no indication of a distinguishable impact of one variable on the other.

11.9.3.3. 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.

11.10. Cause-and-Effect Diagram.

11.10.1. General Concepts. A cause-and-effect diagram (also known as an Ishikawa or a fish-bone 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 causing a product or service quality problem usually relate to unwanted changes in manpower, work processes, equipment, or raw materials. To find the elements coming into play, follow a logical approach to identify the potential causes of a problem. **Figure 11.13** illustrates the structure of a cause-and-effect diagram.

Figure 11.13. Example of Cause-and-Effect Diagram.

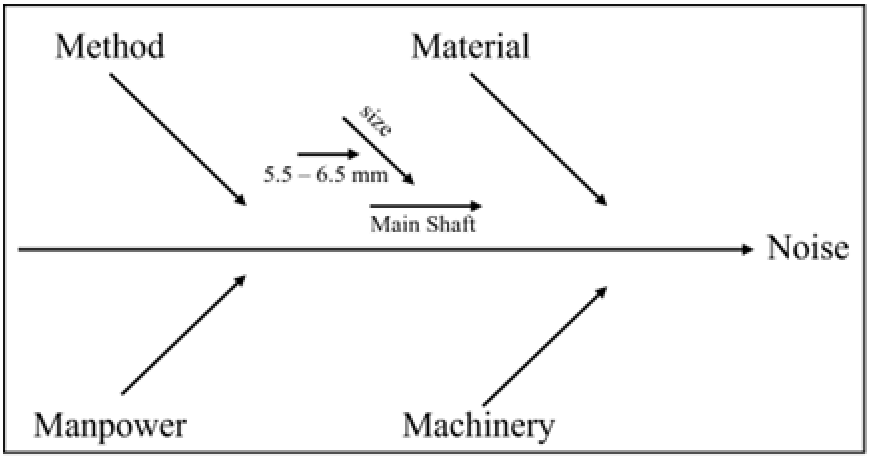


11.10.2. Procedures to Develop a Cause-and-Effect Diagram. Identify what the problem is and briefly state it on the right side of the diagram. Enclose this statement in a box. Draw an arrow towards the problem statement extending to the left.

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

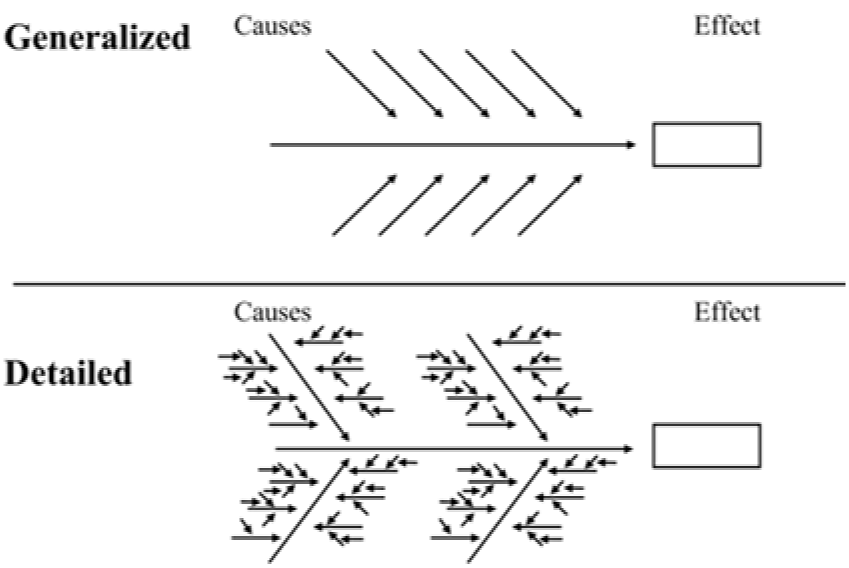
11.10.2.2. List the factors in each of these categories that could cause the problem, using an idea generating methodology such as the nominal group technique or brainstorming. Each of these branches can have branches identifying more specific causes of the stated problem. See **Figure 11.14** for an example of this branching.

Figure 11.14. Example of Detailed Listing of Causes.



11.10.2.3. A very important element of identifying the potential causes of a stated problem is to have personnel 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 11.15**.

Figure 11.15. Generalized and Detailed Listing of Causes in Cause-and-Effect Diagram.



11.10.3. Benefits of Using a Cause-and-Effect Diagram. Any type of problem can be displayed on a cause-and-effect diagram. It does not have to relate to quality or timeliness. For example, personnel, safety, and scheduling problems can also be analyzed using this diagram.

11.10.3.1. Greater knowledge about the factors influencing the problem will result in making the potential causes of the problem more evident.

11.10.3.2. 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.

11.10.3.3. 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 impacting the problem being addressed.

Chapter 12

SIMULATION MODELING

12.1. General Concepts.

12.1.1. Simulation is an analysis technique using computer software that can be used in the MEP to model organizational systems. These models can be used to evaluate system changes prior to implementation and without the need for a complete re-study of a function's processes. This chapter does not provide instruction for any specific simulation software package but is intended to provide general philosophy, methods, and practices for guiding an analyst using simulation.

12.1.2. Simulation software provides an environment for building a representation (model) of the system under study and simulating the dynamic behavior of that system. When the simulation is run, the software typically displays an animation of the modeled system and components (which can be of value to the analyst). The simulation can be run many times to characterize probabilistic differences in the timing of the processes of the modeled system; software compiles summary statistics for the simulated system runs. No model is a perfect representation of real-world. The focus should be on enabling USAF leadership to make defendable, data-driven decisions.

12.2. Typical Applications for Simulation Modeling. Based on the study's purpose, most simulation models may contain several applications found in **Table 12.1**.

Table 12.1. Typical Application of Simulation Modeling.

Application	Use
Bottleneck Analysis	A more defined form of capacity analysis which identifies system bottlenecks and how marginal changes at the bottlenecks affect the studied system's overall performance.
Capability Analysis	Evaluate system capability to meet specific performance requirements (e.g., throughput or waiting times).
Capacity Analysis	Maximize processing or capacity of the system.
Cycle Time Reduction	Explore ways to reduce cycle time within the system.
Inventory Reduction	Evaluate ways to reduce inventory and decrease costs from storage, expiration and destruction.
Layout or Facility Analysis	Analysis of various facility layout designs and the effect on throughput.
Performance Analysis	Evaluate how well a system behaves under various scenarios by exploring levels of service or other scenarios (e.g., peacetime vs. wartime, quantifying the resultant impact on resource utilization, throughput, or cycle-time).

12.3. Criteria for Selecting Simulation Modeling.

12.3.1. Many, but not all, functions are candidates for simulation modeling. Simulation modeling may not be desirable when there is a more appropriate tool for the situation.

12.3.2. Other tools may preclude the need for a simulation model when an organizational system lacks process interdependencies; is well-defined and repetitive; and/or can be represented with simplistic, static, mathematical models. However, if "what-if" analyses are desired, standard models may require extensive or complete rework to evaluate changes.

12.3.3. Simulation modeling builds representations of complex systems (complete with interdependencies and variability) and numerically evaluates probabilistic processes to estimate characteristics of the system being studied. Once the simulation model is built, the analyst can run the simulation over different time horizons with the ability to perform various "what-if" scenarios. The animated representation of the system typically provided by simulation software can be useful in communicating study results. Once simulation models are developed, the model is maintained as a function's processes are modified, removed, or added, which can save time and money in future development costs.

12.3.4. A requirements determinant may use simulation modeling alone or in conjunction with other tools.

12.4. Classification of Simulation Models.

12.4.1. Below are the four dimensions by which simulation models can be classified.

12.4.1.1. Static vs. Dynamic Simulation Models. A static simulation model is used to represent a system that does not change over time, while a dynamic simulation model is able to represent the system as it changes over time.

12.4.1.2. Deterministic vs. Stochastic Simulation Models. With deterministic models, the output of the model is "determined" when the set of inputs are specified, with no variability (randomness) in the output for the specified, non-random input. When the input or modeled processes introduce randomness to the system, a stochastic (probabilistic) simulation model must be used. The output of a stochastic simulation model will also be random, lending the results to analysis using statistical methods. **Note:** While a system may have elements (processes) that are both random and deterministic, a model with any random components is considered stochastic.

12.4.1.3. Continuous vs. Discrete Simulation Models. In a continuous simulation, the state of a modeled element changes continuously over time. Continuous simulations are generally utilized when differential equations describe the behavior of the modeled systems. In a discrete simulation, the state of modeled elements changes instantaneously at separate points in time. A simple context for understanding the difference is vehicle refueling. As a continuous simulation, consider the rate of fuel flow over time and model the refueling process as percent full at a given time; with a discrete simulation, the model would simply show the vehicle as full at a specific time governed by the specified distribution for that process.

12.4.1.4. Terminating vs. Non-terminating Simulation Models. Terminating simulation models end with a specific event (or certain time period). Non-terminating models do not have a specific event that stops the simulation. With non-terminating simulations, we are usually interested in the system's behavior once steady state is achieved (which can be difficult to define).

12.4.2. Simulation models that are discrete, dynamic, and stochastic (of both termination varieties) tend to be the most flexible and useful. These simulations are called discrete event simulations and will be the focus of the remainder of this chapter.

12.5. Advantages, Disadvantages, and Pitfalls of Simulation Modeling.

12.5.1. Advantages.

12.5.1.1. Simulation lends itself to representation of complex, real-world systems where mathematical models may lack an analytical solution.

12.5.1.2. Allows the analyst to estimate system performance based on forecasted changes and/or evaluate an alternative's effect on system performance. An example would be evaluating the effect of different levels on system performance.

12.5.1.3. Provides an environment for system experimentation at a reduced cost, and with better experimental control than experimentation with real-world systems.

12.5.1.4. Simulation provides the ability to either compress timeframes to study systems in the long-term or expand timeframes to understand more detailed aspects of the system studied.

12.5.2. Disadvantages and Pitfalls.

12.5.2.1. Resource Intensiveness. Developing simulation models can be a resource intensive process requiring significant time, as well as the cost of acquiring and maintaining access to appropriate simulation modeling software.

12.5.2.2. Planning and Execution. Simulation models may fail due to poor planning and execution. Simulation fails to produce useful results often due to a poor understanding of system dynamics rather than to a lack of software proficiency. This may be due to an unskilled analyst, unavailability of data, or unsupportive management. A simulation may also fail to meet decision maker needs due to unclear objectives or unmanaged expectations. Therefore, the best way to guarantee success is to ensure everyone involved in the study understands the process, benefits, and limitations of simulation.

12.5.2.3. Documentation Requirements. Documentation of facts, assumptions, data, and analysis is important for any study. However, it becomes more critical to the success and durability of the model when using simulation. Provide detailed model assumptions and rationale on the assumption decisions. By documenting the assumptions, the analyst facilitates functional communities', other analysts', and ultimately the decision maker's ability to understand the simulation model's context. Clear and concise assumptions provide credibility to the simulation model. Simulation modeling software provides the capability to capture all the study's documentation, facilitating quick and timely changes to the model for a particular function for years into the future.

12.5.2.4. Data Preparation and Analysis. The simulation model is only as good as the data collected and analysis conducted. Process activities are accurately and clearly defined to facilitate accurate work measurement. Critical analysis is required for process activities and work measurement data throughout the study. Ensure the data gathered is logical and supportable.

12.6. Principles of Simulation Modeling.

12.6.1. Define the Model's Purpose. By focusing on the model's purpose, the analyst focuses on the information relevant to designing the model within the study scope, the formulation of key performance measures and experiments to be simulated (e.g., manpower required at different levels of service), and ultimately the success of the study. This is arguably the primary overarching principle of simulation modeling.

12.6.2. Simulation Modeling is an Iterative Process. Simulation models are built iteratively, progressing from simple to complex over time.

12.6.3. Avoid Unnecessary Detail. The idea behind this principle is to capture the primary processes of the system rather than every minute detail. For example, there is no need to model lunch breaks unless the work center is required to be manned to service customers during that time. Analysts may run into situations that may seem relevant initially, which subsequent analysis does not support. Remove the element or feature once it is determined to be unimportant to the model's purpose. A key economical consideration is to not design for peaks that only occur occasionally or rarely.

12.7. Simulation Study Process. Each study requires a model based on the current system. When developing improvements to the system, a model is altered to proposed specifications or different scenarios are used. The analyst should not improve the model until understanding the current system and validating the system's "as-is" model. This should not prevent identifying potential improvements when developing the "as-is" model.

12.7.1. Proper data collection and data analyses are critical before the simulation model is developed. Process flowcharts and data may be collected within or outside of the software tool. Use all required techniques and tools (i.e., histograms, Pareto charts, etc.) available to verify the data is logical and correct.

12.7.2. When developing improvements, consider eliminating or realigning workload, optimizing manpower resource skill mix, and changing processes or procedures to reduce backlogs and/or improve cycle and process times. Identify potential risks and mission impacts.

12.7.3. When conducting requirement determinant studies, consider developing models or scenarios to evaluate the impact of issues on the current workforce, such as training, staffing, backlog, or projected increases to workload.

12.7.4. Document both the current and proposed simulation model results in terms of resources, cycle and process times, and backlogs. Through use of scenarios, it is possible to provide leadership with sound data to make decisions on level-of-service issues.

12.7.5. The following is a summary of the procedure used in simulation modeling.

12.7.5.1. Step 1. Define Purpose, Objectives, Scope, and Requirements. Clearly document the study purpose, objectives, scope, and requirements. This helps all involved parties to understand what is included in the simulation model, and what questions it should and should not answer. The analyst follows the documented plan, allowing for modifications as new in-scope information is discovered. Modifications to the plan should be documented and shared with all involved.

12.7.5.2. Step 2. Collect and Analyze System Data. Systematically collect data needed to build the model. Data collection is more productive when the end result is taken into account. Keep the study purpose, objectives, scope, and scenario in mind when determining what data is required. The output of this step is the initial development of a conceptual model and a data document (with participant concurrence that it contains data representative of the process to be modeled).

12.7.5.3. Step 3. Build the Simulation Model. A system being modeled should first be defined in terms listed in **Table 12.2**. Begin with the conceptual model developed in the data-gathering effort. Remember, the model is a simplified representation of reality based on the study purpose, scope, and scenario, therefore, changes to the model should not be arbitrary, but rather systematic and documented.

Table 12.2. Structural Elements of a Simulation Model.

Object	Represents	Characteristics	Collected Statistics
Entity	Inputs and Outputs	Follow one or more for routing. Processes performed on entities. Arrive from outside system or created within. Normally exits system. Use entity attributes to determine routing or gather information.	Cycle-time Throughput Process time Wait time Work-in-Progress
Location	Places in system for processing, waiting or decisions	Room, workstation, entry point, queue, or storage. Buffer capacity. Availability times. Prioritization.	Queue/average contents Process time Utilization Downtime Idle time
Resources	People, equipment and/or facilities used to process entities	Static (stationary) examples: fax machine, computer, or a facility. Dynamic (moving) examples: people or automated equipment.	Utilization Availability Response time Quantity needed
Paths or Routing	Defines course of travel for entities or resources	May be isolated between activities for entity flow. May be connected to create travel paths for material handling equipment.	Move time

12.7.5.4. Step 4. Simulation Model Verification and Validation. Do not neglect verification and validation. It is an ongoing activity that is accomplished throughout the study. Facilitate verification and validation by: validating the study purpose, scope and scenario are consistent with the simulation model; reducing the amount of complexity in the model; building the model and including notes so it is readable and understandable; using object-oriented techniques to organize the model data; and thoroughly documenting model data and logic.

12.7.5.5. Step 5. Conduct Experiments. Run the simulation for each scenario to be evaluated and analyze the results. Analysis involves both subjectivity and statistical procedures. When developing experiments, keep in mind the purpose and scenario to avoid wasting valuable time. Prior to running the simulation, there are decisions to make concerning the modeling parameters to facilitate output analysis.

12.7.5.6. Step 6. Present the Results. Present the findings based upon standard reporting procedures for a requirements determinant. Simulation models provide various statistically relevant output reports, charts, and graphics that may be used to support study assumptions and recommendations.

Chapter 13

MANPOWER MODEL DEVELOPMENT AND SELECTION USING CORRELATION AND REGRESSION ANALYSIS

13.1. General Concepts.

13.1.1. General Uses and Principles of Correlation and Regression (C&R). There are many uses for C&R analysis in the Air Force MEP, including:

13.1.1.1. Development of a man-hour or manpower equations using work measurement data.

13.1.1.2. Determination of FEEs and functional models using non-measurement data.

13.1.1.3. Evaluation of multiple potential WLFs.

13.1.1.4. Evaluation of differing levels of service (e.g., performance metrics) for varying levels of manpower.

13.1.2. A good manpower forecasting model developed using C&R provides a mathematical equation that provides an acceptably accurate prediction about the relationship between varying levels of workload and required man-hours or manpower for the function.

13.1.3. Although C&R may create the aforementioned manpower forecasting models, C&R statistics never prove a cause-and-effect relationship between the potential WLF and the function's required manpower. Rather, it is logic or science that ultimately proves a true cause (e.g., the function's WLFs) and the effect (e.g., the function's required manpower) relationship.

13.2. Workload Factors and Work Units.

13.2.1. Selecting WLFs or WUs for Statistical Model Development.

13.2.1.1. When using C&R analysis to develop a statistical manpower model, potential WLFs are identified and collected.

13.2.1.2. When C&R is not utilized (e.g., ratio unit times (RUT) approach), WUs are identified and collected for use during the process flowcharting of the SWD in developing the requirements determinant equation. If it is later determined during analysis that C&R is a better approach, a WU may become a viable WLF. See **Chapter 16** on RUT.

13.2.1.3. Although valid WUs and WLFs share many required attributes (as discussed below), the terms are not interchangeable. A key distinguishing difference between the two terms is a WU is a direct product of an individual process, while a WLF represents a broader driver and/or indicator of workload (i.e., relates to more than just one process, if not all processes).

13.2.2. Technique Determination. Weigh several factors when determining which man-hour equation development technique to use. Such factors include the future determinant's ease of application, cost associated with data collection, and the maintainability in future years.

13.2.2.1. Advantages and Disadvantages of WUs and RUT Techniques.

13.2.2.1.1. Advantages:

13.2.2.1.1.1. WUs are readily identifiable when the SWD is constructed properly.

13.2.2.1.1.2. Functional communities easily relate to WUs because WUs are something produced routinely.

13.2.2.1.1.3. Work centers often have systems in place to assist with data collection efforts.

13.2.2.1.1.4. These techniques can be used with any size population.

13.2.2.1.2. Disadvantages:

13.2.2.1.2.1. Work centers often have many WU counts, making it difficult to apply the equation.

13.2.2.1.2.2. There may be an increased number of computations due to a greater number of WU counts.

13.2.2.1.2.3. It is likely that the lack of predictability and programmability of WUs does not assist in quantifying required manpower in the future.

13.2.2.1.2.4. Management information systems or practices may not currently be in place to accurately capture WUs.

13.2.2.1.2.5. WUs can often be manipulated by the work center.

13.2.2.2. Advantages and Disadvantages of WLF and C&R Techniques.

13.2.2.2.1. Advantages:

13.2.2.2.1.1. WLFs can greatly reduce the amount of data that is collected to apply the equation.

13.2.2.2.1.2. Programmable WLFs are easier to predict future required manpower.

13.2.2.2.2. Disadvantages:

13.2.2.2.2.1. May not find a suitable WLF meeting minimum statistical test requirements.

13.2.2.2.2.2. Functional personnel may complain about the final equation not representing the function's workload or is not sensitive enough to mission changes to be a practical requirements determinant.

13.2.2.2.2.3. Cannot be used with less than seven data points.

13.2.3. Identifying WUs. WUs are quantifiable, direct outputs of work processes. Using process flowcharting and analysis, a SAT is determined for a specific WU by mathematically summing all intermediate activity SATs within the process. See **Chapter 16** on RUT.

13.2.3.1. Key WU Attributes. Identify WUs for each defined work activity or process. For maximum utility, WUs should be:

13.2.3.1.1. Directly related to the time and effort spent on the associated process.

13.2.3.1.2. Economical and convenient to report and use.

13.2.3.1.3. Mutually exclusive, so no item is counted under more than one WU.

13.2.3.1.4. Open to audit, so the accuracy of a work count is readily verified by setting up a work count system or through existing internal work measurement programs or management information systems.

13.2.3.1.5. Readily understood by those who plan, schedule, and control the work and readily identifiable when seen produced.

13.2.3.1.6. Individually standardized in terms of the procedures needed for production.

13.2.3.2. WU Uses. Depending on the established or intended use of the WU, each of the above attributes assumes a varying degree of importance. The most important characteristic of a WU is it defines a specific amount of work; thus, avoid vague WU titles, definitions, methods of counts, and sources of count.

13.2.4. Identifying WLFs. WLFs normally drive and can be logically related to major man-hour or manpower expenditures in a function. The ultimate objective is to select a potential WLF that is logical, collectable, relatable, predictable/programmable, and not within the control of the function. Of these attributes, the two significant WLF attributes are:

13.2.4.1. Relatability. The potential WLF logically and statistically relates to manpower requirements to the extent any change in the value of the WLF produces a corresponding change in the man-hours or manpower needed to do the work (i.e., as the volume of work increases, so do required man-hours or manpower). Relatability presents a difficult problem because accurate data for correlation analysis is rarely available early in the effort. Identification of potential WLFs should begin during preliminary research.

13.2.4.2. Predictability. To make the equation useful as a forecasting tool, the quantification of the WLF value should be programmable (i.e., programmed in the DAF budget, or can reasonably be predicted for future time periods). Identify the predictability of a factor by examining available functional information.

13.2.4.3. Relationships Between Attributes. WLF selection can be challenging due to the relationship that often exists between accuracy and programmability. With a highly finite, precisely defined WU, there is a high probability of correlation, but the chance of predicting the future workload volume is usually small. As the definition of the WU is broadened into a WLF, the chance of accurately predicting the future volume increases, but the likelihood of getting an acceptable degree of correlation goes down.

13.2.5. Procedures for Defining Potential WLFs. WLFs should be both accurate and programmable. Factors which are also used for programming are preferred over those which are not. However, do not sacrifice accuracy for programmability in developing the equation. When needed, a separate equation can be developed for programming manpower requirements. Identify potential WLFs using the following procedures:

13.2.5.1. Identifying Factors. First, identify external or work generator-type factors. Typical examples are: number of aircraft assigned; average monthly flying hours flown; or military population served. All of these examples also have the advantage of being programmable.

13.2.5.2. Review WUs. Second, refer to WUs identified during analysis of outputs of the work center (i.e., those associated with processes with the greater man-hour requirement).

These are the internal or production-type WUs such as a jet engine overhauled, an airframe repaired, an item issued, or a form processed.

13.2.5.3. Review Potential WLFs. Prepare a list of the potential WLFs identified from the above procedures, listed in the order of development (i.e., the external or work generator-type, first). Leave out any potential WLFs that are not readily identified or easily counted, and any internal ones that are relatively insignificant. To obtain valid counts for all the potential WLFs during measurement, define the potential WLF:

13.2.5.3.1. Title. Briefly identify what is to be counted. Use singular noun form, verb past tense (e.g., should read “vehicle repaired”, not “vehicles repaired”).

13.2.5.3.2. Definition. Define, in precise terms, the WLF. Vague definitions are not acceptable. From the title example above, what types of vehicles are to be counted? For another example, if population served is the potential WLF, clearly state whether the count includes tenants, on-base population, off-base population, transients, average daily student load, Reserve, National Guard, and/or individual mobilization augmentees.

13.2.5.3.3. Source of Count. Specifically identify the source from which the count is to be obtained. It is critical that workload data is collected from the same exact source.

13.2.5.3.4. Method of Count. Once the source of count has been found, how is the potential WLF counted? Is the WLF count a monthly average over the past 6 to 12 months? Is it a current account of primary aerospace vehicle (aircraft) inventory (PAI) supported? Are there specific counts excluded? Ensure the WLF count can be adequately counted and reported.

13.2.5.3.5. Rationale. Include the reasons for selecting WUs or WLFs. Describe how and why the selected WUs or WLFs are expected to relate to the measured man-hours or manpower.

13.2.5.3.6. After Selection. Once a WLF is selected for use in the requirements determinant, the preceding WLF title, definition, source of count, and method of count are revised as needed to ensure accuracy and placed in the equation.

13.2.6. Workload Data Collection and Analysis. When possible, work count procedures should call for a minimum of six months historical data, although 12 months of data are preferred. Additional years of data can assist in analysis of trends and/or peaks and valleys in volume. (**Note:** Work count should be collected by month and not averaged for the period.) Validate as representative before use in further analysis.

13.2.6.1. Establishing a Work Count System. Ideally, there are existing resource management systems, output measurement programs, or management information systems from which the data can be obtained. Existing reporting systems should be validated to ensure accurate workload information. When acceptable workload counts are not readily available, work with the functional OPR to establish a work count system.

13.2.6.2. Collection System. The collection system should be established as early as possible in the development, and only address workload data essential to equation development (and, possibly for future requirements determinant application).

13.2.6.3. Safeguards. Establish safeguards (e.g., a random external audit of the workload reports) to minimize the possibility of a duplicated or missed count, or a non-representative count.

13.2.6.4. Potential Equivalent WLFs. To increase overall standard accuracy and ease of requirements determinant application, consider the use of equivalent WLFs. An equivalent WLF is used to get a count for similar work that has different workload content (i.e., PATs). See below for an example of establishing an accurate work count system using equivalent WLFs.

13.2.6.4.1. Consider the WLF "a vehicle maintained for a vehicle maintenance unit." To produce a more accurate accounting of the WLF consider using equivalents to accurately portray the workload associated with the preventative maintenance on a sedan versus a truck.

13.2.6.4.2. Suppose during work measurement, it was determined it takes 120 man-hours to service a truck compared to 100 man-hours to service a sedan. Since the vehicle mix may vary considerably from location to location, the use of vehicle equivalencies may be the correct way to calculate the accurate manpower for total vehicles maintained for any given installation.

13.2.6.4.3. Using the PAT relationship to establish a mathematical equivalency between truck and sedans, the following equality can be established:

$$\frac{120\ man\text{-}hours}{truck} = \frac{100\ man\text{-}hours}{sedan}$$

13.2.6.4.4. When this type of WLF is used, a baseline output is valued at 1.0, (in this case the sedan is given a 1.0) and the other outputs are valued in relation to this baseline (i.e., the truck could be given a 1.2).

13.2.6.4.5. The total WLF count is obtained by adding all equivalents (i.e., (10 sedans x 1.0) + (5 trucks x 1.2) = 16.00 total equivalents).

13.2.6.4.6. Identify potential equivalent WLFs early. Data collection should be designed to allow creation of equivalent values. Remember, the time value of the measurement should be the same for all vehicles used in the equivalent, and it should be equal to the baseline output (in this case the sedan). This is necessary because the WLF value is being adjusted to compensate for the differences in time needed to service the sedan and the truck.

13.2.7. Result. The end result of C&R is only as good as the logic and data the analysis is based upon. Dedication to the fidelity of the input data is requisite for a good result.

13.3. Developing a Correlation and Regression Model. The basic steps for developing regression equations are similar regardless of the final manpower model selected. However, C&R calculations can become more complex depending on equation form, and the number of potential WLFs regressed in the case of multivariate regression.

13.3.1. Although C&R analysis is truly two separate processes, these calculations are usually both performed to provide a more complete picture. **Note:** Although the Air Force MEP has traditionally used the acronym C&R, in actuality, regression analysis is performed first with correlation analysis evaluating the resulting regression line’s goodness of fit.

13.3.2. Regression analysis involves the pairing of a dependent variable with an independent variable(s) to define a mathematical relationship (i.e., regression fits a line to the data that may be described mathematically, with an equation).

13.3.2.1. For example, this process involves pairing the measured and/or calculated man-hours (Y_m) required on the vertical (or Y) axis) with the data of an independent variable on the horizontal (or X) axis). **Note:** In reality for multivariate regression, as more independent variables are added, multiple axes are paired with the Y-axis.

13.3.2.2. The regression analysis ultimately yields a man-hour equation (Y_c), in a linear or curvilinear form, that can then be used for the prediction of manpower requirements under varying workload within specified extrapolation limits. For example, regression analysis might yield the following a man-hour equation, where Y_c is the regression equations calculated required man-hours and X_1 is a WLF, such as PAI, supported by the work center:

$$Y_c = 28.61 + 104.6X_1$$

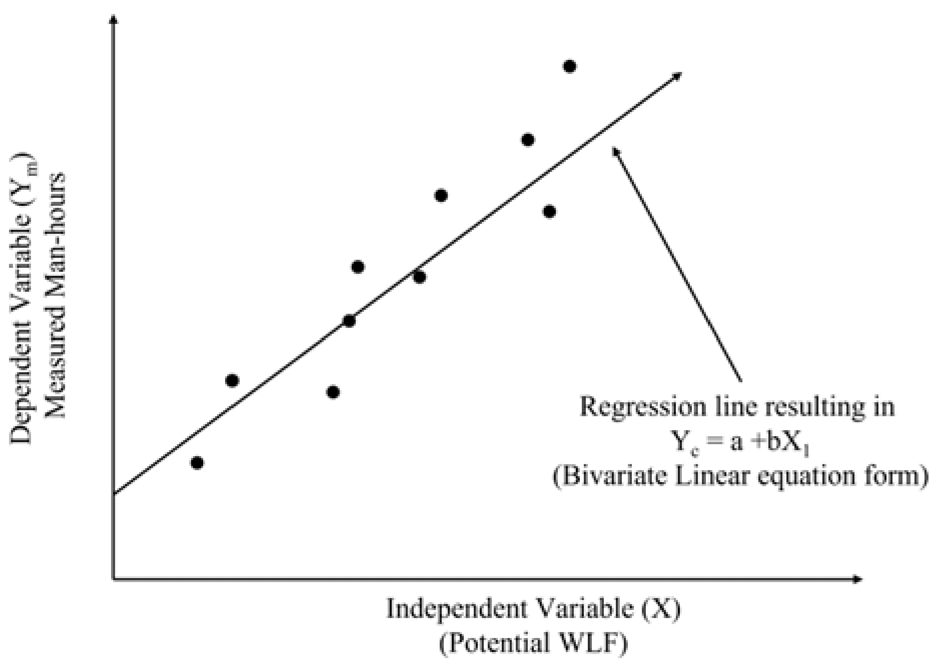
13.3.2.3. For instance, in the case of a work center servicing 18 aircraft (PAI), this example man-hour equation would yield 1911.41 required direct man-hours.

$$Y_c = 28.61 + 104.6X_1$$

$$= 28.61 + 1882.80 = 1911.41$$

13.3.2.4. **Figure 13.1** shows a scatter diagram with a regression line drawn to fit the paired data (X, Y_m). **Note:** Although FTEs instead of man-hours can be used in the development of an equation, this approach is generally not recommended due to updates in MAFs that change the hours required to earn FTEs.

Figure 13.1. Scatter Diagram Pairing a Single Independent and Dependent Variable with Regression Line Shown.



13.3.3. Correlation analysis, on the other hand, is the process of calculating key statistics about the regression equation. These key correlation statistics and tests give an indication of just how good the regression equation predicts manpower requirements.

13.4. Manpower Models Derived via Regression Analysis.

13.4.1. Types of Models. Acceptable models resulting from a C&R analysis can be classified as one of the following categories:

13.4.1.1. Bivariate model (using a single WLF) or multivariate model (using multiple WLFs).

13.4.1.2. Linear model (an equation resulting in a straight line) or curvilinear model (an equation whose function does not result in a straight line, i.e., the equation's line curves).

13.4.2. Equation Forms. Manpower models derived via regression analysis can be identified by the equation forms as:

13.4.2.1. Linear bivariate model (a general linear form).

13.4.2.2. Linear multivariate model (a general linear form).

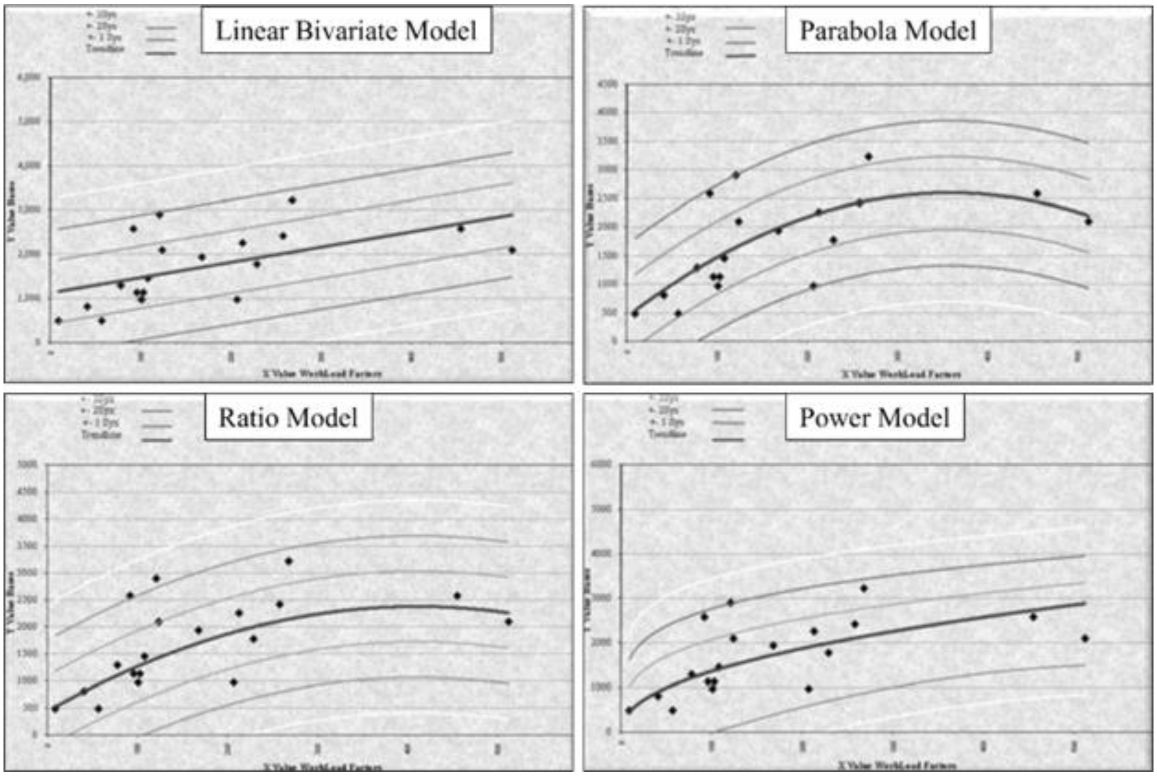
13.4.2.3. Parabolic model (a special bivariate, curvilinear form).

13.4.2.4. Power model (a special bivariate form).

13.4.2.5. Ratio model (a special bivariate form).

13.4.3. Model Example. **Figure 13.2** shows linear bivariate, parabola, ratio, power equation models, all using the same data.

Figure 13.2. Regression Model Examples.



13.4.4. General and Special Mathematical Equation Forms. The general and special mathematical equation forms of the most common manpower models created by regression analysis are provided in **Table 13.1**. In each equation, the dependent variable (Y_c) represents man-hours, and the independent variable (X) or variables (in the case of multivariate regression), represent WLF volume(s).

Table 13.1. General and Special Equation Forms.

General Equation Forms		
Model	**Description**	**Equation Form**
Linear Bivariate Model	Simplest and most direct relationship between the dependent and independent variable.	$Y_c = a + bX$
	Shows a constant slope (*b*) in a line.	
	Has 2 coefficients, *a* and *b*.	
Linear Multivariate Model	Used when more than one independent variable is appropriate to create a useful manpower model.	$Y_c = a + b_1X_1 + b_2X_2 + \ldots b_nX_n$
Special Equation Forms		
Model	**Description**	**Equation Form**
Parabolic Model*	A relationship between 2 variables that allows for a change in the way *X* is influencing *Y*.	$Y_c = a + bX + cX^2$
	Allows the line to curve up if the value of *c* is positive, or down if the value of *c* is negative.	
	Has 3 coefficients; *a*, *b*, and *c*.	
Power Model	An exponential curve that requires both the dependent and independent variables to be transformed.	$Y_c = aX^b$
	To make linear, transform the equation by taking the log of each side. The resulting equation becomes $\log Y = \log a + b(\log X)$	
Ratio Model*	A hyperbolic curve that requires the dependent variable to be transformed.	$Y_c = \frac{X}{a + bX}$
	To make linear, transform the equation by taking the reciprocal of both sides of the equation and then multiply each side by *X*. The resulting equation becomes $\frac{X}{Y} = a + bX$	
	Has 2 coefficients: *a* and *b*	
* For manpower purposes, these models are only useful until the apex of the data, since it is unrealistic for workload to increase and man-hours to decrease		

13.4.5. Further Discussion of the Use of Special Equation Forms.

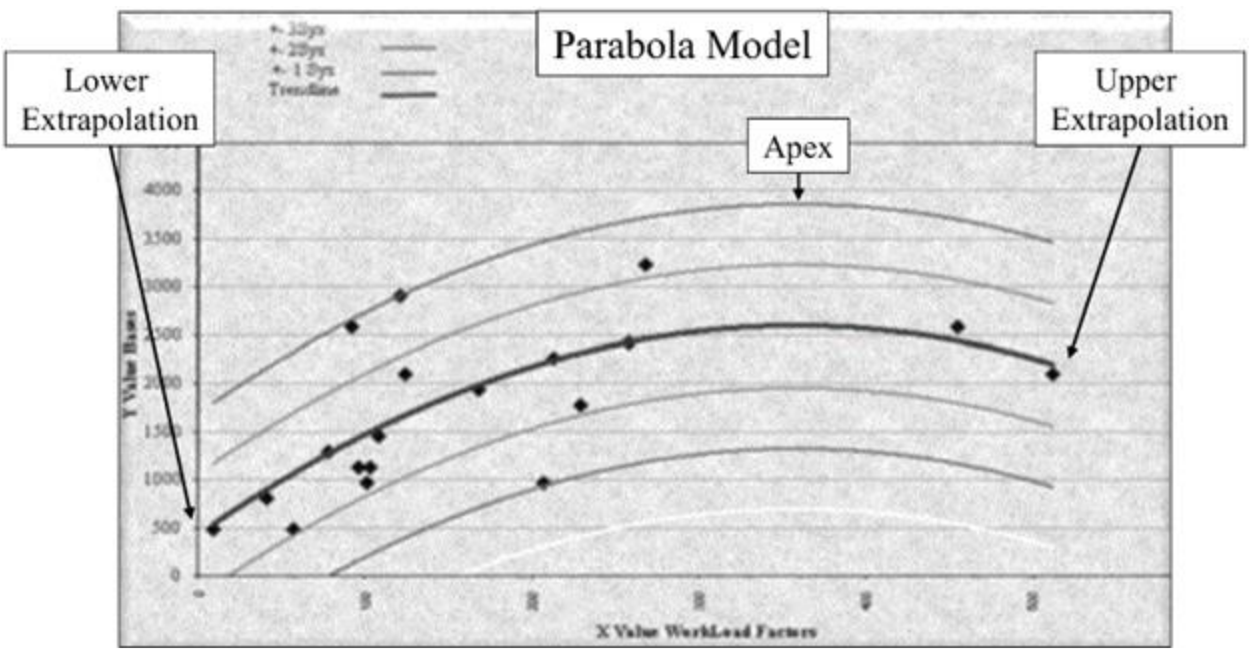
13.4.5.1. The power, ratio, and parabola are models that show a general deceleration in the rate (i.e., slope) at which manpower is increased for increased workload. In effect, acceptable curvilinear regression models show a certain economy of scale in a work center's required manpower as the WLF volume increases.

13.4.5.2. While the ratio and power curves are legitimate mathematical forms, each cannot be directly compared statistically to the linear and parabolic forms because of the data transformations involved. These data transformations change the distributional properties upon which the statistical tests are based.

13.4.5.2.1. Therefore, use the power and ratio models with caution and use when a parabola fits the data better than a linear equation and the apex is either within or just outside the data range.

13.4.5.2.2. A comparison of the models shown in **Figure 13.2** demonstrates that a parabola model form fits the data better than a linear equation, and the resulting parabola's apex is within the data's extrapolation range. In this case, since the parabolic model's apex occurs prior to the upper extrapolation limit (see **Figure 13.3**), the equation's slope becomes negative; and thus, required manpower illogically decreases as workload increases. In this case, one of the special equation forms may still represent the curvilinear nature of data in the same manner as the parabola but without the issue of the parabola model's apex.

Figure 13.3. Parabolic Equation with Apex within Extrapolation Limits.



13.4.6. Understanding the Regression Coefficients. The regression coefficients for the different regression model forms, are the values resulting from regression analysis computations to form the regression equation. **Figure 13.4** shows a synopsis of the various equation forms discussed up to this point, with the last column showing the total number of coefficients realized for the linear bivariate, parabolic, ratio, and power curve as well as two examples of a linear multivariate form. (**Note:** Any given multivariate form could have more than three *X* variables if more than three potential WLFs need to be explored.)

Figure 13.4. Relationships Between Equation Forms and the Regression Analysis Terms.

Model Form	Terms Used in Regression Analysis	Number of Regression Coefficients
Linear	$Y = a + b X$	2 (a, b)
Parabolic	$Y = a + b X + c X^2$	3 (a, b, c)
Multivariate (2 independent variables example)	$Y = a + b_1 X_1 + b_2 X_2$	3 (a, b_1, b_2)
Multivariate (3 independent variables example)	$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3$	4 (a, b_1, b_2, b_3)
Power (after transformation)	$\log Y = \log a + b (\log X)$	2 (log a, b)
Ratio (after transformation)	$\frac{1}{Y} = b + a \left(\frac{1}{X}\right)$	2 (b, a)

Regression Coefficients
Dependent Variable
Independent Variables

13.4.6.1. The *a*-value represents the point where the regression line crosses the y-axis. The *a*-value should never be referred to as the *open-the-door cost* or fixed man-hours. Rather, the *a*-value is simply the *y*-intercept determined through regression computations and helps account for some of the unexplained variation within the equation.

13.4.6.2. Each *b*-coefficient of the individual independent variable(s) represents an amount of influence from its corresponding *X*-variable given that all of the other independent variables are held at a constant value. For example, the coefficient value b_1 for X_1 in the bivariate equation $Y_c = a + b_1X_l$ would not have the same coefficient value estimated for the same X_1 in the multivariate equation $Y_c = a + b_1X_1 + b_2X_2$, since the additional WLF (X_2) now comes into consideration.

13.4.7. Meeting Minimal Statistical Criteria for Manpower Models Developed Using C&R. Requirements determinant equations developed by the study team using regression analysis must meet certain minimum correlation statistical requirements. (**T-2**) These minimal requirements are shown in **Table 13.2**. Additionally, each requirements determinant equation must meet the realistic and economic test criteria as shown in **Table 13.3** (**T-2**)

Table 13.2. Minimal Statistical Criteria for Equations Developed Using C&R.

Statistical Criteria	Minimum Value
Coefficient of Determination (R^2) (used for all bivariate equation forms)	$R^2 \geq 0.70$
Coefficient of Determination (Adjusted R^2) (used for all multivariate equation forms)	Adjusted $R^2 \geq 0.70$
Coefficient of Variation (V)	$V \leq 0.25$

Table 13.3. Realistic and Economic Test Criteria.

The manpower model		is realistic when	is economic when
Linear	$Y = a + bX$	$b > 0$	realistic criteria is met
Parabola	$Y = a + bX + cX^2$	$b > 0$ and $X_u \leq -b/2c$ where X_u = WLF	$c < 0$
Power	$Y = aX^b$	$a > 0$ and $0 < b < 1$	realistic criteria is met
Ratio	$Y = \frac{X}{a + bX}$	$a > 0$ and $b > 0$	realistic criteria is met

13.4.8. Least Squares Regression Analysis. This technique yields an equation (Y_c) that best fits the observed data (Y_m) by minimizing the total variation (i.e., the residuals) for the observed data above and below the regression line.

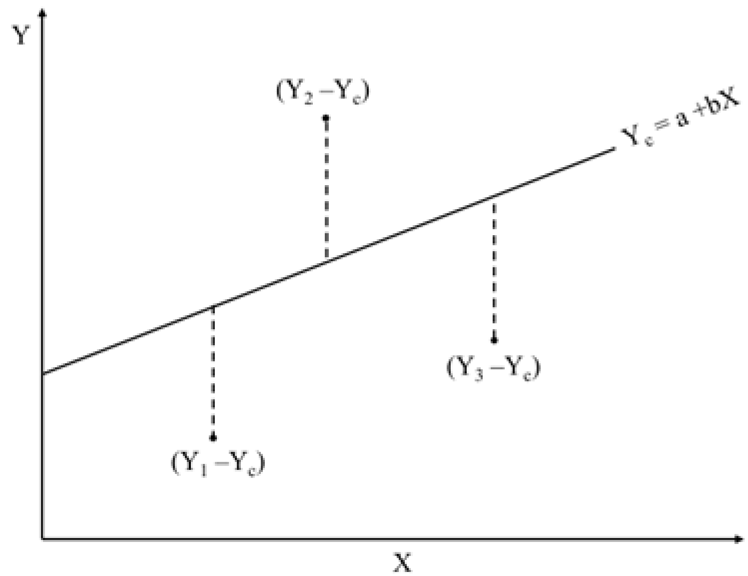
13.4.8.1. The residuals are defined as the difference between the observed and calculated man-hours (Y_m-Y_c). Assumptions regarding residuals follow:

13.4.8.1.1. Residuals are independent of each other. Residuals are normally distributed with zero mean and constant variation (i.e., which is saying that the data points are normally distributed around the regression line and as the *X*-values increase or decrease), the amount of dispersion stays constant and does not correspondingly go up or down. **Figure 13.5** provides a graphical depiction of the residual differences between the regression line and specific data points.

13.4.8.1.2. In order for an equation to qualify for linear regression analysis, it should be of the form $Y_c = a + b_1X_1 + b_2X_2 + ... + b_n X_n$, or be of a form that can be reduced to an equation of this type; that is, linear with respect to the regression coefficients (*b*). This qualification still allows for the transformation of the independent (i.e., WLF) variables (*X*) into a power (X^2), reciprocal ($1/X$), or *log X* as needed for an equation form.

13.4.8.1.3. The values of the independent variable(s) (i.e., the WLF(s)) can be measured with little or no variability.

Figure 13.5. Residual Differences Between Measured Data (Y_m) and the Regression Equation (Y_c).



13.4.8.2. Before performing least squares regression computations:

13.4.8.2.1. Verify the accuracy of the input data and purge it of any data collection errors. Tools such as control charts and scatter diagrams assist in determining if data are reasonable and logical.

13.4.8.2.2. Obtain at least the minimum number of required data points when performing C&R. The number of input points in regression analysis becomes important in testing the significance of the regression line.

13.4.8.2.3. Generally, the more input points that are used to determine the regression line, the more information that can be gained about the nature of the work center under investigation. To have a meaningful test, there should be enough data inputs to allow a good estimation of the variability within the data after the coefficients are estimated.

13.4.8.2.4. Never perform regression analysis on less than seven data points. 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 there is to add validity to the statistical test. The inputs should adequately portray the behavior of the data at various levels of workload. Understanding the nature of the data cannot be done with just a few data points.

13.4.9. Determining the Regression Coefficients and Equations. Use work measurement, data collection, and statistical software to develop an equation that meets the statistical criteria and model selection guidelines (see **Chapter 14**).

Part 6

COMPUTATION

Chapter 14

CORRELATION STATISTICS

14.1. General Concepts. Correlation statistics are needed to evaluate how well an equation (Y_c) represents the measured data (Y_m). These measures are essentially derived from the measures of the measured man-hour data's central tendency, the variation within the measured man-hours, and the regression equation itself.

14.2. Exploring a Linear Bivariate Equation.

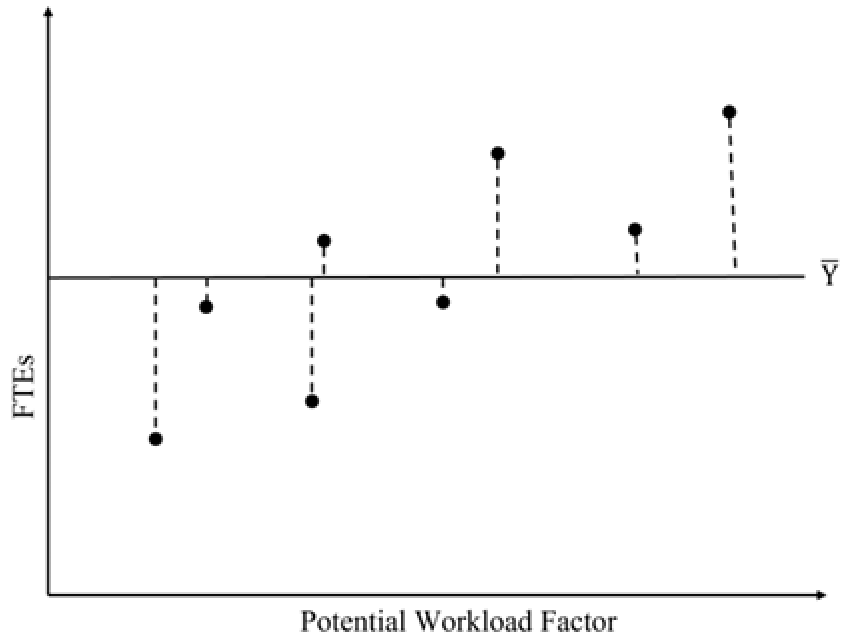
14.2.1. Linear Bivariate Data Example. **Table 14.1** shows the paired *X,Y* data (Y_m data here shown in FTE) and the resulting regression equation: $Y_c = 1.375 + 0.5333X$. **Table 14.1** further shows the calculated value (placing each *X* value into the equation to determine Y_c). (**Note:** This example is shown in FTEs for simplicity's sake, normally, all equations developed should remain in man-hours to accommodate the potential use of different MAFs during requirements determinants application.)

Table 14.1. Basic Relationship for Overall Statistics.

Potential WLF	**FTE**	**$Y_c = 1.375 + 0.5333X$**						
X	Y_m	Y_c	$(Y_m-\bar{Y})$	$(Y_m-\bar{Y})^2$	$(Y_c-\bar{Y})$	$(Y_c-\bar{Y})^2$	(Y_m-Y_c)	$(Y_m-Y_c)^2$
3	2	2.975	-5.375	28.891	-4.400	19.361	-0.975	0.950
8	4	5.641	-3.375	11.391	-1.734	3.005	-1.641	2.694
5	6	4.042	-1.375	1.891	-3.334	11.112	1.959	3.836
9	8	6.175	0.625	0.391	-1.200	1.441	1.825	3.332
13	6	8.308	-1.375	1.891	0.933	0.870	-2.308	5.326
14	10	8.841	2.625	6.891	1.466	2.150	1.159	1.343
18	9	10.974	1.625	2.641	3.599	12.956	-1.974	3.898
20	14	12.041	6.625	43.891	4.666	21.772	1.959	3.838
$\bar{Y} = 7.375$ $TSS = \Sigma (Y_m - \bar{Y})^2 = 97.875$ $SSR = \Sigma (Y_c - \bar{Y})^2 = 72.666$ $SSE = \Sigma (Y_m - Y_c)^2 = 25.217$								

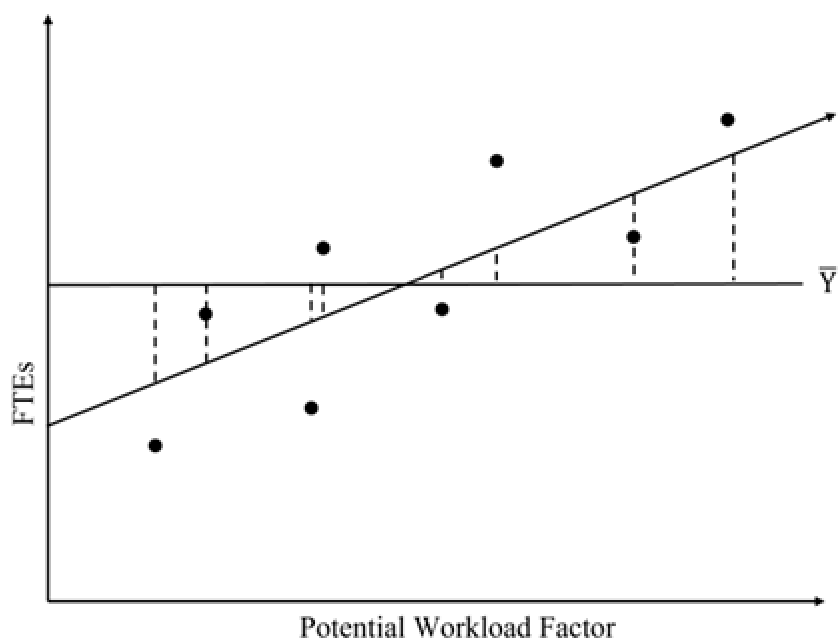
14.2.2. Total Sum of Squares (TSS). When the data contained in the *X*-values are not used for prediction purposes (i.e., just the Y_m-values are used), the best prediction of a new *Y*-value is simply the measure of central tendency ($\bar{Y}$). Hence, the total variation within the system is associated with the TSS deviations of the *Y*-values about its own mean ($\bar{Y}$). The equation to calculate TSS is as follows, $TSS = \sum(Y_m - \bar{Y})^2$. Data in **Table 14.1** shows that TSS = 97.875. **Figure 14.1** depicts the computations graphically.

Figure 14.1. Graph Depicting TSS, Delta Between the Y_m and the Mean ($\bar{Y}$).



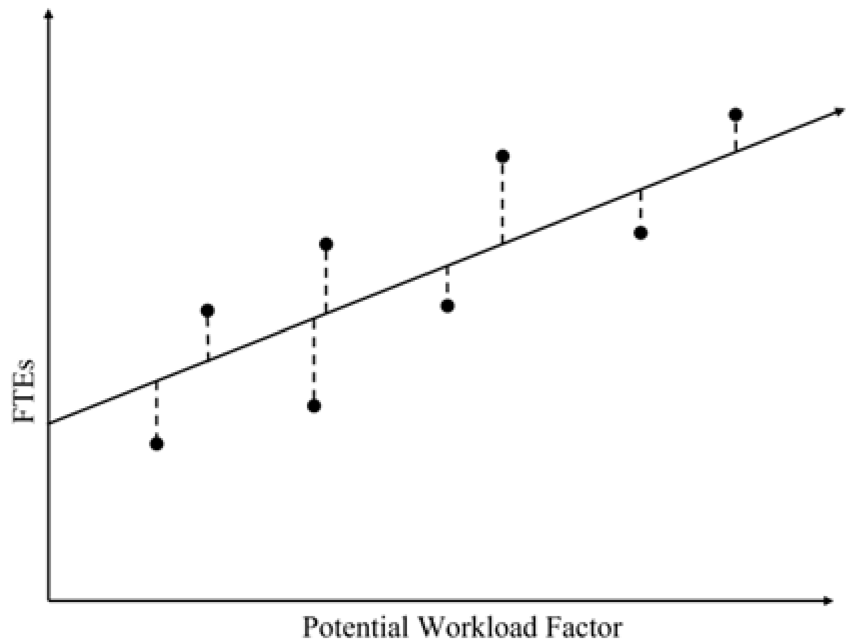
14.2.3. Sum of Squares Explained by Regression (SSR). When the data contained in the *X*-values is used to form a prediction equation (such as, $Y_c = a + bX$), the best estimate of a new *Y*-value is Y_c instead of $\bar{Y}$. The variation in the system is reduced by using Y_c. The amount of reduction is defined as the SSR. The degrees of freedom for SSR are (*m*-1). The equation to calculate SSR is as follows, $SSR = \sum(Y_c - \bar{Y})^2$. Data in **Table 14.1** shows that SSR = 72.666. **Figure 14.2** depicts the computations graphically.

Figure 14.2. Graph Depicting SSR, the Delta Between the Y_c and the Mean ($\bar{Y}$).



14.2.4. Sum of Squares Unexplained by Regression (SSE). The remaining variation in *Y* is defined as the SSE. Here, the word "unexplained" is used only to indicate that the relationship between *X* and *Y* is not completely explained mathematically by the calculated regression line. The equation to calculate SSE is as follows, $SSE = \sum(Y_m - Y_c)^2$. Data in **Table 14.1** shows that SSE = 25.217. **Figure 14.3** depicts the computations graphically.

Figure 14.3. Graph Depicting SSE, the Delta Between the Y_m and the Regression Line (Y_c).



14.2.5. Relationships between TSS, SSR, and SSE.

14.2.5.1. The sum of SSE and SSR equals TSS. This can be expressed mathematically as:

$$\sum(Y_m - \bar{Y})^2 = \sum(Y_c - \bar{Y})^2 + \Sigma(Y_m - Y_c)^2$$

or TSS = SSE +SSR

14.2.5.2. Dividing both sides of the equation by the TSS, results in two proportions that sum to 1.0:

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

$$1.0 = \frac{SSE}{TSS} + \frac{SSR}{TSS}$$

14.2.6. Coefficient of Determination (R-Squared). R^2 is defined as the proportion of the total variation (TSS) that is explained by the regression line:

$$R^2 = \frac{EXPLAINED\ VARIATION}{TOTAL\ VARIATION} = \frac{SSR}{TSS}$$

14.2.6.1. Determining the R-Squared. When the regression coefficients in the equation are estimated with the least squares method, a relationship needs to be calculated to determine the equation's goodness of fit.

14.2.6.2. The R-Squared Values Range from Zero to One. When the regression line explains most of the variation, R^2 approaches the value of 1.0. When there is a large amount of unexplained variation, i.e., a poor fit, R^2 approaches zero. An R^2 approaching zero, would visually appear as a shotgun pattern in a scatter diagram.

14.2.6.3. Example Computation of R-Squared. Using the data in **Table 14.1.**, SSR = 72.666 while TSS = 97.875. Computations of the R^2 will demonstrate that the regression equation explains 74.2% of the total variation.

$$R^2 = \frac{EXPLAINED\ VARIATION}{TOTAL\ VARIATION} = \frac{SSR}{TSS} = \frac{72.666}{97.875} = 0.742$$

14.2.7. The Coefficient of Correlation (r). The square root of the R^2 is defined as the coefficient of correlation (r), which ranges from -1.0 to +1.0. The sign of r is the same as the slope of the regression equation. This is determined by the sign of the b-coefficient in the linear model or can be seen in the scatter diagram.

$$r = \pm\sqrt{1 - \frac{SSE}{SSR}} = \pm\sqrt{1 - \frac{\sum(Y_m - Y_c)^2}{\sum(Y_c - \bar{Y})^2}}$$

14.2.8. Adjusted R-Squared. For multivariate regression analysis and dealing with sampled data, an adjustment to the R^2 value needs to be made that takes into consideration the sample size (n) and the number of regression coefficients (m) being tested to compensate for a potentially inflated R^2.

14.2.8.1. The adjusted R^2 is determined by the following formula:

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

14.2.8.2. For example, if a multivariate analysis yielded an R^2 value of 0.874 using 14 data inputs (n) and regressing 5 test potential WLFs, the adjusted R^2 value would be:

$$Adjusted\ R^2 = 1 - (1 - R^2)\left(\frac{n-1}{n-m}\right) \xrightarrow{yields} 1 - (1 - 0.874)\left(\frac{14-1}{14-5}\right)$$
$$= 1 - (0.126)\left(\frac{13}{9}\right)$$
$$= 0.765$$

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

14.2.9.1. The S_y is determined by the following formula:

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

14.2.9.2. This equation for S_y is the same as the equation for the sample standard deviation (s), even though they look different. When basic algebraic procedures are used, this expression can be put in a form that is easier to compute:

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

14.2.10. Standard Error of the Estimate (S_{yx}). When SSE is divided by the appropriate 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 (S_{yx}):

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

14.2.10.1. Using the data from **Table 14.1**., SSE = 25.217 and n = 8. There are two regression coefficients (a and b) in the bivariate equation of $Y_c = 1.375 + 0.5333X$ with m = 2. This leaves 6 (8-2) degrees of freedom. Placing this information into the formula, S_{yx} is calculated as:

$$S_{yx} = \sqrt{\frac{SSE}{n-m}} = \sqrt{\frac{25.217}{8-2}} = 2.05$$

14.2.10.2. The S_{yx} is used to calculate the coefficient of variation (V).

14.2.11. 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 (V) is defined as the standard error of the estimate divided by the average measured man-hours.

14.2.11.1. The V is determined by the following formula:

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

14.2.11.2. Using the data in **Table 14.1**., $\bar{Y}_m$ = 7.375 and S_{yx} = 2.05 as determined in **paragraph 14.2.10.1**. The coefficient of variation (V) is calculated as:

$$V = \frac{S_{yx}}{\bar{Y}_m} = \frac{2.05}{7.375} = 0.278$$

14.3. Significance Tests. Regression analysis incorporates significance testing which is used to measure the reliability of either the sample regression coefficients, the sample R^2, or both. The reliability aspect is pertinent, because the input data (Y_m) are only a sample of values usually taken from an infinitely large population.

14.3.1. The F-test. To be useful in prediction, an equation needs to explain or account for more of the variability in the man-hours than is left unexplained. The F-test is a significance test used for this determination. To accomplish the F-test, two values are needed: the test statistic (F) and the critical value (F*).

14.3.1.1. The test statistic (F) is the ratio of the variation explained by regression to the unexplained variation. These variances are obtained by dividing appropriate sum of squares with the respective degrees of freedom. Notice that because of the relationship between SSR and R^2, this test statistic can be derived from either value. Notice also that when the double fraction is simplified (as in the first part of the relationship) the degrees of freedom for the numerator (m-1) appear in the denominator (as in the second part). The same switch occurs with the degrees of freedom for the denominator (n-m).

$$F = \frac{SSR/(m-1)}{SSE/(n-1)} = \frac{SSR(n-m)}{SSE(m-1)} = \frac{SSR/TSS(n-m)}{SSE/TSS(m-1)}$$

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

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

14.3.1.3. The critical value for the F-test, [F* = F(1−∝, −1, −)], comes from the F-Table (see **Attachment 2**).

14.3.1.3.1. First determine the confidence level desired (80 percent, 90 percent, or 95 percent confidence) and choose the appropriate F-Table (see **Attachment 2**). **Note:** The C&R APPLICATION TOOL defaults to 80 percent confidence.

14.3.1.3.2. Next find the degrees of freedom for the numerator (m-1) arrayed across the top of each of the tables. The degrees of freedom for the denominator (n-m) are listed down the left-hand side of the tables. Cross-reference both the degrees of freedom for the numerator with the degrees of freedom with the denominator to obtain F*.

14.3.1.3.3. For example, if the analyst wished to be 80 percent confident, and the data and regression analysis yielded 12 degrees of freedom in the numerator and 30 degrees of freedom in the denominator, using **Table A2.1**, the F* value = 1.446.

14.3.1.4. If the test statistic is larger or equal to the critical value (F ≥ F*), the equation explains a significant amount of variation in the sampled man-hours.

14.3.1.5. For example, an analyst has performed an initial C&R analysis using 30 samples (*n*) and four potential WLFs (*m*) and achieved a coefficient of determination (R^2) value of 0.8728.

14.3.1.5.1. Step 1. First, calculate the F-value.

$$F = \left(\frac{R^2}{1-R^2}\right)\left(\frac{n-m}{m-1}\right) = \left(\frac{0.8728}{1-0.8728}\right)\left(\frac{30-4}{4-1}\right) = 59.468$$

14.3.1.5.2. Step 2. Using **Table A2.1** (at 80 percent statistical confidence, ∝ = 0.20), with 3 (m-1) degrees of freedom in the numerator, and 26 (n-m) degrees of freedom in the denominator, to get an F* value of 1.660.

14.3.1.5.3. Step 3. Since F ≥ F * (59.468 ≥ 1.660), at least one or more of the coefficients is significantly different from zero, and the equation does explain a significant amount of variation in the sampled man-hours.

14.3.2. The t-test. The individual coefficients of an equation must also be significantly different from zero to keep the associated factor in the equation. This determination is made with a t-test. A variable whose coefficient is not different from zero (not significant) contributes virtually nothing to the prediction equation. As with the F-test, a test statistic and a critical value are needed to perform this test.

14.3.2.1. To calculate the test statistic for multivariate coefficients (t_{bi}) use the following equation:

$$t_{b_i} = \frac{b_i}{s_{b_i}}$$

14.3.2.1.1. In this equation, b_i is the regression coefficient in equation being tested and s_{bi} is the standard error of the slope of the equation for the individual coefficient being test.

14.3.2.1.2. The standard error of the slope is calculated using X_i, where X_i represents the particular tested coefficient's potential WLF values. The s_{bi} is determined by the following equation:

$$s_{b_i} = \sqrt{\frac{\frac{\sum(Y_m - Y_c)^2}{n-2}}{\sum(X_i - \bar{X})^2}}$$

14.3.2.1.3. The test statistic (t_{bi}) 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 those t-values (confidence levels) will be acceptable.

14.3.2.2. The critical value, [t* = t(1- α /2, *n*-1)], comes from the t-Table (see **Table A2.4**.). The significance level (1-α) is set at 80 percent which means alpha (α) = 0.20. This is based on the decision that to take a workload 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) the alpha-level is split and the critical value becomes [t* = t(0.90, n-1)]. The degrees of freedom for the t-test are the number of measurement samples less one (*n*-1).

14.3.2.3. If the test statistic (t) calculated from the data (considering it as an absolute value) is greater than or equal to the critical value (t ≥ t*), the coefficient in question is significantly different from zero and should be used in the equation.

14.3.2.4. For example, suppose an analyst is given 4 WLFs, with 10 samples for the data shown in **Table 14.2**.

Table 14.2. Example Data—t-Test Example.

Y_m	X_1	X_2	X_3	X_4
798.70	36	5431	88	645
1124.60	41	16342	210	1276
608.70	24	3839	62	389
491.20	24	16118	185	1034
576.80	32	6393	108	1100

1607.50	48	3217	72	1284
889.70	35	3012	95	753
363.30	12	2014	48	239
704.00	33	6932	91	480
1300.00	44	4102	81	799

14.3.2.4.1. To obtain the necessary information to calculate the t-test statistic for each coefficient, develop the man-hour equation using multivariate regression to determine the individual coefficients and calculate the SSE:

$$Y_c = -112.05 + 30.913X_1 + 0.008916X_2 - 2.668X_3 + 0.1986X_4$$
$$b_1 = 30.913 \quad b_2 = 0.008916 \quad b_3 = -2.668 \quad b_4 = 0.1986$$
$$SSE = \Sigma(Y_m - Y_c)^2 = 189562$$

14.3.2.4.2. Step 1. Find the standard error of the slope of the equation for the first coefficient tested, with *n* = 10:

$$s_{b_1} = \sqrt{\frac{\frac{\sum(Y_m - Y_c)^2}{n-2}}{\sum(X_1 - \bar{X})^2}} = \sqrt{\frac{\frac{189562}{10-2}}{1026.9}} = 4.8036$$

14.3.2.4.3. Step 2. Calculate the t-test statistic for the first coefficient being tested:

$$t_{b_1} = \frac{b_1}{s_{b_1}} = \frac{30.913}{4.8036} = 6.435$$

14.3.2.4.4. Step 3. Using **Table A2.4** (at 80 percent statistical confidence), and with 9 (*n*-1) degrees of freedom, the t-value = 1.3830.

14.3.2.4.5. Step 4. Since $t_{b1} \geq t^*$ (6.435 ≥ 1.383), the coefficient b_1 is significantly different from zero and should be used in the equation.

14.3.2.4.6. Step 5. Repeat calculations in steps 1- 4 to find the t-test statistic for the second coefficient being tested:

$$s_{b_2} = \sqrt{\frac{\frac{\sum(Y_m - Y_c)^2}{n-2}}{\sum(X_2 - \bar{X})^2}} = \sqrt{\frac{\frac{189562}{10-2}}{246035476}} = 0.009814$$

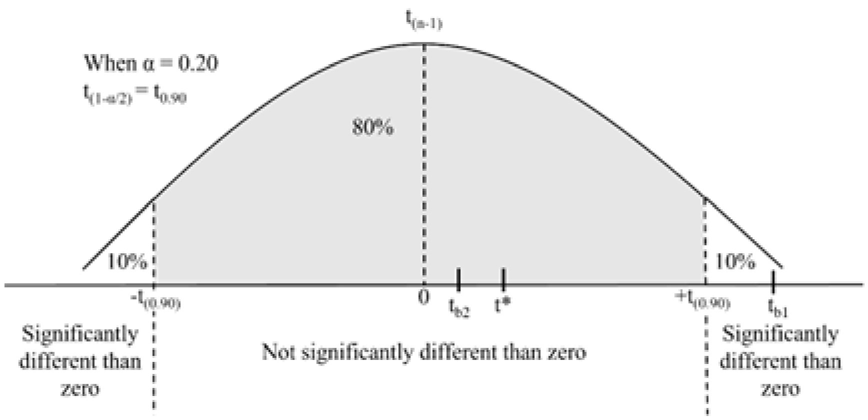
$$t_{b_2} = \frac{b_2}{s_{b_2}} = \frac{0.008916}{0.009814} = 0.9085$$

14.3.2.4.7. Step 6. Since $t_{b2} \geq t^*$ (0.9085 ≥ 1.383), the coefficient b_2 is not significantly different from zero and should not be used in the manpower equation. (**Note:** In some instances, a functional community may be concerned a specific WLF be include in the final equation even if the coefficient failed the t-test. At the discretion of the analyst, the failed coefficient can be kept in the equation; however, this practice should be kept at a minimum since it drives additional cost of data collection for requirements determinant application with little effect.)

14.3.2.4.8. Step 7. Repeat, steps 1- 4, for the remaining test coefficients b_3 and b_4.

14.3.2.4.9. **Figure 14.4** shows the two tailed test and rejection areas for the null hypothesis when performing the t-test. (**Note:** The calculations of the t-test statistics for b_1 and b_2 for the example in Steps 1 through 6 are shown on the figure.)

Figure 14.4. Decision Rule for the t-Test.



14.4. Potential Problems Encountered When Doing C&R.

14.4.1. Sometimes during multivariate C&R analysis, two or more of the independent variables may be highly correlated with each other. This situation is called multicollinearity, and it is an undesirable condition. This means there are correlated independent *X*-variables adding similar (thus, little additional) information to the model.

14.4.1.1. Identifying Multicollinearity. Although the best defense against multicollinearity is applying logic early in the effort, the analyst can spot multicollinearity occurring by viewing and/or conducting the pairwise analysis and take appropriate action by not regressing these particular potential WLFs together.

14.4.1.2. Pairwise Analysis of WLF Values. The C&R APPLICATION TOOL provides a pairwise analysis of WLFs to assist analyzing the C&R results. This pairwise analysis regresses each WLF (X_i) against each of the other WLFs, resulting in a coefficient of correlation (r) as shown in the matrix in **Table 14.3**. The WLFs X_1-X_7 reveal a high degree of multicollinearity occurring between certain pairs.

Table 14.3. C&R APPLICATION TOOL Pairwise Analysis.

	Y	X1	X2	X3	X4	X5	X6
X1	0.5534						
X2	0.7850	0.6138					
X3	0.6315	0.4493	0.7246				
X4	0.2532	-0.1334	0.0288	0.3046			
X5	0.5903	0.5044	0.7950	0.8140	-0.0748		
X6	0.5111	0.4323	0.8298	0.8157	0.0995	0.8016	
X7	-0.1261	-0.1497	-0.1005	-0.0843	0.5998	-0.1199	-0.0387

14.4.2. Using only the statistic R^2 (coefficient of determination) as a measure of absolute "goodness" can be misleading when the number of coefficients is very near the number of input data sets. For example, three data points fit exactly an equation with three coefficients ($Y = a + bX + cX^2$), thus producing a misleading R^2 value of 1 (perfect correlation). The objective is to find an equation that accurately explains most of the variation within a system not to achieve a perfect mathematical fit.

14.4.3. While evaluating C&R results, the analyst needs to understand the difference between measured man-hours that are fixed (man-hours that remain constant relative to changes in WLF counts) and those that are variable (man-hours that do vary (positively) with changes in WLF counts). It is possible the statistical R^2 value can be improved and made more relevant by regressing only the measured variable man-hours that relate to a potential WLF and adding back the fixed man-hours as constant man-hours to the final man-hour equation.

14.5. Guidelines for Final Manpower Model Selection. After creating multiple manpower models, the analyst is often left with the task of evaluating one or more manpower equations for final posting in a requirements determinant. The final acceptance selection a manpower model for that work center needs a balance between several different factors.

14.5.1. Absolute Minimum Criteria for Selection. Any given model is required to first pass the following minimum criteria for selection as a manpower model:

14.5.1.1. All equations, regardless of equation form, are required to meet minimum statistical criteria previously outlined in **Table 13.2**. No further consideration can be given to those models that do not meet these criteria.

14.5.1.2. Equations should not have a high resultant *a*-value in a manpower model. A model is unacceptable when its *a*-value quantifies the majority of the work center's manpower requirement.

14.5.1.2.1. For example, examine the equation $Y = 540.52 + 0.0015X$ (where X = base military population). The equation's *b*-value when combined with the WLF (X) results in relatively insignificant man-hours; that is, an increase of 10,000 military personnel (i.e., the X-value) only creates 15 man-hours of additional required man-hours.

14.5.1.2.2. In this example, the slope of the regression line is basically flat, and therefore, the WLF has little effect on determining the work center's total man-hour requirement.

14.5.2. Additional Criteria for Selection. If one or more possible manpower equations remain after meeting the criteria outlined in paragraphs **14.5.1.1** and **14.5.1.2**, then the following criteria, in order of precedence, for selecting the final manpower model are as follows:

14.5.2.1. Model Impact. The prime consideration for any model selection is accuracy and if that accuracy is manifested through the equation's impact. Generally, those models with the higher R^2 and lower V values have the more favorable impact. However, always check this assumption against an actual equation application, and the lead and functional team's insight into the logic of the by-location impact.

14.5.2.1.1. A manpower equation's impact is judged by each location and not in the aggregate. In other words, the model's impact is logical and reasonable at each location where the model applies.

14.5.2.1.2. Judging a manpower equation by its aggregate impact, i.e., adding together all the manpower increases and decreases together for all affected bases in an effort, means little to the true accuracy of the requirements model.

14.5.2.2. Ease of Requirements Determinant Application. If two or more equations still continue to pass acceptable impact, the next model selection criteria is focused on ease of application. Specifically, consider the total workload in applying the determinant:

14.5.2.2.1. First, select equations with programmable WLFs (i.e., an equation with some or more programmable WLFs should be selected over equations with no or fewer programmable WLFs).

14.5.2.2.2. Next, if all is still equal, choose the equation with the fewest WLFs to reduce the workload involved with the collection of WLFs and equation application required.

14.5.3. Selecting the Simplest Regression Equation Form. If all other criteria still put the remaining potential manpower equations as equal, select the simplest equation beginning with linear bivariate, curvilinear bivariate, and finally linear multivariate.

14.5.4. Realistic and Economic Criteria. Equations that do not satisfy the realistic and economic criteria are not acceptable as requirement determinant models. Reasons why a model may not have the desired attributes include such things as incorrect input data, non-representative input data, limited range of workload values, two or more distinct levels of operation included in the data, non-standardization of the system, extreme values included in the data, and inappropriate model selection. Man-hour equation coefficients meet both the realistic and economic criteria when the *b*-coefficient is positive in the linear model ($Y = a + bX$). Increases in workload result in a constant positive increase in manpower.

14.5.4.1. In a multivariate model ($Y = a + b_1X_1 + b_2X_2 + \ldots + b_nX_n$), a given *b*-value may be negative; however, in all realistic scenarios, an increase in workload should yield a total increase in required man-hours.

14.5.4.2. In the parabolic model ($Y = a + bX + cX^2$), the *b*-coefficient is positive, and the value of cX^2 is negative, and workload values do not exceed the point where $X = -b/2c$ (i.e., the parabola's 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.

14.5.4.3. In the power model ($Y = aX^b$), the *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.

14.5.4.4. In the ratio model ($Y = X/(a + bX)$), the *a*-coefficient and *b*-coefficient are greater than zero.

14.6. Extrapolation Limits.

14.6.1. General Concepts. Extrapolation is defined as extending the regression line beyond the range of input data.

14.6.1.1. Any man-hour equations developed via C&R analysis techniques as well as man-hour equations developed via RUT equations, are bounded by extrapolation limits.

14.6.1.2. Man-hour equation extrapolation limits are established, at 25 percent 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.

14.6.1.2.1. Based upon the definition of the upper and lower extrapolation limits, sample large and small bases during equation selection. Getting large and small work centers in the original analysis allows for a wider (if not widest possible) application of the new requirements determinant.

14.6.1.2.2. Upper and lower extrapolations limits are established, as the MEP would assume too much risk in further presupposing an equation's behavior remains the same beyond the established extrapolation limits. For example, a function's manpower initially determined by a bivariate linear equation may truly become non-linear beyond a certain point.

14.6.2. Calculating Extrapolation Limits.

14.6.2.1. Determining the Upper Extrapolation Limit. To determine the upper extrapolation limit of the man-hour equation, the following formula is used, where Y_c is the largest calculated value based upon the original sample data to create the equation:

$$\text{Upper Extrapolation Limit} = \max Y_c \times 1.25$$

14.6.2.2. Determining the Lower Extrapolation Limit. To determine the lower extrapolation limit of the man-hour equation, the following formula is used, where Y_c is the smallest calculated value based upon the original sample data to create the equation:

$$\text{Lower Extrapolation Limit} = \min Y_c \times 0.75$$

14.6.2.3. Example Calculation. **Table 14.4** shows an example of the calculation of lower and upper extrapolation limits. The upper extrapolation limit is 25 percent above the highest value (Base E) and equals 2718.55 man-hours. The lower extrapolation limit is 25 percent below the smallest value (Base A) and equals 644.67 man-hours.

Table 14.4. Determining Extrapolation Limits Example.

$Y = -327.40 + 1.604X$ $R^2 = 0.954$ $V = 0.072$			
Base	**Y**	**WLF (X)**	**Calculated (Y_c)**
A	966.72	740	859.56
B	1127.83	980	1244.52
C	1772.31	1270	1709.68
D	1450.07	1100	1437.00
E	2094.55	1560	2174.84
F	966.72	8905	1100.16
G	2094.55	1500	2078.60
H	1772.31	122	1637.50

Lower Extrapolation Limit Calculation = min Y_c x *0.75*
859.56 x *0.75 = 644.67*
Upper Extrapolation Limit Calculation = max Y_c x *1.25*
2174.84 x *1.25 = 2718.55*

14.6.2.4. Final Requirements Determinant Range. The final applicability range of the requirements determinant is simply the range from the lower to the upper extrapolation limit.

Chapter 15

MODULAR EQUATIONS

15.1. 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 appropriate, nor needed for every work center, it does give visibility to the required man-hours for a work center by processes and may aid in the maintenance of the determinant man-hour equation. This advantage warrants careful consideration of the modular equation approach at the outset of any study effort. Specific guides for when and where to use this technique follow these general comments:

15.1.1. 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.

15.1.2. 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.

15.1.3. By virtue of design, calculate a "man-hour cost" associated with each process when using modular equations.

15.1.4. Modular equations make it easy to analyze a work center for "what-ifs."

15.1.5. Represent individual processes not performed at all locations with a standard at the process level. Development of variances is therefore eliminated.

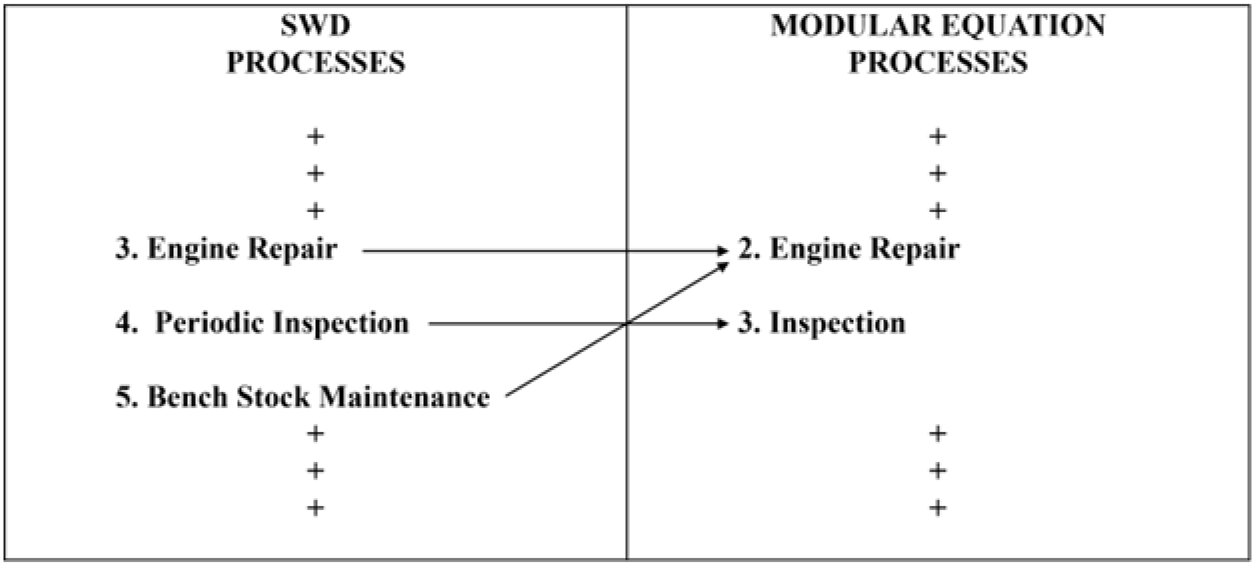
15.2. Specific Design Considerations.

15.2.1. The first and perhaps the most critical step in using a modular equation in requirements determination development is the preliminary 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 SWD. Limit the number of modules to a minimum to reduce the complexity involved in using such a determinant.

15.2.1.1. 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. In other words, 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.

15.2.1.2. See **Figure 15.1** for a simplistic example indicating a potential use for SWD processes in a modular equation.

Figure 15.1. Example Relationship between SWD and Modular Equation Processes.



15.2.1.2.1. In **Figure 15.1**., SWD 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.

15.2.1.2.2. SWD 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.

15.2.2. Each module should have at least one WLF that is logically and statistically related to the work described.

15.2.3. Each module must meet the minimum number of locations.

15.2.3.1. Only include modules of work that are present in at least seven of the work center locations. Any fewer is considered a variance or a small population.

15.2.3.2. Measure some locations with all modules present. This produces a more accurate statement of the required work.

15.3. Indirect Man-hours.

15.3.1. When OA is the primary measurement method, use the IAF to credit indirect man-hours. Use the IAF 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. Develop the IAF factor as follows:

$Y = (a + bX)(IAF)$

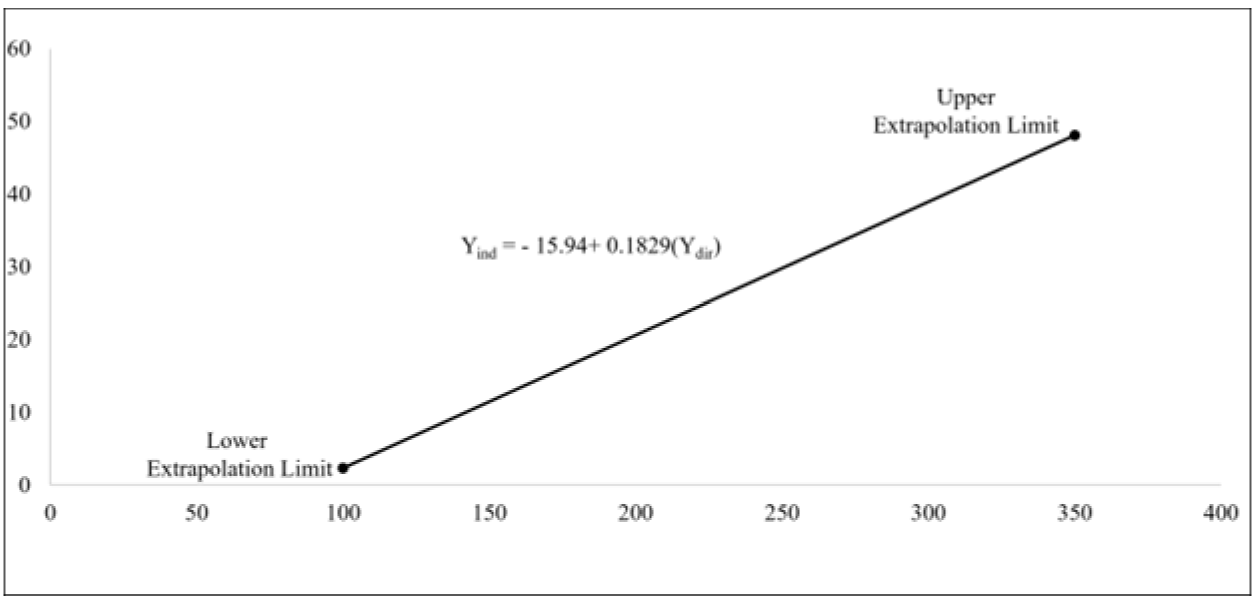
15.3.2. When WS is the primary measurement method in multi-location modular studies, use measured indirect man-hours to form a separate indirect module. Represent this with an equation that expresses the indirect man-hours as a function of the direct man-hours. Equation development and procedures outlined for OA also apply to WS.

15.3.2.1. The *b*-value in the linear case represents the proportion of indirect time to direct time. **Table 15.1** shows relationships between direct and indirect percentages. Use this information as a guide. In **Figure 15.2**, a typical indirect equation was computed to be: $Y_{ind} = -15.94 + 0.1829\ (Y_{dir})$. This allows an additional 18 percent (approximately) of the direct time for indirect work.

Table 15.1. 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	0.053
90	10	0.111
85	15	0.177
80	20	0.250
75	25	0.333
70	30	0.429

Figure 15.2. Graph of the Example Indirect Man-hour Equation.



15.3.2.2. 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 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.

$Y_c = -15.94 + (0.1829)(950.0) = 157.82$

15.4. Developing Modular Equations.

15.4.1. After a work center has met specific design considerations, develop a modular equation as follows:

15.4.1.1. 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 WU (end item). Using the output task lists, develop a SWD so each independent process becomes a module, and each module has its own WU. Structure the modules to account for all of the work described in the SWD. Be certain each process is included in one and only one module. Identify the relationship between the modules and the associated WLFs. To avoid confusion during equation computation, clearly specify all relationships from the beginning.

15.4.1.2. 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.

15.4.1.3. Step 3. Aggregate the data to the levels necessary for the separate modules.

15.4.1.4. Step 4. Perform regression analysis for each module. Keep the statistics (R^2, S_{yx}, and V) with each equation.

15.4.1.5. Step 5. Combine the information from each of the modules with the procedures.

15.4.2. An alternative to developing modular equations as described above is to use RUT. 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 RUTs of all of the measurement locations.

Chapter 16

RATIO UNIT TIMES DETERMINANTS

16.1. General Concepts. Utilization of RUT for development of requirements determinants has been expanded to include large populations, as well as single location and small population determinants. The decision to use RUT 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, RUT is 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. This chapter addresses development procedures to be followed when using RUT.

16.1.1. Population Definition.

16.1.1.1. Single location is applicable when the function under study is specific to one location, or the service furnished (mode of operation) is very different from other locations.

16.1.1.2. Small population is defined as a population consisting of two to six locations.

16.1.1.3. Large population is defined as a population of seven or more locations. (**Note:** It is possible that large populations can be broken down to smaller populations based on analysis of workload data).

16.1.2. Input Data.

16.1.2.1. 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.

16.1.2.2. When using OA as the primary measurement method, get multiple time estimates to find the best representation of the per accomplishment times (see **Chapter 5**). Evaluate these measurements carefully, using available statistical analysis techniques.

16.1.2.3. Accuracy is also critical when WS is selected as the prime measurement method (see **Chapter 24**).

16.2. Ratio Unit Times.

16.2.1. 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: The IAF is not used in WS; therefore, the final equation developed using WS does not need adjustment.

16.2.2. Equations developed by RUT take one of two forms, depending on whether or not the fixed man-hours are separated from the variable man-hours.

16.2.2.1. 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 the respective WLFs.

16.2.2.2. The second equation form is $Y = b_1X_1 + b_2X_2 + \ldots + b_nX_n$ and is the same as the first equation except there is no *a*-value. Use of the second equation is optional.

16.2.2.3. Associate variable man-hours with processes or steps that are expected to show a relationship with the selected WLF.

16.2.2.4. An example of using RUT for a single location determinant with the first equation form is shown in **Table 16.1**.

Table 16.1. Instructions for the Single Location Ratio Unit Times.

<table>
<tr><th>Step</th><th>Action</th><th colspan="4">Example</th></tr>
<tr><td>1</td><td>Select the man-hour model.</td><td colspan="4">$Y = a + b_1X_1 + b_2X_2 + b_3X_3$</td></tr>
<tr><td rowspan="7">2</td><td rowspan="7">Classify measured direct man-hours as fixed or variable.</td><td rowspan="2">WLF</td><td rowspan="2">AVG WLF COUNT</td><td colspan="2">MAN-HOURS</td></tr>
<tr><td>FIXED</td><td>VARIABLE</td></tr>
<tr><td>1</td><td>10.20</td><td></td><td>65.07</td></tr>
<tr><td>2</td><td>15.50</td><td></td><td>199.00</td></tr>
<tr><td>3</td><td>5.00</td><td></td><td>134.65</td></tr>
<tr><td colspan="3">TOTAL</td><td>398.72</td></tr>
<tr><td colspan="4">TOTAL MAN-HOURS = 47.00</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Divide the variable man-hours (V_i) by their associated WLF count (X_i) to determine a ratio (b_i) for each WLF.</td><td colspan="4">$b_1 = \frac{V_1}{X_1} = \frac{65.07}{10.20} = 6.379$</td></tr>
<tr><td colspan="4">$b_2 = \frac{V_2}{X_2} = \frac{199.00}{15.50} = 12.84$</td></tr>
<tr><td colspan="4">$b_3 = \frac{V_3}{X_3} = \frac{134.65}{5.00} = 26.93$</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Combine values into the appropriate equation and add IAF.</td><td colspan="4">$Y = (a + b_1X_1 + b_2X_2 + b_3X_3) \times IAF$</td></tr>
<tr><td colspan="4">$Y = (47.00 + 6.379X_1 + 12.84X_2 + 26.93X_3) \times IAF$</td></tr>
</table>

16.2.2.5. The RUT procedure can be extended to develop small population and large population determinants. To do so:

16.2.2.5.1. 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 16.2**.).

16.2.2.5.2. When more than one WLF is used, develop a ratio for each WLF (see **Table 16.3**.).

Table 16.2. Instructions For Small & Large Population Ratio Unit Times - Single WLF.

Step	Action	Example			
1	Select the man-hour model.	$Y = a + b_1X_1$			
2	Classify measured direct man-hours as fixed or variable.		AVG WLF COUNT	MAN-HOURS	
				FIXED	VARIABLE
		Base A	20	120.50	350.75
		Base B	15	95.60	275.90
		Base C	25	130.70	395.65
		Base D	29	125.60	397.35
		TOTAL	89	472.40	1419.65
3	Compute the variable man-hours ratio.	$b_i = \frac{V_i}{X_i} = \frac{1419.65}{89} = 15.95$			
4	Compute the *a*-value.	$a = \frac{FIXED\ MAN\text{-}HOURS}{NUMBER\ OF\ LOCATIONS} = \frac{472.40}{4} = 118.10$			
5	Combine values into the appropriate equation and add IAF.	$Y = 118.10 + 15.95X_1 + IAF$			

Table 16.3. Instructions For Small & Large Population Ratio Unit Times - Multiple WUC.

Step	Action	Example				
1	Classify measured direct man-hours as fixed or variable.		AVG WUC		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
2	Total the workload values and associated variable man-hours.	WUC		TOTAL (*X*)	MAN-HOURS (*V*)	
		X_1		199	789.20	
		X_2		74	1029.45	
		X_3		1185	2572.35	

Step	Action	Example
3	Compute the variable man-hour ratio for each workload	$b_1 = \frac{V_1}{X_1} = \frac{789.20}{199} = 3.966$
		$b_2 = \frac{V_2}{X_2} = \frac{1029.45}{74} = 13.91$
		$b_3 = \frac{V_3}{X_3} = \frac{2572.35}{1185} = 2.171$
4	Compute the *a*-value.	Not applicable to example data due to no fixed man-hours.
5	Combine values into the appropriate equation and apply the IAF.	$Y = (3.966X_1 + 13.91X_2 + 2.171X_3) \text{ x } IAF$

Chapter 17

AIR FORCE SPECIALTY SKILLS AND GRADES DETERMINATION

17.1. General Concepts. The process of skill and grade determination converts total manpower 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 requirements determinant final report.

17.2. Skill and Grade Determination without Correlation and Regression.

17.2.1. Step 1. Total man-hours are derived by summing the direct and indirect man-hours.

17.2.2. Step 2. Divide the man-hours in step 1 by the correct MAF. Round the resulting fractional manpower requirement to the correct whole manpower requirement.

17.2.3. Step 3. Consult with the work center supervisor and local OPR to get a proposed distribution. Record the recommended distribution.

17.2.4. Step 4. Check recommendations and rationale, average the recommendations for each level on the manpower table, and complete the table. Reconcile 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.

17.3. Skill and Grade Determination with Correlation and Regression.

17.3.1. During SWD development, determine the AFSCs based on steps in each process. Skill distribution is also decided and shown as a percentage of each step. Complete the following:

17.3.1.1. Investigate manpower currently used in the work center, including current authorized and assigned military and civilian strengths along with their respective grades and skills by MAJCOM and base. MPES is a source for military and civilian authorizations while local base products will give assigned strength data.

17.3.1.2. Check corresponding Air Force Specialty descriptions in the Air Force Officer Classification and the Air Force Enlisted Classification Directories, and Specialty Training Standard.

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

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

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

17.3.1.4.2. 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. Officer requirements must be justified by responsibilities or duties specifically needing an officer.

17.3.1.5. Document the skill percentage requirement in matrix format for each step as displayed in **Table 17.1**. **Note:** 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.

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

Table 17.1. AFSC Percent Distribution Matrix.

PROCESS / STEP	ENLISTED								OFFICER	
	AFS AAAXX				AFS BBBXX				AFS CCXX	
	9	7	5	3	9	7	5	3	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			

17.3.2. During work measurement, complete the following:

17.3.2.1. 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 **Table 17.2**.

Table 17.2. AFSC Man-hour Matrix.

BASE A	TOTAL MEASURED MAN-HOURS	ENLISTED								OFFICER	
PROCESS/ STEP		AFS AAAXX				AFS BBBXX				AFS CCXX	
		9	7	5	3	9	7	5	3	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			
TOTAL	663.60	30.20	149.20	61.10		3.62	132.98	119.60	130.40		36.50

17.3.2.2. Total all man-hours by AFSC. This is the last line on the AFSC man-hour matrix (see **Table 17.2**.). It is also the first line on **Table 17.3** that shows the computed and recommended manpower.

Table 17.3. 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	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	0.204	1.007	0.413		0.024	0.898	0.807	0.880		0.246	4.480
RECOMMENDED FRACTIONAL MANPOWER	0.000	1.211	0.413		0.000	0.922	0.807	0.880		0.246	4.480

17.3.2.3. Divide the total man-hours for each AFSC by the correct MAF to arrive at the computed fractional manpower needed.

17.3.2.4. 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 0.5 of a whole person requirement must be documented to show rationale for the change.

17.3.2.5. Due to rounding, strict use of the fractional manpower breakpoints may yield more or less than the total work center requirement. Together, with the functional OPR find the correct rounding point that maintains the total requirement.

Chapter 18

CURRENCY REVIEW

18.1. General Concepts. The purpose of this chapter is to provide information on how requirements determinant studies posted on the AFMAA SharePoint (or ANG/AFRC SharePoint equivalent) are reviewed for currency and how to revise those that need updating. A CR guidebook and checklists are posted on the AFMAA SharePoint to assist with CR completion.

18.1.1. Improving Work Center Processes and Procedures. Work with SSR and functional OPRs to improve existing processes and procedures. Additionally, incorporating process improvements from initiatives developed throughout the Air Force is an integral part of model maintenance.

18.1.2. Updating Requirements Determinants. Requirements determinants may become outdated when the extrapolation limits are exceeded or when there are changes in one or more of the following: mission, organization, processes or procedures, and/or equipment. Updates may require no measurement, partial measurement, or complete remeasurement of all activity responsibilities.

18.2. Reviewing the Requirements Determinant for Currency.

18.2.1. Once a requirements determinant is approved and posted, a CR is scheduled based on current policy. At the initiation of the CR, a request for MAJCOM/A1M feedback is sent requesting their perspective of requirement determinant currency. In addition, reach out to the functional OPR to begin the CR functional review.

18.2.1.1. Develop the CR using current policy and CR guidebook. Complete the following steps:

18.2.1.1.1. Review available requirement determinant products to gain an understanding of the function's workload, WLF(s) selected, how the equation was developed, what factors affect the equation(s), how WLF(s) relate to equation, etc.

18.2.1.1.2. Perform a review of AFIs, directives, and/or manuals listed in the report's Glossary of References. Review changes to functional directives to determine if SWD is still valid, reviewing organizational change proposals, reviewing variances, performing trend analysis on WLF and/or WUC volumes, obtaining and reviewing functional OPR policy or procedural letters, participating in functional OPR conferences, etc.

18.2.1.1.3. Pull a UMD baseline for analysis. This will identify how many MAJCOMs have the function, where the function is located, standardization of the organizational structure, use of FAC and Manpower Standard Implementation (MSI) codes, AFSCs utilized by function, Manpower Table (MANTAB) limits, and other relevant information.

18.2.1.2. Work with SSR or a functional OPR to review the requirement determinant products to get a functional perspective of the currency. Some of the questions to ask are:

18.2.1.2.1. Have approved mission changes occurred that altered the work being done at the time the requirements determinant was developed or updated?

18.2.1.2.2. Has policy and guidance changed causing procedures to change?

18.2.1.2.3. Is the activity still operating with the approved organizational structure that existed at the time of development or update? If not, have the realigned responsibilities or workload made the requirements determinant invalid?

18.2.1.2.4. Is the SWD current? Do changes significantly increase or decrease process time? In some cases, minor changes can be made that do not affect process time or make the equation invalid.

18.2.1.2.5. Is the WLF and/or WUC definition still current and is the indicated workload source of count current? Has it proved reliable?

18.2.1.2.6. Has experience shown the models to be reliable in predicting required manpower? If not:

18.2.1.2.6.1. Has the requirements determinant been used to allocate manpower?

18.2.1.2.6.2. Are application points falling outside of extrapolation limits?

18.2.1.3. Work with MAJCOM/A1M to review the requirements determinant products for currency with MFMs and provide a perspective from a MAJCOM point of view. Variances applicable to a single MAJCOM should be revalidated, approved by MAJCOM/A1Ms, and approved variances are sent to team lead for inclusion in update. **Chapter 4** provides more information on variance development.

18.3. Evaluating Currency Results.

18.3.1. Review all findings and recommendations provided to complete a CR report with recommendation. The report should provide an assessment of the key elements (SWD, equations, WLFs, MANTAB, applicability, statement of conditions, etc.) that determines if the requirements determinant is current.

18.3.1.1. A CR has the following potential outcomes:

18.3.1.1.1. Administrative Update. Current as written and only needs administrative updates.

18.3.1.1.2. Technical Update. Some technical updates that were completed during CR effort or can be completed in a short duration (90 days or less) after CR is completed.

18.3.1.1.3. Re-study. Has technical issues and needs to be restudied due to changes in mission organization, procedures or when extrapolations limits are being exceeded. If the function needs to be restudied, the disposition of the posted requirements determinant needs to be determined.

18.3.1.2. If the requirements determinant is still usable even with updates needed, "For Reference Only" is added to title. It can still be used with caution depending on errors (missing work, work not being done anymore, etc.).

18.3.1.3. If the requirements determinant is not valid, or totally outdated and not usable, "Obsolete" is added to title and it is available on the AFMAA SharePoint for informational purposes only.

18.3.2. Complete a CR package, which includes CR report and recommendation of posted requirements determinant, draft Interim Change with recommended updates and other documentation as needed supporting the recommendation. Package is submitted to the AFMAA Commander (or appropriate A1M chain for the ANG and AFRC) for a decision.

18.3.3. After AFMAA Commander (or appropriate A1M chain for the ANG and AFRC) decision, the requirement determinant is posted and another CR or restudy is scheduled.

18.4. Changes Outside of a Currency Reviews. MAJCOM/A1Ms or functional OPRs will submit updated requirement determinant changes for revision whenever circumstances warrant during the life of the requirements determinant.

Part 7

WARTIME REQUIREMENTS DETERMINATION

Chapter 19

WARTIME REQUIREMENTS DETERMINATION

19.1. General Concepts. The main goal of the wartime study process is to quantify the total force, Active and Air Reserve Component (ARC), deployment and critical home-station manpower requirements for wartime and low density/high demand functions.

19.1.1. The only difference between the wartime and traditional manpower requirements determination goal is wartime is total force focused. Both wartime and traditional manpower requirements determination require a reliable, understandable, and defendable means of quantifying manpower requirements. Wartime organizations do not have home-station assigned missions. These organizations train and exercise their capabilities in-garrison in preparation for deployment. Low density/high demand organizations do have home-station assigned missions; however, their wartime demand far exceeds their home-station demand. The requirements determinant development process for wartime functions and low density/high demand organizations only differs slightly from traditional organizations. The difference is typically in the preliminary research phase and utilization of war planning methodology.

19.1.2. All wartime requirements determinants studies are completed by AFMAA's Total Force Analytics Division's wartime manpower analysts.

19.2. Preliminary Research.

19.2.1. Overview. In addition to preliminary research steps discussed in **Chapter 2**, wartime requirements determination requires the understanding of strategic guidance directed by the Defense Planning Guidance from the Office of the Secretary of Defense and the Joint Strategic Capabilities Plan from the Joint Chiefs of Staff. These documents provide basic guidance for planning and programming the combat and support forces essential for attaining national security strategy. The planning guidelines developed from this information describes the "worst case" scenario that include things like the conflict type, the magnitude or size of the conflict, the theaters where the conflict will occur, how fast the conflict will escalate, what the timing of major events in the conflict will be, what forces will be used, the conflict planning period, etc. These requirements represent the use of a capability already available in the Air Force.

19.2.2. The Unit Type Code (UTC). The basic manpower module used by a wartime manpower analyst is the UTC and the associated Manpower Force Element (MFE). UTCs contain a statement of the workload this manpower element can support (e.g., 12 F-16 aircraft with a given flying program), the personnel needed, the skill set(s) personnel must have (i.e., AFSCs), and the logistics detail necessary to do the stated workload.

19.2.3. UTC Validation. A UTC is a capability focused on accomplishing a specific mission. It consists of a Mission Capability Statement (MISCAP) and a combination of two additional UTC elements; MFE and/or Logistics Detail (LOGDET). The objective of the UTC validation process is to use MEP techniques to enhance the credibility and accuracy of deployment force manpower requirements. The UTC validation process begins with preliminary research of historical deployment data. This is to identify deployment trends if UTCs are rightsized or tailored. A right-sized UTC provides a generic building block capability for ease of planning and enables optimal support to the combatant commander.

19.2.3.1. Utilization of these building blocks may task organize Air Expeditionary Task Forces in support of the DAF's force presentation and generation policies. The result of the validation process is the assignment of a code to each UTC in the Manpower Force Packaging (MANFOR) data file.

19.2.3.2. This code shows the validated UTC. A UTC with the validation code is comparable to a work center covered by a manpower determinant. A UTC without the validation code is comparable to a work center covered by a manpower guide.

19.2.3.3. The focal point of analysis during the validation process is the manpower and workload expressed in the UTC. The relationship between these two factors is vital. The relationship is critical because it provides the linkage needed to define or identify the man-hours of work necessary to produce a military output, e.g., defining man-hours into the number of required spaces.

19.2.3.3.1. The workload represents a military capability (e.g., the capability to obtain a specified number of aircraft sorties).

19.2.3.3.2. Capabilities are either explicitly stated or implied (e.g., by the number of aircraft identified and planned sortie rates per aircraft).

19.2.3.3.3. The manpower required represents the spaces to fill with individuals from the total force (Active and ARC).

19.3. Critical Home-Station Requirements Determination. Manpower requirements for critical home-station functions/missions are quantified using the exact same tools, techniques, and methodology as detailed in Parts **1-6** of this AFMAN. Wartime organizations typically have home-station support functions that facilitate their training, equipping, and exercising requirements. Low density/high demand organizations have assigned home-station missions.

19.4. Wartime Manpower Requirements Determination. This is a four-step process completed by the wartime manpower analysts in the Total Force Analytics Division of AFMAA.

19.4.1. Step 1. Validate the UTC(s) as explained in **paragraph 19.2.3**.

19.4.2. Step 2. Develop/validate the deployment concept of operations. This step involves working with the functional community to create a UTC matrix that identifies the UTC(s), both numbers and combinations, required to support all levels of operational capability. A key element in the creation of the matrix is the UTC MISCAP. It is imperative that during UTC validation the MISCAP is very detailed, clear, and accurately defines the capability of each UTC.

19.4.3. Step 3. Work with the functional community to apply the UTC matrix to the Defense Planning Guidance directed wartime scenario. Utilize the Time Phased Force Deployment Document or war plan that identifies the beddown locations, assigned operational mission platforms, various threat levels, base size, projected service populations, and other factors based on the wartime scenario. Use this war plan to apply the UTC matrix developed in Step

2 to determine the UTC(s) required at each location. When applying the UTC matrix, there may be a need to adjust the validated UTC(s) based on the requirements needed at each deployment location.

19.4.3.1. For example, the UTC MISCAP for a particular function is based on service population. The validated UTCs' required manpower is 3 for every increment of 750 serviced population. A deployment location in the plan has a service population of 2,473. Should this population drive a requirement of 9 (supports population of 2,250), 12 (supports population of 3,000), or something in-between?

19.4.3.2. To determine the answer, perform an assessment to determine if a new/smaller UTC needs to be developed to support a smaller population size, or more detail in the UTC MISCAP is required to explain when a cutoff is exceeded what is the level reached before adding the additional 3 manpower requirements.

19.4.4. Step 4. Aggregate the manpower requirements for all deployed locations to derive the total wartime manpower requirement.

19.5. Total Manpower Requirements. Intuitively, the AFMD or MA identifies the manpower requirements for both home-station support/missions and wartime demand. Use traditional equations, staffing patterns, post/position manning, etc., to calculate home-station manpower requirements. There are no traditional means of calculating wartime manpower requirements, simply express them as whole numbers. Often, the functional community requests that the AFMD or MA disperses the wartime requirements by installation/unit to reflect their enterprise deployment construct.

19.6. Review and Staffing. The review and staffing process for wartime AFMDs and MAs is exactly the same as traditional home-station AFMDs and MAs.

Part 8

LOGISTICS COMPOSITE MODELING

Chapter 20

LOGISTICS COMPOSITE MODEL

20.1. General Concepts. LCOM is a determination of direct aircraft maintenance and munitions requirements using simulation software and associated tools. LCOMs capture the variety, complexity, and uncertainty of maintenance environments; and are easily amendable for AoA. Maintenance and munitions management, supervision, and support are captured in other types of determinants.

20.2. Program Management Office.

20.2.1. AFMAA LCOM Program Management Responsibilities.

20.2.1.1. Integrate Air Force MEP policy and principles into developing, fielding, and maintaining the software, tools, policy, and guidance required to quickly and accurately quantify minimum and essential direct manpower requirements for those functions being modeled and simulated using the LCOM software.

20.2.1.2. Ensure LCOM product templates are technically and administratively compliant with applicable manpower instructions, manuals, and guides while clearly communicating senior leader expectations.

20.2.1.3. Mitigate errors and recognize patterns in the use of LCOM tools or techniques that reduce costs or improve the validity, timeliness, or effectiveness of LCOM products.

20.2.1.4. Provide a forum for involved program management, community information, training opportunities, and LCOM software requirements and modifications.

20.2.2. Training Oversight Responsibilities.

20.2.2.1. Direct, coordinate, oversee, and report highly complex projects; define scope, priority, and team; provide technical direction and training in project management, team building, facilitation, process improvement analysis, methodologies and tools required to develop, substantiate, and report manpower results.

20.2.2.2. Identify, document, and coordinate LCOM specific training requirements.

20.2.2.3. Motivate, mentor, and provide guidance to LCOM teams.

20.2.2.4. Provide quality checks to ensure projects are on track, information is accurately documented, and results are logical.

20.2.2.5. Provide LCOM product and process briefings.

20.2.3. Operations Analysis Responsibilities.

20.2.3.1. Advise and propose options and innovative solutions to difficult problems that is actionable, relevant, and timely in responsible areas.

20.2.3.2. Research, create, and deliver senior level presentations and products that are technically accurate, relevant, timely, and actionable; message usually aligned with established agency strategy and objectives.

20.2.3.3. Analyze and improve the effectiveness of LCOM program, processes, and products through continuous improvement and innovation (CI2), benchmarking, problem solving, and analysis.

20.2.3.4. Evaluate and test all LCOM software modifications to determine benefit of change and potential impact on determining and/or validating manpower requirements.

20.3. Software Tools.

20.3.1. The LCOM Data Analysis Processing Tool (LDAPT) is an OA software used for maintenance data summarization, field validation, audit analysis, and input database creation.

20.3.2. The LCOM Analysis Tool Kit (ATK) is a comprehensive simulation software used to modify input databases, run simulations, optimize resources, and provide statistical reports for analysis. The software allows relationship analysis of resources (manpower, parts, support equipment, facilities) with each other and their impact to aircraft sortie generation capability. The detailed nature of LCOM and its sensitivity to input data changes makes it a critical tool essential for weapon system acquisition and sustainment; and in validating proposals affecting reliability and maintainability improvements or modifications.

20.3.3. Munitions Assessment LCOM Tool (MALT) is a software application with scenario-based interface that uses standardized munitions networks to create an input database, run simulations, and produce a manpower requirement report.

20.4. Study Deliverables.

20.4.1. LCOM Scenario. States study assumptions, deliverables, participants, operating parameters, maintenance parameters and functional statements. It is developed by the study team in collaboration with functional authorities and coordinated with the appropriate logistics, operations, and plans staff functional representatives to assure operational and maintenance concepts are accurately depicted.

20.4.2. LCOM Report. Contains an executive summary with impact analysis summary, study background, LCOM process description, and application summary. When applicable, it provides a previous to new model functional comparison to support the analysis. It contains a trial application workbook containing each applicable location using UMD baseline. Provides part-time and full-time ARC contributions within the trial applications and executive summary.

20.4.3. LCOM. Establishes the maintenance and munitions manpower requirements to support approved scenario objectives. It consists of application instructions, statement of conditions, manpower requirement tables, grade factors, functional statements, UTC requirements, and any additionally requested modeling points.

20.4.4. LCOM Analysis of Alternatives.

20.4.4.1. An AoA provides decision makers with reliable, objective maintenance and munitions manpower assessments in response to varying levels of change (alternatives). AoAs provide comparative manpower requirement data to assess the impact of change to a baseline; this baseline is typically the current LCOM.

20.4.4.2. AoA requests include modification of functional work, change of scenario performance objectives, maintenance policy adjustments, tuning of failure data, and new model creation from engineering estimates.

20.5. Study Process.

20.5.1. Announcement. Signals the start of the LCOM process, is sent out to applicable MAJCOMs, the Air Force Deputy Chief of Staff, Manpower, and Personnel (AF/A1) and the Air Force Deputy Chief of Staff, Logistics, Engineering and Force Protection (AF/A4), and requests key points of contact.

20.5.2. Project Design. Consists of preliminary research to determine what information is needed to design and conduct the LCOM. It requires comprehensive research via UMD analysis, previous study review, documentation examination, preliminary surveys, and functional meetings on the following categories:

20.5.2.1. Aircraft force structure.

20.5.2.2. Missions.

20.5.2.3. Organizational structure.

20.5.2.4. Maintenance metrics.

20.5.2.5. Maintenance and munitions procedures.

20.5.2.6. Special work requirements.

20.5.2.7. Required locations.

20.5.3. Work Data Collection.

20.5.3.1. Measurement and data collection are accomplished based on project design. All data is examined to ensure it is complete, accurate, and logical. Historical workload data and associated man-hours may not show the function's real needs. Over- or under-manning affects level of effort and historical workload production level. A minimum of twelve months of maintenance data documentation is analyzed for inconsistencies in crew sizes, AFSCs, and task times as compared against known task profiles. Additionally, this data is used in conjunction with the previous study as a baseline for an on-site audit.

20.5.3.2. Maintenance data records, process action task times, frequencies, and required crew sizes are validated with qualified maintenance technicians at functionally selected locations using OA.

20.5.3.3. Maintenance manpower requirements are based on workload for inspections, unscheduled maintenance (aircraft maintainability), support equipment, and directed shop tasks. Maintenance action rates (expressed as mean sorties between maintenance actions) are developed using previous study, maintenance data documentation records, and maintenance personnel interviews. Maintenance task times include all work from job dispatch to job completion, to include equipment set-up, scheduled or unscheduled tasks including facilitate other maintenance actions, equipment tear down, annotation of aircraft forms, and updating the Maintenance Information System (MIS), as appropriate. Support equipment maintenance, reconfiguration, major maintenance processes, time change items, and overall aircraft maintenance flow are collected. Maintenance task times do not include idle time such as waiting for aerospace ground equipment, tow clearance, fuel delivery, etc.

20.5.3.4. Distinct maintenance policies for repair centers (e.g., avionics, hydraulics, and engines), inspection sections, multi-leg missions, etc. must be captured and standardized, as applicable.

20.5.4. Scenario. From the culmination of project design and work data collection, a clear and comprehensive LCOM Scenario is developed to guide accomplishment of study objectives. This document incorporates data collected and functional decisions made during these processes.

20.5.5. Model Development.

20.5.5.1. The model is based upon the scenario and audit data. It contains all aircraft, parts, and support equipment repair networks necessary to support aircraft. It also includes major inspection and repair process flow networks with linkages back to mission generation networks.

20.5.5.2. Models reflect missions within a continuous range of military operations from testing through major operations. Unless specifically waivered by the Air Force Directorate of Manpower Organization and Resources (AF/A1M), simultaneous models are built to address all operations for applicable units.

20.5.5.3. Discrete aircraft mission scheduling may be required to replicate the way the annual Flying Hour Program (FHP) is executed (to include attrition overhead requirements, flying hour restrictions, TDYs, maintenance recovery teams, readiness exercises, surges, and other deviations) and is determined on an as-needed basis.

20.5.5.4. Minimum Essential Subsystem Listing (MESL) is utilized to determine mission limiting criteria based on functionality and serviceability of aircraft systems. The key is to select aircraft that maintenance personnel can return to mission capable status the quickest. The MESL is not necessarily the final determinant of whether an aircraft can be utilized, but it must be consulted as the basis for reporting aircraft status. LCOM ATK is capable of simulating MESL failures separately from delayed discrepancies. LCOM models must be networked to reflect appropriate MESL usage and defined within the LCOM scenario.

20.5.5.5. Maintenance task cross-utilization (general AFSC substitution) is used for the shared flightline tasks of aircraft tow, aircraft refuel, aircraft defuel, aircraft jacking, and aircraft wash. Specialized utilization such as the Multi-Capable Airmen (MCA) initiative is designed to effectively execute Agile Combat Employment (ACE) maneuver while deployed and is not modeled unless requested and approved within the LCOM scenario.

20.5.5.6. A single OJT/upgrade training accounting process is used to standardize LCOM accounting for 3-level impacts to the simulated manpower requirement and derive a more accurate maintenance model. This method equally applies to all specialties in the model. LCOM ATK simulates with a probability that OJT is performed on a task, increases the time by a percentage and increases crew size if the crew size is one. The probability of occurrence is determined from the most accurate data source of 3-skill levels for units under study. The task time percentage increase uses the Total Force Indicator Round Table approved factor of 40 percent until otherwise rescinded. Task crew sizes of less than two have a trainer position added for training to occur or if the normal crew size would not be sufficient to properly train. The OJT task pool includes all work except high repetition general tasks (e.g., tows, engine runs, wash, jacking, Joint Oil Analysis Program, launch, recovery, refuel, defuel, and loading).

20.5.5.7. Due to the uneven nature of Time Compliance Technical Order (TCTO) issuance and in conjunction with functional community perspective, workload associated with TCTOs is not currently included in the model. However, TCTO data is collected and documented in a “historical capacity” to determine the impact this type of maintenance plays in day-to-day functioning to be revalidated for inclusion in future studies.

20.5.5.8. Aircraft parts cannibalization actions may be necessary when a condition prevents the accomplishment of a mission, and the required assets are not immediately available from supply. Maintenance management cannibalization decisions for the expenditure of man-hours and potential damage to equipment are weighed against the expected benefit. Cannibalization actions are a documented and accepted practice and is integrated into the models based on valid historical maintenance data documentation.

20.5.5.9. End of runway (EOR) activities are included in the simulation model and are based on specified airframe inspection requirements. Methodology for simulation is to insert EOR activities prior to and after sortie task, if applicable. EOR is annotated within the scenario to include crew composition.

20.5.5.10. Alert is considered when tasked by higher headquarters. This mission is defined in the scenario or AoA with quantity of aircraft, within what operations alert is applicable, and minimum standby crews to perform alert tasks. When modeling alert with other operations for the same unit, remove alert aircraft leaving less aircraft to accomplish a reduced flying goal. Add scenario-defined standby alert crew positions to the simulated manpower resources for each function prior to applying MAF.

20.5.6. Simulation and Analysis.

20.5.6.1. Models are first set up to run a “wide-open” analysis (unlimited parts and manpower resources). This analysis verifies the model is operating correctly within scenario parameters and sets the baseline for all follow-on analyses. This debugging process checks for loops, blocks, unexpected network flow, and incorrect failure counts. Also, during this process, the study lead examines for common maintenance logic and scenario agreement.

20.5.6.2. Only long-term average behavior of the model is analyzed. This is reached when simulation model variables reach a state of equilibrium. This is the point when variables (e.g., Total Non-Mission Capable Supply (TNMCS), sortie rate, manpower resource utilization rate) converge to approximately the same distribution. For this analysis, the model is run for a 182-day warm-up period with 364 continuous operating days following to allow all maintenance processes opportunity to occur. Additionally, 30 independent trials are ran then merged and analyzed to ensure 95 percent of data points are within scenario performance measures. Each trial uses a different random number seed generator for each failure clock, inspection, etc., creating a different starting point. Length of simulation and number of trials remains constant throughout the analysis process.

20.5.6.3. Model input resources (parts and manpower) are constrained by the analyst.

20.5.6.3.1. Parts are reduced in the model to achieve the scenario TNMCS rate. This puts a sortie generation strain on the model to mimic aircraft maintenance dynamics.

20.5.6.3.2. Next, manpower is optimized to concurrently attain scenario required sorties and TNMCS rate while not exceeding Maintenance Indirect Factor (MIF) maximum utilization rates.

20.5.6.3.3. Each function is analyzed to ensure minimum crew size is met on at least one shift. The maximum crew size for any task in a function establishes the post/position manpower resources needed for at least one shift in that function. Other shifts may have less than minimum crew if workload can be deferred without a negative impact on sortie production.

20.5.6.3.4. Optimized results represent validated workload including indirect work, safety requirements, and PF&D. Workload transfer (backorder leveling) and shift scheduling is used during optimization to reduce standby time. A final optimized model results in the simulated manpower resources needed to achieve scenario objectives, whether fully utilized or not.

20.5.6.4. LCOM core model is compared to previous model, as applicable. This comparative analysis is the basis for the LCOM report executive summary and impact explanations.

20.5.6.5. The MAF is used to quantify number of FTEs for a given function.

20.5.6.6. The LCOM requirement is based on the most demanding scenario by function; therefore, the results may be comprised of more than one scenario operation within a specified location. This is the final requirement to use for grade breakouts.

20.5.6.7. Required skills are determined by analyzing task level workload, the experience and ability to complete the tasks, and the minimum requirements to cover multi-shift operations. Skills are translated into grades using only production level (TSgt–A1C) grades.

Part 9

INDUSTRIAL ENGINEERING

The following section includes techniques that serve as the foundational basis of today's Management Engineering Program. These techniques are labor intensive and may not be the most appropriate measurement methodology for today's environment.

Chapter 21

TIME STUDY

21.1. General Concepts. Time study is a work measurement method where the analyst uses a stopwatch to record the time a worker takes to do each element of an operation in a specified way. This technique is used to measure operations that are repetitive, of relatively short duration, and accomplished at one work station. Leveled time is an average time adjusted to reflect differentiating factors in operator performance, such as effort, skill, and work conditions. Leveled time is computed by applying a leveling factor (reference **Chapter 22**, **paragraph 22.2.3**) to the productive time. The leveled time is multiplied by an allowance factor to determine the elemental allowed time. The total of the elemental allowed times then gives the ST for the operation. The cost of performing a time study is higher than other work measurement techniques; however, it is the most accurate means to determine STs.

21.1.1. Purposes of Time Study.

21.1.1.1. To analyze the operations and job conditions to improve existing methods.

21.1.1.2. To increase the effectiveness of worker effort by using only necessary motions.

21.1.1.3. To establish standard conditions for an efficient operation.

21.1.1.4. To establish consistent and fair standards of performance.

21.1.1.5. To furnish reliable data for use in constructing man-hour equations.

21.1.2. Additional Uses. Time study is also used to develop elemental standard data for use in synthesizing time standards for operations containing the same elements in different combinations. This eliminates the need for re-measurement.

21.1.3. Prerequisites for Time Study. Very few situations in the Air Force meet the time study prerequisites of being both highly standardized and repetitive. If these prerequisites are not met, then this method is not to be used.

21.1.4. Verification of the SWD. Time study, in most cases, is neither a practical nor an economical method to use to develop an entire manpower determinant within most Air Force functions. However, when this measurement method is selected (generally for some portions of the SWD) the following procedures are necessary:

21.1.4.1. Verify the portion of the SWD to be time studied is properly designed. Each process activity is identified in the sequence of performance with definite beginning and ending points.

21.1.4.2. Ensure all processes are in-line with current governing directives and local performance procedures. Significant differences from location-to-location may cause variation in timing and result in inaccurate values. Resolve any differences prior to beginning timing operations.

21.2. Procedures for Conducting a Time Study. Establish a system to record daily work counts. If the work center activities do not allow this to be done, record the WU count as the work is finished. Production reports may be used but collect sufficient data to make valid comparisons and to set an average workload level.

21.2.1. Find the time study method that best fits the work situation to accurately measure the various steps. Snapback and continuous are two basic methods of reading a watch when doing a time study. Each of these basic methods is addressed separately below.

21.2.2. In the snapback (repetitive) method, record a reading after timing each element, and then reset the watch back to zero.

21.2.2.1. Advantages of this method are: (1) it eliminates the need for making subtractions to find element time and (2) it also facilitates rapid analysis of variations in readings for each element per cycle.

21.2.2.2. Disadvantages of this method are: (1) it does not present a clear picture of the sequence in which the elements were done and (2) the extent and nature of foreign elements upon occurrence are not always recorded. In addition, unavoidable errors occur due to the time needed to reset the watch back to zero.

21.2.3. In the continuous method, the watch runs continuously from the beginning to the end of the process being measured. Record the time at the end of each element.

21.2.3.1. An advantage of this method is every event that occurs is recorded and is traceable back to the actual sequence of occurrence. This makes it easy to handle elements occurring out of normal sequence.

21.2.3.2. The disadvantage of this method is additional time is needed to develop the elemental time.

21.2.4. The use of either the snapback or continuous method is at the discretion of the analyst. The various characteristics contributing to the use of each method are displayed in **Table 21.1** and should be taken into account when selecting a particular timing method. For example, when checking a job situation to be timed, use **Table 21.1** 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.

Table 21.1. Timing Method 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 MEP development 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 usually performed in one location - Is climate controlled - Does not require workers to wear additional apparel or safety equipment
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 and/or darkness - Elements are performed in several locations in sequence - Has a climate variable in nature - Requires workers to wear additional apparel or safety equipment

21.2.5. When identifying elements to be timed, ensure the elements are recognizable and have obvious beginning and ending points. Clear beginning and ending points make the time study process easier. Make a sketch showing the equipment used, flow of work, significant distances traveled by the operator, and unusual working conditions.

21.2.6. Take readings for five to 20 cycles to find the number of good readings needed. Pace rate each timed element. Compare the observed pace (speed) of work done to the normal time (NT). See **Chapter 22** for more details on pace rating.

21.3. Determining Sample Size. Find the required number of readings after measuring a relatively small number of cycles. The initial cycle readings may be included as part of the required 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 necessary for any one element. **Table 21.2** provides instructions and an example of how to compute the number of samples needed. For the particular example shown in **Table 21.2**., a 95 percent statistical confidence with a +/-5 percent relative accuracy is desired with 25 time study samples given.

Table 21.2. Determining Necessary Time Study Sample Size for Given Statistical Confidence and Accuracy Requirements.

STEP	Action	Variable/ Equation/ Computation	Example
1	Take time readings for 25 cycles.	n = number of samples X_i = individual time reading (in decimal minutes)	$n = 25$
2	Compute summary statistics.	$\sum X$	$\sum X = 270.2$ mins (see **note**)
3	Compute sample mean.	$\bar{X}$ = sample mean $\bar{X} = \frac{\Sigma X}{n}$	$\frac{270.2}{25} = 10.808$ mins
4	Compute sample standard deviation.	s_x = sample standard deviation	$s_x = 0.981$ (see **note**)
5	Calculate desired accuracy.	d = desired accuracy $d = 0.05(\bar{X})$	0.05(10.808) = 0.5404
6	Determine confidence factor using a t-Table (**Table A2.4**) and the number of readings (n) where $t^* = t_{(1-\alpha/2,\, n-1)}$.	From t table value at 95% confidence (α =0.05) and 25 samples ($n = 25$; $n - 1 = 24$ degrees of freedom) $t^* = t_{(0.975,24)}$	$t^* = 2.0639$
7	Compute the precision obtained with this sample.	E = precision $E = \frac{t^* \text{ x } s_x}{\sqrt{n}}$	$E = \frac{2.0639 \text{ x } 0.981}{\sqrt{25}}$ = 0.4049
8	- If the precision obtained is less than or equal to the desired accuracy, then the sample is sufficient. - If not, additional samples are needed. Proceed to Step 9.	If $E \leq d$, no further samples needed; else, if $E > d$, go to Step 9.	0.4049 < 0.5404; therefore, $E \leq d$, no further samples required.
9	Calculate estimated sample size needed using values calculated (t^*, s_x, and d). Collect additional samples to meet this new sample size and repeat the procedures in this table until $E < d$.	n' = new sample size needed $n' = \left\lvert \frac{t^* \text{ x } s_x}{d} \right\rvert^2$	
Note: Actual summation of data values and calculation of standard deviation are not shown here.			

Chapter 22

THE PACE (PERFORMANCE) RATING SYSTEM

22.1. General Concepts. In pace rating, compare the observed pace, or speed, of work performance to a predetermined value of normal pace.

22.1.1. Consider the difficulty of each step and adjust 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 1.00 or 100 percent of normal pace.

22.1.2. Observed (or measured) time is adjusted by the pace rating to determine NT. Normal hand speed used in the Air Force MEP is determined as the hand speed required to deal a deck of cards in four even piles in 30 seconds (see **paragraph 22.2.8**.). Normal walking speed used in the Air Force MEP is three miles per hour walking across a flat surface (see **paragraph 22.2.10**.).

22.2. Using Pace (or Performance) Rating.

22.2.1. Overview. The requirements determination process utilizes the practice of figuring the pace at which work is accomplished. The terms pace rating and performance rating are used interchangeably. Using the average pace ratings for individual workers results in a leveling factor that is applied to productive time. Leveling is limited to the observed activity.

22.2.2. Techniques Utilizing Pace Rating. Pace rating is used only in WS (see **Chapter 24**), time study (see **Chapter 21**), or good operator timing (see **Chapter 5**). Time values coming from the directed frequency, historical records, or technical estimate methods are not pace-rated (or leveled).

22.2.3. Processes Incompatible with Pace Rating. The leveling factor is used to adjust productive time to a norm. Some processes do not lend themselves to pace rating. For example, supervision and mental work. For these activities, use a pace rating or leveling factor of 1.00.

22.2.4. Training for Pace Rating. Analysts should be proficient with rating and familiar with the job to effectively pace rate. Training is needed prior to requirements determination efforts where pace rating is required. Avoid using pre-established ranges for average leveling factors because these ranges bias the value of leveling.

22.2.5. Number of Ratings Required. The number of ratings needed varies with the work measurement method used.

22.2.5.1. Time study and good operator timing technique will rate each timed element.

22.2.5.2. WS will rate a minimum of 25 percent of the observations of each worker.

22.2.6. Computing an Average Pace Rating. Pace rating results in a number of separate ratings used to figure the overall leveling factor. At the end of the study, find the average of these ratings (leveling factor) and use this average to compute leveled time. The example in **Table 22.1** shows the computation of a leveling factor from six separate pace rating values.

Table 22.1. Leveling Factor Computation Example.

Rating No.	Pace Rating (R)
1	0.95
2	0.90
3	0.95
4	1.05
5	0.90
6	0.95
	ΣR = 5.70
Average Pace Rating (R) = $\frac{\Sigma R}{n} \rightarrow \frac{5.70}{6}$ Leveling Factor = 0.95	

22.2.7. Creating Pace Rater Proficiency. Training the analyst to develop a "mental image" of a normal pace and how to rate in a consistent manner is critical. The analyst needs to have many images of normal since a wide variety of jobs are studied. This makes the need for training greater and the training more difficult. While it is just about impossible to give the analyst every possible "norm" that may be found, there are some point-of-departure norms that can be used.

22.2.8. Hand Speed Pace Rating Practice. The following exercise is suggested to create pace rater proficiency:

22.2.8.1. Deal 52 playing cards in 4 piles in 30 seconds (0.50 min). To deal the cards, hold the deck in the left hand and with the thumb, take off and move the top card each time. With the right hand, grasp the pre-positioned corner of the top card between the thumb and first finger, carry it to the correct pile, release it, and bring the hand back to the pack. Form the four piles in front of the dealer and the other three corners of a one-foot square. This training method needs at least three people; the trainee, the card dealer, and a person with a stopwatch. The dealer deals the cards, the person with the stopwatch times the operation, and the trainee rates the operation. The true rating is found by dividing the known NT (0.50 min) by the stopwatch reading. For example:

$$True\ Rating = \frac{NT}{Stopwatch\ time} = \frac{0.50}{0.40} = 1.25\ (125\%)$$

22.2.8.2. Comparing the true rating with those given by the trainee is a good way to show where the trainee is rating in relation to the actual pace of the dealer.

22.2.9. Walking Speed Pace Rating Practice. The Air Force MEP standard for walking speed is 3 miles per hour on a flat surface. To become proficient at pace rating walking speeds, analysts may view pace rating tapes or pace rate fellow workers across a known distance. This training routine, like hand speed, also takes three MEP analysts to perform: one to perform the practice pace rating, one to act as the walker, and another to time the walker using a time device. As the practice pace rating is taken of the walker across a known distance, the timer records the time from start to crossing the line. With the time known, the actual rate (in miles per hour) can be determined and a comparison of pace rating and actual calculated pace can be determined.

22.2.10. Determining NT.

22.2.10.1. Once the analyst has measured a process and performed the pace rating, NT can be computed. For example, if a process has a measured time of 10 min with a pace rating of 125 percent of normal pace, then the NT is calculated as:

NT = *Measured Time* x *Pace Rating* = 10 x 1.25 = 12.5 min of *NT*

22.2.10.2. Likewise, if the pace rating had been determined to be 80 percent, then the calculations would be:

NT = *Measured Time* x *Pace Rating* = 10 x 0.80 = 8 min of *NT*

22.2.10.3. Thus, both above and below average normal pace observations can be estimated to determine the NT.

Chapter 23

DETERMINING PERSONAL, FATIGUE, AND DELAY ALLOWANCES

23.1. General Concepts. Personal, Fatigue, and Delay allowances are added to Normal Times to create Standard Time when time study, good operator timing, or WS are the measurement techniques. Allowances add time to account for personal human needs, the external and operational environment, and the nature of the work.

23.1.1. Do not add PF&D allowances to the OA techniques of technical estimate and historical record. When directed requirements technique is used for PAT, PF&D allowances may be added; but do not add PF&D allowances for directed requirements when whole manpower positions are directed, e.g., First Sergeant position in a squadron. Add PF&D allowances for PATs determined via good operator timing.

23.1.2. Personal allowances take into account time given for personal breaks, e.g., rest room breaks. Do not confuse personal time with annual or sick leave, or any other factor already considered in the NAT of the monthly MAF.

23.1.3. Fatigue allowances recognize the limitation of the human condition and take into account the time a worker needs to rest and recuperate due to the physical and mental demands of the job.

23.1.4. Delays that are unavoidable and cause the worker to stop immediate operations, but also prevents the worker from doing other productive work, should also be considered, and added to NT. Do not credit idle time that is truly avoidable, i.e., the worker may have been stopped at the immediate activity, but he or she can begin working on other productive work in the meantime.

23.1.5. At the discretion of the analyst, a standard PF&D allowance can be used for the entire work center or each activity in a SWD. However, when specific activities within a single SWD represent considerably different nature of the work or under significantly different work conditions, then PF&D allowances should be determined and applied at the activity level.

23.1.6. The MEP treats time for work center clean-up as part of an IAF. Therefore, do not add work center clean-up time to the PF&D allowance.

23.1.7. Standard Time is calculated by multiplying the computed PF&D allowances (expressed as the allowance factor) by an activity's NT, such that:

ST = *NT* x *Allowance Factor*

Note: Recall NT is the measured (i.e., observed) time that has been adjusted by a pace rating or leveling factor.

23.1.8. To compute the PF&D allowance factor, use the following equation:

$$PF\&D\ Allowance\ Factor = \frac{100\%}{100\% - PF\&D\%}$$

23.1.8.1. Where the PF&D allowances as depicted are expressed as a percentage of the total workday. For example, to compute the allowance factor for 30 min per 8-hour duty day for PF&D:

$$PF\&D\ (as\ a\ percentage) = \frac{30}{480} = 6.25\%$$

23.1.8.2. Where 480 equals the number of min in an 8-hour duty day. Thus, the allowance factor would equal:

$$Allowance\ Factor = \frac{100}{100 - 6.25} = 1.067$$

23.1.9. Continuing, if the NT of an activity was measured at 12 min, then to determine the ST (the final manpower credit the DAF would pay for this activity) for an allowed PF&D time of 30 min per duty day as in the example above, then:

ST = *NT* x *Allowance Factor* = 12 x 1.067 = 12.80 min

23.2. Determining PF&D Allowances.

23.2.1. Overview. Based on the characteristics of the function being studied, PF&D allowances can be determined either by:

23.2.1.1. Measuring the allowances via a work measurement technique, e.g., good operator timing.

23.2.1.2. A combination of measured and predetermined allowance factors.

23.2.2. Using Predetermined Allowance Factors. The base personal (i.e., minimum) allowance factor is 1.067 (i.e., 30 min per 8-hour duty day). If DAF policy for a given work center directs longer base PF&D allowance, annotate the authority source, and recompute the base PF&D allowance. Use **Table 23.1** to add to the base personal allowance factor (as a percentage) if applicable:

Table 23.1. Allowed Adjustments for Base Personal Allowance.

Conditions	Percent Added to Base Allowance
Normal office conditions.	0
Normal shop with central heat and/or air but slightly dirty or greasy.	1
Slightly disagreeable conditions. Personnel are exposed to inclement weather part of time, poor heating, or poor cooling.	3
Adjunctive allowance-allowed for work performed in “super” clean rooms. Required when operators routinely don and doff special Personal Protective Equipment (PPE), e.g., caps, boots, etc.	4
Work center personnel are exposed to extremely disagreeable conditions most of the time, e.g., proximity to hot objects, continuous exposure to disagreeable odors and fumes, or to excessive temperature fluctuations.	6

23.2.3. Calculating Allowances for Fatigue. Fatigue allowance can be categorized as physical or mental fatigue.

23.2.3.1. Physical Fatigue for Lifting Objects. When a work center’s activities involve the lifting of objects, consider the following conditions:

23.2.3.1.1. The average weight handled per worker.

23.2.3.1.2. Percent of time for the defined activity actually under load.

23.2.3.1.3. The height the load is manually lifted (for the most likely situation).

23.2.3.1.4. The basic percentages for fatigue allowances in **Table 23.2** are based on the effective net weight of the object(s) that are placed at a height somewhere between the worker's chest and the floor. **Table 23.2** also applies when sliding or rolling the work objects along a flat surface.

Table 23.2. Predetermined Fatigue Percentages.

When the effective net weight (lbs.) lifted is between:	and the percent of time the worker is under load is:				
	1-12%	13-25%	26-50%	51-75%	76-100%
1-10	0	1	2	3	4
11-20	1	3	5	7	10
21-30	2	4	9	13	17
31-40	3	6	13	19	25
41-50	5	9	17	25	34
51-60	6	11	22	X*	X*
61-70	7	14	28	X*	X*
71-80	8	17	34	X*	X*
Table values are multiplied by the following factors as dictation by conditions: When the worker places load above chest-height, multiply basic allowance by: 1.20. When the worker places the load from above chest-height, multiply basic allowance by: 0.50. X* = Exceeds ergonomic safety-redesign activity to lower weight or time spent lifting.					

23.2.3.2. Physical Fatigue Allowance for Worker Position. Consider the position(s) the worker normally assumes to perform the operation. Choose the mostly likely scenario from **Table 23.3**.

Table 23.3. Fatigue Delay for Worker Position.

When the normal worker position is:	then added percentage for worker position is:
Approximate equal amounts of sitting or standing	0
Constant sitting	1
Constant walking	1
Constant standing	2
Climbs and/or descends ramps, stairs, or ladder	4
Working in close, cramped position	7

23.2.3.3. Mental Fatigue Allowance due to Nature of the Work. This considers the concentration necessary to perform the activity and the amount of variety in the activities. Use **Table 23.4** as a reference.

Table 23.4. Consideration for Mental Fatigue Allowance, Nature of the Work.

When the activity is/or involves:	then the percentage to add for mental fatigue is:
- Mostly routine, known by habit - Simple calculations - Reading easily understood material, e.g., routine or familiar instructions - Counting and recording numbers - Simple inspection requiring attention but little worker discretion is required - Arranging documents by letter or number	0
- Full worker attention, e.g., copying numbers, addresses or instructions - Memory of part number or name while checking stock or parts list - Attention between work at hand and other worker activities - Simple mental calculations - Filing documents by subject of familiar nature	2
- Requires concentrated attention, such as reading - Checking numbers, e.g., parts, documents, etc., that requires cross reference or double-check - Division of attention between three components such as accounting, inspecting, and grading - Navigating unfamiliar routes, watching vehicle traffic and route signs	4
- Work requires deep concentration - Swift mental calculations or calculations - Inspection where work requires interpretation and discretion - Routinely involved handling work of an unfamiliar nature, e.g., working against non-routine specifications - Highly divided attention between phases of work, the operations of others, or specific work hazards	8

23.2.3.4. Mental Fatigue for Lighting. In addition to mental fatigue due to nature of the work, typical lighting in terms of the amount of light on the work surface, the fineness of details, the amount of glare on the work surface, and rapid changing or "hypnotic" effect of the work should also be considered. Use **Table 23.5** as a reference.

Table 23.5. Consideration for Mental Fatigue Allowance, Lighting.

If the work involves either:	then the percent to add to mental fatigue for lighting is:
- Continual glare on work areas - Work requiring constant change in light on work area	2

- Less than 75-foot candle power on work surface for normal job - Less than 125-foot candle power on work surface for detailed work	

23.2.3.5. Mental Fatigue for Noise. Consider the general noise of the work areas as well as any annoying, sharp, staccato, or intermittent noises occurring during more than 50 percent of the workday. If ear plugs, noise cancelling headphones, or earmuffs are required to be worn, the protective sound device's noise reduction effect is considered using the allowance in **Table 23.6**.

Table 23.6. Consideration for Mental Fatigue Allowance, Noise.

When the work environment's noise level is:	then the percent to add to mental fatigue for noise is:
Constant, loud noises, such as in machine shops, etc. (over 60 decibels)	1
Average constant noise level but with loud, sharp, intermittent, or staccato noise such as nearby riveters, punch presses, aircraft engine starts, auxiliary power units, e.g., flight line or machine shop	2

23.2.3.6. Mental Fatigue for Wear of PPE. Consider the mental fatigue resulting from wearing PPE during work, as depicted in **Table 23.7**.

Table 23.7. Consideration for Mental Fatigue Allowance, Wear of PPE.

When the PPE involves:	when the percent to add for mental fatigue for wear of PPE is:
Safety glasses	0
Face shield	2
Rubber boots	2
Goggles or welding mask	3
Tight, heavy protective clothing	4
Filter mask	5

23.2.4. Allowances for Unavoidable Delay.

23.2.4.1. Unavoidable Delay. An unavoidable delay is just that, unavoidable. If a worker can be doing any other productive work instead of waiting for the task at hand, the reason for delay cannot be considered unavoidable.

23.2.4.2. Base Allowance for Unavoidable Delay. A predetermined base allowance for delay can be estimated based upon the need for close coordination between defined activities. Use **Table 23.8** as a reference. **Note:** Consult the SWD(s) to ensure understanding of the process flow and the inter-related nature of specific activities.

23.2.4.3. Other unavoidable delay situations can be included once measured and computed.

Table 23.8. Base Allowance for Unavoidable Delay.

When the activities in a process are:	then the base allowance for unavoidable delay is:
Isolated, but requires some coordination with adjacent activities	1
Fairly close coordination with adjacent activities	2

23.3. Application of the Allowance Factors. These tables normally provide realistic PF&D allowances. However, in some situations, using these predetermined factors results in a total allowance ≥ 100 which yields a zero or negative denominator in the allowance factor formula. Assuming the PF&D allowances have been correctly characterized and computed, when this situation occurs, reshape SWD activities so realistic PF&D allowances are obtained.

23.3.1. Suppose a work center has the following PF&D allowances:

23.3.1.1. Allows two, 15-minute personal breaks.

23.3.1.2. Works under slightly disagreeable working conditions.

23.3.1.3. For this specific activity, requires grasping an 8-pound object 30 percent of total activity time and placing it above chest level.

23.3.1.4. Lighting is considered adequate without glare and noise levels are under 60 decibels.

23.3.1.5. Requires cross checking parts number with a shipping document.

23.3.1.6. Requires the wear of rubber boots PPE.

23.3.1.7. Requires some coordination with adjacent activities.

23.3.2. Calculations to determine the PF&D allowance on the activity described above is shown in **Table 23.9**.

Table 23.9. Example of Computing an Allowance Factor.

Basic Allowance Category	Percentage	Multiplier (if applicable)	Final Allowed Percentage
Personal Allowance – Basic	6.25	N/A	6.225
Personal Allowance – Adjustment for Environment	1.00	N/A	1.00
Fatigue Adjustment for Lifting	2.00	1.20	2.40
Mental Fatigue – Nature of Work	4.00	N/A	4.00
Fatigue for PPE – Rubber Boots	2.00	N/A	2.00
Delay Allowance for Some Coordination with Adjacent Activity			1.00
Total PF&D Allowance (as percentage)			16.65

Chapter 24

WORK SAMPLING

24.1. General Concepts. Work sampling is considered an engineered work 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 recorded. The WS method relies heavily on analysts to visually observe the work and collect accurate samples and workload information. The WS method defines processes, makes observations, computes percentage of occurrence for each process, and applies these percentages to man-hours sampled.

24.2. Applying Work Sampling. WS is commonly used to determine equipment utilization, analyze work distribution, conduct methods improvement efforts, and compute and verify PF&D allowances.

24.2.1. WS is very effective and an appropriate work measurement technique when a work center's workload is:

24.2.1.1. Non-repetitive or irregular work.

24.2.1.2. Many different categories of work.

24.2.1.3. Performed by many workers in a relatively small area when activities can be grouped for simultaneous observations.

24.2.2. 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 nearly impossible, to sample. For these work centers, consider using productive and nonproductive sampling. 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.

24.3. Types of Work Sampling Efforts. WS efforts can be designed to be either productive or nonproductive (Level I), or at the process level (Level II).

24.3.1. Level I. In Level I WS efforts, samples are broadly classified as productive, nonproductive, nonavailable, and lunch. Sample nonproductive categories, such as PF&D and idle time, at the category level since these categories are easily distinguishable. This provides information to support the allowance factor and to brief the OPR.

24.3.1.1. To breakout Level I by process category, use percentage estimates to distribute productive time (direct and indirect) into processes. However, the effort's work measurement data can no longer be considered derived via an engineered work measurement technique with this approach.

24.3.1.2. 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. Ensure percentage estimates equal 100 percent.

24.3.1.3. **Table 24.1** shows an example of estimated process distribution percentages. Estimates were obtained from the both the work center supervisor, estimate A, and the foreman, estimate B. The percent of total column is used to distribute the productive direct time into processes.

Table 24.1. Percentage Distribution of Productive Processes.

Process Number	Estimate A (%)	Estimate B (%)	Total (A+B) (%)	Percent of Total (A+B)/200%
1	9	7	16	0.08
2	30	26	56	0.28
3	15	13	28	0.14
4	8	8	16	0.08
5	25	21	46	0.23
I1	8	4	12	0.06
I2	4	4	8	0.04
I3	4	2	6	0.03
I4	3	3	6	0.03
I5	1	1	2	0.01
I6	1	1	2	0.01
I7	1	1	2	0.01
TOTAL			200%	1.00

24.3.2. Level II. Level II WS efforts are measured at the process level. In most WS efforts, 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 activity level of accomplishment. If a sample is misclassified as direct when it is really indirect, there is no change to total productive time.

24.3.2.1. Because measured indirect time is based on actual observations, do not use an IAF with Level II WS efforts. In this case, application of an IAF double counts indirect time.

24.3.2.2. Productive direct time is sampled at Level I and prorated by percentages to get direct process and indirect category time.

24.3.2.3. Productive indirect time is sampled at Level II (process level).

24.3.3. Economic Desirability. WS's economic desirability increases with the number of workers being sampled. Measure a minimum of five workers; however, those being sampled may be assigned to more than one work center. When several input points have four or less workers to be measured, it is not economical to conduct a WS effort. Generally, measure a work center with two or less workers by OA unless it is necessary to observe standby time or the need for an assistant.

24.3.4. Measurement. The work force being measured should consist of personnel who spend most available time in a place which permits observation of work. Account for work done away from the immediate work center for extended periods of time as follows:

24.3.4.1. Observe the worker at the out-of-area location.

24.3.4.2. If it is not feasible to observe the worker, sample as out-of-area and OA this time. Account for out-of-area samples by applicable process. For multi-location determinants, study teams furnish guidance for treatment of these samples if applicable.

24.3.4.3. Do not plan for more observations than an analyst can accomplish in a reasonable period. Assigning too many personnel or work centers may not allow timely observations and may bias the sampling data. Conversely, assigning too few personnel is not economical.

24.4. Briefings for Work Sampling.

24.4.1. In-briefing. Make sure the work center supervisor and workers fully understand the principle of WS during the in-briefing. Because its statistical basis makes WS difficult to understand, use illustrations without technical terms. Use simple explanations to eliminate confusion. Some examples of situations similar in principle to WS are testing antifreeze in a car radiator or taking blood samples. Since each of these samples represent the original source, the opinions formed from the samples are valid for the whole product. Explain during in-briefing that WS daily observation sheets are not shown to supervisors or managers and are treated as given in confidence. Sampling data is never used by superiors to evaluate individuals.

24.4.2. Out-briefing. Summarize process percentages during out-briefings. Charts are a convenient way to graphically present this information. Brief local OPRs on measured man-hours and WLF values. Cover the treatment of assumed and inferred work. Inform local OPRs measurement results do not represent the final determinant. C&R analysis computes the final determinant using data from the measurement locations.

24.5. Work Sampling Process Development. Develop the processes for WS at the same level as for OA (Level II), or if appropriate, at the broader process level (Level I). Derive activity or step times by using the percentage estimates described in **paragraph 24.3**. Write the processes to facilitate observation during sampling. Processes should cover all required work, be clearly defined, and be mutually exclusive.

24.5.1. Select processes for both direct and indirect work. Refer to **Chapter 4** for more information regarding work classification. Further define the process by using steps. Each step is discrete and understandable to the observer. Failure to clearly define processes distorts process percentages and later makes analysis and determinant maintenance difficult.

24.5.2. WS efforts 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, etc. Additional processes, such as additional duties, may be described and measured during WS for management's information.

24.5.3. Nonproductive categories, for sampling purposes, are personal fatigue, idle (e.g., extended lunch), and unavoidable delay. Other nonproductive categories, such as assumed and inferred, may be added as needed. Do not use "other" and "miscellaneous" for nonproductive category titles as they become catchalls during WS efforts. Usually, productive indirect and nonproductive activities are sampled at the process level. Data collected for these processes is useful when out-briefing WS results.

24.5.4. Sample lunch to account for productive time expended during the lunch period and to account for nonproductive time taken for an extended lunch.

24.5.4.1. 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, when applicable.

24.5.4.2. The following example illustrates the need for caution in sampling lunch. Assume three observations per hour are being taken and the lunch period for half the work center is from 1100 to 1200. Assume the other half takes lunch from 1200 to 1300. Select random times so three observations occur between 1100 and 1200 and three occur between 1200 and 1300. Normally record three samples for lunch for each worker.

24.5.4.3. However, if worker A (from the first group) was working at 1145 (observation time) and did not take his/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/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.

24.5.4.4. 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 effort to verify representativeness.

24.5.5. An unscheduled category is useful for keeping accountability of samples. Use this category when:

24.5.5.1. Shift changes are staggered during a multi-shift operation.

24.5.5.2. Workers are doing required work before the beginning or after the end of a scheduled shift.

24.5.6. As part of the verification process, accomplish the following:

24.5.6.1. Investigate the operation of the work center thoroughly before beginning the effort. Check organizational structure, mission requirements, directives, and other pertinent factors, such as backlogs, work cycles, and historical production.

24.5.6.2. Measure steps separately. The study team, in cooperation with the OPR during data analysis, makes the final decision to include or exclude these steps in the manpower determinant. The study team updates the processes if it is determined the added steps apply to all locations.

24.6. Collecting Work Unit Counts and Potential Workload Factors.

24.6.1. Setting Up a Work Count System. Man-hours collected during WS efforts represent only one portion of the data needed to compute an equation. The other important part is workload data. 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 available, but make periodic checks to validate its accuracy. Ensure the production report period corresponds with the development period. Do not include WUCs for days sampled but dropped from computations for non-representativeness. Adjust the average daily work counts to an average monthly figure. Use this figure as the independent variable for the determinant 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.

24.6.2. Determining Sampling Period. Sample at least one complete cycle during the measurement period. The normal sampling period is 21 days (minimum of 15 usable duty days). When necessary, extend the sampling period to ensure it covers a complete cycle.

24.6.2.1. Conduct WS over a representative period or work cycle. Ideally, use WS when a normal period of productivity is to be measured and when relatable WUs are available. When a work cycle is longer than a month, the study team decides the feasibility of using WS. In a seven-day work center, ensure a representative proportion between weekend days and weekdays is maintained during the sampling period. For example, when 21 usable duty days are needed, six of those days should be weekend days. Evaluate each day's sampling results for representativeness. If a day is not considered representative, extend the sampling period.

24.6.2.2. Use the experience of work center personnel to set up an average work cycle and 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.

24.6.3. Supplementing WS with OA. During a WS effort, samples may be taken for a process previously identified for measurement by OA. When this occurs, maintain sample accountability, and avoid double counting.

24.6.3.1. Evaluate the supplemental OA for non-routine work based on total review of OA work. No adjustment is needed for non-routine work if the sampling period is considered representative. Project teams provide 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.

24.6.3.2. 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 non-routine required steps that occur less frequently than monthly. Be particularly careful when supplementing WS data for indirect tasks. When Level I (productive and nonproductive) sampling is being used, a supplemental OA for indirect tasks is not required.

24.6.4. 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 and 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.

24.6.5. Observation Schedule Development. When scheduling the time between observation samples, use a random process. 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 the randomness of the sample observations. Computer software can be utilized to generate a series of random numbers with the needed number of digits to ensure randomness.

24.6.5.1. Sampling period, work center operating hours, desired accuracy, and the number of people assigned determine the number of observation rounds needed for each work center during a WS effort. 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 10:15 in a seven-man work center yields seven samples.

24.6.5.2. Determine the observation schedule. Project teams determine the cycle, which days to sample, and the strata to use (e.g., stratified hourly or stratified daily random sampling). Develop the schedule to collect no fewer than 1,111 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-effort. Taking fewer than 1,111 samples will cause the effort to fail statistical significance. If this happens, extend the measurement period through the next cycle. Prior to sampling, consult the work center supervisor regarding scheduled nonavailable activities, such as leave, medical absences, or TDY.

24.6.5.3. Select observation times so 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 during the duty day.

24.6.5.4. When an observation schedule cannot be met because locations are widely dispersed, develop a randomized location schedule. 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 enough samples are collected to achieve accuracy, a complete cycle is sampled, and the minimum sampling period is covered. Operationally audit overtime when this method is used.

24.6.5.5. Often it is desirable to ensure 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, follow the predetermined schedule per hour until completion of the sampling period. Ensure the number of observation times for lunch is representative before sampling. The following example illustrates how to determine the number of observations needed per hour:

24.6.5.5.1. Assume a work center size of seven people and a sampling period of 21 workdays.

24.6.5.5.2. One observation of seven people per hour, assigned for an 8-hour day over a 21-day period, yields 1,176 samples (1 x 7 x 8 x 21 = 1176). This meets the minimum requirement of 1,111 available samples. However, if normal non-availability for military personnel (e.g., 11.09%) occurs during the effort, then only 1046 available samples would be obtained, i.e., 88.91% of 1,176 available samples. Therefore, increase the minimum number of observations per hour to two. Increasing the number of observations per hour above the minimum improves the accuracy and efficiency. Make allowances for loaned time when setting up observation schedules.

24.6.6. Man-hour Shift Profile Sampling. The purpose of the man-hour shift profile chart is to reduce standby. When post/position manpower is not clearly defined and it is not possible to accurately sample standby, construct a present and proposed man-hour shift profile chart. When collecting WS data to build the man-hour shift profile chart:

24.6.6.1. Use stratified hourly sampling.

24.6.6.2. Designate each productive process as transferable or nontransferable.

24.6.6.3. Construct the present man-hour shift profile chart directly from information on the daily observation and recapitulation sheets.

24.6.6.4. Construct the proposed chart by analyzing and improving the present chart (see **Chapter 8**, **paragraph 8.4** for more information on constructing man-hour shift profile charts).

24.6.6.5. Use the proposed chart to support the standby time allowed in the determinant. Also, use the chart to graphically support reduced standby to the OPR.

24.6.7. Work Sampling Procedures. Make observations at scheduled times without distracting workers. Enter the work center inconspicuously. Sometimes it is best to remain in the work center between closely spaced observations because distractions caused by entering could bias samples.

24.6.7.1. Classify the sample instantaneously so 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 nonproductive and reconcile it later. The worker's activity immediately before or after the scheduled observation may give a clue to proper classification.

24.6.7.2. Conduct trial sampling to reduce the number of questions during observation rounds. When possible, wear apparel similar to the personnel in the work center being sampled. Likeness in clothing causes the analyst to blend with work center personnel and helps reduce apprehension. Avoid unnecessary conversation but be friendly and answer questions regarding the study process.

24.6.7.3. Properly classify PF&D, standby, and idle time. Accurate identification provides rationale for using the allowance factor or for proving a larger factor that includes additional fatigue or delay. Identify potential areas for assumed and inferred work. The key to proper identification is the familiarity with the work center. Identify inferred and assumed work separately. Later, credit inferred work to the proper work center, or remove it from allowed man-hours. Always remove assumed work from allowed man-hours.

24.6.7.4. Sample pre-duty and post-duty periods. The analyst 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 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.

24.6.7.5. Follow the same measurement technique for all determinant 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 fewer people (see **paragraph 24.3.3**.). 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 ensure lunch samples are representative.

24.6.7.6. Avoid sampling at the lower task levels unless these tasks are easily identifiable by observation. Sampling a large number of tasks increases the time needed to make an observation round and results in a need for more analysts to complete coverage. Sampling at the task level disrupts work center personnel because questions need to be asked to properly classify samples.

24.6.7.7. Between samples, accomplish daily accumulations, compute control chart limits, collect WUs or potential WLFs, conduct OAs, observe personnel who might be working out-of-area, and investigate process improvement opportunities.

24.6.7.8. Treat standby time during sampling according to **Chapter 8, section 8.3.2**.

24.6.7.9. Analysts should be able to recognize all workers, their duty schedule and lunch period, and the work accomplished. Analysts should also be familiar with the layout and boundaries of the work center. Devise coding systems to expedite sampling and facilitate recall. Use mutually agreed-on codes when more than one analyst is involved in the effort.

24.6.8. Protection of Data. Daily WS observation data points are considered sensitive information and are not releasable by name.

24.6.8.1. Use codes for identification in lieu of names.

24.6.8.2. Devise a code for idle and sensitive processes. Use codes familiar to other analysts. Memorize codes for productive indirect and nonproductive categories and omit the legend on the form, however, include a legend for all omitted entries as part of the study plan.

24.6.8.3. Data Leveling. Pace rating for WS efforts is a study team option. Pace rating is used to determine a leveling factor. The leveling factor adjusts productive time to a norm. The analyst needs to 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 determinant development process of using least squares regression, helps ensure the norm. If pace rating is used, the pace rating range is specified by the study team. If pace rating is not used, the leveling factor is 1.00. Refer to **Chapter 22** for information on pace rating.

24.6.9. Allowance Factor Computation. Allowances are computed to recognize PF&D. Allowances are applied at the process level for WS efforts. When the base personal allowance factor is used for the work center, apply it to all productive and leveled processes. When a larger allowance factor is computed, apply it only to the affected process. Use the base personal allowance factor for the remaining productive processes. The study team determines whether the base personal allowance factor is pertinent. If it is not, the study team computes the allowance factor to be used according to **Chapter 23**. The allowance factor, fixed or computed, is evaluated during the first three days of the measurement period, and then coordinated with the functional OPR. The coordinated allowance factor is then put in the SWD for all input locations to use.

24.7. Work Sampling Data Control Charting. The two types of control charts used with WS data are productivity charts and WLF control charts (see **Chapter 11**, section **11.7** for more information about control charting). Exercise caution when examining productivity control charts and excluding non-representative samples to ensure adequate sample size is maintained.

24.7.1. Productivity Charts. Productivity charts, or P-charts, are effective for determining representativeness of daily productivity. By comparing productivity control charts with the WLF control chart more information is apparent to the analyst.

24.7.1.1. A productivity chart is a graph that has a center line, UCL and lower control limit (LCL) and the daily productivity to be analyzed.

24.7.1.1.1. The center line is the average productivity for the period the chart represents.

24.7.1.1.2. Set UCL and LCL by adding and subtracting three standard errors of proportion from the center line.

24.7.1.1.3. 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.

24.7.1.2. Frequently in the first few days (possibly a week) of sampling, greater productivity is observed than in the remaining days of the effort. This is usually caused by the analyst's presence in the work center. After personnel in the work center become accustomed to the analyst, data are usually more representative of the normal situation. When this situation causes high productivity followed by low productivity, include both in the effort. Consider alternating analysts daily and compare odd and even days. This helps identify any observer bias.

24.7.2. Control Chart Preparation.

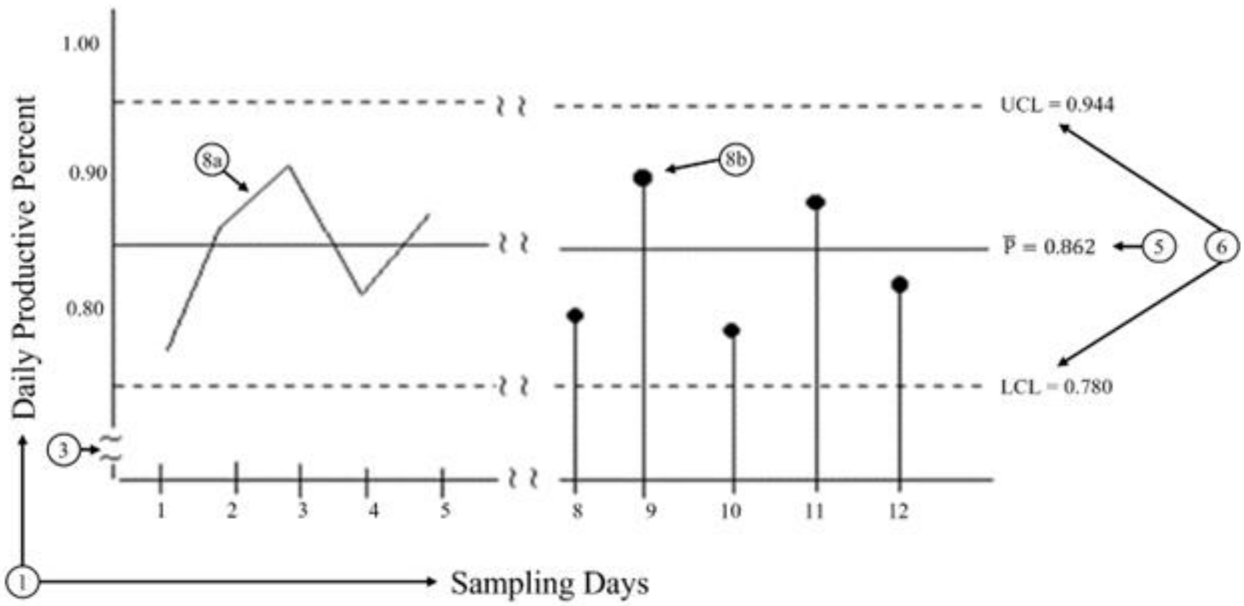
24.7.2.1. The same general procedures for preparing control charts (**Table 24.2** and **Figure 24.1**) apply to all types of control charts. However, the computations of the needed values differ for variable data (measurements of time, length, etc.) and attribute data (percent or proportions). WS uses attribute data.

Table 24.2. 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 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 UCL and LCL. Indicate the value of each.
7	Plot the points to be evaluated on the control chart.

STEP	ACTION
8	Connect all the points to aid the visual analyses, either by: (a) using a solid line between each of the points, or (b) using a vertical line between each point on the X-axis.

Figure 24.1. Preparation of a Control Chart, Example.



24.7.2.2. Attribute data are suitable for a P-chart that evaluates changes in the percent of 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 24.3**.

Table 24.3. Preparation of a P-Chart for Attribute Data.

STEP	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.	Productive Day	Daily Available Samples (n)	Productive Samples (X)	Productive Percent (P)
2	Compute the percent productive for each day. $P = X/n$ Carry one or two extra decimals during computations.	1	162	137	0.8457
		2	180	158	0.8778
		3	184	157	0.8533
		4	188	159	0.8457
		5	190	156	0.8211
3	Calculate the average value, where: $\overline{P} = \Sigma X/\Sigma n$ $\overline{n} = \Sigma n/\Sigma K$ K= number of sampling days	$\overline{P} = \frac{767}{904} = 0.8485$			
		$\overline{n} = \frac{904}{5} = 180.80$			
4	Compute the standard error of the proportion: $\sigma_P = \sqrt{\frac{(\overline{P})(1-\overline{P})}{\overline{n}}}$	$\sigma_P = \sqrt{\frac{(0.8485)(0.1515)}{180.80}} = 0.0267$			
5	Determine control limits: $UCL = \overline{P} + 3\sigma\overline{P}$ $LCL = \overline{P} - 3\sigma\overline{P}$	$UCL = 0.8485 + 3(0.0267) = 0.929$ $LCL = 0.8485 - 3(0.0267) = 0.768$			
6	Prepare a P-control chart using an automated program. Label all values and each axis clearly.				

24.7.3. WLF Control Charting. A WLF control chart often helps determine the representativeness of the data collection period, verifies the accuracy of the work count, and identifies normal workloads. The WLF control chart is used in combination with P-control charts. Make a WLF control chart when the WLF count is available on a daily basis. Development of a work center determinant during other-than-normal workload periods might result in a distortion of the determinant.

24.7.3.1. Get the historical workload (minimum of 6 months of data) and create a control chart (dividing monthly totals by the number of working days per month) to determine the normal expected average and control limits.

24.7.3.2. As the effort develops, plot each day's WLF count cumulatively. Valuable questions to analyze points that deviate from the historical line include:

24.7.3.2.1. Are the daily and historical counts based on the same WLF? Check the definition of the WLF.

24.7.3.2.2. Is a regular cycle appearing? Plan to stop sampling as close as possible to the completion of a cycle.

24.7.3.2.3. Is productivity commensurate with high or low current workload compared to historical workload? Check rating factors for indications of high or low ratings.

24.7.3.2.4. 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.

Chapter 25

QUEUEING

25.1. General Concepts. The primary intent of this chapter is to relate queueing analysis to the Air Force MEP. General procedures are presented to give analytical direction and a feel for queueing situations. The following are basic queueing principles.

25.1.1. During post/position manpower situations in particular, queueing analysis is useful in determining the total number of positions needed to meet varying levels of service.

25.1.2. Defining the queueing system is critical to ensure the application of the correct queueing formulas.

25.1.3. Queueing analysis results in a deterministic result, i.e., using process averages always ends in the same mathematical result.

25.1.4. Queueing and simulation modeling hold much in common.

25.1.4.1. For simple solutions with Poisson distributed arrivals and an exponentially distributed service time, choose queueing analysis.

25.1.4.2. As the model becomes more detailed, or the system is inherently complex, choose simulation modeling. Refer to **Chapter 12**.

25.2. Queueing Systems and Analysis.

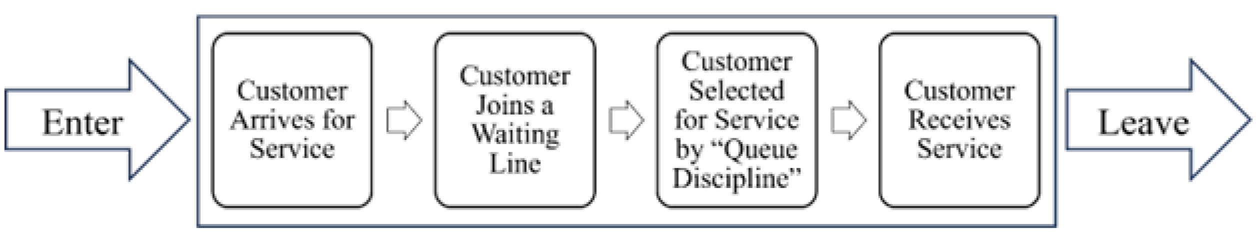
25.2.1. A queueing system refers to the entire process of a customer arriving, being served, and leaving the system. **Figure 25.1** illustrates the basic steps of a queueing system. A specific definition is needed to understand the term customer. In queueing, customer is used in a general sense and does not necessarily refer to a human customer and could represent anything, animate or inanimate, awaiting service. The following are examples of customers:

25.2.1.1. A vehicle waiting to enter a US Air Force base's main gate.

25.2.1.2. A morale call waiting to be answered by a telephone operator.

25.2.1.3. A patron waiting in line at checkout at the commissary.

Figure 25.1. General Flow of a Queueing System.



25.2.2. Queueing analysis can be a powerful addition to data analysis when developing a manpower determinant. Although 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 systems where the workload develops (arrives) randomly, queueing theory applies. For example, and in keeping with examples above, queueing analysis could provide considerable insight when:

25.2.2.1. An analysis of the appropriate number of posts or positions is in question. For example, the number of Security Force posts required to maintain a specified wait time or average number of vehicles in the queue at a base entry control point.

25.2.2.2. There are differing levels of service, particularly when a function's performance measures deal with customer wait time, and the resultant manpower impact is being explored. For example, the number of telephone operators required to answer a customer phone call within 10, 20, or 30 seconds.

25.2.3. After completing the mathematical analysis of a queue and the creation of a queueing model, the following queueing system metrics can be predicted:

25.2.3.1. The probability of a customer(s) waiting or not waiting.

25.2.3.2. The average number of units waiting to be served.

25.2.3.3. The average time spent in the queue.

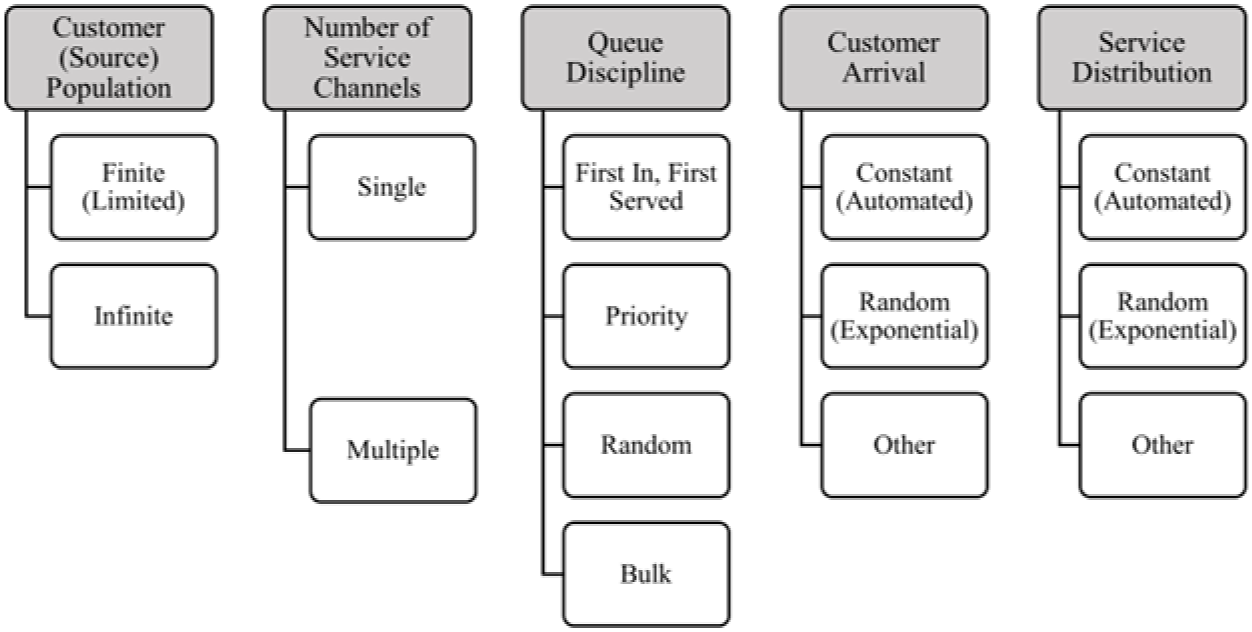
25.2.3.4. The average time spent in the system.

25.2.4. Given any of the aforementioned metrics as part of the function's performance criteria, a decision can be made regarding what level of service is acceptable and the resulting manpower impact. For example, the analyst can determine the number of cashiers needed to make sure a customer's desired average waiting time is not exceeded.

25.2.5. In the final analysis, a queueing model does not result in the final decisions. Rather, the model provides important information to base decisions upon. Thus, it becomes important to objectively apply the tools of work measurement and analysis to ensure the best information is provided.

25.3. Defining a System for a Queueing Analysis and Queueing Formulas. Before doing a queueing analysis, carefully research and define the entire queueing system. **Figure 25.2** presents the type of information needed and further delineations of that information needed to perform a queueing analysis. It is critical to correctly define the system in terms of these information categories as specific queueing formulas are needed to correctly compute the accurate solution for a specific type of queueing system.

Figure 25.2. Types of Information Needed in Queueing.



25.3.1. Customer (Source) Population. The size of the customer population, also known as source, is a count of the actual system user population and is classified as either finite or infinite.

25.3.1.1. Finite Customer Populations. A customer population that has a fixed size is finite. Once a customer has arrived and been serviced, the total customer population to be serviced is reduced by one and directly affects the probability of arrival of the remaining customers. In a fixed customer population, the probability of a customer arriving for service is based on the number of customers already in the system. For example, consider repairing lathes. A machine shop has five lathes (i.e., customer population equals five) that are serviced by a single repairman. These machines break down occasionally (arrive for service). When this occurs, the down machine is repaired and put back in service. While the one machine is down for repair, the customer population is not the same as now only four remain in service affecting the probability of occurrence of the next arrival.

25.3.1.2. Infinite Customer Populations. When a customer population is so large it is unaffected by the service capacity of the system, the population can be considered infinite. In an infinite customer population, the probability of a customer arriving for service is independent of the number of customers already in the system.

25.3.1.2.1. For example, assume the aforementioned machine shop has now been equipped with a sufficient number of spare lathes. When one machine is down, a spare lathe is immediately substituted. Hence, the customer population to be serviced remains constant at five, even if one lathe is down for repair. Since a machine down no longer affects the customer population, the population in this case can be correctly termed infinite.

25.3.1.2.2. For another example, consider a commissary's customer population. Here, the commissary's customer population is finite because only people with commissary privileges are customers. However, this customer population is so large when compared to the service capacity of the commissary, the population effectively becomes infinite as the customer population is considered inexhaustible.

25.3.2. Service Channels. Service channels are concerned not only with the number of service facilities but also with the associated queue(s). A queue is characterized by the maximum number of customers it can hold. A queue is considered finite when a given number of customers are already waiting in a queue and customers are denied entry into the queue until others are served. An infinite queue does not have such restrictions and can handle an unlimited number of customers. Service channels can be considered single or multiple. A single service channel has only one queue or waiting line. 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. Multiple service channels can each be served by different queues, such as a commissary with several checkout lines.

25.3.3. Queue Discipline. A queue's discipline refers to the method used to select customers to be served from the queue. Some of the common queue disciplines are listed below.

25.3.3.1. First-Come, First-Served. The next available server services the first customer in the queue line.

25.3.3.2. Priority. A customer is given some sort of priority on entering the queue. Those customers 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.

25.3.3.3. Random Selection. With random selection, the order of customers being served is independent of arrival time and customers are selected to be serviced with no particular pattern.

25.3.3.4. Bulk Selection. In a bulk selection, a group of customers are selected for service at one time.

25.3.3.5. **Note:** Importantly, queue disciplines may alter when customers do not behave as expected. For instance, a customer may jump from one service channel to another. A customer may also balk, i.e., leave prior to entering the waiting line; or leave the queue after becoming impatient and deciding to no longer wait in line.

25.3.4. Customer Arrivals and Inter-arrival Time. The arrival pattern of customers to a queueing system can be described by:

25.3.4.1. Customer Arrival Rate. The average number of customer arrivals to the system per some unit of time (i.e., the mean arrival rate). For example, four commissary customers per minute arrive in the system.

25.3.4.2. Customer Inter-arrival Time. The average time between successive customer arrivals (i.e., the mean inter-arrival time). For example, a commissary customer arrives to the system on average every 15 seconds.

25.3.4.3. **Note:** The customer arrival rate is measured in customers per unit of time, and the inter-arrival rate is measured in time between customer arrivals. For the same system and data, one measure is the reciprocal of the other.

25.3.5. Service Patterns. The service pattern of customers within a non-empty queueing system can be described by its:

25.3.5.1. Customer Service Rate. The average number of customers served per some unit of time (i.e., mean service rate). For example, 400 customers are served per day.

25.3.5.2. Average PAT. The average time to service a customer (mean service time). For example, it takes two hours per aircraft inspection.

25.3.5.3. **Note:** The relationship between customer service rate and average PATs are simply the reciprocal of the other measure.

25.4. Further Queueing Analysis. To complete queueing analyses, analysts should consult available textbooks and online resources.

Part 10

CONSULTANT SERVICES AND MANAGEMENT ADVISORY STUDIES

Chapter 26

CONSULTANT SERVICES

26.1. Overview.

26.1.1. General Concepts. A core capability within the manpower function is providing consultant services to unit commanders and functional managers at all organizational levels. Organizations may request manpower consultant services to facilitate problem solving or for general information and advice regarding manpower management or process related issues.

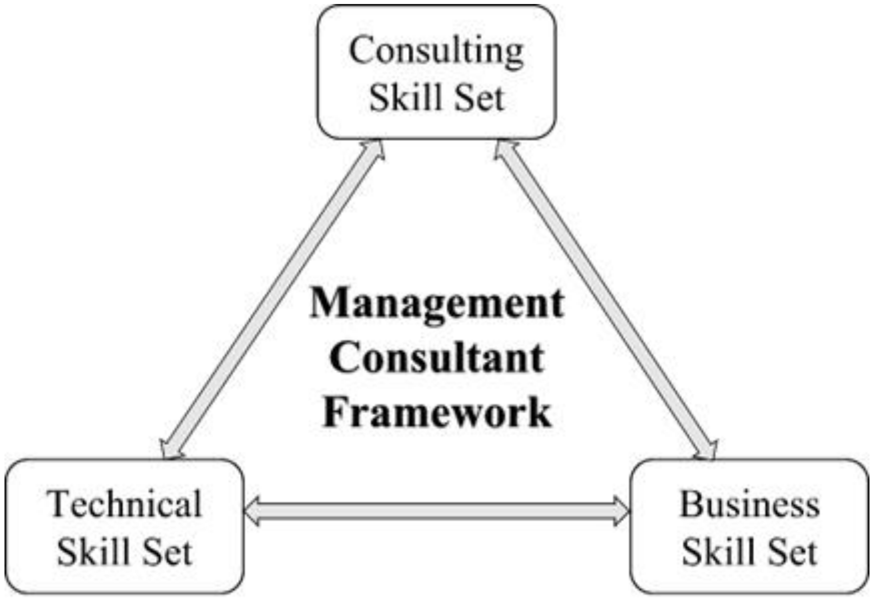
26.1.2. Definition. Consultant services direct manpower competency toward problem resolution, effective resource usage, or mission performance improvements. These services may include brief consultation with management, or a more in-depth consultation requiring a study contract and report. Analysts should acquire broad based management skills, knowledge, and behaviors to be successful consultants. **Table 26.1** lists three categories of skill sets key to providing successful consultation services. **Note:** The OMM can be used as a consultant tool to help identify improvement opportunities in an organization (refer to **Chapter 3**).

Table 26.1. Three Categories of Skill Sets.

Consulting Skill Set	Business Skill Set	Technical Skill Set
Facilitation	Analytical & Proactive Thinking	Effective Communication
Project Management	Business Acumen	Emotional Intelligence
Developing/ Managing Client Relationships	Negotiating	ME/CI2 Skills & Tools
Creativity: Solutions, Project Design	Goal Setting & Action Planning	Organizational/ Functional Research
Implementation	Strategy Development	Presentation Skills
Planning	Business Writing	Designing Implementation Plans
Personal & Professional Growth	Decision Making and Problem Solving	Change Management
		Diagnostics/ Root Causation
		Data Gathering & Analysis
		Interviewing

26.1.3. Management Consultant Framework. It is important to recognize no skill set is greater than the other and a balance is needed to perform at the optimal level to provide maximum value to clients. The management consultant framework at **Figure 26.1** illustrates a continuous flow of various skill sets whereby usage is dependent on the scope and complexity of the provided consultant service.

Figure 26.1. Management Consultant Framework.



26.2. Consulting Skill Sets.

26.2.1. Facilitation. The facilitator's primary role is making sure the group comes to a designated outcome in an effective and efficient manner. The facilitator accomplishes this by providing structure and keeping things on schedule. Effective facilitators focus on two main elements during a consultation:

26.2.1.1. Content. Defining the tasks to be accomplished and ensuring the group stays focused.

26.2.1.2. Process. The flow of the session(s) and the methods used to achieve the objectives. This includes procedures; format and tools; group dynamics; norms; and cultural climate.

26.2.2. Tools and Processes. A process or technique is the approach used by a facilitator to help participants achieve the goals of a workshop or meeting, such as sharing information, generating and organizing ideas, or making decisions. Several different processes are usually employed during a workshop. Models or methodologies provide a framework. Processes, tools, and techniques are used to compliment that framework. Tools and techniques include, but are not limited to: brainstorming or idea generation; affinity diagramming; value stream and process mapping and criteria matrix; and ranking.

26.2.2.1. Example Technique for Brainstorming, Affinity, and Ranking. The Nominal Group Technique is a useful problem-solving and idea-generating strategy. This technique is controlled by the facilitator and includes these steps: silent generation, round robin listing, clarification, and voting and ranking.

26.2.2.1.1. Step 1. Silent Generation. The silent generation step typically takes about 10 min. During this step, the facilitator prompts the group to independently generate as many ideas as possible in the time allowed.

26.2.2.1.2. Step 2. Round Robin Listing. The facilitator then calls on participants, in turn, to read one of their written responses. This phase continues until all the ideas produced by the group are listed and displayed.

26.2.2.1.3. Step 3. Clarification. Once all the items have been recorded, the facilitator calls on the author of each item to offer clarification if needed.

26.2.2.1.4. Step 4. Voting and Ranking. After ideas have been developed, facilitators work with the group to categorize and rank similar ideas. Affinity diagrams are a useful technique for categorizing ideas. Ranking can be done utilizing several methods such as multi-voting.

26.2.2.2. Additional Techniques. More detailed accounts of other resources, tools, and methods can be found online or in other manuals.

26.2.3. Project Management. A project manager is tasked with overseeing all aspects of a study, ensuring it is on task, on time, and within budget. They follow the project management process: initiating; planning; executing; monitoring and controlling; and closing.

26.2.4. Managing Client Relationships. A consultant displays competency in this area when the techniques required to develop, maintain, and manage relationships with clients are understood. This includes managing client expectations; establishing and maintaining relationships at all levels of the organization; and increasing commitment and support throughout the course of engagement and after project closure.

26.3. Business Skill Sets.

26.3.1. Analytical and Proactive Thinking. Consists of working systematically and logically to resolve problems, identifying root cause, and anticipating unexpected results. Involves a methodical step-by-step approach to thinking that allows consultants to break down complex problems into single and manageable components. This type of thinking also requires consultants to compare sets of data from different sources, identify possible cause and effect patterns, and draw appropriate conclusions from these datasets to arrive at appropriate solutions. Analytical thinking can be broken into the following steps:

26.3.1.1. Gathering Information. Gather all the necessary information required to solve the problems. Ask appropriate questions to gain the necessary insights to make more effective decisions about the problems being solved.

26.3.1.2. Performance Data. Take statistical information to evaluate how an organization is performing. Review performance data to determine which products/services, staff, or departments are most efficient and determine areas of improvement.

26.3.1.3. Consultant Acumen. Consultants with this skill tend to display a superior understanding of the following four areas:

26.3.1.3.1. Understanding Thought Processes. The consultant is mindful of the context, scope, and details of the situation at hand; is prepared to make sense of complexity and confusion; and demonstrates the ability to react, showing resilience and flexibility.

26.3.1.3.2. Developing Consultant Knowledge. Knowledge relating to elements of an organizational model.

26.3.1.3.3. Effective Use of Management Processes. Management processes are the tools, procedures, and ideas that give structure to organizational thinking and communication about activities.

26.3.1.3.4. Management and Leadership Skills. The ability to manage the various personal relationships essential to the enterprise's success.

26.3.2. Negotiation. A method by which people settle differences. It is a process by which compromise or agreement is reached while avoiding argument and dispute. Follow a structured approach to achieve a desirable outcome:

26.3.2.1. Preparation. Before any negotiation, decide when and where a meeting will take place and who will attend to discuss the problem. To clarify positions, ensure all relevant facts of the situation are known. Preparing before discussion avoids further conflict and wasted time during the meeting.

26.3.2.2. Discussion. Participants put forward their understanding of the situation. Key skills during this stage include questioning, listening, and understanding. It is helpful to take notes during the discussion stage to record all points put forward in case there is need for further clarification. Each side should have an equal opportunity to present its case.

26.3.2.3. Clarification of Goals. Clarify all differing goals, interests, and viewpoints from the discussion. Clarification is an essential part of the negotiation process; without it, misunderstandings are likely to occur which may cause problems and barriers to reach a beneficial outcome.

26.3.2.4. Negotiate Towards a Positive Outcome. This stage focuses on an outcome where both sides feel their points of view have been taken into consideration. It is essential for participants to keep an open mind to achieve an acceptable solution. A win-win outcome is usually the best result. If this is not possible, then alternative strategies and compromises need to be considered. Compromises can often achieve greater benefit for all concerned compared to holding to the original positions.

26.3.2.5. Agreement. This is achieved once both sides viewpoints and interests have been considered. Decisions need to be definitive and communicated clearly to participants.

26.3.2.6. Course of Action. After agreement on a decision, a course of action must be implemented.

26.4. Technical Skill Sets.

26.4.1. Effective Communication. Combines a set of skills, including nonverbal communication, engaged listening, stress management in the moment, the ability to communicate assertively, and the capacity to recognize emotions.

26.4.1.1. While effective communication is a learned skill, it is more effective when it is spontaneous rather than formulated. It takes time and effort to develop these skills to become an effective communicator.

26.4.1.2. There are four key skills that translate to better and more effective communication: active listening, attention to nonverbal signals, managing stress, and assertiveness.

26.4.2. Emotional Intelligence. The ability to recognize emotions, understand what has been said, and realize how those emotions affect others. This allows consultants to manage relationships more effectively. Emotional intelligence is made up of four core skills under two primary competencies, personal competence, and social competence.

26.4.2.1. Personal Competence. Made up of self-awareness and self-management skills, focusing more on the individual than interactions with other people. Self-awareness is the ability to accurately perceive emotions. Self-management is the ability to use awareness of these emotions to stay flexible and positively direct personal behavior.

26.4.2.2. Social Competence. Made up of social awareness and relationship management skills. Social awareness is the ability to understand moods, behavior, and motives to improve the quality of relationships. Relationship management is the ability to use awareness of those emotions and the emotions of others to manage interactions successfully.

26.4.3. Continuous Innovation and Improvement Skills and Tools. As a consultant, competence and skills in the MEP methodology, tools, and techniques, and the CI2 process is necessary to be successful. The purpose of CI2 engagement is to document, improve, and standardize the processes of an Air Force function. This guides a process improvement team logically from problem definition to implementing solutions linked to root causes.

26.4.3.1. The Practical Problem Solving Method (PPSM) provides a standardized approach similar to Plan, Do, Check, Act (PDCA), and Define, Measure, Analyze, Improve, and Control (DMAIC). The activities of the PPSM are listed below:

26.4.3.1.1. Clarify and validate the problem.

26.4.3.1.2. Break down the problem and identify performance gaps.

26.4.3.1.3. Set improvement targets.

26.4.3.1.4. Determine root cause.

26.4.3.1.5. Develop counter measures and implementation plan.

26.4.3.1.6. See countermeasures through.

26.4.3.1.7. Confirm results and process change.

26.4.3.1.8. Standardize successful processes.

26.4.3.2. Consistent application of the PPSM provides a concise and common format for presentation of data, problem solving facts, and information. The common structure provides a common language which easily translates into a common understanding. To attain superior understanding of both the CI2 process and PPSM and MEP methodologies requires knowledge and practical application of a multitude of CI2 skills. Effective consultants are proficient using the tools found in **Table 26.2**.

Table 26.2. CI2 Tools.

CI2 Tools	
Six Sigma	Project Plans
Lean Methodology	Brainstorming

Supplier, Input, Process, Output, Customer (SIPOC)	Strengths-Weaknesses-Opportunities-Threats (SWOT) Analysis
Five-Whys	Theory of Constraints
Process Flow Map	Pareto Chart
Value Stream Map	Control Chart
OMM	Cause-and-Effect Diagram
SWD	Gap Analysis

26.5. Providing Consulting Services.

26.5.1. Providing effective management consultant services requires the manpower consultant to continuously develop and improve a myriad of skills. The key to being a successful consultant is to strike an appropriate balance amongst the various skill sets that meets the needs of the Air Force community.

26.5.2. Do not agree to provide consultant services if the sole purpose is to justify predetermined manpower increases or decreases or there is an expectation for the consultant to make a line management decision for the client.

Chapter 27

MANAGEMENT ADVISORY STUDY

27.1. General Concepts. Analysts can provide a MAS in-house at base, command, and Air Force-wide levels.

27.1.1. Any client (AF commander, functional manager, or supervisor) may request MAS assistance. The base manpower function may perform a MAS for any base or tenant unit. With the client's permission, official parties may receive the study results. The client has the final authority to reject or accept and implement proposed initiatives. AFMAA can be used as a sounding board by the base-level manpower function during a local advisory study. However, these communications should not violate the client-consultant relationship.

27.1.2. Every organization should constantly seek improvement. Improvement can be measured in dollars, time, and quality factors. It leads to improved operational effectiveness and cost-savings. The improvement process should be managed if it is to have a significant and lasting effect. The changing military environment creates challenges each organization adapts to meet. Completing a MAS is helpful in the following situations:

27.1.2.1. A short-term analysis is needed to resolve an issue.

27.1.2.2. A client cannot devote time to the problem.

27.1.2.3. Specialized knowledge and skills are not available within a client's own resources to identify or solve a problem.

27.1.2.4. An objective and/or impartial viewpoint is needed to give a fresh approach to a problem or to resolve conflicting issues.

27.1.3. Do not use a MAS in the following scenarios:

27.1.3.1. To justify manpower changes.

27.1.3.2. Approve or lend credence to a preconceived solution.

27.1.3.3. Discredit another organization or individual.

27.1.3.4. When the client expects the manpower enterprise to assume the decision-making role of organizational management.

27.1.3.5. To quantify manpower or man-hours for the purpose of programming future requirements.

27.2. Conducting a Management Advisory Study.

27.2.1. Skills. Use a wide range of skills involving organizational analysis, investigation of management functions, work methods and procedures, and resource utilization. These skills are acquired through formal training and practical experience.

27.2.1.1. It is critical to gain the client's confidence, accurately define the problem, build a solution, and persuade the client to adopt the recommendations.

27.2.1.2. Effective communication and mutual understanding between the client and consultant are essential to the success of the study.

27.2.2. Scope. The length, approach, and degree of formality depends on the MAS. At times, the client and the consultant can decide informally on the scope. However, more often, an expanded study is needed, especially if the client cannot clearly define the problem, or the problem is too complex or broad.

27.2.3. Preliminary Research.

27.2.3.1. Identifying and Defining the Problem. Most MASs are problem-solving exercises. The problem statement describes symptoms and probable causes. It provides guidance for use during analysis. Problem symptoms are often mistaken for causes, therefore, probe for the root of the problem. While the problem definition may show only the client's limited viewpoint, the study may produce other views.

27.2.3.2. Stating the Goals and Limitations.

27.2.3.2.1. Goals are desired outcomes clearly identified during preliminary research. Some typical goals are: to decrease total processing time; to improve work procedures or workflow; to decrease space requirements; to improve the use of critical skills; to improve work quality; or to decrease resource expenditures (people, money, or material). Goals are stated in specific terms and ranked in priority. In final form, these goals spell out the study objectives.

27.2.3.2.2. Limitations or restrictions put barriers on study goals. Occasionally, certain specific limitations identified in preliminary research (e.g., regulatory requirements, local managerial preferences, etc.) may prove to be direct contributing causes to the problem. Attempt to mitigate these limitations.

27.2.3.2.2.1. At times, the client wants to study the cause and effect of directives that are controlled by an authority higher than the client. When this occurs, it is better to charter the study at the level that can change the directive. Although it is a limiting factor not to have a charter at that level, it is not a reason to not do the study. There are proper channels for staffing directive changes, either through the client's functional OPR or Air Force MEP channels.

27.2.3.2.2.2. On occasion, a good MAS solution to a problem is dismissed by the client. Do not treat this as a study limitation unless the client wants it to be listed accordingly.

27.2.3.3. Determining Feasibility. Factors such as cost, study timing, consultant and client workload, time needed to build a solution, and study priority impact the feasibility of the study.

27.2.3.4. Proceeding with the MAS. After the problem is defined and the study goals, scope, limitations, and anticipated benefits identified, the consultant (perhaps jointly with the client) decides whether the study can continue. If the study does not currently warrant consultant resources, decline, or recommend a study delay or cancellation.

27.2.3.5. Memorandum of Understanding (MOU). Make sure that both the client and consultant clearly understand and agree to the objectives and scope of the study in a MOU. **Figure 27.1** details the purpose and content of the MOU.

Figure 27.1. Memorandum of Understanding.

Purpose: The main purpose of a MOU is to state the goals, the authority, and the responsibility of all parties. It is like a contract. The client wants certain results, and the consultant agrees to give services needed to get those results. The MOU is usually prepared by the consultant for the client and is signed by both. A formal MOU is not used for most advisory studies but can be a big benefit in complex or sensitive studies.

Content: The MOU includes but is not limited to:

Title of Effort. A descriptive title of the subject.

Problem. A clear statement that defines and describes the problem. Do enough research during Preliminary Research to ensure the problem, and not the symptoms, is defined.

Objectives. A statement of the improvement objectives. This statement is definitive (e.g., a 10% reduction in overtime, or a 15% decrease in the abort rate).

Scope. Document what limits may affect the effort, such as anticipated program changes, known limits of funds and space, and operational constraints.

Location. Provide the location of the installation, organization, and function.

Recommendations. Explain the level of detail and format to be provided for recommendation(s).

Authority to Approve, Implement, and Release Recommendations. State the agreed upon client's organizational level that has the authority to approve and implement improvements, and release recommendations and results. Information to include the report and abstract is not to be released without the approval of the client.

Designating the Consultant. List all personnel who are to be involved in the effort, their security clearances, and the access they need to classified material.

Access Authority of Team. A statement that provides consultant personnel access to existing reports and data, work areas, and personnel need to get information to conduct the effort.

Responsibility of Other Elements. A statement that documents the involvement of other units and personnel to support and help the consulting team. This may need prior coordination with supporting units.

Reports. Describe the type and frequency of status reports to be provided to the client.

Signatures. Signature blocks are provided for the consultant and client. This document is to be signed before any significant work is accomplished.

27.2.3.6. Study Design. Study design is an extension of the initial study definition, as specified in the MOU. Design efforts complement and support feasibility.

27.2.3.6.1. During study design, formalize plans and schedule for conducting the study. Careful planning lays the groundwork for efficient use of consultant personnel and helps save the client's time. A plan serves to focus effort on common objectives and maintains consistency of action.

27.2.3.6.2. Study design includes study approach (e.g., measurement techniques, a synopsis of the nature of the work); strategies for study completion (e.g., data collection methods); and any other pertinent information needed to facilitate study completion. Develop a working plan for fact-finding and to determine the type data to acquire; the sources of data; the techniques to collect the data; and the reporting format.

27.2.3.6.3. Define study team personnel requirements and qualifications and possible sources of expertise (e.g., consultants, client operating personnel, and other outside offices and/or agencies). Identify each individual study team member's roles and responsibilities.

27.2.3.6.4. State how findings are to be coordinated and exchanged (such as interim briefings, reports, and interim decisions).

27.2.3.6.5. Identify the required study actions and/or milestones. Identify when vector checks are to be conducted to check on study progress and/or for updating the study plan.

27.2.3.6.6. Consider cost in the design process so that the benefit outweighs the cost. Obviously, there is a point of diminishing returns in the amount of time that can justifiably be spent improving a management practice. Study benefits can take on intangible forms, such as improved morale, increased service, or better managerial control.

27.2.4. Data Gathering. Data gathering forms the basis for later analysis and recommendations for improvement. The data gathered should be accurate, unbiased, and comprehensive. Failure to collect and document pertinent and accurate facts could undermine the validity of the results. These are the three objectives for data gathering:

27.2.4.1. Objective 1. Collecting Facts. Usually, three versions of "the facts" are discovered; what the directives state, what operating officials think is being done (or should be done), and what is actually being done. For this reason, direct the examination at the regulatory, managerial, and performance levels.

27.2.4.2. Objective 2. Collecting Opinions and Suggestions. Encourage client personnel to voice opinions. Opinions are personal judgments, not specific events or facts. Good ideas may come from client personnel, their suggestions should be recorded and given careful consideration.

27.2.4.3. Objective 3. Promoting Acceptance of Improvements. The technical aspects of a study are often relatively straightforward if the proper study technique is selected. In fact, the most challenging task may be to convince operating personnel and the client to accept needed improvements. To help facilitate acceptance of improvements, identify a test period for new procedures, layout, or organization, as needed. Advise who is responsible, and when, for procedural development, briefings, orientation of personnel taking part in the test, conducting the test, and evaluating the results.

27.2.4.4. Basic Principles for Data Gathering:

27.2.4.4.1. Stay within the scope, schedule, and objectives stated in the plan.

27.2.4.4.2. Determine the breadth and depth needed for fact gathering by starting at the top and working down. This approach gains proper perspective and support from each level of supervision.

27.2.4.4.2.1. Only a few aspects of the overall problem dominate others. Focus data collection on identifying these issues, unless causes and workable solutions are found, the study may have little or no value. But when solved, the issues create a chain reaction for resolution of lesser concerns.

27.2.4.4.2.2. How much data is enough? Irrelevant data or data defined as only "nice to know" are a waste of consultant time. It is better to have too much data than too little. Remain flexible when deciding how, when, where, and what data to collect. In the end, the experienced judgment of the consultant is essential for these decisions.

27.2.4.4.3. Record data in a planned, orderly fashion so that valuable facts are not lost later in the study. Clearly identify each item so that an audit trail is left which shows when, where, and from whom data was obtained.

27.2.4.4.4. Personnel and documentation are two main sources of information in data gathering. These sources complement each other and are to be used in every possible case. Obtain information from these sources by one or more of the following methods: documentation review, interviews, observation, and questionnaires.

27.2.4.4.5. Validate data. Errors, omissions, or misunderstandings in data can lead to unsound recommendations and result in confusion, excessive expense, and personal embarrassment. Make sure that analyses and recommendations are based on facts, not on unfounded rumors or misunderstandings. Verify all important information against basic documents or factual data.

27.2.5. Data Analysis.

27.2.5.1. Use proper techniques to display data to find relationships, verify facts, and ensure that all required facts or information is known.

27.2.5.2. Pick the type, detail, and arrangement that best answers the questions of who, what, where, when, why, and how it is done. The most creative part of the improvement process is developing new methods or procedures.

27.2.5.3. Improvement recommendations are often obvious. At other times, a systematic study of operations, processes, relationships, or procedures are needed to find good solutions.

27.2.6. Developing Recommendations. Strive to develop practical recommendations that are realistic in terms of resources and the client is most willing to accept. Remember resistance to change is normal, so take every opportunity to discuss new proposals with everyone involved.

27.2.6.1. Make every effort to get client personnel involved with the improvement process. The more personnel are involved in developing improvements, the more readily the changes are accepted.

27.2.6.2. Periodic discussions centered on tentative recommendations help the client and consultant focus on developing sound and practical solutions.

27.2.7. Briefing the Results.

27.2.7.1. Address all the main facts surrounding the data gathering process, the conclusions reached, the recommended improvements, and the detailed implementation plan. State all facts, conclusions, and recommendations in positive terms.

27.2.7.2. Be prepared to discuss major ideas with alternatives in mind. Many times, an alternative is preferred by a client and results in the improvement being implemented.

27.2.7.3. Ensure recommendations that involve other functions are properly coordinated and documented.

27.2.8. Implementing Study Results. The client is responsible for implementation of study findings with the assistance of the consultant.

27.2.9. Ending the Study. The client may want a final briefing to end the study after improvements are implemented and the follow-up visits are conducted.

27.2.9.1. This is a good opportunity to discuss initial improvements the client chose not to implement or new ideas that resulted from implementation of recommendations.

27.2.9.2. Be careful to avoid being involved in a never-ending study of a single organization. Stay within the boundaries of the scope established in the MOU.

27.3. MAS Documentation. The MAS report provides the client enough information to make valid decisions and carry out the recommendations.

27.3.1. MAS Report. The report meets the client's needs by providing solid justification for all recommended actions. Additionally, if approved for release, it provides findings and recommendations for other potential users and documents the efforts of the consultant.

27.3.2. Client Approval and Reporting Criteria. To protect the client-consultant relationship, be sure the client concurs with the release of the abstract and/or MAS report (i.e., have the client sign an acknowledgement for release). If the client has agreed to release, then forward a copy of the abstract to AFMAA for cross-feed purposes. If the client does not concur, note this in the report and abstract and file it along with the other study documents. Do not forward MAS documents that have not been released by the client.

ALEX WAGNER
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Attachment 1

GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

References

DAFPD 38-1, *Manpower and Organization*, 20 February 2024

AFPD 32-10, *Installations and Facilities*, 20 July 2020

DAFI 38-401, *Continuous Process Improvement (CPI)*, 23 August 2019

AFI 1-2, *Commander's Responsibilities*, 8 May 2014

AFI 33-322, *Records Management and Information Governance Program*, 23 March 2020

AFI 36-128, *Pay Setting and Allowances*, 17 May 2019

AFI 38-101, *Manpower and Organization*, 29 August 2019

Prescribed Forms

None

Adopted Forms

DAF Form 847*, Recommendation for Change of Publication*

Abbreviations and Acronyms

AFI—Air Force Instruction

AFMAA—Air Force Manpower Analysis Agency

AFMAN—Air Force Manual

AFMD—Air Force Manpower Determinant

AFMM—Air Force Mission Model

AFPD—Air Force Policy Directive

AFRC—Air Force Reserve Command

AFS—Air Force Specialty

AFSC—Air Force Specialty Code

ANG—Air National Guard

AoA—Analysis of Alternatives

API—Aircrew Position Identifier

ARC—Air Reserve Component

ATK—Analysis Tool Kit

AUoF—Arming and Use of Force

C&R—Correlation and Regression

CI2—Continuous Improvement and Innovation

CME—Contract Manpower Equivalent

CPI—Continuous Process Improvement

CR—Currency Review

CRM—Comment Resolution Matrix

DAFI—Department of the Air Force Instruction

DAFMAN—Department of the Air Force Manual

EOR—End of Runway

FAC—Functional Account Code

FEE—Functional Estimating Equation

FNDH—Foreign National Direct Hire

FNIH—Foreign National Indirect Hire

FREQ—Frequency

FTE—Full-Time Equivalent

IAF—Indirect Allowance Factor

IMO—Installation Manpower Office

LCL—Lower Control Limit

LCOM—Logistics Composite Model

M&O—Manpower and Organization

MAF—Man-hour Availability Factor

MAJCOM—Major Command

MALT—Munitions Assessment LCOM Tool

MANTAB—Manpower Table

MA—Manpower Assessment

MAS—Management Advisory Study

MEP—Management Engineering Program

MESL—Minimum Essential Subsystem Listing

MFE—Manpower Force Element

MFM—MAJCOM Functional Manager

MISCAP—Mission Capability Statement

MOU—Memorandum of Understanding

MPES—Manpower Programming and Execution System

NAT—Nonavailable Time

NT—Normal Time

OA—Operational Audit

OJT—On-the-Job Training

OMM—Organization Maturity Model

OMP—Optimistic, Most Likely, and Pessimistic

OPR—Office of Primary Responsibility

PAI—Primary Aerospace Vehicle (Aircraft) Inventory

PAT—Per Accomplishment Time

PEC—Program Element Code

PEF—Program Estimating Factor

PF&D—Personal, Fatigue, and Delay

POC—Point of Contact

PPE—Personal Protective Equipment

PPSM—Practical Problem Solving Method

PQT—Post/Position Qualification Time

PRP—Personnel Reliability Program

PRT—Post/Position Related Time

r^2—Coefficient of Determination

RPF—Requirements Position Formula

RUT—Ratio Unit Times

SAT—Standard Activity Time

SME—Subject Matter Expert

SOC—Statement of Conditions

SPPBE—Strategy, Planning, Programming, Budgeting, and Execution

SS—Study Sponsor

SSE—Sum of Squares Unexplained by Regression

SSR—Sum of Squares Explained by Regression

SSR—Study Sponsor Representative

ST—Standard Time

SWD—Standard Work Document

Sy—Standard Deviation of Y

TCTO—Time Compliance Technical Order

TDY—Temporary Duty

TNMCS—Total Non-Mission Capable Supply

TSS—Total Sum of Squares

UCL—Upper Control Limit

UMD—Unit Manpower Document

USAF—United States Air Force

USDH—United States Direct Hire

UTC—Unit Type Code

V—Coefficient—of Variation

WLF—Workload Factor

WS—Work Sampling

WU—Work Unit

WUC—Work Unit Count

Ym—Measured and/or Calculated Man-hours

Yc—Dependent Variable

Office Symbols

AF/A1—Air Force Deputy Chief of Staff, Manpower and Personnel

AF/A1M—Air Force Directorate of Manpower Organization and Resources

AF/A4—Air Force Deputy Chief of Staff, Logistics, Engineering and Force Protection

AFMAA/CC—Air Force Manpower Analysis Agency Commander

ANG/A1M—Air National Guard Directorate of Manpower Organization and Resources

AFRC/A1M—Air Force Reserve Command Manpower, Organization and Resources Division

MAJCOM/A1M—Major Command Manpower, Organization and Resources Division

SAF/MR—Secretary of the Air Force, Manpower and Reserve Affairs

Terms

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 determinants) before applying rounding procedures. This definition is applicable only when the term is associated with fractional manpower.

Air Force Manpower Determinant—A management and programming tool that quantifies the manpower requirements for an organization, work center, or function. This tool determines the minimum level of manpower required based on the approved SWD. The AFMD may contain Air Force approved variances (see variance definition). Applies to two or more commands.

Air Force Mission Model—A management and programming tool that quantifies the manpower requirements for an organization, work center, or function. This tool determines the minimum level of manpower required based on the approved SWD. The AFMD may contain Air Force approved variances (see variance definition). Applies to one command.

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, Fatigue, and Delay (PF&D). It is usually applied as a percentage of the normal or leveled time to determine Standard Time (ST).

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 PF&D as appropriate.

Analysis of Alternatives—An analysis of direct aircraft maintenance and munitions requirements using simulation software and associated tools. An AoA provides decision makers with reliable, objective manpower assessments in response to varying levels of current LCOM change (alternatives) or new model engineering estimates.

Assigned Strength—Computed monthly average number of military and civilian personnel assigned to a work center during the data collection period (e.g., the personnel actually in-place to accomplish the collected workload). Includes full-time and/or part-time over hires, CMEs accomplishing work center responsibilities, borrowed personnel from other functions to include ARC augmentation (e.g., man-days), and documented uncompensated overtime. Excludes personnel deployed or loaned out to other functions.

Assumed Work—Work being done that is not necessary to work center productivity. Assumed workloads are not compensated for in the requirements determinant.

Available Time—Assigned man-hours dedicated to performance of primary duties, plus time specifically allowed for PF&D, standby, and travel activity. This is computed by subtracting the nonavailable hours from the assigned hours.

Avoidable Delay—Any unnecessary delay, regardless of source, that causes work stoppage. Time lost to avoidable delay is not included in the determinant.

Bivariate—A type of equation that contains only two variables, such as X and Y.

Borrowed Time—Time on loan from another work center.

Continuous Improvement and Innovation—Anchored in Lean, an operating philosophy that emphasizes the relentless eradication of non-valued activity in pursuit of mission effectiveness. CI^2 uses several widely accepted methodologies, including application of Lean tools, Six-Sigma Analysis, Theory of Constraints Analysis, and Business Process Reengineering Analysis. Enables Airmen to eliminate waste while maximizing customer value.

Contract Manpower Equivalent—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 determinants are computed. CME values (representing workload included in the determinant) 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 is 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.

Desired Accuracy—The maximum amount of error acceptable in a sample. This is stated as absolute accuracy or relative accuracy.

Determinant Application—A systematic determination of required or allowed manpower authorizations for Air Force activities using manpower determinants. The process consists of relating prescribed workload factor volumes to manpower models or tables resulting in a numerical identification of whole authorizations normally by AFS, skill level, and grade. Often referred to as "pricing out a determinant."

Determinant Development—A study process that designs, measures, analyzes, and determines a work center or function's manpower requirements.

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.

Directed Requirement Technique—An OA 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.

Extrapolation—Extension of the regression line beyond the range of the input data to increase the determinant's utility, to expand the manpower determinant's applicability, and to prevent rapid obsolescence due to workload changes.

F-Test—Any statistical test in which the test statistic has an F-distribution under the null hypothesis. It is most often used when comparing statistical models that have been fitted to a data set, in order to identify the model that best fits the population from which the data were sampled.

Facilitator—An individual who functions as the coach/consultant to a group, team, or organization and ensures all parties are heard, the team starts and finishes on time, and all objectives of the activity are met.

Fatigue Allowance—An allowance made in a manpower determinant to account for mental or physical weariness caused by job difficulty and environmental conditions.

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 process flowchart.

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.

Function—A group of personnel that use similar machines, processes, methods, and operations to do homogeneous work usually located in a centralized area.

Functional Estimating Equation—An estimating equation that is used to predict manpower requirements for a functional group. Each functional estimating equation has two parts: a mathematical equation and a series of percentage factors by program element code.

Functional Model—A mathematical representation of the relationship between the manpower in a specific function and relevant policy, program, or workload variable.

Gemba—A Japanese word meaning "the actual place." In Lean practices, the Gemba refers to "the place where value is created," or where the work of an organization actually takes place (e.g., shop floor in manufacturing, the job site on a construction project, workstation of an office worker, etc.). "Gemba walks," denotes the action of going to see the actual process, understand the work, ask questions, and learn from members who do the work.

Groupthink—A pattern of thought characterized by self-deception, forced manufacture of consent, and conformity to group values and ethics.

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 PF&D. Idle time is not included in a manpower determinant. An individual who goes to the base exchange, commissary, barber shop, etc., and meets the above conditions, is classified as being on idle time.

Indirect Allowance Factor—Represents a portion of total productive work and is used to quantify productive, indirect work man-hours associated with nine standard indirect work activities. It is applied as a percentage of total monthly direct man-hours to determine the total monthly allowed man-hours required by the work center.

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 Work—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.

Input—Products and/or services received from suppliers in order to perform a process.

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.

Lean——A process improvement methodology used to establish a continuous, proactive method of identifying opportunities for improvement, implementing changes based on such opportunities, measuring the impact of such changes, and eliminating waste from an organization's processes.

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. See Pace (Performance) Rating.

Loaned Time—Time loaned to other work centers. This time is not accountable to the work center providing the loaned time.

Logistics Composite Model—A determination of direct aircraft maintenance and munitions requirements using simulation software and associated tools. LCOMs capture the variety, complexity, and uncertainty of maintenance environments; and are easily amendable for AoAs.

Manpower Assessment—Assessments are special efforts or initiatives, which serve a useful purpose in evaluating required manpower when formal determinant development is not feasible. Due to their situational application, assessments may or may not follow the discipline or rigor of the more formal manpower determinant development process.

Management Advisory 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 office of primary responsibility.

Man-hour—A unit of measuring work. It is equivalent to one person working at a normal pace for 60 min, two people working at a normal pace for 30 min, or a similar combination of people working at a normal pace for a period of time equal to 60 min.

Man-hour Availability Factor—A factor reflecting the average number of man-hours per month an assigned individual is available to do primary duties.

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 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.

Modular Equations—A series of equations that represent one work center. These equations are appropriate when all required man-hours for a work can be subdivided into separate independent modules.

Multicollinearity—An undesirable condition when two or more of the independent variables are found to be highly correlated with each other during multivariate correlation and regression analysis. The correlated independent X-variables add similar (thus, little additional) information to the model.

Multivariate Equation—A type of 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.

Normal Time—A Per Accomplishment Time adjusted by pace rating.

Observation—In WS, 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.

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.

Organization Maturity Model—A scalable, web-based assessment tool used to objectively baseline and prioritize improvement opportunities within an organization.

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 scatter gram, (for example, data points that are beyond established control limits or that are significantly divergent from an otherwise apparent trend).

Overtime—Time expended in excess of regularly scheduled working hours.

Output—A final product or service rendered. The result of a process with required steps that has a definitive beginning and end.

Pace (Performance) 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.

Per Accomplishment Time—The time it takes to accomplish a single task one time.

Personal Allowance—Time included in a determinant 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).

Post/Position Manpower—A method of developing a determinant that couples a functional OPR-approved requirement with a predetermined manpower factor.

Post/Position Manpower Factor—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 these individuals may not be continuously productive.

Post/Position Qualification Time—A constant man-hour requirement directed by higher headquarters policy. It is used to determine the post/position manpower factor.

Post/Position Related Time—Consists of the average monthly man-hours needed for processed which must be done either before or after position coverage starts. Applies only to Security Forces post requirements.

Practical Problem Solving Method—Standardized approach to properly define a problem, its root cause, countermeasures, and countermeasure implementation. Provides a concise and common format for presentation of data, problem solving facts and information. Eases benchmarking and sharing of leading practices when similar problems arise in other areas. The structure provides a common language which more easily translates into common understanding.

Predictability—A significant attribute that allows reliable predictions for future time periods to make a determinant useful for programming future requirements.

Primary Aerospace Vehicle (Aircraft) Inventory—The aircraft assigned to meet the primary aircraft authorization.

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 sequence of work activities needed to accomplish the output. It is a procedure with a definitive input and output. A process involves worker interaction with such things as equipment, material, other people, and information. In other words, the process produces a product or service for a customer.

Process Flowchart—A diagram is created by using connecting lines and a set of conventional symbols; shows the relationships between different activities and helps to communicate how the process is performed.

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 Element Code—A code representing the aggregations of organizational entities and resources needed to perform a specific activity/assigned mission.

Queueing—A queue is defined as a waiting line, and queue analysis involves the mathematical study of these waiting lines.

Rater Proficiency—Skill of a technician to gain a mental image of normal and to rate in a consistent manner.

Ratio Unit Times—A computational method using a ratio of man-hours required to workload accomplished to develop a determinant. This method is generally used for single location determinants.

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.

Rest—An allowance made in a manpower determinant to account for mental or physical weariness caused by job difficulty and environmental conditions.

Sample—A single recorded status of one person during an observation of a work center.

Sample Size—The number of samples taken usually for a desired level of accuracy.

Scatter Diagram—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 non-measurement method used to determine total work center manpower requirements. The most common technique is queueing.

Staffing Pattern—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 Activity Time—A validated Per Accomplishment Time included in a Standard Work Document.

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.

Standard Work Document—A document reflecting a list of improved standard processes, activities, standard activity times, outputs, sources/methods of count, and ancillary work required for AFMD and AFMM development.

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.

Statement of Conditions—A part of the requirements determinant that identifies the environment and impact of conditional factors on the time needed to perform work center activities and identifies the basis for deviations and the projected impact, i.e., potential benefits from new equipment, automation, facilities, etc.

Statement of Work—An official document that specifically defines and outlines the scope (the breadth and limitations) and performance requirements (tasks developed to satisfy program needs) of a contract.

Study Sponsor—The HAF functional representative for DAF studies, MAJCOM functional representative for MAJCOM studies, or wing-level functional representatives for single point studies.

Study Sponsor Representative—The subject matter expert appointed by the study sponsor that works closely with the study lead to ensure completion of a study.

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 variation 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.

Unavoidable Delay—An occurrence that is essential and outside the worker's control or responsibility that prevents the accomplishment of productive work.

Unit Manpower Document—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.

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 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.

Workflow—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 WS, time study, and good operator timing and technical estimate. Usually results in a manpower determinant 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 determinants.

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.

Work Unit Count—The number of work units done during a specified time period.

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—(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 workload factor) or something that is external to, but served by, the work center (referred to as a work generator-type workload factor).

Attachment 2

F-TABLES AND T-TABLES

Table A2.1. F-Table at 80% confidence (a=0.20).

Values for F (0.80, df_1, df_2)												
	Degrees of Freedom in the Numerator (m-1)—df_1											
Degrees of Freedom in the Denominator (n-m)—df_2	1	2	3	4	5	6	7	8	9	10	11	12
1	9.472	12.000	13.064	13.644	14.008	14.258	14.439	14.577	14.685	14.772	14.844	14.904
2	3.556	4.000	4.156	4.236	4.284	4.317	4.340	4.358	4.371	4.382	4.391	4.399
3	2.682	2.886	2.936	2.956	2.965	2.971	2.974	2.976	2.978	2.979	2.980	2.981
4	2.351	2.472	2.485	2.483	2.478	2.473	2.469	2.465	2.462	2.460	2.457	2.455
5	2.178	2.259	2.253	2.240	2.228	2.217	2.209	2.202	2.196	2.191	2.187	2.184
6	2.073	2.130	2.113	2.092	2.076	2.062	2.051	2.042	2.034	2.028	2.022	2.018
7	2.002	2.043	2.019	1.994	1.974	1.957	1.945	1.934	1.925	1.918	1.911	1.906
8	1.951	1.981	1.951	1.923	1.900	1.883	1.868	1.856	1.847	1.838	1.831	1.825
9	1.913	1.935	1.901	1.870	1.846	1.826	1.811	1.798	1.787	1.778	1.771	1.764
10	1.883	1.899	1.861	1.829	1.803	1.782	1.766	1.752	1.741	1.732	1.723	1.716
11	1.859	1.870	1.830	1.796	1.768	1.747	1.730	1.716	1.704	1.694	1.685	1.678
12	1.839	1.846	1.804	1.768	1.740	1.718	1.700	1.686	1.673	1.663	1.654	1.646
13	1.823	1.826	1.783	1.746	1.717	1.694	1.676	1.661	1.648	1.637	1.628	1.620
14	1.809	1.809	1.765	1.727	1.697	1.674	1.655	1.639	1.626	1.615	1.606	1.598
15	1.797	1.795	1.749	1.710	1.680	1.656	1.637	1.621	1.608	1.596	1.587	1.578
16	1.787	1.783	1.736	1.696	1.665	1.641	1.621	1.605	1.591	1.580	1.570	1.561
17	1.778	1.772	1.724	1.684	1.652	1.628	1.608	1.591	1.577	1.566	1.555	1.547
18	1.770	1.762	1.713	1.673	1.641	1.616	1.596	1.579	1.565	1.553	1.543	1.534
19	1.763	1.754	1.704	1.663	1.631	1.605	1.585	1.568	1.554	1.542	1.531	1.522
20	1.757	1.746	1.696	1.654	1.622	1.596	1.575	1.558	1.544	1.531	1.521	1.512
21	1.751	1.739	1.688	1.646	1.614	1.588	1.567	1.549	1.535	1.522	1.511	1.502
22	1.746	1.733	1.682	1.639	1.606	1.580	1.559	1.541	1.526	1.514	1.503	1.494
23	1.741	1.728	1.676	1.633	1.599	1.573	1.552	1.534	1.519	1.506	1.495	1.486
24	1.737	1.722	1.670	1.627	1.593	1.567	1.545	1.527	1.512	1.499	1.488	1.479
25	1.733	1.718	1.665	1.622	1.588	1.561	1.539	1.521	1.506	1.493	1.482	1.472
26	1.729	1.713	1.660	1.617	1.583	1.556	1.534	1.516	1.500	1.487	1.476	1.466
27	1.726	1.709	1.656	1.612	1.578	1.551	1.529	1.510	1.495	1.482	1.470	1.461
28	1.723	1.706	1.652	1.608	1.573	1.546	1.524	1.505	1.490	1.477	1.465	1.455
29	1.720	1.702	1.648	1.604	1.569	1.542	1.519	1.501	1.485	1.472	1.461	1.451
30	1.717	1.699	1.645	1.600	1.565	1.538	1.515	1.497	1.481	1.468	1.456	1.446
40	1.698	1.676	1.620	1.574	1.538	1.509	1.486	1.467	1.451	1.437	1.424	1.414
60	1.679	1.653	1.595	1.548	1.511	1.481	1.457	1.437	1.420	1.406	1.393	1.382
120	1.661	1.631	1.571	1.522	1.484	1.454	1.429	1.408	1.390	1.375	1.361	1.350

Table A2.2. F-Table at 90% Confidence (α = 0.10).

Values for F (0.90, df_1, df_2)													
		Degrees of Freedom in the Numerator (m-1)—df_1											
Degrees of Freedom in the Denominator (n-m)—df_2		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	1	39.863	49.500	53.593	55.833	57.240	58.204	58.906	59.439	59.858	60.195	60.473	60.705
	2	8.526	9.000	9.162	9.243	9.293	9.326	9.349	9.367	9.381	9.392	9.401	9.408
	3	5.538	5.462	5.391	5.343	5.309	5.285	5.266	5.252	5.240	5.230	5.222	5.216
	4	4.545	4.325	4.191	4.107	4.051	4.010	3.979	3.955	3.936	3.920	3.907	3.896
	5	4.060	3.780	3.619	3.520	3.453	3.405	3.368	3.339	3.316	3.297	3.282	3.268
	6	3.776	3.463	3.289	3.181	3.108	3.055	3.014	2.983	2.958	2.937	2.920	2.905
	7	3.589	3.257	3.074	2.961	2.883	2.827	2.785	2.752	2.725	2.703	2.684	2.668
	8	3.458	3.113	2.924	2.806	2.726	2.668	2.624	2.589	2.561	2.538	2.519	2.502
	9	3.360	3.006	2.813	2.693	2.611	2.551	2.505	2.469	2.440	2.416	2.396	2.379
	10	3.285	2.924	2.728	2.605	2.522	2.461	2.414	2.377	2.347	2.323	2.302	2.284
	11	3.225	2.860	2.660	2.536	2.451	2.389	2.342	2.304	2.274	2.248	2.227	2.209
	12	3.177	2.807	2.606	2.480	2.394	2.331	2.283	2.245	2.214	2.188	2.166	2.147
	13	3.136	2.763	2.560	2.434	2.347	2.283	2.234	2.195	2.164	2.138	2.116	2.097
	14	3.102	2.726	2.522	2.395	2.307	2.243	2.193	2.154	2.122	2.095	2.073	2.054
	15	3.073	2.695	2.490	2.361	2.273	2.208	2.158	2.119	2.086	2.059	2.037	2.017
	16	3.048	2.668	2.462	2.333	2.244	2.178	2.128	2.088	2.055	2.028	2.005	1.985
	17	3.026	2.645	2.437	2.308	2.218	2.152	2.102	2.061	2.028	2.001	1.978	1.958
	18	3.007	2.624	2.416	2.286	2.196	2.130	2.079	2.038	2.005	1.977	1.954	1.933
	19	2.990	2.606	2.397	2.266	2.176	2.109	2.058	2.017	1.984	1.956	1.932	1.912
	20	2.975	2.589	2.380	2.249	2.158	2.091	2.040	1.999	1.965	1.937	1.913	1.892
	21	2.961	2.575	2.365	2.233	2.142	2.075	2.023	1.982	1.948	1.920	1.896	1.875
	22	2.949	2.561	2.351	2.219	2.128	2.061	2.008	1.967	1.933	1.904	1.880	1.859
	23	2.937	2.549	2.339	2.207	2.115	2.047	1.995	1.953	1.919	1.890	1.866	1.845
	24	2.927	2.538	2.327	2.195	2.103	2.035	1.983	1.941	1.906	1.877	1.853	1.832
	25	2.918	2.528	2.317	2.184	2.092	2.024	1.971	1.929	1.895	1.866	1.841	1.820
	26	2.909	2.519	2.307	2.174	2.082	2.014	1.961	1.919	1.884	1.855	1.830	1.809
	27	2.901	2.511	2.299	2.165	2.073	2.005	1.952	1.909	1.874	1.845	1.820	1.799
	28	2.894	2.503	2.291	2.157	2.064	1.996	1.943	1.900	1.865	1.836	1.811	1.790
	29	2.887	2.495	2.283	2.149	2.057	1.988	1.935	1.892	1.857	1.827	1.802	1.781
	30	2.881	2.489	2.276	2.142	2.049	1.980	1.927	1.884	1.849	1.819	1.794	1.773
	40	2.835	2.440	2.226	2.091	1.997	1.927	1.873	1.829	1.793	1.763	1.737	1.715
	60	2.791	2.393	2.177	2.041	1.946	1.875	1.819	1.775	1.738	1.707	1.680	1.657
	120	2.748	2.347	2.130	1.992	1.896	1.824	1.767	1.722	1.684	1.652	1.625	1.601

Table A2.3. F-Table at 95% Confidence (α = 0.05).

Values for F (0.95, df_1, df_2)

Degrees of Freedom in the Numerator (m-1)—df_1

Degrees of Freedom in the Denominator (n-m)—df_2	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	161.448	199.500	215.707	224.583	230.162	233.986	236.768	238.883	240.543	241.882	242.983	243.906
2	18.513	19.000	19.164	19.247	19.296	19.330	19.353	19.371	19.385	19.396	19.405	19.413
3	10.128	9.552	9.277	9.117	9.014	8.941	8.887	8.845	8.812	8.786	8.763	8.745
4	7.709	6.944	6.591	6.388	6.256	6.163	6.094	6.041	5.999	5.964	5.936	5.912
5	6.608	5.786	5.410	5.192	5.050	4.950	4.876	4.818	4.773	4.735	4.704	4.678
6	5.987	5.143	4.757	4.534	4.387	4.284	4.207	4.147	4.099	4.060	4.027	4.000
7	5.591	4.737	4.347	4.120	3.972	3.866	3.787	3.726	3.677	3.637	3.603	3.575
8	5.318	4.459	4.066	3.838	3.688	3.581	3.501	3.438	3.388	3.347	3.313	3.284
9	5.117	4.257	3.863	3.633	3.482	3.374	3.293	3.230	3.179	3.137	3.102	3.073
10	4.965	4.103	3.708	3.478	3.326	3.217	3.136	3.072	3.020	2.978	2.943	2.913
11	4.844	3.982	3.587	3.357	3.204	3.095	3.012	2.948	2.896	2.854	2.818	2.788
12	4.747	3.885	3.490	3.259	3.106	2.996	2.913	2.849	2.796	2.753	2.717	2.687
13	4.667	3.806	3.411	3.179	3.025	2.915	2.832	2.767	2.714	2.671	2.635	2.604
14	4.600	3.739	3.344	3.112	2.958	2.848	2.764	2.699	2.646	2.602	2.565	2.534
15	4.543	3.682	3.287	3.056	2.901	2.791	2.707	2.641	2.588	2.544	2.507	2.475
16	4.494	3.634	3.239	3.007	2.852	2.741	2.657	2.591	2.538	2.494	2.456	2.425
17	4.451	3.592	3.197	2.965	2.810	2.699	2.614	2.548	2.494	2.450	2.413	2.381
18	4.414	3.555	3.160	2.928	2.773	2.661	2.577	2.510	2.456	2.412	2.374	2.342
19	4.381	3.522	3.127	2.895	2.740	2.628	2.544	2.477	2.423	2.378	2.340	2.308
20	4.351	3.493	3.098	2.866	2.711	2.599	2.514	2.447	2.393	2.348	2.310	2.278
21	4.325	3.467	3.073	2.840	2.685	2.573	2.488	2.421	2.366	2.321	2.283	2.250
22	4.301	3.443	3.049	2.817	2.661	2.549	2.464	2.397	2.342	2.297	2.259	2.226
23	4.279	3.422	3.028	2.796	2.640	2.528	2.442	2.375	2.320	2.275	2.236	2.204
24	4.260	3.403	3.009	2.776	2.621	2.508	2.423	2.355	2.300	2.255	2.216	2.183
25	4.242	3.385	2.991	2.759	2.603	2.490	2.405	2.337	2.282	2.237	2.198	2.165
26	4.225	3.369	2.975	2.743	2.587	2.474	2.388	2.321	2.266	2.220	2.181	2.148
27	4.210	3.354	2.960	2.728	2.572	2.459	2.373	2.305	1.731	1.672	2.166	2.132
28	4.196	3.340	2.947	2.714	2.558	2.445	2.359	2.291	2.236	2.190	2.151	2.118
29	4.183	3.328	2.934	2.701	2.545	2.432	2.346	2.278	2.223	2.177	2.138	2.104
30	4.171	3.316	2.922	2.690	2.534	2.421	2.334	2.266	2.211	2.165	2.126	2.092
40	4.085	3.232	2.839	2.606	2.450	2.336	2.249	2.180	2.124	2.077	2.038	2.003
60	4.001	3.150	2.758	2.525	2.368	2.254	2.167	2.097	2.040	1.993	1.952	1.917
120	3.920	3.072	2.680	2.447	2.290	2.175	2.087	2.016	1.959	1.910	1.869	1.834

Table A2.4. t-Table with Columns Representing 80, 90, and 95% Confidence Levels.

df	80%	90%	95%	df	80%	90%	95%
1	3.0777	6.3138	12.7062	**17**	1.3334	1.7396	2.1098
2	1.8856	2.9200	4.3027	**18**	1.3304	1.7341	2.1009
3	1.6377	2.3534	3.1824	**19**	1.3277	1.7291	2.0930
4	1.5332	2.1318	2.7764	**20**	1.3253	1.7247	2.0860
5	1.4759	2.0150	2.5706	**21**	1.3232	1.7207	2.0796
6	1.4398	1.9432	2.4469	**22**	1.3212	1.7171	2.0739
7	1.4149	1.8946	2.3646	**23**	1.3195	1.7139	2.0687
8	1.3968	1.8595	2.3060	**24**	1.3178	1.7109	2.0639
9	1.3830	1.8331	2.2622	**25**	1.3163	1.7081	2.0595
10	1.3722	1.8125	2.2281	**26**	1.3150	1.7056	2.0555
11	1.3634	1.7959	2.2010	**27**	1.3137	1.7033	2.0518
12	1.3562	1.7823	2.1788	**28**	1.3125	1.7011	2.0484
13	1.3502	1.7709	2.1604	**29**	1.3114	1.6991	2.0452
14	1.3450	1.7613	2.1448	**30**	1.3104	1.6973	2.0423
15	1.3406	1.7531	2.1314	>**30**	1.2820	1.6450	1.9600
16	1.3368	1.7459	2.1199				