Chapter 1

Facilities in a Changing Environment

"The dogmas of our quiet past are inadequate to the stormy present. As our situation is new, we must think anew."

— Abraham Lincoln

Working facilities are the land, buildings, and equipment that provide the physical capability to add value. This book is about operational facilities used for a wide range of business, government, institutional, and charitable activities. It applies to offices, factories, and fast-food restaurants. It applies to any facility that houses value-adding operations. For convenience, terms such as "business facility" or "factory" are used, although the changing nature of work has blurred many of these distinctions. The principles herein apply to a wide range of situations the industrial engineer commonly encounters.

Facilities are both durable and expensive, lasting for decades and sometimes even spanning centuries. A firm's facilities are among the most expensive of its possessions. They represent the largest asset item on most balance sheets.

The durability of facilities, their cost, and their primary role in adding value make them an important strategic element. Just as gunpowder made the fortresses of medieval Europe indefensible, changes in technology, culture, and politics can quickly render today's industrial facilities obsolete. Conversely, facilities that adapt to the nature of their competitive environment can be a continuing source of advantage for their owners.

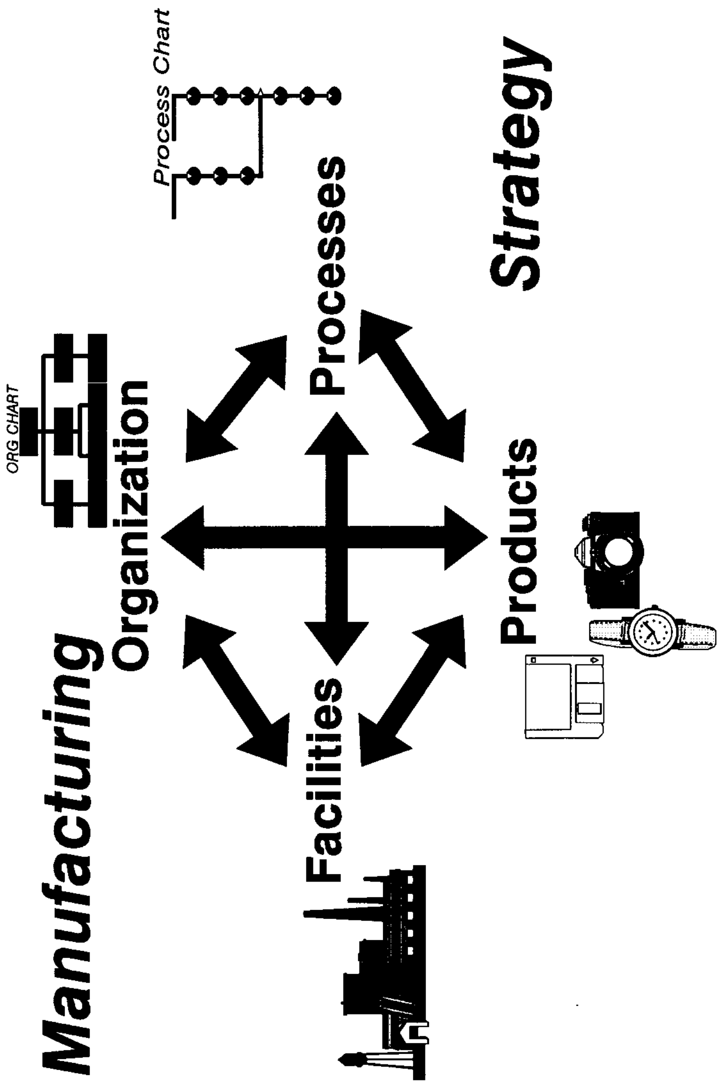


Figure 1.1 - Strategic Relationships

Figure 1.1 depicts the interaction of facilities, organization, products, and processes. The understanding, design, and development of these varied elements into a functioning business system are referred to in various terms. Among these are: manufacturing strategy, corporate reengineering, and business architecture.

The importance of facilities does not lie solely in their cost and durability. They are also the most tangible element of the business system, the element to which everyone in every area of the business can relate. They can be a central, common reference for the restructuring/reengineering/strategic debate.

Working facilities in modern history

Industrial facilities

Shops that served the needs of individual artisans were the industrial facilities of the Middle Ages. These were small and centered around a single skill such as armory or saddlemaking. They had simple and clear arrangements.

During the Industrial Revolution, power sources and the movement of raw materials determined facility design. Textile mills required streams for water power, and cumbersome shafts and belts dominated their arrangement. Early iron and steel mills were located on waterways, railroads, or mining sites; coal, iron ore, and limestone transportation dominated their design.

Early large-scale production shops such as the Pickering Piano Factory (fig. 1.2) developed in the nineteenth century. These large

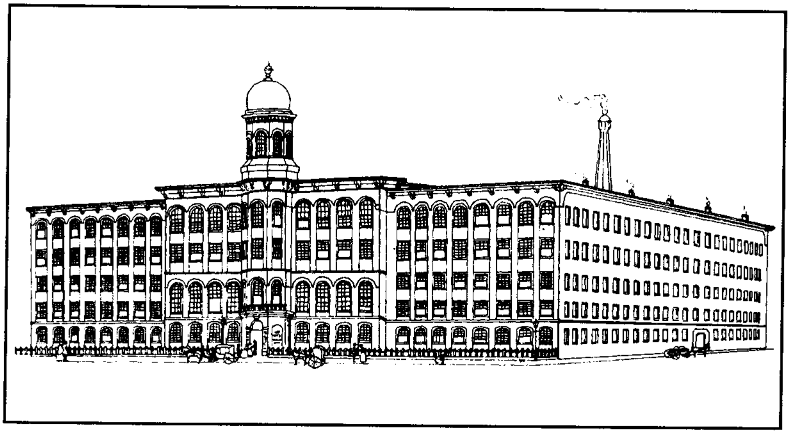


Figure 1.2 - The Pickering Piano Factory, Boston, Mass, Circa 1870

buildings turned out high numbers of manufactured products. At one time, the Pickering factory turned out 400 pianos each day.

In the early twentieth century, the progression of mass-production technology required facilities that optimized material flow. The micro-division of labor made skill less important than efficient movement of product.

In the second half of this century, information and knowledge began to dominate industrial production. The education and skills of the workforce in industrialized parts of the world increased. As a result, industrial facilities must now optimize the coordination of people, processes, and products.

Government facilities

In the Middle Ages, the most important government facilities were town fortresses. Their primary mission was defense against roving bands and neighboring city-states. The fortified town of Rocroi, on the northern plain of France, is an example. Still largely intact, it is a lasting testimony to the durability, cost, and obsolescence of these fortresses.

With the advent of gunpowder, battle technology advanced. New tactics evolved and armies became more disciplined. These massive works drained the treasuries of many dukes and kings and became indefensible and obsolete. By the time of the Renaissance, fortresses had evolved into palaces. Their primary mission was comfort for the inhabitants, as well as the projection of power and prestige. The builders of many governmental buildings wanted to intimidate potential enemies, both foreign and domestic.

Governments no longer can survive only through warfare or the threat of warfare. Their constituents demand added value in a wide range of human activity. Accordingly, many governmental facilities now are being designed for efficient operations rather than projection of power.

The United States Postal Service provides an excellent example. Post offices built in the early part of this century were architectural landmarks. Their mission was to display the power, stability, and prestige of the federal government. Postal facilities built today are near transportation centers and optimize mail flow. Their primary mission is the efficient distribution of mail.

Knowledge-based facilities

Facilities in which knowledge is the primary means of work have always been more varied than other types. The medieval monastery, for example, was a primary depository of knowledge in its time.

The church used this knowledge to vie with governments for power and influence.

During the Renaissance and Industrial Revolution, knowledge became an important source for commercial competitive advantage. Individual professionals such as doctors, lawyers, and financiers were primary keepers of knowledge. Other knowledge resided in libraries. Factories imbedded it in their facilities and processes. Peter F. Drucker was among the first to recognize the increasing value of what he termed "knowledge work." He put forth these ideas in his landmark work, *The Practice of Management,* in 1955. Knowledge work depends primarily on brainpower rather than manual skills or strength. In today's manufacturing environment, most work requiring pure strength of muscle has long been automated away. Much of the work that once required manual dexterity has been taken over by computerized equipment such as numerically controlled machine tools or coordinate measuring machines. Therefore, knowledge and the information behind it now have become primary sources of value in their own right. Many organizations exist for the sole purpose of processing information and distributing it. Their facilities should reflect and enhance this role.

Facilities in a changing environment

Facility designers have always worked with materials, products, processes, information, and people. Their task is to arrange work processes on land and in buildings for optimum performance. This has not changed and will not change, but rapid shifts in technology, politics, and culture require a more fundamental understanding and analysis from the facility designer. It no longer is sufficient (if it ever was) to copy an assembly line just because it was successful somewhere else.

In addition to the long-term trend toward increased knowledge-based work, other trends of a stretigic nature are affecting business. The facility planner should catalyze or lead an organization's adaptation to ever-changing surroundings.

The environmental imperative

Harmony with the environment is an increasingly important business concern that will not go away. Population growth is a principal factor dictating this concern; the spread of the suburbs through increased mobility is another. Organizations that survive and prosper in coming years will anticipate and lead with their environmental policies.

Location requirement changes

Information is the raw material of the knowledge worker. With the confluence of information processing and communication, the information superhighway has opened. The ability to distribute vast amounts of information makes it less important for facilities to locate near the source of information. This is similar to the distribution of materials in an earlier day. As material transportation became more efficient, manufacturers could locate farther from their sources.

Knowledge-based facilities now locate where their workers wish to live—often far from traditional industry. Industries that require specialized knowledge often converge in small areas: manufacturers of overhead cranes congregate in Milwaukee, Wisconsin; Wichita, Kansas, has a high concentration of vinyl printers for decorative decals; and "Silicon Valley" in California is the home for many electronics plants. These changes affect global facilities planning decisions such as site selection and planning.

The changing nature of work

As products become more sophisticated, their knowledge component becomes more important. It is no longer enough to manufacture a commodity product. Competition demands variety, frequent change, and distribution systems that deliver physical product, service, and knowledge.

The nature of work has changed. Today, individuals seldom work alone. Knowledge teams are necessary in product design, process design, finance, and even law. Teams, by their nature, require proximity. Facilities can inhibit or promote teamwork. They can smooth the operation of complex and ethereal knowledge processes or they can isolate people and prevent communication.

The socio-technical system

Socio-technical systems have always existed, although few managers recognized the phenomenon until recently. Management thought was caught in the Newtonian concept that organizations were like machines, giant clockwork mechanisms that ticked away in a predictable, mechanical manner. Eric Trist of the Tavistock Institute developed the socio-technical idea in the early 1950s. Teamwork, total quality management (TQM), and other techniques for employee involvement have their roots in the concept of the socio-technical system (fig. 1.3).

The social system includes people and their habitual attitudes, values, behavioral styles, and relationships. It is the formal power structure depicted on organization charts and the informal structure derived from knowledge and personal influence. The technical system includes machinery, processes, procedures, and their physical arrangement (layout).

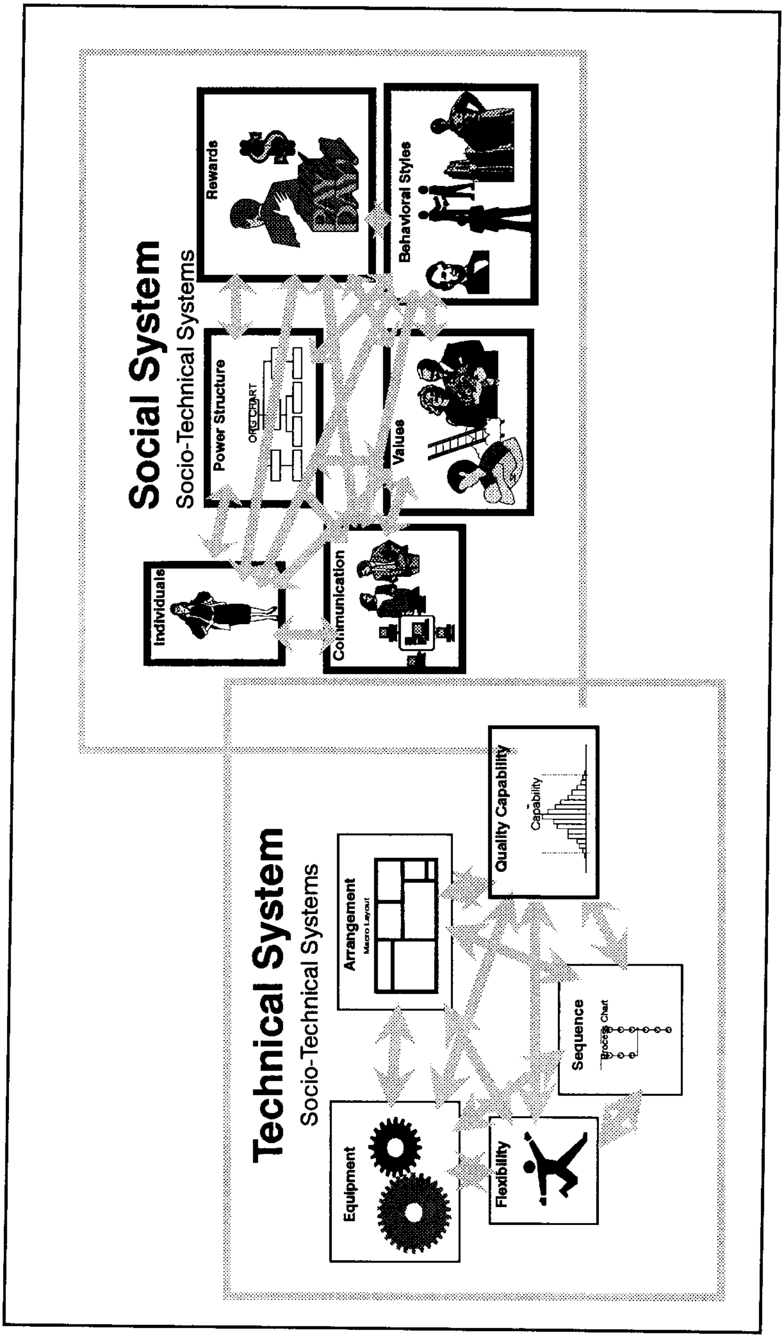


Figure 1.3 - Socio-Technical Systems (Eric Trist, 1952)

To be effective, the social and technical systems must integrate and assist one another. Facilities planning plays a major role in this integration. Businesses where people have isolated workstations, large inventory buffers, and few sequential processes have difficulty implementing teamwork. A manufacturing work cell that requires extensive teamwork will not produce in an environment of suspicion, individual rewards, and command-control.

Non-hierarchical organizations

Hierarchical organizations with functional divisions of work evolved from the Roman Legions, the Catholic Church, and medieval guilds. Such organizations are ill-suited for today's work, where the work product requires input from many functional specialties and where coordination between specialties is a primary requirement.

While TQM emphasizes cross-functional teamwork, more fundamental reengineering emphasizes elimination of functional structures in the organization. This puts special demands on the facilities planner. Non-hierarchical organizations must constantly change to accommodate changes in business volume and product life cycles.

In these organizations there is less division between traditional management and labor functions. Many engineers and others who traditionally worked in office areas now have their desks in the manufacturing plant. Many of today's high-tech manufacturing operations demand more cleanliness and order than the traditional office. Therefore, facilities must be more open with few walls and barriers. They require constant rearrangement to accommodate changing work cells and changing team structures.

Global business restructuring, reengineering, and facilities

Thanks in part to the changing nature of work, global economics, and technological advances, large-scale restructuring is occurring in many organizations. As a result, many facilities that are no longer contributing to company missions will close. Other facilities will be built. Many more will have products realigned and processes reengineered.

Facilities planning is often a large-scale reengineering project. It is an opportunity to rethink processes as well as supporting elements. During a facilities planning project, the designers can help management clarify missions and rationalize product lines.

Layout is an integral part of reengineering and restructuring. Meaningful restructuring requires corresponding changes in the layout.

Conversely, a layout redesign can be the catalyst for restructuring. Many symptoms of inappropriate business architecture appear as layout or material handling issues. Factory layout can demonstrate the need for reengineering to an organization reluctant to tear itself apart and rebuild.

Approaches to facility planning

Those who plan and build facilities take many approaches. Some are highly organized; others are ad hoc. Examples of approaches (fig. 1.4) are *experiential*, *master building*, *cloning*, *bottom-up*, *systematic*, and *strategic*.

Experiential

In this approach, people plan their facilities based on past experience, common sense, and instinct. In any organization, the experience of senior members is valuable for information on what has worked and what has not worked in the past. Organizations, as well as individuals, need this experience to function.

A facility designed from experience taps into the rich knowledge of those who have gone before; however, experience-based facilities planning has limitations. Experience, by definition, is based on the past, and new technology and organization structures can make it obsolete. In addition, planning by experience is usually unorganized. It frequently is the result of the memories of only one or a few individuals, and others may have had additional or contradictory experiences. Such hindrances, as well as forgotten details, haunt these efforts.

In planning a major facility, experience cannot be ignored but must be gathered from the widest field of experience possible and applied with judgment and discretion.

Master building

Master building focuses on construction and buildings. The final product is often impressive and sometimes a work of art, but it may not fit the operational needs of the enterprise. Master builders can be found at many levels in both large and small organizations: a company president building a new headquarters or a department manager focusing on technological impressiveness rather than actual needs. Using a building to display financial strength, technological prowess, or artistic accomplishment is a legitimate form of advertising. However, this purpose should be balanced with other business needs.

Cloning

Cloning simply duplicates an existing facility or portion of it. This approach is fast. If the existing facility is proven and if conditions are the same, this type works well. McDonald's uses cloning to build its hamburger "factories" throughout the world. For most facilities, however,

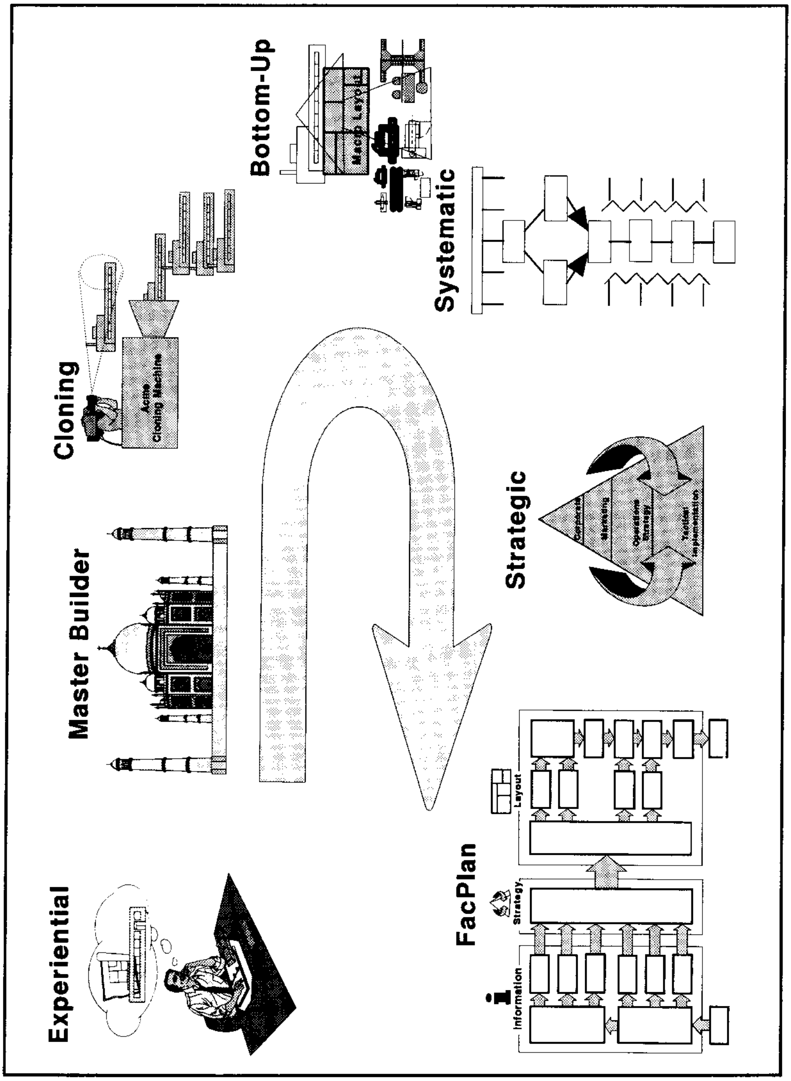


Figure 1.4 - Spaceplanning Approaches

cloning has limited use because sites, processes, and people are different. Cloning should be applied only when appropriate.

Bottom up

The bottom-up approach starts with the details. How many desks? How many and which machines? How many people? From them, departmental units and, eventually, the overall facility plan are built. It is a satisfactory approach if the details and how they will be assembled into a larger system are known, if there is time, and if the details will not change. Such conditions are often met for smaller facilities in stable environments.

Bottom-up planning does not lend itself to new operations strategies. Because all details have to be worked out before final design and construction, construction lead times are often too long. On large projects, the details become so overwhelming it is often difficult to maintain schedules.

Systematic

Systematic layout planning (SLP) uses procedures, conventions, and phases. It helps layout planners know what to do at each step of a project. This provides layout planning with system and structure, saving time and effort. However, many layouts created with systematic methodology are simply better versions of what went before. The primary concern is how to arrange blocks of space. A more fundamental issue is what blocks of space should be arranged.

Strategic

The strategic approach is top-down. It sets policy first and arranges the technology, organization, and facilities to support it. Starting with business and corporate strategy such as global site location, it moves to operations strategy and finishes with details like locations of equipment and furniture.

A strategic approach is direct and has purpose. It allows everyone involved in the project to follow a common direction. Used alone, however, strategic direction is insufficient. It does not tell facility designers and those who use the facilities what to do.

FacPlan

The FacPlan method combines the best of various approaches. It has system and structure and adds strategic dimension. It taps into the experience and knowledge of those who use the facilities. It can work from detail to general and vice versa when appropriate.

FacPlan uses a hierarchy of detail levels. It focuses on strategic issues at the appropriate time and minutiae at the appropriate time, using a model project plan to guide and structure each project. Procedural flow charts guide the planner through each task and assist with decision making. Charts, forms, and design aids contribute to the organization of information.

The industrial engineer's role in facility planning

The central, strategic role of facilities places their designers in a unique position. Industrial engineers can assume narrow roles as technical equipment arrangers or they can take broader roles as educators and catalysts for organizational strategic debate.

The latter requires more than skills in layout design and technical procedure. Strategic perspective, well-developed interpersonal skills, patience, and understanding are also necessary.

This work provides insight into the basic technical tools industrial engineers need for facilities planning. The broader skills will require experience, insight, maturity, and education.

Chapter 2

The Framework for Facilities Design

The complete design of a facility requires work from many disciplines within an organization: sales and marketing, purchasing, human resources, accounting, and more. More visible is the work of architects, structural engineers, process engineers, and management. Architects and structural engineers check soil conditions, building codes, and infrastructure, detailing the structure, appearance, and internals of the building and site. Process engineers may plan the production procedures. To guide and coordinate all these efforts, management sets strategic policies.

Industrial engineers also play key roles. They often manage the overall project and report to top management, and they may perform some or all of the above tasks. Most importantly, they plan the use of space. These space plans, at various detail levels, become the centerpiece for coordinating the entire project.

The levels of spatial design

Layout, or space planning, is the central focus of facilities design and dominates the thoughts of most managers. But factory or office layout is only one detail level. Ideally, a facility design proceeds from the general to the particular—from global site location to workstation. Larger strategic issues are decided first.

It is useful to think of space planning in five levels as shown in figure 2.1. Figures 2.2 through 2.6 show typical outputs at each level. These range from the global maps of site location to engineering drawings of tools and workstations.

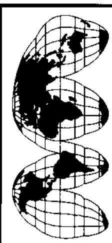
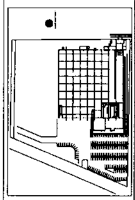
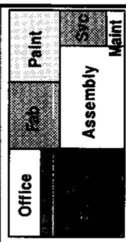
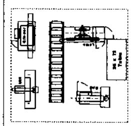
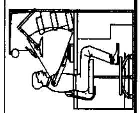
Level	Activity	Typical SPU	Environment	Output
I Global	Site Location & Selection	Sites	World Or Country	
II Supra	Site Planning	Buildings Or Site Features	Site	
III Macro	Building Layout	Cells Or Departments	Building	
IV Micro	Department Or Cell Layout	Workstations Or Cell Features	Cells Or Departments	
V Sub-Micro	Workstation Design	Tool Locations	Workstation	

Figure 2.1 - The Levels of Space Planning

Level 1—Global site location

During global location, the site location level, the firm decides where to locate facilities and determines their missions. A facility mission statement is a concise summary of products, processes, and key manufacturing tasks. A facility rarely can perform more than two or three key manufacturing tasks well. The mission statement is therefore an important guide for facilities planners and others as they consider various design trade-offs.

Other outputs at this level usually include a report to management. For multiple sites, maps showing site locations and customer activity are common. Figure 2.2 illustrates.

The cost of space planning at Level 1 is small. Global location usually involves a few top executives and one or two industrial engineers or consultants. Each level below requires more and more people, analysis, and detailed engineering. Yet, the corporate budget process frequently demands that all significant planning be delayed until after a decision is made to proceed with site acquisition. Those levels with the

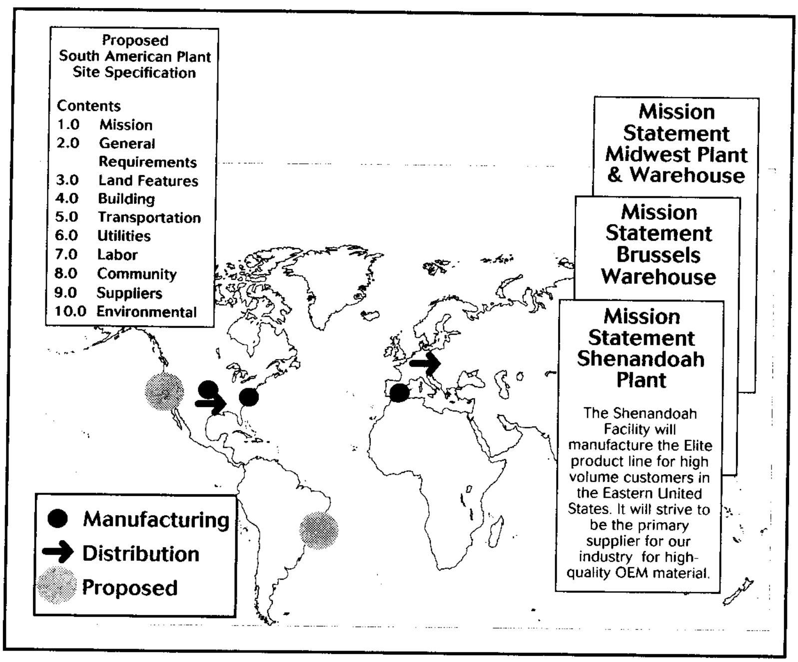


Figure 2.2 - Level I - Site Location

most strategic impact and the lowest planning cost receive the least attention. Consequently, the decisions with the most strategic impact are sometimes made with the least reliable knowledge.

Overall business strategy is most important at the global level. Determining the number and location of sites requires far more than simply searching for the lowest labor rates and largest tax breaks. Available labor skills and attitudes toward work, supporting services such as tool production and material supply, and politics, and sometimes geopolitics, must also be major considerations. For example, if a plant is located in the wrong country, it may become a geopolitical pawn. Technological prowess could then shift to other regions. If there is political instability locally, it can destroy a firm's ability to produce. Important raw materials might be depleted or replaced. Such problems are not easy to correct.

Appropriate planning results in facilities optimized for the markets and located near the most important resources—resources that, increasingly, involve knowledge, skills, and infrastructure rather than raw materials.

Level 2—Supra-space plan

At the supra-space plan level, site planning takes place. This includes number, size, and location of buildings, as well as infrastructure such as roads, water, gas, and rail. This plan should look ahead to plant expansions and eventual site saturation.

The documents from a site planning project almost always include a site drawing (fig. 2.3). Frequently, they involve a series of drawings showing past, present, and future configurations (there may be several options for these). A major site study also might include narratives on site history and descriptions of the considerations and rationale for the site plans.

At this level, planning still has long-term and far-reaching consequences. A well-designed infrastructure supports future expansion or conversion to new products. Proper location and building design provide for logical expansion in suitable increments.

Level 3—Macro-space plan

At the macro-space plan level, a macro-layout (fig. 2.4) plans each building, structure, or other sub-unit of the site. Usually this is the most important level of planning, for it sets the focus, or basic organization, of the factory. The designers define and locate operating departments and determine overall material flow.

Macro-space plan decisions may result in new-product flexibility,

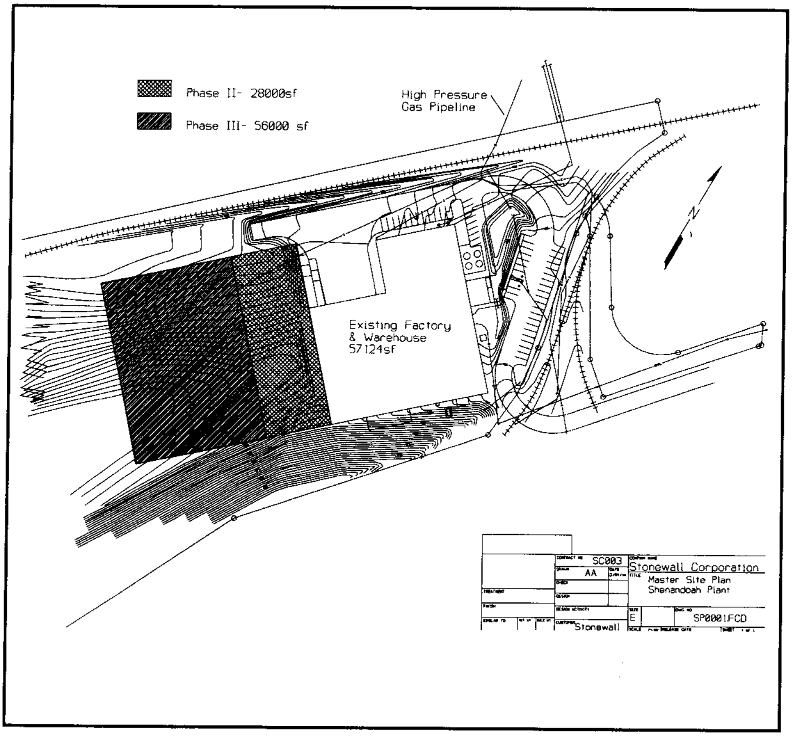


Figure 2.3 - Level 2, Site Planning
Master Site Plan, Shenandoah Plant, Stonewall Corp.

lower costs, high quality, or a flexible labor. Fundamental macro-space plan decisions usually are easier to correct than site-level decisions. Still, a poorly planned facility can bring high handling costs, confusion, and inflexibility. These problems, in turn, can cause difficulty in launching new products, erratic deliveries, and too much inventory. Correcting such problems may require a complete rearrangement with major investments in process equipment and infrastructure.

Level 4—Micro-space plan

The location of specific equipment and furniture is determined in the micro-space plan. The emphasis shifts from gross material flow to personal space and communication. Socio-technical considerations dominate. If production teams are an important element of the operations strategy, the work at this level may inhibit or discourage teamwork. Figure 2.5 shows a space plan for an operating department.

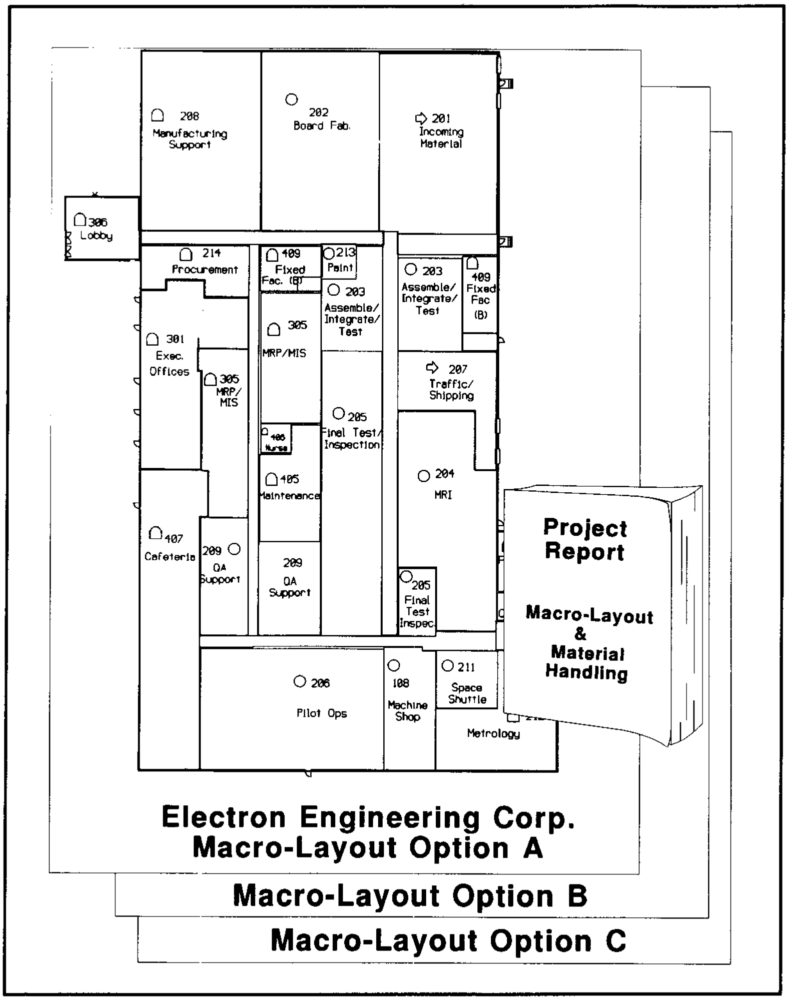


Figure 2.4 - Level 3, Macro Layout
Project Report: Macro-Layout and Material Handling

Level 5—Sub-micro-space plan

Individual workstations and workers are the concern of the fifth level. Here, workstations are designed for efficiency, effectiveness, and safety. Ideally, the industrial engineer plans for the correct tools in the most appropriate places, using fixtures that properly hold the work piece. Materials are introduced at optimal locations and large items are provided with appropriate material handling aids. Some typical outputs are shown in figure 2.6.

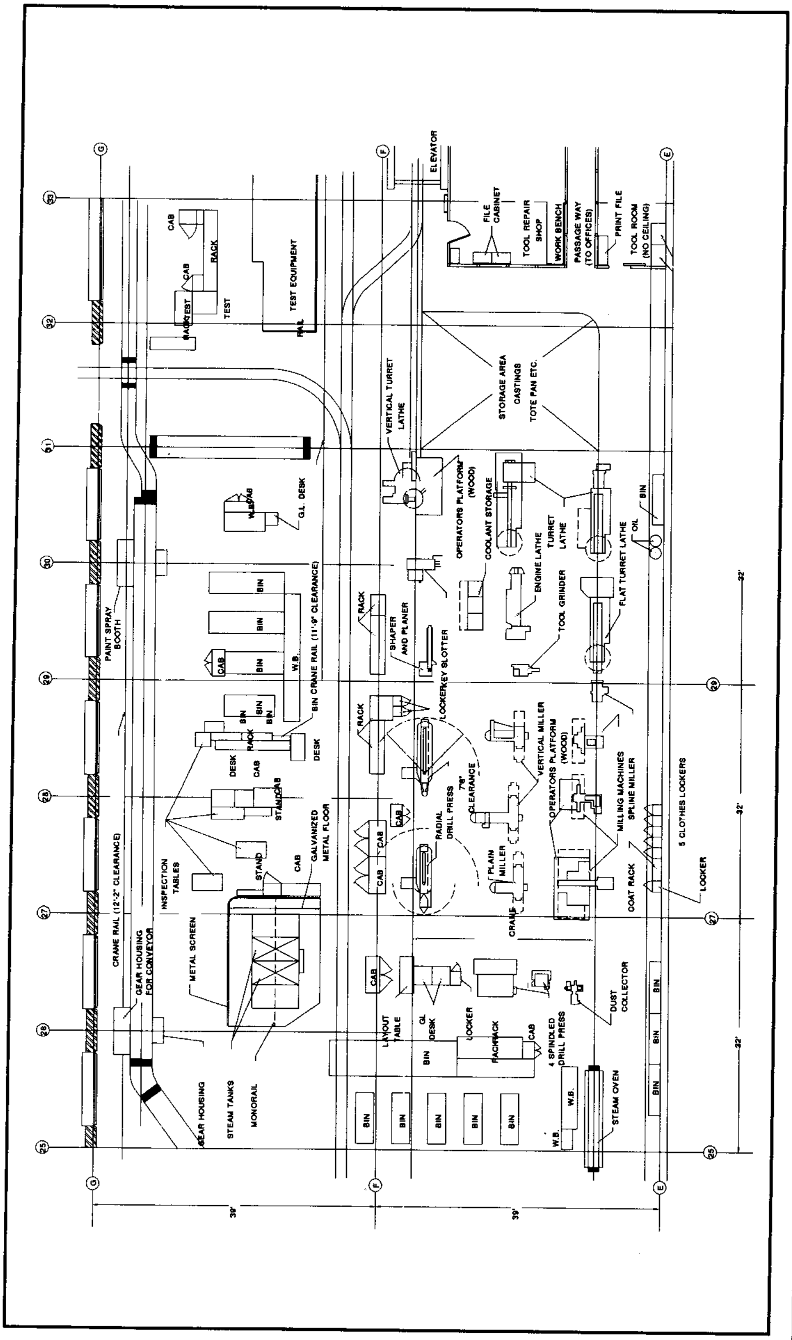


Figure 2.5 - Level 4, Micro-Layout
Maypro Manufacturing Pump Machining Dept. Detail Layout

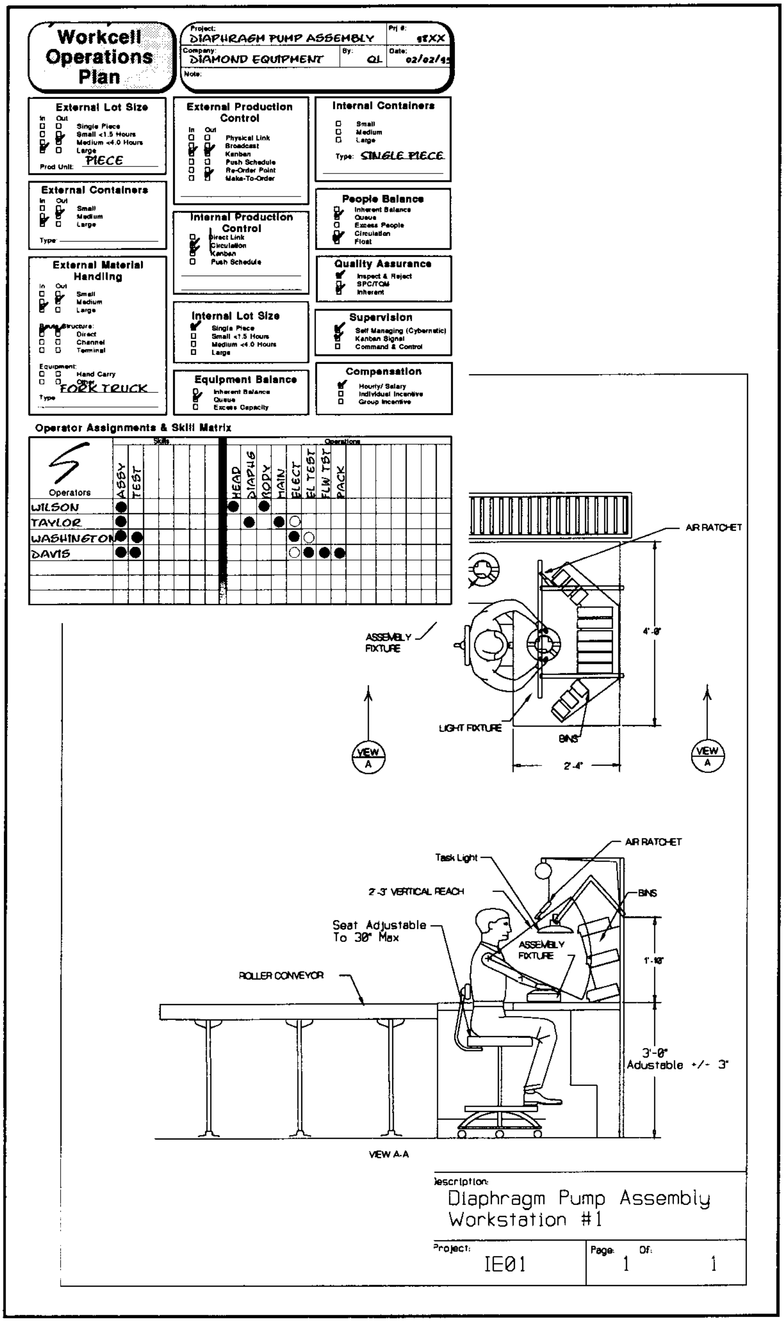


Figure 2.6 - Level 5, Workstation Layout

Levels 4 and 5 are the more detailed levels of space planning; therefore, equipment and issues are more localized. When changes are necessary, there is usually less danger of major production interruptions.

The phasing of space design

Ideally, design progresses from the global level to the sub-micro level in distinct, sequential phases. At the end of each phase, the design is "frozen" by consensus. This settles the more global issues first and allows smooth progress without continually revisiting unresolved issues. It also prevents details from overwhelming the project. Figure 2.7(A) illustrates this logical progression and shows the strategic impact of the work in each phase. Strategic impact affects the long-term ability of the firm to compete and profit.

Industrial engineers rarely have the opportunity to design a facility in accordance with the normal phasing shown in figure 2.7(A). There are several reasons for this. Sites and buildings that have evolved over many years outlive technologies and their original purpose, and therefore must be rearranged. Another reason may be management's belief that the existing space plan is simply not optimal. In both cases, planning

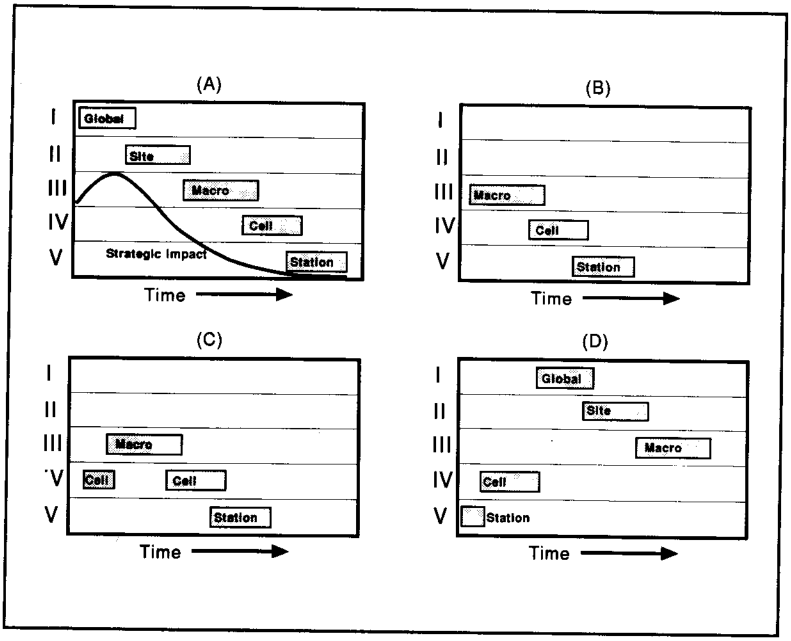


Figure 2.7 - Time Phasing the Design Levels

begins at the macro-space plan level. Figure 2.7(B) illustrates this. The phasing demonstrated in figure 2.7(B) also occurs when management makes global and site-level decisions without the benefit of advice and counsel from their facilities planner(s).

The size and organization structure of cells in a macro-space plan may be indeterminable when processes and strategies are untried. This often happens when firms make a transition from functional to cellular manufacturing. Pilot cells must then be developed to prove the concept or technology. Figure 2.7(C) reflects this. A cell or micro-space plan (Level 4) then becomes the first phase. Upon completion of this pilot, people can agree on the general approach. Then the designer can shift back to Level 3 and prepare a macro-space plan. The details of remaining cells are defined in their optimal sequence.

The phasing demonstrated in figure 2.7(D) is common for large office layout projects. First, the details of workstation layout are established. This may come from standardizing space and equipment based on each person's position in a hierarchy. Secretaries, for example, may get a 175-square-foot workstation with filing space and word processing equipment, while a Grade I engineer gets a 110-square-foot cubicle and a supervisor, a 150-square-foot cubicle. From the organization charts and staffing forecasts, the space for each department and the arrangement between departments can then be developed. At this point, the project moves upward in detail to the global or, more commonly, macro- level.

Separating the work into phases and levels is the ideal approach. Nevertheless, there may be some overlap. For example, the space plan of a particular work cell may not fit the boundaries previously decided in the macro phase. This may then require minor changes to the previously designed and agreed upon macro-space plan. For these and other reasons, phasing should be flexible.

Proper phasing should be considered in the earliest stages of the project, perhaps after the initial discussions and certainly before any significant work effort begins. Here are some guidelines:

- work from the most general to the most specific level (highest to lowest) unless special conditions dictate otherwise;
- clearly communicate the phasing plan to all participants;
- resist the temptation to jump ahead before a particular phase is complete;
- obtain agreement on the plan for each phase before moving on to the next phase; and
- recognize that there may be some overlap between phases.

The space plan elements

Every space plan at each level has four fundamental elements and two derived elements. The fundamental elements are: *space planning units (SPUs)*, *affinities*, *space*, and *constraints*. When developing a space plan, the designers first define and identify SPUs. They then evaluate affinities. Using the affinities, they join SPUs to form one or more *affinity diagrams*. The affinity, or configuration, diagram is the first of the derived elements. Space added to the configuration diagram produces a *space plan primitive*, the second derived element. Constraints applied to the space plan primitive produce the space plan. Figure 2.8 shows this progression.

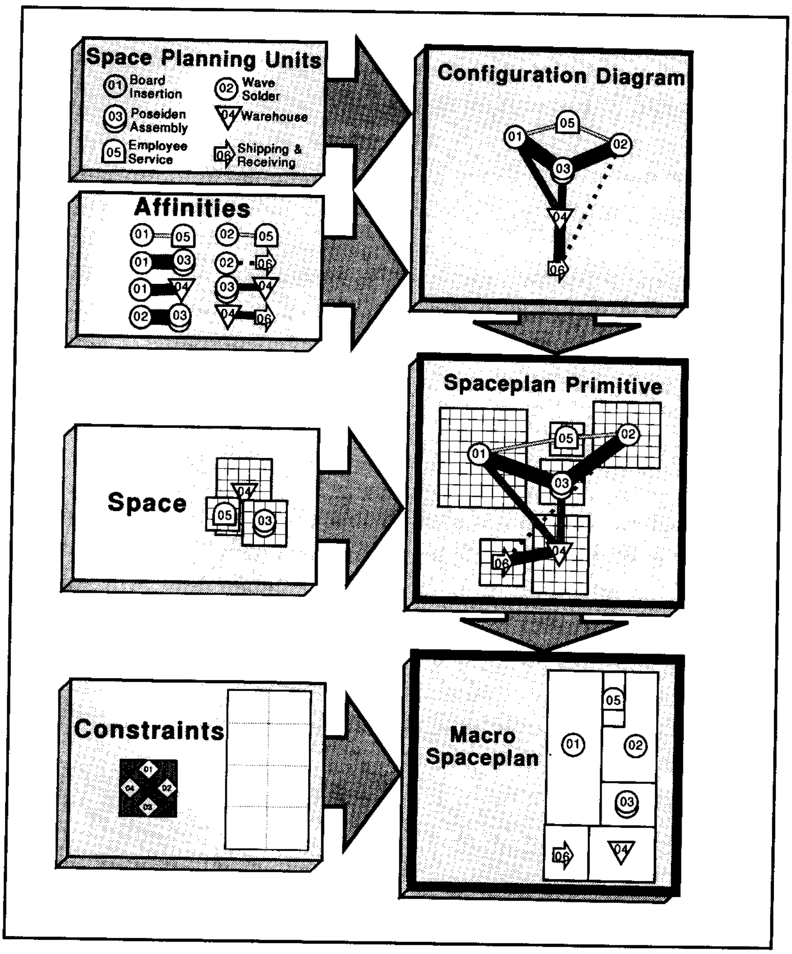


Figure 2.8 - Elements of a Spaceplan

The concept of fundamental and derived elements is valid at all levels. However, it is most useful and direct at the macro- and site levels. The chapters that follow explore its application.

Space planning units

SPUs are the entities arranged by space plan designers. At the macro-level, they are referred to as *cells*. (The systematic layout planning [SLP] system used the term *activity area*.) A cell might be a work department, a storage space, a building feature, or a fixed item. Each cell initially is represented by a symbol and identifier.

Most of these symbols are taken from ANSI Y15.3M-1979, the American National Standards Institute standard for process charts, which show the type of activity that acts on a product. For space planning, the symbol that best represents the space's dominant activity is used. Figure 2.8 shows the symbols, their meanings, and color codes.

The standard symbols represent operation, transport, inspection, delay, and storage. For space planning, two additional symbols—handling and product cells—are added. The handling symbol designates areas used for repackaging, transfers, or other elements that are partly transport and partly operation. The product cell designates space used for multiple activities on a single product or small group of products. The definition of SPUs is one of the most strategic tasks in facility planning. This definition decides the basic organization of the factory.

Affinities

Affinities represent various factors that demand closeness between any two cells in a space plan. For example, communication or personal interaction between workers might give rise to an affinity. Affinities are rated using a six-level scale, with numerical values ranging from +4 to -1. The scale has four positive levels that mean SPUs should be close. Such high-value affinities may result from frequent material movement between the cells. Negative ratings mean that the SPUs should be apart. There also is a neutral rating, 0.

A vowel scale, A-E-I-O-U-X, may also be used for rating affinities; this scale was first popularized by Richard Muther. Here, "A" represents the highest affinity rating, "U" represents a neutral affinity, and "X" is a negative affinity. This scale has a mnemonic advantage. The vowels have corresponding word associations as illustrated in figure 2.9. Chapter 3 discusses the methods for evaluating affinities.

Figure 2.9 shows the affinity conventions developed by building on the original SLP system. The multi-line representation works well

Description	Vowel Rating	Scalar Rating	Manual Graphic	CAD Graphic	Color
Absolute	A	4			Red
Exceptional	E	3			Yellow
Important	I	2			Green
Ordinary	O	1			Blue
Unimportant	U	0	(None)	(None)	(None)
Apart	X	N/A			Black

Figure 2.9 - Affinity Conventions

for manual graphics. On many CAD systems and other computer graphics software, it is easier to use varying line widths, gray scales, and color. When color is available, it dramatically illustrates the nature of the affinity network.

Figure 2.10 shows the typical range of affinity distributions for macro- and micro-layouts.

Affinity diagram

SPUs combine with affinities to form an affinity diagram—the first of the derived elements. This diagram is an idealized spatial arrangement that eventually becomes a space plan. In the diagram, symbols represent SPUs and lines represent affinities between them. A single line is the lowest value affinity and a four-part line is the highest. Squiggly lines represent negative affinities. These conventions are illustrated in figure 2.9.

Using an iterative process, the designer manipulates the diagram to create an optimal or near-optimal arrangement. A near-optimal arrangement has very short high value affinities at the expense of lower value affinities. It minimizes the crossing of affinity lines

Figure 2.11 illustrates the iterative improvement of an affinity diagram. It is interesting that many computerized planning systems emphasize this specific process when, in fact, it is the part of the layout process to which computers are least suited.

Space

Each SPU has a unique space requirement. Some SPUs may require only a few square feet, while others may require tens or hundreds of thousands of square feet.

The nature of space and the calculations required changes with each planning level. At the higher levels, space is "elastic," and the calculations may not need to be as accurate. At the lower levels, space can be more rigid but also less definite. For example, a particular machine or desk requires a certain amount of space, and the designer cannot make it fit in less space. In other instances, a piece of equipment may require a certain type of space because it has a peculiar shape, such as a U. But, under certain conditions, other items may also fit in that U shape.

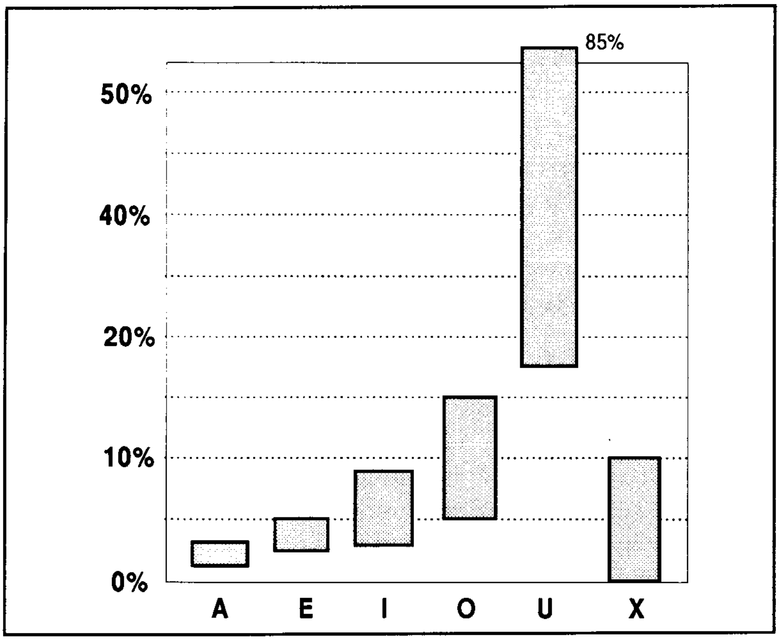


Figure 2.10 - Usual Affinity Distribution

The space plan primitive

When space is added to the affinity diagram, it distorts the diagram into the space plan primitive. It is an idealized representation and does not include design constraints.

Constraints

Design constraints are those conditions that limit an ideal space plan. Such constraints might be building size and shape, columns, floor loading, utility configurations, external features, and many others.

Space plan

The fusion of a space plan primitive and constraints produces a space plan. Several viable space plans should emerge. A set of cells, affinities, and constraints may give rise to several equally valid configuration diagrams and primitives. Each of these primitives may result in multiple macro-space plans. The nature of the design problem precludes an optimal space plan, except in the simplest situations.

The designer's experience is a key factor, for it helps him or her decide which configurations have the most potential. It helps scale the myriad of possible space plans down to a reasonable number.

Figure 2.11 illustrates the complete progression from fundamental

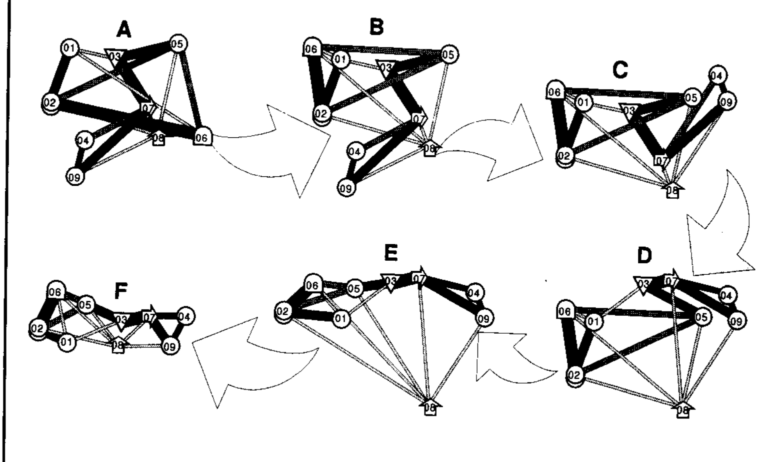


Figure 2.11 - Optimizing a Configuration Diagram

elements of cells, space, affinities, and constraints to the macro-space plan. These elements and the progression are valid for any size facility and at any level.

The design project

The elements of facility space plans are simple; execution of the tasks required to develop them is not. Rarely do the tasks neatly correspond to the development as described above. At each level of design, the approach changes to accommodate the amount of detail, available information, and the dominant issues.

At each level, an approach that fits a wide range of projects and situations can be developed. These are called *model projects*. With minor variations, the model project for a macro-space plan, for example, applies to almost any macro-space plan regardless of size, complexity, or industry. Similarly, the model projects for cell design and site planning apply to almost any cell design or site-planning project. The scope, resources, methods, formality, and time required vary according to size and complexity. The sequence, procedures, and deliverables are essentially constant. Model projects for each level of design can be found in Chapters 3, 4, 5, 6, and 7.

Chapter 3

The Macro-Space-Plan

The macro-space-plan often is the most important level of facility planning. It sets the fundamental organization of the factory and patterns of material flow with long-term effects. From personnel turnover to quality to delivery, the macro-space-plan influences almost every measure of facility and organization performance.

Done well, it is a platform for reengineering business. It can force reexamination of markets, products, and processes. It can achieve quantum improvements in productivity and profit. It can position a firm for profitability and growth. Done superficially, it can leave real issues unquestioned.

This chapter explains how to design macro-space-plans using a structured, step-by-step approach that results in a near-optimal space plan and wide acceptance of the results. This approach has several parts: *conceptual framework*, *model project plans*, *task procedures*, *conventions*, and *design tools and aids*.

Chapter 2 introduced the conceptual framework with its levels of detail that narrow the project to a manageable level. These fundamental and derived elements show how a space plan develops. Arranging the levels in phases helps plan the project. In the pages that follow, macro-space-planning—one of the more important phases—is examined. With a model project plan, tasks are arranged. Procedure diagrams illustrate how to conduct each task. The technical tools and other aids provide the means to complete each task. Figure 3.1 is the model project plan for a macro-layout. It shows the required tasks and their sequence. This model evolved from the systematic layout planning (SLP) approach developed by Richard Muther almost thirty years ago. It has been used for hundreds of projects and suffices for almost any size and type of macro-space-plan. From project to project, the depth of analysis changes along with the methods for each task, the resources, and the time. Occasionally, a project requires a few additional tasks. However, the basic structure and sequence remain the same.

Each task has a two-part identification number. The two digits before the decimal show the task level. The digits following the decimal identify the specific task, roughly in sequence. Task 03.04, for example, is the fourth task at Level 3, the macro-space-plan.

The tasks of the model project occur in three distinct groups: data acquisition, strategy development, and layout planning. These groups are near the top of figure 3.1. Two tasks, 03.01 and 03.21, are outside these groups. Task 03.01 starts the project, with plans for activities, timing, and resources. Task 03.21 is the actual selection of the preferred layout option. It closes the project and allows preparation for Level 4, the micro-space-plan.

A procedure diagram is provided for some tasks. For example, figure 3.3 is the procedure diagram for Task 03.02. Such diagrams illustrate the logic flow and sub-tasks required. These procedures are sometimes iterative. Most early layout models emphasized the third task group, where geometric arrangement takes place. Of course, this is important, but far more important is the determination of what spaces to arrange. The definition of these layout cells establishes the organization of a facility's work. Embodied in cell definition, it has far more impact on facility performance.

Figure 3.1 also guides designers through their first layouts using the system described in this chapter. The design task at hand should always be the central focus and any temptations to jump ahead prematurely to other tasks should be resisted. Completed tasks also should not be revisited. Figure 3.1 helps designers concentrate on the current task, its procedure diagram, and specific discussions. If each task is done in proper sequence, the space plan will take shape and the project objective will be reached.

It is vital to keep managers throughout the organization informed during the entire planning process, a responsibility best suited to the designer. Many facility projects result in fundamental changes and restructuring. Managers and others need time to learn new information and form new views. If they are not kept informed and involved in the learning and reasoning process, agreement and consensus will not be achieved. This could result in the rejection of an excellent layout.

There are several formal and informal ways of involving managers. Formal methods include using a steering committee to oversee and review progress and adding update meetings to the model project. A kickoff meeting can follow Task 03.01. During such a meeting, key members of the organization could review tasks and confirm that resources are available. An additional meeting, at which time factual data would be presented in a non-threatening manner, might follow the

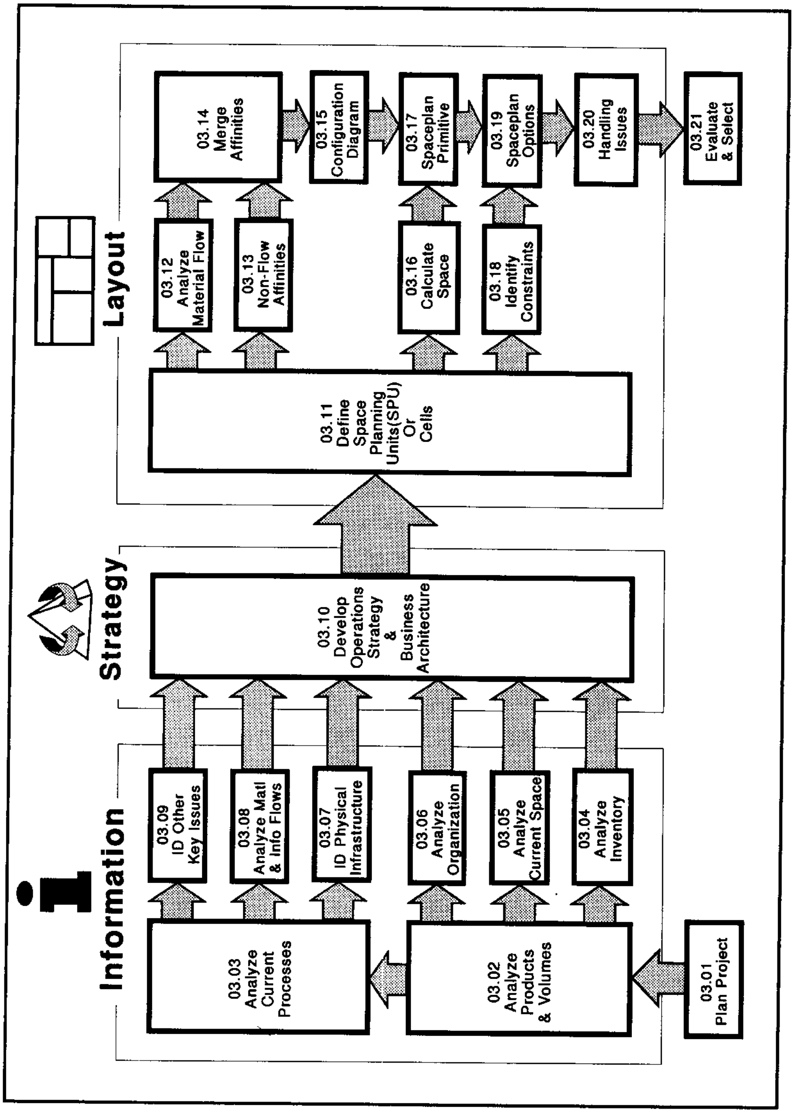


Figure 3.1 - Macro-Space-plan Model Project

data acquisition tasks.

A formal meeting is valuable for developing operations strategy and can be an important consensus builder. Agreement and commitment to the operations strategy are vital for later agreement on a facility plan. Task 03.21, the evaluation and selection of space plan options, is also a good consensus builder. Extensive interviews and informal conversations with managers and others throughout the organization are also important.

Introducing Cosmos Products

Cosmos Products is the company used as a model in this chapter to illustrate the processes of facilities planning at the macro-level. Cosmos Products converts high-grade vinyl film into decorative material. The firm has two broad product lines with different processes, markets, and distribution channels. Roll products—pin-striping material in many colors, patterns, widths, and combinations—sell in the automotive aftermarket. Custom sheet products sell to manufacturers that use them for labels, logos, and decoration. Manufacturers of campers, boats, chain saws, and agricultural equipment are typical customers. Cosmos often prepares the artwork for these customers. Custom products are flat sheets of material with imprinting, adhesive, and a paper backing.

Cosmos Products started as a small operation about twenty-five years ago. The firm has grown significantly each year at an average rate of 22 percent. To accommodate this growth, there have been a number of additions to the current facility. In recent years, management has experienced difficulty that has manifested itself in too much inventory, shipping delays, and general confusion.

The company's current project is reengineering the facility and related processes. The objectives are to: reduce material handling costs; reduce operating costs; improve delivery performance; improve teamwork, communication, and quality; allow for new products; accommodate 1998 production; and deliver the project under a budget of $800,000. The steering committee for this project consists of: O. W. Holmes, president and chief executive officer; J. Marshall, chief financial officer; W. Burger, vice president, operations; and E. Warren, vice president, sales and marketing.

Planning the project

Task 03.01, "Plan Project," develops a specific project plan. Developing a sound macro-space-plan demands significant resources. In this step, the disposition of those resources is mapped out. The model project in figure 3.1 works for almost every macro-space-plan project, whether large or small. Small or simple projects may need less formality, rigor, and documentation than larger or complex projects. Nevertheless, the essentials of each task must be done.

Step 1 establishes the key decision-makers for the project. After they are interviewed and their objectives are established, the time and resources needed for each task should be defined. With the above information and the model, the designer then plans the project. Project planning software is useful for this task, although for most macro-space-plans, a simple Gantt chart will suffice. Figure 3.2 is the schedule for a new macro-space-plan for Cosmos Products.

In addition to statements outlining tasks, elapsed time, and responsibility, the deliverables for each task should be identified. A deliverable is a tangible output for the task. A written summary of findings is a valid deliverable, as are a material flow diagram and physical infrastructure checklist. "Understand material flow" is not a valid deliverable because there is no way to see, measure, or judge completion. The designer should confirm that these deliverables accurately reflect the intentions of key decision makers before proceeding.

For Task 03.01, "Plan Project," the deliverables are a task list, a Gantt chart, and a summary that includes the project objectives. A PERT chart is useful but not necessary.

The typical time frame for completing a project of Cosmos's size and complexity is about forty working days. Almost half is used for information acquisition and strategy. This provides a firm foundation for the layouts to follow, thereby eventually reducing total project time. This is sometimes difficult for impatient managers to accept because it takes longer for a space plan to appear. However, far less time is spent on changes and debate. Moreover, a consensus for the plan is more likely when all participants have been through the information and strategy stages.

Information acquisition tasks

Once there is approval for the project plan, the first set of tasks involves the gathering of information, both quantitative and qualitative, needed to develop sound macro-space-plans.

This phase has another purpose that may be more profound and less obvious: raising awareness throughout the organization and asking difficult questions that many in the organization may not have considered previously. At this time, the process of building support and consensus for the outcome is begun.

In addition to analysis skills, space plan designers must have an understanding of individual and organizational psychology. Consensus

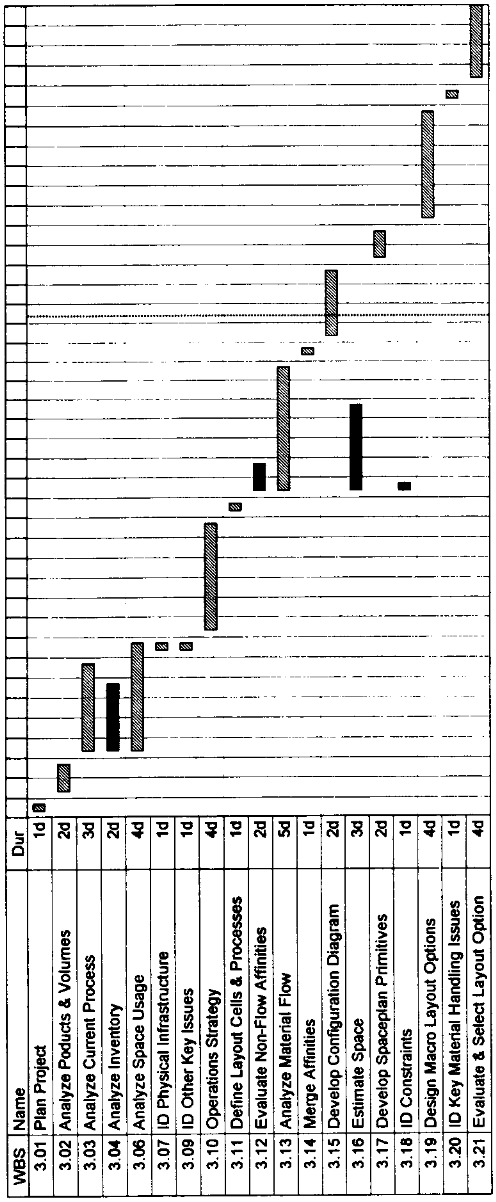


Figure 3.2 - Facility Re-Engineering

means time and common understandings that must begin early in order to bear fruit at the end of the project.

Product-volume analysis

Product-volume (P-V) analysis examines the current and future time frames for the products and their volumes. This analysis helps the designer understand the relationships between various products. High-volume and low-volume products, for example, may require different equipment and production modes. The analysis also defines future requirements, helps select the best planning horizon, and allows for changes beyond the immediate space plan.

The results of the P-V analysis provide important input for many later tasks, and, therefore, should be completed early in the project. Facility designers that have been long-time employees sometimes believe they know the products well enough to skip this task, but this is not recommended.

The procedure diagram for product-volume analysis is in figure 3.3. Block 1 documents the gathering of information. This may be accomplished in the following ways: visually examining a range of finished products; reviewing sales catalogs and other information for an overview of the product line; and interviewing sales and marketing people. It is also important to obtain overall sales volume history (usually, five to ten years is adequate). Where markets and technologies are changing rapidly, two to three years may be a more appropriate time frame.

Sales forecasts for the following five to ten years should also be requested. An absence of this information indicates uncertainty. It may require multiple contingencies in the facility plan. Unfortunately, sales people and other managers may be unwilling to commit to a forecast. In such a situation, high, low, and optimistic forecasts could be asked for, with the explanation that they are needed for facility planning purposes and extreme accuracy is unnecessary.

A request for a sales forecast may touch off a flurry of executive activity because the requested information may not exist or may be questionable. Generating the numbers will help build management awareness. It is sometimes the beginning of an important strategic debate that ultimately leads to better facility plans. This debate also can lead to important and profound changes in management thinking.

In Block 2, the forecast data is plotted on a line chart along with sales histories. If they are available, optimistic and pessimistic forecasts should also be added. After examining the chart, plotting a regression line like that in figure 3.4 may be helpful. Where seasonality is a concern, a separate chart could be used to show monthly sales for the past two to four years. Visual presentation is more meaningful than a list of numbers. A simple chart often reveals previously unrecognized trends.

In Block 3, the products are examined for appropriate grouping. If the facility will only produce a few products, such grouping is unnecessary. Most facilities, however, have many products or variations in anywhere from three to fifty groups. Preferably, these groups have common manufacturing characteristics as well as customer requirements. Sometimes the distribution channel determines sales groups.

During this task, the groups may have either a marketing or manufacturing orientation, or both. A marketing orientation means the items within a group are similar for the customer. A manufacturing orientation means the items within a group are similar for manufacturing purposes. These groups may or may not be the same. Sometimes

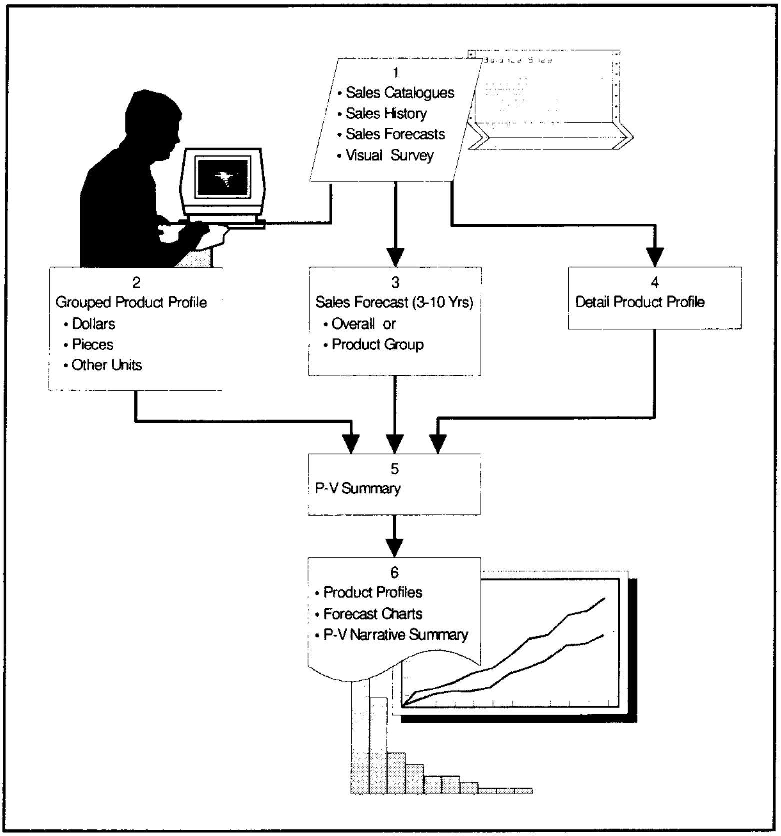


Figure 3.3 - Task 3.01, Product-Volume Analysis

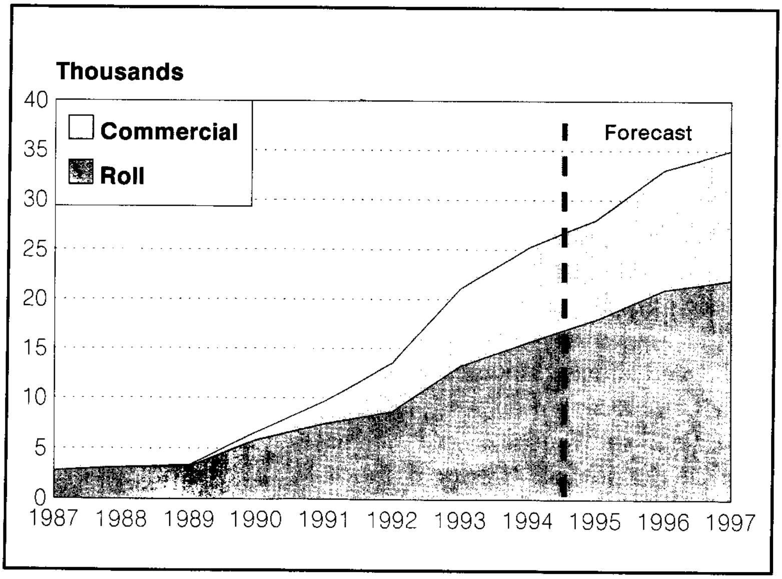


Figure 3.4 - Sales History/Forecast

operations people adopt product groups originally devised by marketing. This can complicate the manufacturing process unnecessarily.

Once the groups have been determined, a grouped product profile should be prepared. Such a profile takes the form of a ranked bar chart showing sales volume for each group (fig. 3.5). Sales volume is measurable in dollars, pieces, or other convenient units. Several profiles showing different units such as tons or pallets may be helpful. A second y-axis on the chart shows cumulative percentage.

A more detailed product profile, Block 4, also might prove useful. There are situations when a product group has significant sales volume, but individual products in the group have few (or no) sales.

The forecasts and P-V analysis become the agreed upon basis for process design, space requirements, storage requirements, and material flow analysis. It is important to confirm the forecasts and other P-V data with managers and especially with the key decision-makers.

The P-V analysis can assist with the development of the manufacturing strategy. High volume and low variety suggest high-speed production line equipment. Low volume with high variety suggests a functional layout. High variety and a wide range of volumes suggest cellular manufacturing. Seasonal variation necessitates specific strategies for inventory and capacity. The section on manufacturing strategy will explore these issues more fully.

A few short paragraphs or bullets can summarize the findings from the P-V analysis as shown in figure 3.3, Block 5.

Figures 3.3 through 3.5 illustrate deliverables for the Cosmos Product Volume Task. The following is its P-V summary, another deliverable.

Cosmos Products: Product-volume summary

The 22 percent growth rate is expected to slow somewhat during the next three years. The 1997 forecast volume of 35,000 units will be the first facility planning horizon. Cosmos has about 10,000 line items in the product database. These are in 192 groups according to significant features such as base material, color, and width. Thirty-four groups represent 80 percent of sales. Of the 192 groups, 63 generate less than $200 per month of income. We may have significant opportunity to rationalize the product offering or modify our inventory policy.

Existing process analysis

Task 03.03, "Existing Process Analysis," involves tracking work product activity, or the sequences in which outside entities act on an organization's work product. For manufacturing space plans, the work product is usually a physical product. In other space plans, the work product may be intangible such as an information packet. In a hospital, the work product may be a patient.

Existing process analysis documents the process currently in place. However, if the product is new, such a process may not exist, and a similar

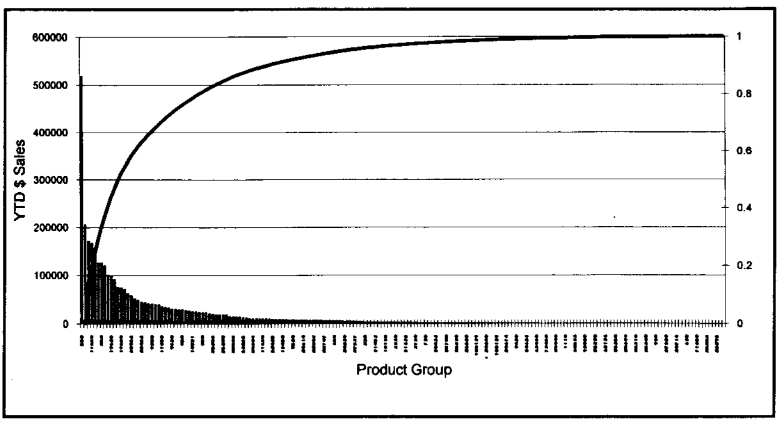


Figure 3.5 - Product Profile

product and process should be studied. If both product and process have no current benchmarks, an initial proposal for the process should be selected. The early completion of this task creates a reference point for process improvements and a space plan. The space plan designer usually performs this task with assistance from production people. This brings detailed knowledge of actual floor operations to the process.

Figure 3.6 shows the procedure for analyzing the existing process. One or more flow process charts are constructed during this task. Modified ANSI conventions (see fig. 3.7) are used in this charting system, whereby symbols represent different types of events that involve a work product.

The *operation symbol* modifies the work product in a way that advances it towards a finished state. The *transport symbol* shows a physical movement of the work product—usually a significant distance, such as ten feet or more. The *handling symbol* represents sorting, positioning, or some other short movement. Inspection checks for quality. The *delay symbol* represents something that halts the process for a time. Often, this is a work-in-process staging.

Storage is a longer wait, usually in a designated area where the location and material have records. A short horizontal line at the beginning of the process shows items from suppliers outside the process under study. Vertical lines on the chart show the sequence of events. Horizontal arrows show where several items of work product merge. Text to the right of each symbol describes the event. These notes also might indicate time, the number of people, or other relevant information.

Process charts and material flow charts should not be confused. There is a notable difference. With process charts, the symbols are not locations or workstations or even machines. Only the text has who, what, and where information. The lines do not represent movement of the work product; instead, they represent only a sequence of events.

Constructing the chart(s) means gathering initial information beforehand; this is illustrated by Block 1 in figure 3.6. Some of this comes from the P-V analysis (Task 03.02) and some from looking at the process and talking with knowledgeable people.

Block 2 (fig. 3.6) of the procedure begins addressing the question of how many and which products to analyze. It asks if there are product groups with similar processes. The answer should be based on the observations and knowledge currently available. Some situations may present thousands or tens of thousands of products.

A definite answer may not be possible without extensive analysis, which is unnecessary at this point. Suppose, for example, an injection planning facility were being planned. The plant supplies 67 molded items but each item comes in any of 19 colors. This gives a total of 1,273 item, or SKU, numbers. However, the plant uses quick color change equipment and has honed their skills in color changes. For manufacturing purposes, color is not a differentiator. The molders can make any given piece in any color or a succession of colors without difficulty. The 19 colors of each part would therefore be grouped as if they were a single product. If such groups cannot be identified, Block 3 is the next step.

Block 3 asks if there are fewer than 25 products. If there are, each

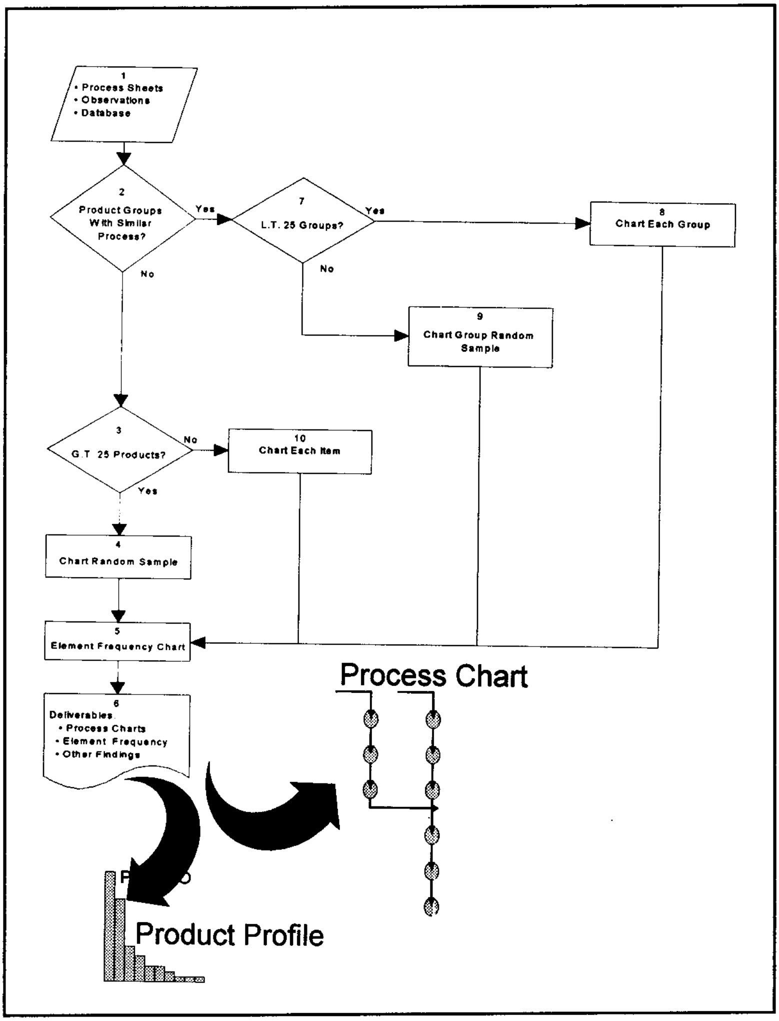


Figure 3.6 - Task 3.03, Analyze Current Process

item is charted. For more than 25, a charting sample of 5 to 25 items should be selected. This is Block 4 or Block 10. Product groups identified in Block 2 are treated similarly, resulting in Block 7. Simply substitute groups for individual products in the process described.

There are several methods of preparing the charts. For a simple process, personal observation is enough. If computerized routings are available, they may be used. A personal interview with someone who knows the process well is sometimes satisfactory. Usually, however, a group approach should be used. It captures a wide range of opinion and knowledge and helps build consensus for the chart as well as for the later space plans.

The group approach gathers the most knowledgeable people available. Together, they construct a chart that follows the material or item and records events that affect it. People often have difficulty distinguishing the product or item, workers, and machines. To help with this, they should imagine they have become the product and have assumed its role. They should then report their experiences.

All elements should be recorded. Frequently, there is an "official" process documented on routings and a computer database. Then there is the "unofficial" process—what really happens. Unofficial elements may include set downs, queues, and repairs. The group may wish to include other information on the chart such as process time or cost. When this is complete, the group should make further comments, particularly about which process elements are troublesome. Some additional questions to bring out important process issues are:

- Which elements generate the most quality defects?
- Which elements are most difficult to set up?
- Where are the largest inventory buildups?
- Which elements have the most scheduling difficulty?
- Which elements demand the most labor?

The analyst guides the group during this task by deciding:

- the level of detail for process elements;
- the number of products to chart;
- whether and how to group products; and
- whether and how to group items that go into a product.

To tally a count for each type of element, the percentage of total elements is calculated. These could be charted on a bar or pie graph. Only the operation symbol adds value. All other elements contribute only cost or time. The percentage of value-adding elements is called the value added index (VAI). VAIs frequently are in the range of 20 to 30 percent. A well-thought-out process should have a VAI of at least 60 percent.

Next, a short summary of the results should be prepared. The flow process charts, element profiles, and written findings are deliverables.

The following is the Cosmos process summary:

Cosmos Products: Existing process summary

The value added index (VAI) for roll products is 13 percent. The VAI for commercial products is 20 percent. These are both quite low. There are a substantial number of opportunities to reduce transport, handling, and storage elements.

In roll products, the processes require special equipment. This equipment is relatively small scale. Changeover times range from five to forty-five minutes.

For commercial products, process scale is very small in the manual operations at pick-and-peel. Die-cutting operates on a medium scale. Silk-screening uses large-scale presses. We may wish to investigate smaller scale processes for silk-screening.

Slit-and-sheet operations all use a single slitter that is quite fast. Both commercial and roll products use the same material. Optimizing the use of each roll saves significant wastage. It seems to dictate continued use of a common slit-and-sheet area for all products.

The process charts for Cosmos Products are fairly simple. In addition to the modified ANSI conventions, figure 3.7 shows the process for one of Cosmos's roll products—a vinyl stock material for signs and other decoration. Figure 3.8 charts the process for a multi-color, die-cut decal, a typical product from one of Cosmos's commercial markets. These decals decorate automobiles and other outdoor equipment. This single chart represents several thousand distinct products.

With complex processes, it is often tempting to combine items, thereby reducing the complexity of the chart. Simplifying the chart, however, is not the same as simplifying the process. Much of the value of a process chart is its accurate representation of the full complexity of a process. It is an important means of building consensus and understanding for a new space plan. A readable chart on large-scale drafting paper may be necessary to convey the full scope and complexity of the process.

Inventory analysis

Task 03.04, "Inventory Analysis," is important for at least two reasons. First, inventory is usually the primary or secondary capital consumer, often vying with facilities for this dubious honor. Second, almost every difficulty, problem, or defect in the business system eventually comes to rest in inventory. Inventory thus can be an indicator of the efficacy of the business system.

The inventory analysis uses financial and warehouse data. The first step in the analysis is to prepare a chart that shows historical annual inventory turns, usually for five to ten years or even further if the information is readily available. Inventory turns are the total inventory from the firm's balance sheet divided into the total sales for the previous year. Sales information usually comes from the income statement. The industry average for the inventory turn also should be listed on the chart. The inventory turns for Cosmos Products are illustrated in figure 3.9.

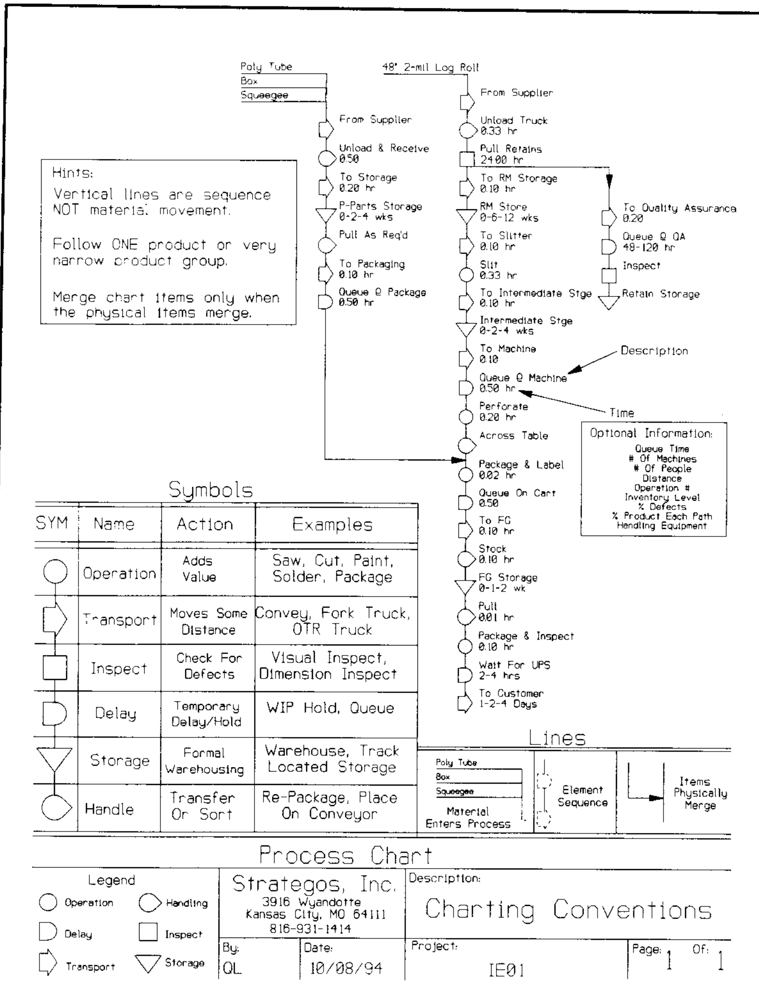


Figure 3.7 - Task 3.03, Product Process Chart

One or more inventory profiles like that in figure 3.10 should be prepared. These are pie charts or bar graphs that show the current distribution of inventory across several classifications. A production class profile should show inventory by raw material, purchased items, finished goods, and work-in-process (WIP). A product class profile shows inventory by product or product group. Other classifications, such as customer type, are useful in special situations.

What does inventory analysis determine? Trends in inventory history can help size storage areas for the new facility or layout. Such

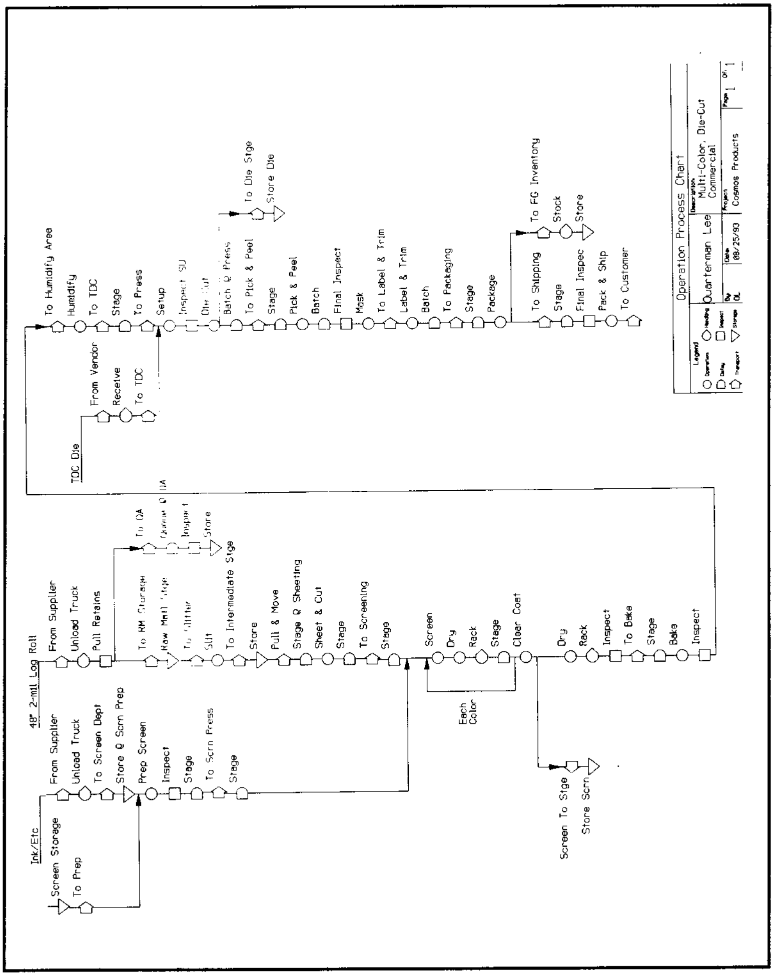


Figure 3.8 - Process Chart for a Multi-color, Die-cut Decal

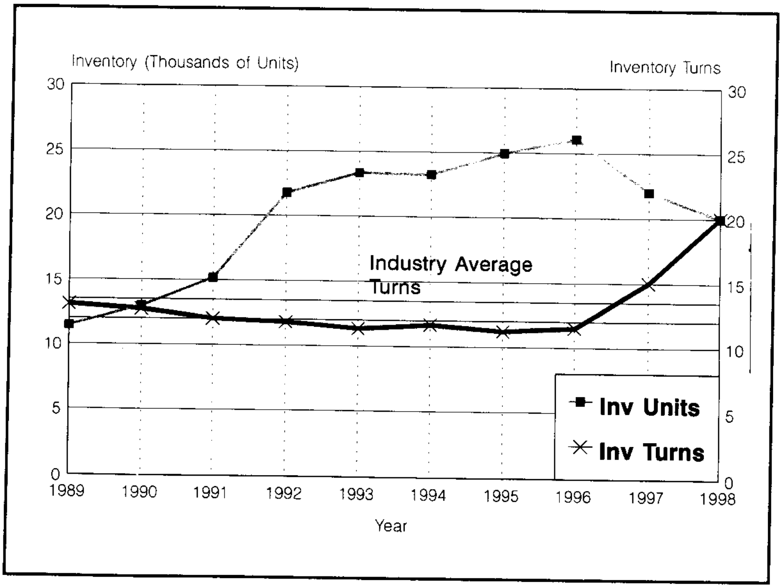


Figure 3.9 - Inventory History/Forecast

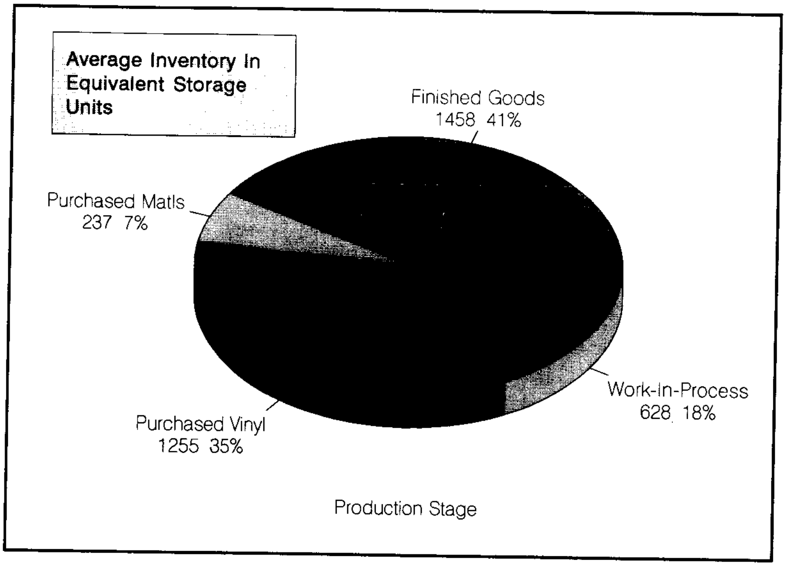


Figure 3.10 - Inventory Analysis

trends provide valuable input for the development of manufacturing strategy. An unfavorable trend might initiate a change in strategy.

The production class profile also can suggest areas for improvement. High levels of raw materials or purchased items indicate a supplier and purchasing issue. High levels of WIP indicate material movement, scheduling, or focus issues. A high volume of finished goods indicate scheduling, sales, or marketing issues. The following is an example of an inventory analysis summary:

Cosmos Products: Inventory summary
Inventory volume has increased significantly during the past six years. This increase is higher than sales growth, resulting in a gradual erosion of the turn ratio. Management anticipates that, as a result of the facility reengineering project, the number of turns will increase, and inventory levels will come down.

The inventory profile [fig. 3.10] shows the portion of inventory at each production stage. This indicates significant opportunities for reducing finished goods and purchased vinyl.

Space Analysis

The space analysis reveals current space use. The space diagrams indicate whether the existing layout is primarily functional, product-focused, or a mixture, as well as which products use line or cellular production and which use functional layout modes. This space analysis also helps define layout cells later in the project and can be a basis for space requirement calculations for the new facility.

The space profile also reveals imbalances in space use. Value-added space generally represents 60 percent or more of total space usage in the best space plans. When value-added space falls below 30 percent, there are significant opportunities for improvement. Large amounts of storage space can indicate a need for more cellular and line production, or it may show a need for scheduling system revisions. Using large amounts of space for inspection or repair may indicate significant quality issues.

When operations focus is an issue, adding a product space class diagram is useful. It classifies space by product. Each product group has a pattern or color. Space used for operations for a single product group will have only one color, while functional space used for operations for many product groups will have many colors. A product-focused layout has a "clean" product space diagram and a "messy" functional space diagram. A process focused (functional) layout has the opposite. The section on operations focus explores these issues in more detail.

The analyst usually performs Task 03.06, "Space Analysis," with assistance from those who are familiar with operations. The analysis begins with a current drawing of the facility, preferably one that shows major departments and, perhaps, details of equipment and furniture locations. The colors or patterns in figure 2.9 are then used to code marked-off space on this drawing. A typical result is the existing space diagram for Cosmos Products in figure 3.11. The area for each space class is totaled and a space class profile similar to the pie chart labeled "Existing Space Profile" in figure 3.11 is prepared.

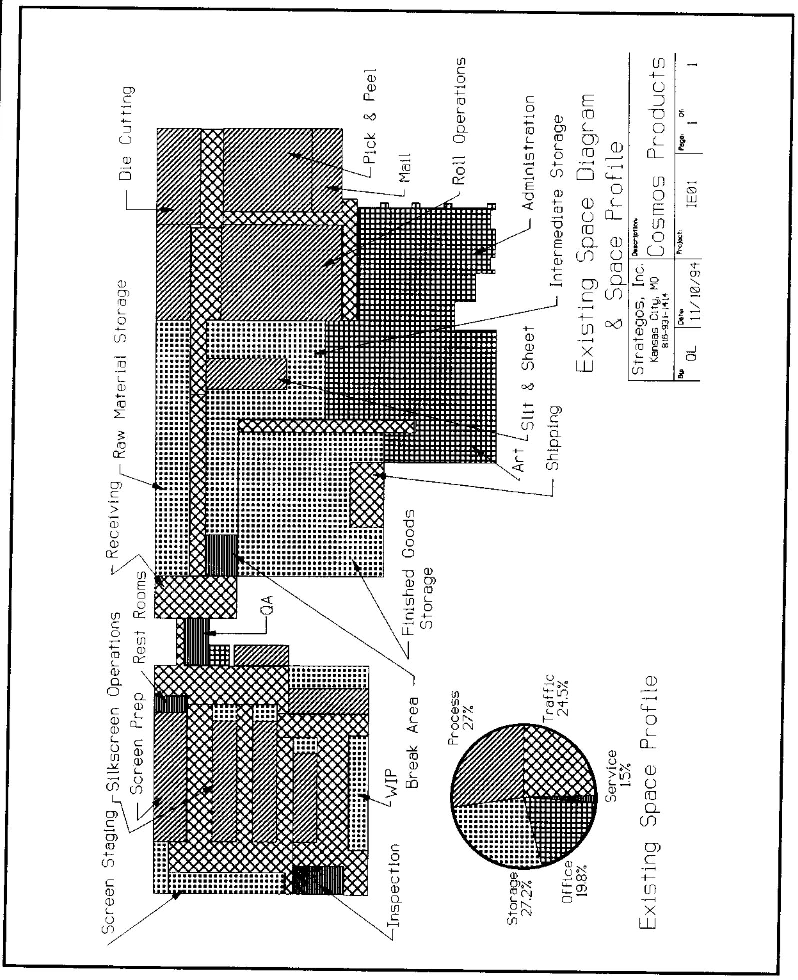


Figure 3.11 - Existing Space Diagram for Cosmos Products

The collection and presentation of this information can alert managers to key issues. As with the other information acquisition tasks, this is an important result of the space analysis. The analyst should encourage managers to begin asking such questions as:

- Why do we use 40 percent of our facility for storage, yet we constantly fall short on customer delivery?
- Why are aisles in our facility so disjointed and chaotic?
- Why does Product A require 18 percent of our facility's space but only generates 3 percent of our sales and 0.5 percent of our profit?

The following is the space analysis summary for Cosmos Products.

Cosmos Products: Existing space summary

Much of our space appears disconnected and scattered. The existing space diagram shows no clear, underlying plan. The proportions of space use are better than in many other industries, but could be improved. Significant opportunities may exist in reducing storage and traffic areas. Some parts of the plant have narrow aisles. Others have overly wide aisles that become WIP storage areas.

Organization analysis

Task 03.06, "Organization Analysis," has several purposes. It can help determine the size of support facilities such as restrooms and cafeterias. In office layouts, it may be essential for planning space based on work station requirements. It can help evaluate the current and proposed space plan. It can assist in formulating a manufacturing strategy or in identifying inconsistencies between strategy and practice.

Organization analysis usually begins with a complete and current organization chart from the personnel department. It should include all departments and employees that use the facility hdown to the lowest level. It also might include departments and people who reside outside the facility but have a major impact on operations. An example might be a corporate engineering department that designs processes and products but is in a remote location. Names and titles for each production worker are not needed, but there should be an approximate count for each supervisor and department.

These charts can become quite large and may have to be plotted on large-scale drafting paper, but the chart should not be broken into small sheets. This may be convenient for the analyst but it disguises the true nature of large, convoluted organizations. Maximum impact is the aim. Managers must develop and approve the strategic basis of the space plan, as well as the space plan itself. Figure 3.12 shows how to construct the chart.

After the organization chart is complete, the current space plan should be examined. A continuous, enclosed line on the organization chart should represent each major area on the layout, surrounding each position or department that inhabits the layout area until all positions are accounted for.

Figure 3.12 illustrates space and organization congruity. It shows consistency between the current organization and the current arrangement. People and positions in the same department generally occupy contiguous areas.

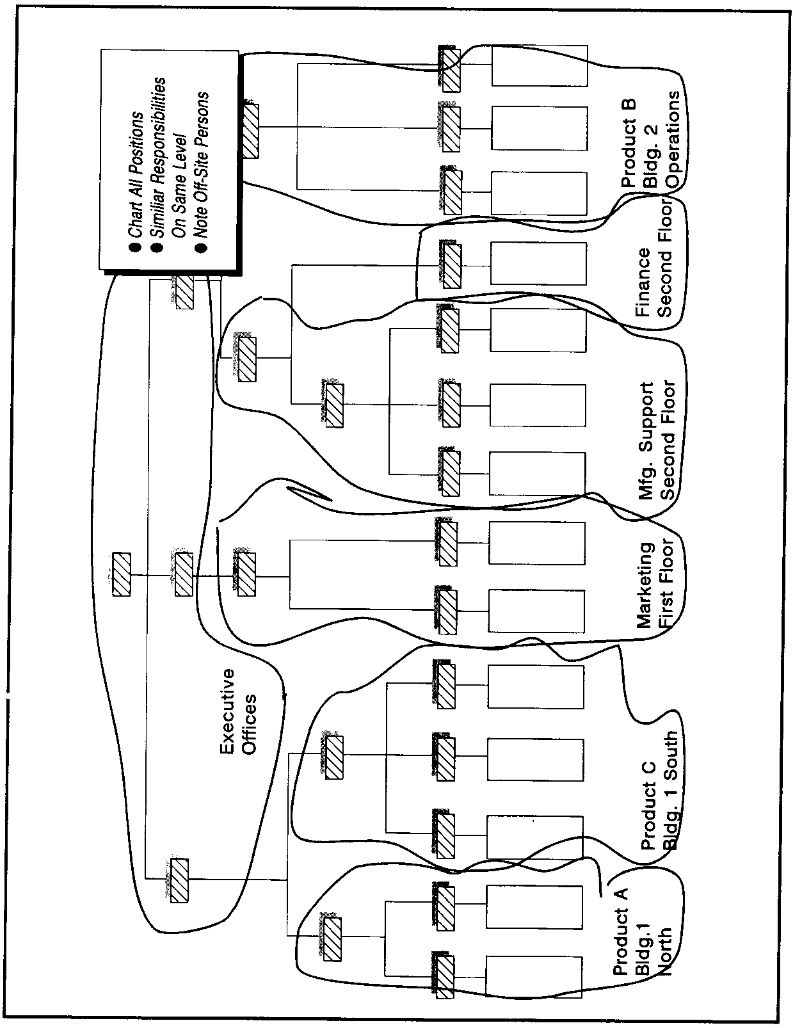


Figure 3.12 - Organizational Analysis

A messy diagram (fig. 3.13) demonstrates how many people in the same organization units are scattered through the facility. The diagram by itself does not tell us whether the facility or the organization is correct; it shows that they are inconsistent.

Identifying physical infrastructure

Physical infrastructure supports operations for all or most of the product line but does not contribute directly to the process. For this

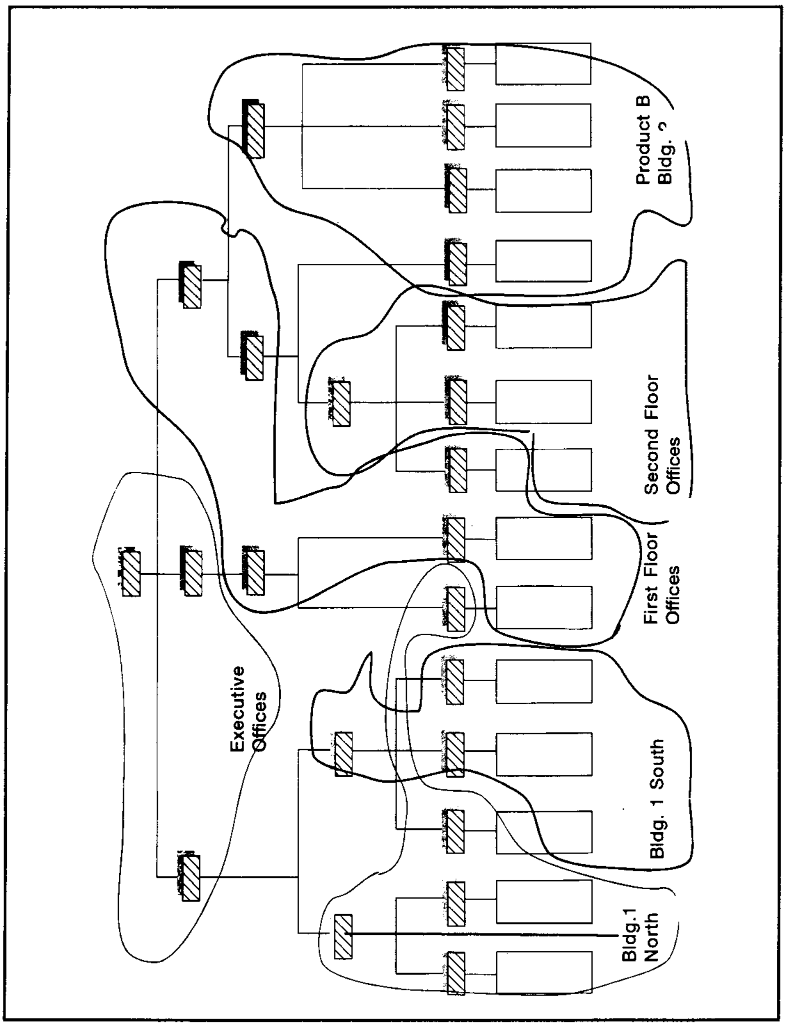


Figure 3.13 - Organizational Analysis

reason, physical infrastructure elements do not appear on the process charts. Infrastructure seldom relates to a single product or product group. Examples are: cafeteria, maintenance department, heating, ventilating and air conditioning space, and electrical switchgear rooms. These elements are necessary for operations and they are essential to the space plan, yet they are easy to overlook.

A physical infrastructure checklist (fig. 3.14) helps catalog these features. Using this form involves stepping through the list with a small group of knowledgeable people. Questions to ask are:

- Is each item in the current facility?
- Will a similar item be needed in the new facility or space plan?

This list will be input for the cell definition task later in the project.

Utilities

Electrical:
● Outdooor Substation
☐ Indoor substations(s)
☐ Switchgear Room
☐ Motor Control Center
☐ Uninterruptible Power
☐ 115v, 1-ph
☐ 230v, 1-ph
☐ 230v, 3-ph
☐ 460v, 3-ph
● 460/277v, 3-ph
☐ ______

Lighting:
● High Intensity
● Low Intensity WAREHOUSE
☐ Natural Light
☐ ______
☐ ______

Water/Sewer:
● Drinking Water
☐ Process Water
☐ Cooling Tower
☐ Water Treatment
☐ ______

Steam:
☐ Boiler Room
☐ Distribution System

Fuel:
☐ Fuel Storage
☐ Fuel Gas Plant
☐ Oil Tanks
☐ Coal Storage
☐ Other

Other Compressed Gas:
● Air Compressors
● Surge Tanks
● Distribution
☐ Oxygen Storage
☐ Acetylene Storage
☐ Other: ______
☐ ______

Cutting Coolant:
☐ Central Filtration
☐ Chip Separation
☐ Chip Conveyors

HVAC:
● Space Heating
☐ Infra-Red Heating
☐ Air Conditioning
☐ Dust Collection
☐ Local Exhaust
● General Ventilation

Other Utilities:
☐ Vacuum
☐ Other: ______
☐ ______

Human Resources

Administration:
● Personnel Office
● Employment Office COMBINE
☐ Credit Union
☐ Library
● Training Facilities

Food Service:
☐ Cafeteria
● Vending Area
● Lounge/Break Room
☐ Executive Dining Room

Health:
☐ Excercise Room
☐ Jogging Track

Safety:
● Medical Center
☐ Disaster Alarm
● Fire Egress
● Sprinkler Controls
☐ Fire Station
☐ Tornado/Fallout Shelter

Personnel
● Toilets
● Washrooms/Showers
● Locker Room
● Water Fountains
● Public Telephones
● Employee Parking
☐ ______

Administration

● Visitor/Reception
● Conference Rooms
☐ Customer Service
☐ Display Room
☐ Training Center
☐ Photo/Artwork

Storage:
☐ Archives
☐ Secure Storage
☐ Catalogue/Display
☐ Microfilm
☐ Surplus Furniture & Equipment
☐ ______
☐ ______

Quality

● Quality Laboratories
☐ Gage Calibration
☐ Formulation Labs
☐ Discrepant Material
☐ ______
☐ ______
☐ ______

Internal Transport

Aisles:
● Pedestrian
● Pallet Truck
● Fork Truck/Tractor

Handling Support:
● Battery Charging
● Maintenance
☐ Central Dispatch

Built-In Handling:
☐ Overhead Cranes
☐ Freight Elevators
☐ Scale
☐ Other: ______
☐ ______
☐ ______
☐ ______

Production

● Production Offices
☐ Tool Room
☐ Tool Crib
☐ Clean Room
● Central Maintenance

Storage:
☐ Packaging Materials
● Lubricant/Cutting Oil
● Discrepant Material
☐ Incidentals
☐ ______
☐ ______
☐ ______

External Transport

☐ Rail Siding
☐ Rail Dock
☐ Truck Turnaround
● Truck Dock
☐ Truck Parking
☐ Truck Scale
☐ Truck Maintenance
● Truck Access/Egress
● Auto Access/Egress
● Auto Parking
☐ ______
☐ ______
☐ ______

Product Development

☐ Prototype Shop
☐ Engineering Lab
☐ Special Test Labs
☐ ______
☐ ______
☐ ______

Figure 3.14 - Physical Infrastructure Checklist

Analyzing material flow

In this task, information from the process analysis is superimposed on the current space plan. The resulting diagrams bring attention to material movement opportunities. They also indicate the need for more cellular or line production modes. This task also provides a baseline for measuring handling improvement due to the new facility or space plan.

For this task, the process charts and layouts developed in Task 03.03 and Task 03.06 should be used to select one or more items to represent typical products or parts. Lines and arrows should trace movement across the layout. The number of moves for each item should be counted and the movement distance for each item totaled. If the analysis is performed for many items, the results should be averaged. Figure 3.15 is an example. It shows long moves, crossovers, and backtracking. This facility has significant improvement opportunity. Moves between organizational departments also indicate improvement opportunity.

Managers are often unaware of the severity of material flow problems. This analysis will document these issues in a dramatic way. It helps management take another step towards consensus, understanding, and support. Other types of material flow diagrams are also useful for a more complete picture of the current material flow.

Other issues

Other issues can affect the layout. They usually arise in initial discussion or during data acquisition. Some examples are:

- a scheduling system that dictates batch movement through the plant;
- difficulties in hiring skilled people that may push a company toward automation; and
- external regulations such as those in the pharmaceutical industry that may dictate functional operations.

Experience and judgment are the best guides. At minimum, a brief listing of these issues is necessary. They may need significant analysis.

The strategic framework

An operations strategy is the dominant approach or philosophy that guides the design of the manufacturing or business system. Operations strategies often determine the competitiveness and ultimate fate of an organization. Strategy leads to structure, as well as the arrangement and interconnection of business elements. Such elements might be machines, information systems, people, or facilities.

Strategies extend over long periods—years or decades. They encompass all the products and processes, permeating every area and aspect of the organization. They affect and determine the behavior of individuals.

Operations strategy may be explicit or implicit. An explicit strategy is stated, orally or in writing. Properly promulgated, it guides decision-makers in their daily work, building a common framework for both operational and structural decisions.

An implicit strategy, by contrast, is not written or publicized as such. It often results from common understandings about what matters for the business. These understandings may be rational or senseless, effective or ineffective, consistent or contradictory.

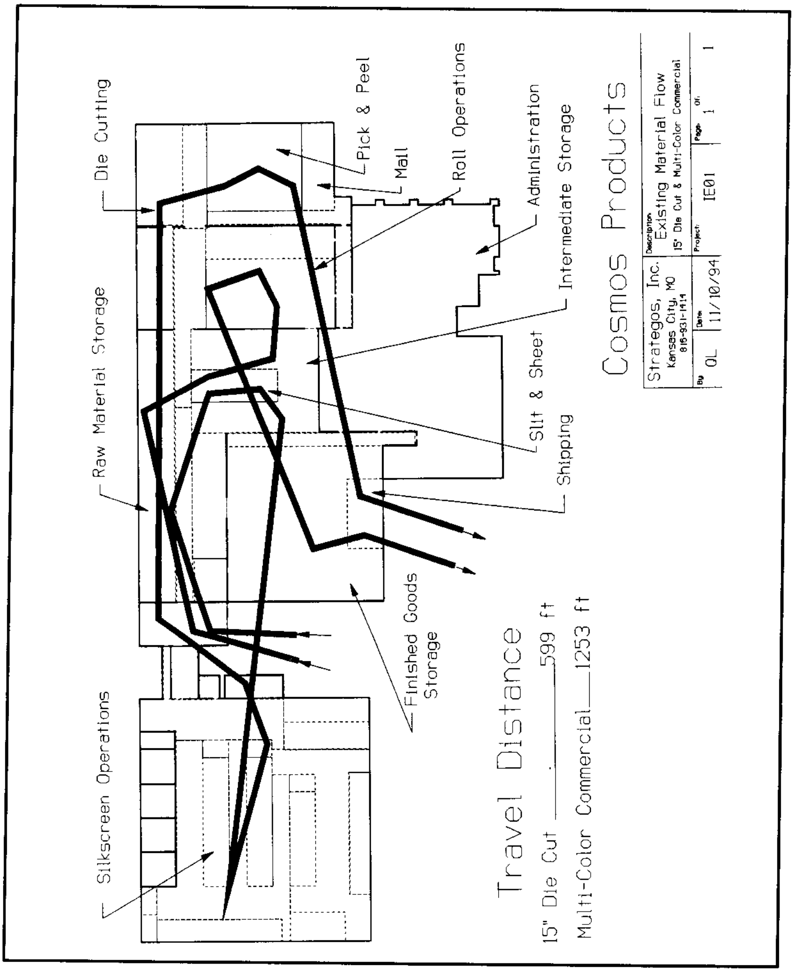


Figure 3.15 - Existing Material Flow

An implicit strategy is determined only by watching patterns of decisions and behavior over time. For example, has the organization evolved along functional rather than product lines? Is new equipment predominantly high-speed and large-scale? Is the scheduling system batch-oriented? Even the absence of patterns is a pattern.

Management is responsible for operations strategy. Top managers can abdicate the task of enunciating that strategy, but they cannot relinquish responsibility for the result.

Determining the framework of an organization's operations strategy hinges on the identification of *key manufacturing tasks*, *focus opportunities*, and *an operations strategy summary* (or statement).

Key manufacturing tasks and focus opportunities

The design of a manufacturing plant or business is like any other engineering design. It optimizes performance on some dimensions, while reducing optimization on others. The business environment and available technology place limits on the design.

This has an analogy in aircraft design. Aerospace engineers can design an aircraft that flies at Mach 3.0 or one that carries 350 people. They can design an aircraft that circles the globe on a few hundred gallons of fuel or one that lands on a 500-foot runway. However, they cannot design an aircraft that does all of the above. In the 1960s Secretary of Defense Robert McNamara tried to buy such a multi-purpose aircraft called the TFX. This aircraft did not achieve many goals.

Yet, many managers demand factories that produce many products quickly for many customers, at the highest quality and the lowest cost with output changing from day to day. Such a factory lacks focus. A business operation rarely performs well on more than two or three of these key dimensions. An unfocused factory has too many tasks or too many products or too many process technologies or too many disparate customers. It is often too large for effective management. Such a factory rarely performs any task well.

Manufacturing focus concerns the organization of products and processes. In the early 1970s, Wickham Skinner recognized that large factories with many products usually performed poorly. Several factors contribute to this effect:

1. A wider range of products usually brings more variety in the process. This requires greater complexity in handling, storage, tooling, changeovers, and skill requirements. It affects almost every facet of operations.

2. A wider range of products often must serve disparate customers and

markets. One market may regard delivery speed as a top priority while another demands quality or customization. Such varied market criteria increase the difficulty for manufacturing and decrease effectiveness.

3. Economies of scale are the usual rationale for increasing factory size. Economy of scale refers to the increasing efficiency as plants and processes grow in size and output. The idea was popularized by Henry Ford's mass production methods. Wickham Skinner coined the term "dis-economies of scale." Increasing scale brings such dis-economies as increased coordination effort, isolation of specialty departments, and isolation from customers. As a factory grows beyond 300 to 500 persons, the dis-economies of scale soon overcome the economies.

4. Larger factories have greater distances between departments. This increases material handling costs and exacerbates the isolation and coordination difficulties.

5. Unfocused factories often have extensive vertical integration. Vertical integration with a wider product range requires more disparate processes. This requires far more technical mastery than a more focused operation.

A focused factory strives for a narrower range of products, customers, or processes. The result is a factory that is smaller and has few key manufacturing tasks.

In recent years, Skinner's concept of the focused factory has been extended. Focus is an issue when organizing any combination of products, technology, and people. It applies to service operations, to factories, and to departments within the factory. It applies to workstations within each department. The issue is: by what criteria shall we divide our space, people, and machines into manageable units?

There are several possible responses. Some examples are: products, processes, markets, customers, geographic areas, and support requirements. For a more complete discussion of operations focus, refer to the first chapter of the *Handbook of Commercial and Industrial Facilities Management*.

For the macro-space-plan of a factory, the focus choice usually narrows to product or process. A product-focused plant groups operations into departments that focus on products. Each department must have all equipment and skills for all operations, yet only process a single product. This eliminates changeovers and reduces coordination and scheduling problems.

A process focus allows each department to specialize in their particular process or craft. It is a common arrangement in many plants, probably taken from the medieval craft guilds.

Many of the perceived advantages of process focus are elusive in practice, although process-focused space plans and organizations do work well in certain, specialized situations. On the whole, product-focused space plans are preferred because they have many more advantages. Designers should aim for the highest degree of product focus attainable, using process focus only when exotic skills and large scale processes make it necessary. The areas in which product focus has advantages include: cost control, coordination, material flow, management and supervision, equipment utilization, knowledge and skills, response time, flexibility, quality, and organization.

Product focus simplifies cost control because it pulls together the same or similar products and converts many indirect costs to direct. Elaborate tracking and allocation schemes are often unnecessary. Because a process-focused operation must address a wider product variety, allocation of indirect costs is more difficult.

Product focus simplifies the coordination of sequential processes. Operations are in small areas, reducing the complications of distance and isolation and simplifying personal communication between operations. Because the product range is narrow, only a small variety of problems and issues will arise. Product focus often uses simpler methods for production control such as Kanban and direct link. In conjunction with MRP-type systems, it reduces the number of work centers the system schedules.

When compared to process focus, material flow reductions of 80 to 95 percent are common for product-focused operations. There are fewer interdepartmental moves, and distances are shorter. Variable flow paths often become fixed upon conversion to product focus. This allows the use of simpler handling devices, such as conveyors, or even manual handling. Process-focused space plans often require expensive automatic guided vehicle systems or even more expensive fork trucks.

Because of the smaller product range and better communication, product focus simplifies management. Product-focused cells often require little or no management because they naturally encourage teamwork. Product focus achieves the shallower organizations now in vogue. More emphasis is placed on products and customers rather than departmental loyalties.

In theory, product focus uses more equipment for the same output than process focus. However, firms seldom realize the theoretical utilization advantage of process focus because of the complex scheduling required. In practice, there are several approaches to mitigate the apparent under-utilization of product focus. One way is to design cells that maximize the use of major equipment while sacrificing usage on less expensive peripheral equipment.

Product focus requires a wider range of employee skills and knowledge. This may place large training burdens on firms that convert from process focus. However, the teamwork and job enrichment that result reduces turnover. Process focus, on the other hand, allows concentration on process skills, and highly complex and technical processes sometimes need this concentration.

Process-focused organizations typically have very long throughput times. As a result, they cannot respond quickly to changes in product mix, volume, or special requirements. Many process-focused plants counter this with extensive inventories, even though inventory is expensive and rarely reduces the response time on customized products. Product focus allows firms to eliminate finished-goods inventory while improving delivery performance and reliability.

Process focus is more flexible, at least in theory. However, several means exist to achieve good flexibility in product-focused layouts. For example, the use of small-scale, mobile equipment can allow product focused cells to be formed, disassembled, and re-formed new products.

Product focus generally achieves high quality levels. This results from quick feedback, good communication, easy coordination, and high commitment. Process focus sometimes may have a quality advantage for complex or technical processes.

Product focus is most compatible with newer approaches based on teamwork and empowerment. Process focus lends itself to traditional command and control management styles, often requiring a substantial hierarchy to deal with increased coordination and complexity.

The concepts of focus and key manufacturing tasks are interrelated. Focus identifies the most important dimensions and optimizes them. The business addresses a narrower market, but addresses it very well. The key manufacturing tasks state what manufacturing must do well to survive in the market.

Process elements are the equipment, people, and operations that add value to a product. They directly transform materials, information, and parts.

Operations strategy summary

A sound operations strategy addresses four areas: *mission*, *process*, *infrastructure*, and *facilities* (physical infrastructure). The site mission states, in a few paragraphs, the purpose of the site. It identifies customers, products, and processes. It defines one to three key manufacturing tasks that directly correlate to success in the marketplace. The mission statement also might address important external issues such as environmental policy. The remainder of the operations strategy summary flows from the mission statement. It states how the firm intends to achieve the key manufacturing tasks.

Infrastructure supports the process but does not directly affect the product. Non-physical infrastructure covers a wide variety of elements. It refers to people and information systems. Examples are: scheduling systems, training operations, personnel departments, and tool design capability.

Physical infrastructure, is tangible and is generally synonymous with facilities. Buildings, utility systems, roads, and docks are not directly in the process stream; rather, they support all processes.

A good summary addresses each major topic at a policy level. Few companies have a strategy summary sufficient for facility design purposes. For such purposes, those elements of strategy and structure that relate to facilities need to be emphasized. For example, compensation systems have major effects on organizational behavior but little consequence for the facility plan.

Figure 3.16 provides a structure for a strategy statement. Such a statement normally consists of one to four pages summarizing the firm's intentions for each structural element. Figure 3.17 is the statement for Cosmos Products.

The absence of an effective summary presents the facilities planner with difficult options:

- proceed without a summary;
- guide management as they develop a strategy;
- write a summary based on an idea of what it should say; or
- write a summary based on what probably will happen.

Development of a strategy summary relies on all of the information collected during the first task group. Even this may be insufficient for a complete statement. Strategic development is a high-level task that encompasses almost every aspect of the business.

Identifying operations strategy

Figure 3.18 is the procedure diagram for Task 03.10, "Identify Operations Strategy." Block 1 of the diagram begins with the assembly of information in a form suitable for a report or presentation. The *operations strategy outline*, Block 2, is also needed.

Block 3, the current position summary, shows the company's present status. A management team should assist with this step or at least concur that the summary reflects the company's current situation.

Blocks 4 through 6 determine management's readiness for change. It is not enough for management, or certain individuals, to express a need for change. The management team also must be capable of carrying through with change. The success of a space plan depends on the organization's ability to support it. For example, a cellular space plan that depends on kanban production control and small lot sizes needs

TechTools

Strategy and Structure Key Issues

1.0 Site Mission

1.1 Site Focus
- 1.2 Products
- 1.3 Markets
- Volumes
- Geography

1.4 Multi-Site Integration

1.5 Key Manufacturing Tasks

1.6 External Strategic Issues

1.7 Political

1.8 Environmental

1.9 Community Involvement

2.0 Process

2.1 Production Mode(s)
- Project
- Functional
- Cellular
- Toyota
- Line
- Continuous

2.2 Process Scale

2.3 Setup/Lot Size

2.4 Capacity
- Lead
- Track
- Lag
- Reserve

2.5 Quality Capability

2.6 Technology Level

3.0 Infrastructure

3.1 Quality Approach
- Quality Police
- Quality at Source

3.2 Personnel Policies
- Technical Skill Depth
- Technical Skill Breadth
- Interpersonal Skills
- Employment Security
- Compensation
- Training
- Performance Measurement
- Safety
- Ethics

3.3 Organization Structure
- Functional
- Product
- Other
- Depth

3.4 Organization Style
- Exploitive
- Bureaucratic
- Consultative
- Participative

3.5 Accounting Policies
- Process
- Job Costing
- Activity-Based Accounting
- Overhead Allocation
- Decision Criteria
- Knowledgebase Investments
- Inventory Accounting

3.6 Production Control
- Make-to-Orders
- Make-to-Stock
- Physical Link
- Broadcast
- Kanban
- MRP
- Re-Order Point

3.7 Supplier Policies
- Selection Criteria
- Single / Multiple Sources
- Contract Time Horizons
- Scheduling Approach
- Shipping Policies

4.0 Facilities

4.1 Site Focus
- Product
- Process
- Market
- Geographic
- Other

4.2 Site Location & Size

4.3 Transportation Access

4.4 Utility Systems

4.5 Expansion Policies

4.6 New Product Flexibility

4.7 New Process Flexibility

4.8 Resale / Disposal Policy

4.9 Hazardous Waste Policy

4.10 Environmental Issues

Figure 3.16 - Strategy and Structure Key Issues

rapid setup techniques and participative management. Management may not have the wherewithal to adopt these techniques.

If management has an acceptable strategy summary, this summary should be used in subsequent space plan work. If management expresses a desire for operations strategies different from current practices, their readiness to make required changes must be evaluated. This is a difficult and sensitive decision that requires years of experience in institutional change. Designers who lack such experience should seek counsel from the management team or others in the organization.

Mission

Site #1 has two distinct missions corresponding to our two major markets. These are:

Roll Products- Supply our customers with the largest variety of roll products in our industry with 24-hour shipment and quality within the top 20% in our industry.

Commercial Products- Supply high quality vinyl decals and appliques to small and medium size manufacturers. Originality and quality of artistic design is an integral part of our product mix. We expect to ship 80% of all orders within two-weeks at a reliability of 98%. Our products will conform to recognized quality standards.

At Cosmos we expect to be a good neighbor and integral part of our community. Cosmos should be known as a satisfactory employers.

Process

Roll Products- Cosmos will strive for a product-focused operation with the exception of primary slitting which serves both Roll and Commercial operations. We will have a mix of large and small scale equipment in Group Technology cells. Rapid setup is an important priority for equipment selection and operation. We will attempt an average equipment utilization between 60% and 85%. We will add process capacity 6-12 months ahead of demand. Processes should have a minimum capability index of 1.4. We will move gradually to higher technology processes provided they are consistent with our focus strategy, cost justified and have adequate support.

Commercial Products- Cosmos will strive for product-focus within the limits set by process and environmental requirements. This may dictate physical separation between silkscreening and subsequent operations. Primary slitting and sheet cutting will remain process focused. Our process scale will be a mix of large and small corresponding to the order mix. Rapid setup is an important priority on the smaller scale, low volume processes. We will attempt an average utilization of 80%-90% on large-scale silkscreen printers and 50%-70% on other equipment. We will add small-scale equipment in advance of demand and large-scale equipment when demand is proven. All equipment will have a minimum capability index of 1.4. We will strive for the latest and highest technology level on large-scale silkscreening.

Infrastructure

Cosmos will strive for a product-focused, shallow, consultative and informal organization. We will gradually move towards a participative team-based organization over the next five years.

Our accounting system should accommodate activity-based costing using cost drivers for overhead allocation. We will use project costing for commercial work and process costing for roll products. We recognize the limitations of conventional accounting systems for management decisions.

Production control will use MRP-type scheduling for commercial products and suppliers. We will use kanban systems for internal scheduling of roll operations. Commercial products will be strictly make-to-order. Roll products will use small finished goods stocks for the highest volume 80% of line items. The remaining 20% of low-volume roll products will be made to order. Unusually large orders of roll products will have extended deliveries and be made to order.

At Cosmos we will strive for long-term relationships with reliable suppliers. We will select suppliers on the basis of quality, delivery reliability and cost in that order.

Facilities

Site focus will follow corporate-level strategies as new sites develop. All sites, now and in the future will have a maximum of 200 employees. Site #1 requires only limited capability for new products and processes. Significantly different processes, such as a casting operation, should have a separate site.

Figure 3.17 - Physical Infrastructure Statement

An organization may not want change or may not be positioned for change. If so, the operations strategy summary should identify the approach that is most likely to be adopted in practice.

If the organization desires and is ready for significant change, initiating a strategic debate is a good idea. This debate should conclude with a proposed operations strategy summary that will help the space plan designer carry out the new strategy during the facilities plan.

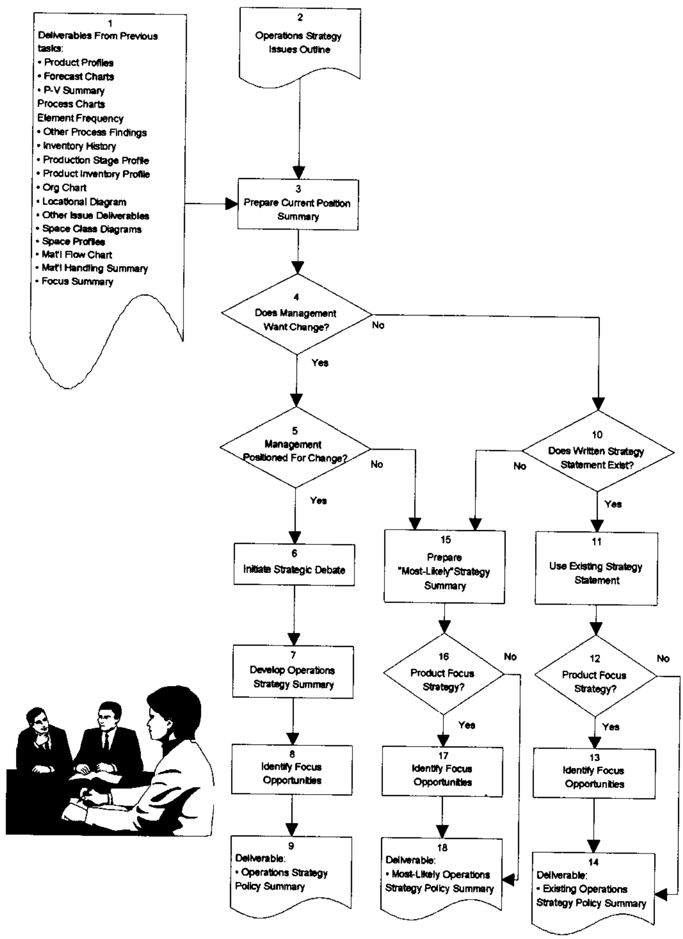


Figure 3.18 - Task 3.10, Identify Operations Strategy & Structure

One sub-task of Task 03.10 is the identification of focus opportunities. The concept of focus applies to space plans, organization structures, and other elements of the enterprise. Developing an appropriate strategy for facility planning means identifying the most appropriate focus for the facilities at each level. This is not a final analysis. Rather, it guides and gives preferred directions to space planners as they proceed with their work.

The flow process charts from Task 03.03 can help sort this out. Figure 3.19 shows the process charts for the manufacture of cosmetic

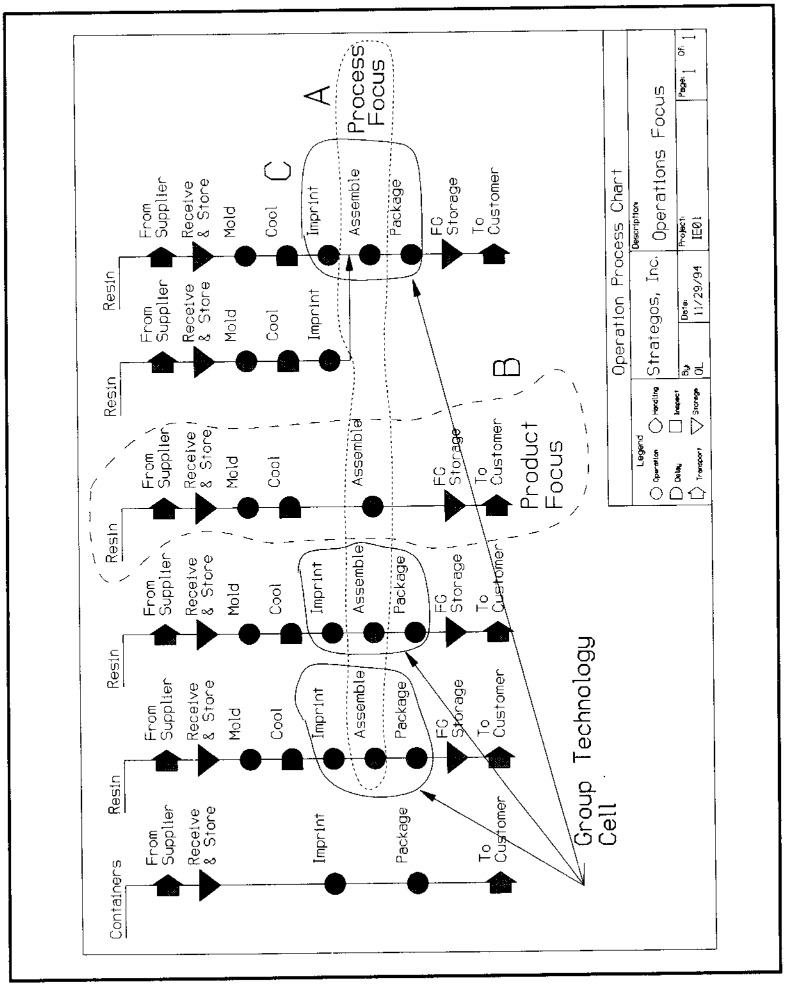


Figure 3.19 - Task 3.03, Product Process Chart

containers. The principal operations are injection molding, assembly, transfer printing, and packaging.

There are four basic containers. Each has varieties of color and print. Because color and print changeovers are fast and easy, the plant considers only container styles different products.

Process elements usually touch the product. At Cosmos Products, people assemble, lathes turn, and molding machines convert powdered resin to solid components. The selection, arrangement, and operation of these and similar elements are part of process design. A purely process focus would group the molding machines into a molding department, printing into a print department, and assembly into an assembly department. Each department would perform operations on all four products. Envelope A shows how assembly operations might fit into an assembly department.

Envelope B shows how all operations for a single product would be coordinated.

Sometimes focusing purely on product is impractical. Instead, group technology cells might be used, whereby a series of operations for several products takes place in a single cell. Envelope C shows how these operations might be coordinated.

Various mixed approaches are common. For example, process focus might be used for receiving, shipping, and molding, while other operations might have a product focus.

Figure 3.20 shows the procedures for identifying focus opportunities. The first is preparation of process charts for all products. This may be done on paper, or, for large numbers of products, forms of computer analysis can be used.

Next, products that are candidates for a plant-within-plant are identified. These would have enough volume to justify separate equipment, people, and infrastructure. Any such products should be set aside and removed from further consideration. A plant-within-plant (PWP) is a self-contained production facility within the walls of a larger facility. Ideally, a PWP is completely independent with its own supporting infrastructure.

We then search for products (or components) that have similar operation "strings"—groups of operations that can use the same equipment, the same people, and perhaps the same tooling. Is there adequate volume to justify dedicating equipment, people, space, and infrastructure to this group? If so, these products or components must be removed from further consideration and assigned to a group technology (GT) cell.

This procedure continues until the only remaining products and operations are those too small and varied for dedicated plants or GT cells. Process-focused cells are then developed for these items. An alternative is a job-shop department similar to a prototype shop.

Some space plans involve a great number of products and components, perhaps thousands or tens of thousands. In these situations, practicality may not allow a detailed analysis at this point in the macro-

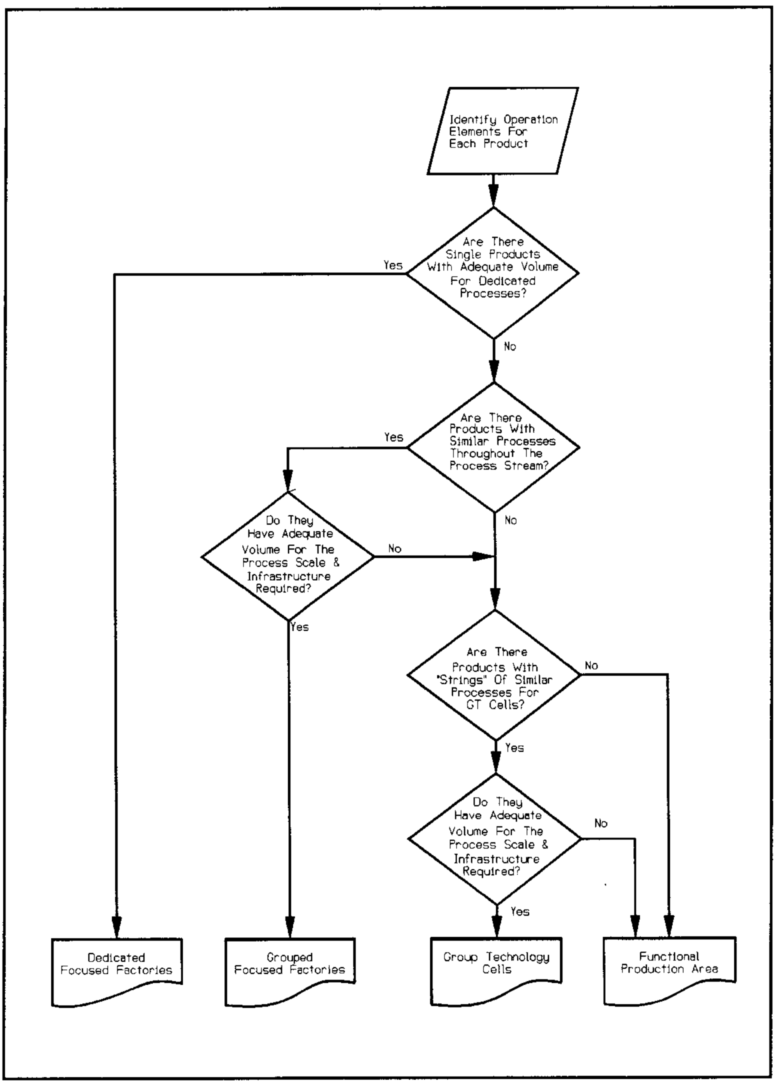


Figure 3.20 -Procedures for Identifying Focus Opportunities

space-plan project. The objective for this sub-task is to identify opportunities, not to make decisions.

For Cosmos Products, the two distinct product lines—roll products and commercial products—separated naturally into focused factories. However, the slit-and-sheet operation served both product lines. Many log rolls, when slit, became stock for both product lines. The narrow widths necessary for roll products are a natural byproduct of slitting for the wider commercial items. Maintenance, quality, and several other functions cannot be split economically. For this reason, the design team's aim became two semi-focused factories within the same facility, i.e., plants-within-plant. Several functional areas serve both focused factories.

Roll product operations lend themselves well to GT cells. However, the large number of items precludes a complete GT analysis at the macro-space-plan level. The team therefore developed a composite cell for roll operations, with the intention of analyzing the process in greater detail and designing GT sub-cells at the next design level.

In commercial products, the silk-screen operations call for tight environmental control. In addition, the existing silk-screen presses use large-scale, high-technology equipment. The team decided to put two composite cells in the commercial area. The first composite cell would include silk-screen and any related operations in the controlled environment. A second composite cell would have post-silk-screen operations such as thermal die-cut, pick-and-peel, and packaging. These smaller-scale processes would be arranged into GT cells.

Designing the space plan

With adequate information and an agreed-upon strategy, the actual space plan can be designed. The activity to this point may have consumed as much as half of the time and resources available to the project. Nevertheless, these expenditures were good investments. Managers from all areas have new perspectives. The factual data has tempered emotions. As the space plans develop, debate should be constructive and rational. The final selection will enjoy wide support thanks to management's broader understanding of both business and technical issues.

Defining space plan cells and processes

Task 03.11, or the definition of space planning units (SPUs), is the most fundamental and important task in space planning. It establishes the organization of space and must fit with a corresponding organization of people and processes. Moreover, all subsequent work flows from this task. An omission or error invalidates all of the work that follows.

A procedure chart for this task is in figure 3.21. Blocks 1 through 3 call for assembling deliverables from all previous tasks. Block 4 reviews operations strategy. If the strategy statement favors a process-focused (functional) space plan, planners should proceed to Block 5 and skip Blocks 11 through 23.

In Block 5, functional and support cells for the space plan are identified by examining the cell definition summary (fig. 3.22), the space analysis, the infrastructure checklist, the process charts, and the

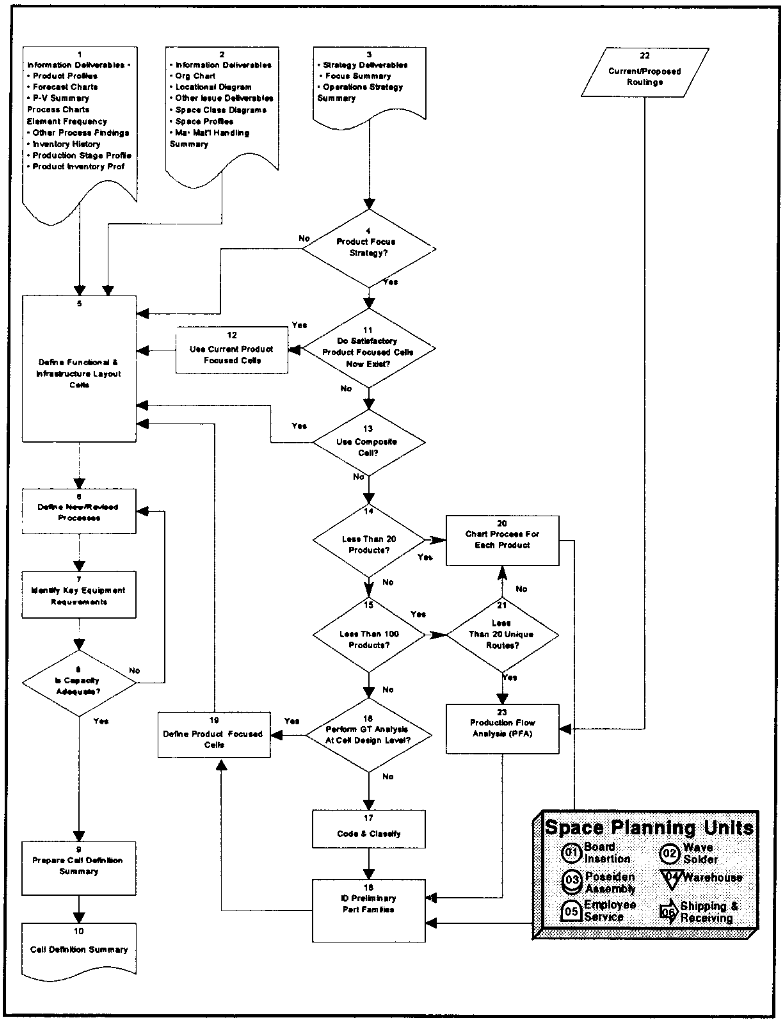


Figure 3.21 - Task 3.11, Define SPUs & Processes

organization chart. We look for activities, people, or equipment that will require space. For each such item, a cell could be defined, or the item could be combined with others into an SPU. Generally, ten to thirty SPUs should be identified.

In the SPU definition summary, the space planners should identify each SPU with a name and number and show those that are included. The space planner may also specify exclusions. The columns

ID	Cell Name	Inclusions	Exclusions	Source: Existing	Source: Process	Source: Org Chart	Source: GT	Source: Infra	Source: Strategy	Source: R&D	Source: Codes	Source:	Source:	Notes
01	SILKSCREEN OPERATIONS	SILKSCREEN DRYING BAKING & HUMIDIFY	SCREEN PREP POST-SCREEN OPS	●	●									1
02	SCREEN PREP	PREP STORAGE	SILKSCREEN PRODUCTION	●	●			●						
03	ROLL OPERATIONS (COMPOSITE CELL)	GT CELLS FOR ROLL SLIT & PACKAGE		●	●		●		●					2
04	POST SCREEN OPS (COMPOSITE CELL)	GT CELLS FOR POST-SCREEN OPS	SILKSCREEN OPS		●		●		●					2
05	SLIT & SHEET	ROLL SLITTING SHEET CUTTING	INTERMEDIATE STGE	●	●									
06	INTERMEDIATE STORAGE	WIP FOR COMMERCIAL & ROLL OPS		●	●									
07	RAW MAT'L STORAGE	ROLL & COMMERCIAL RAW MAT'LS		●	●									
08	FINISHED GOODS STORAGE	ROLL FINISHED STORAGE	COMM'L FINISHED STORAGE		●									

Notes:
1) A/C & SEMI CLEAN ENVIRONMENT
2) GT WORKCELLS IN THIS AREA DEFINED AT LEVEL 05

Approvals:
A. Jacken 11/11/94
C. Hacker 11/12/94
G. Washington 11/12

Figure 3.22 - Cell Definition Summary

that show the source of the cell definition should be examined (e.g., does this activity show up on the organization chart, process chart, or both?).

If the operations strategy summary calls for a product-focused space plan (line, cellular, or Toyota), support cells still need to be identified. However, a product-focused space plan may absorb many indirect activities within the product-focused cells. For example, in an electronics plant, assembly-integrate-test cells each had one of seven major products. Schedulers, test engineers, and process engineers sat in the cells. A subsequent organization realignment had these people report to cell managers rather than functional managers.

If the plan's strategy calls for product focus, planners should proceed to Block 11 to decide whether a current cell definition is satisfactory. If the factory has previously operated with product-focused cells, rearranging them may be all that is needed. Suitable definitions may have been developed during Task 03.10, "Identify Focus Opportunities." Now, additional product-focused cells should be defined. If the current definition is unsatisfactory, the next step is Block 13.

For a product-focused space plan, the planner can define product-focused cells at the macro- or micro-level. Defining work cells at the macro-level is satisfactory if the likely result is a manageable number and if the effort required is reasonable. Sometimes this is not the case. For example, an adequate definition might require an extensive group technology analysis, which is inappropriate at the macro-level. Or there might be many small cells that are difficult to arrange. If so, the planner should consider using one or more composite cells.

A composite cell consists of several smaller cells. In the Cosmos Products example, post-screen operations and roll operations lend themselves to cellular manufacture. Designing the individual cells and deciding which products go in them is a prolonged, detailed, and difficult task that, in this case, has been postponed until the next design level. Therefore, post-screen operations and roll operations have been defined as composite cells. This was not absolutely necessary. A group technology analysis might have been conducted at this macro-level to identify families and define the subcells.

If composite cells are not used at the macro-level, Blocks 14 through 16 are the next step. Planners evaluate the number of products and select an appropriate analysis tool. For a small number of products, twenty or less, the planners should go to Block 20, chart the process for each, and then use the process charts in Blocks 18 and 19. In Block 18, the space planner identifies preliminary part families; in Block 19, the cells are defined.

For a moderate number of products, less than 100 but more than twenty, production flow analysis is used. The process then moves to Block 18 for defining product families and Block 19 for defining the corresponding cells.

Many products (more than 100) will probably require a classification and coding analysis. This is an extensive undertaking but one with significant benefits.

After defining SPUs, it is time to review the processes for improvement. The process analysis at this level may be general. Examining the process further may be done during the detailing of the layout at the micro-level.

In Block 7, the space planner determines key equipment requirements. This is not always a complete list; rather, it identifies major equipment that occupies significant space or needs significant funding. In Block 8, capacity is checked. Normally, this capacity analysis is confined to key equipment or known bottlenecks. Process charts for any significant process revisions and a list of key equipment might also be helpful.

When complete, a cell definition summary is in place. Cell definition should include every space or feature necessary for the new plant. It is not always an elaborate document. Everyone involved should know what each SPU contains and what it will not contain. These are the building blocks for the new layout.

Because cell definition is so crucial to the remaining activities, planners should circulate it widely for comment and input. In addition, decision-makers must approve it before space planning can go forward.

Cosmos cell and process definition

Part of the cell definition for Cosmos Products is illustrated in figure 3.22. The operational cells come directly from the focus study of Task 03.11. Other cells are derived from the existing process charts and the physical infrastructure checklist.

For example, SPU 01 is silk-screen operations. It includes silk-screen printing, drying, baking, and humidifying and excludes screen preparation and subsequent operations. The team created this SPU from the existing space diagram and also from the existing process chart.

Cell 04 is post-screen operations. It includes thermal die-cutting, pick-and-peel, masking, labeling, inspection, and packaging. The existing space plan had no area with this label. This SPU was derived from the process charts and the strategy statement.

Figure 3.23 is the revised process sheet for Cosmos's multi-color commercial family of products. Comparing this illustration to figure

3.8 reveals that the value added index (VAI) has increased from 0.20 to 0.30. The number of elements has decreased from 78 to 50. Improvements of this magnitude (30 to 50 percent) are not uncommon in layout-reengineering projects. The dotted envelopes in figure 3.23 represent the cells where the process activities occur. Most of the

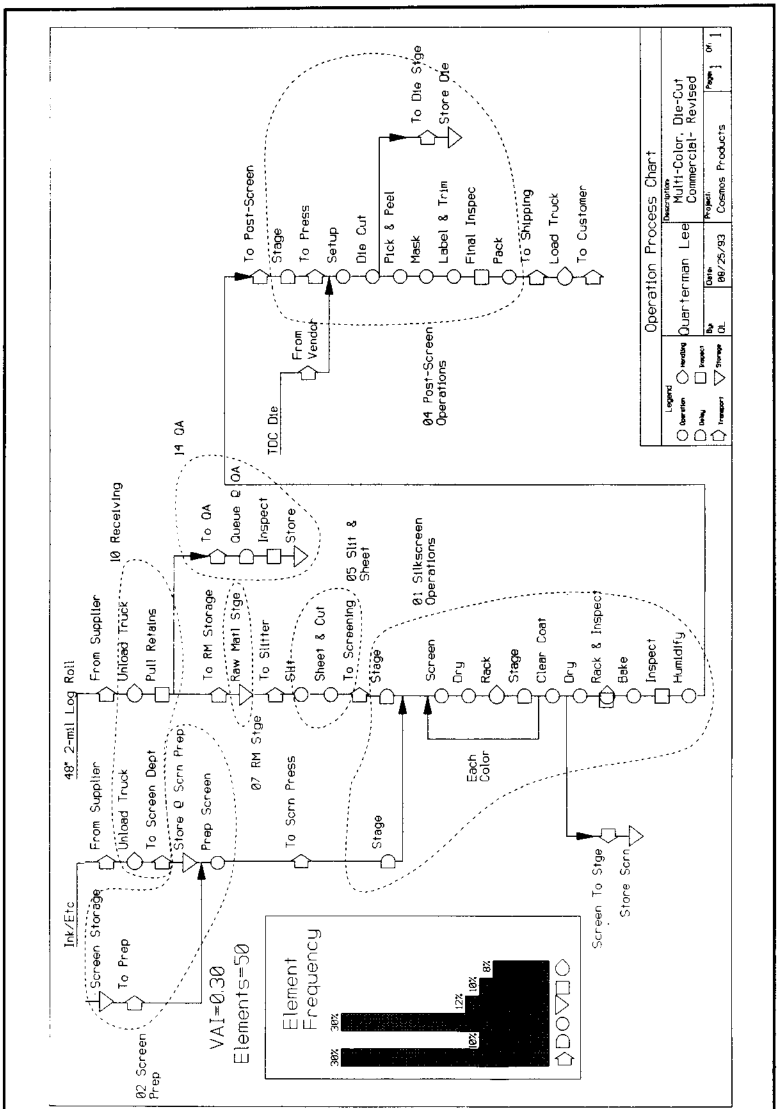


Figure 3.23 - Revised Process For Multi-Color Die Cut Product

process improvements at Cosmos are from the elimination of transport, storage, and delay elements, which are rendered unnecessary when processes occur in the same location. This is the power of a product-focused space plan.

Material flow analysis

In Task 03.12, the analyst uses information gathered earlier to calculate material flow between each combination of SPU pairs. Additional data may be needed for this calculation to establish the affinities associated with material flow. Figure 3.24 shows the procedure for this analysis.

In manufacturing, material flow is usually an important factor in layout. For non-manufacturing space plans, material flow may not be relevant, and this task probably will not apply. Between the extremes, the relative importance of material flow for establishing affinities will vary considerably.

Material flow values are one of two inputs for affinity development. As space plan design progresses and several options are under consideration, the material flow analysis can assist in evaluating these options. Later, flow calculations provide a basis for handling system design.

From the P-V summary, process charts and observation (Block 1) materials are classified into manageable groups (Block 2). This classification assists in developing a common unit for measuring flow, the equivalent flow unit (EFU). A classification summary is one of the deliverables for Task 03.12.

Usually these groups number less than twenty-five. They are based on material-handling characteristics. Structural shapes might be one group in a metal-working factory. It would include steel and aluminum shapes that are ten to twenty feet in length. Another group might be small parts—items defined as less than four ounces and less than three inches on any dimension.

In Block 3 of the procedure, planners choose an EFU. This is a two-part measure: material-units per time-unit such as pallets per day (metalworking); cartons per hour (grocery distribution); tons per day (steel foundry); or totes per day (electronics).

When there is one type of material, this step is easy. It uses the normal unit such as tons or pieces. Such situations are rare, however. Most layouts deal with a wide range of material movement.

Materials also may change form. A sheet metal cabinet for computers begins as a flat sheet that is difficult to handle. Cutting and forming increases the difficulty and bulk by an order of magnitude. Paint makes it delicate and susceptible to damage. Packaging then allows it to be nested and stacked, rendering it less delicate.

Figure 3.25 illustrates these changes in a quantified schematic flow diagram. The lines represent movement, and their width represents the flow rate in equivalent pallets per week. The flow rate in units per week is constant throughout the process. However, the change in size, features, delicacy, and packaging changes the equivalent flow as it moves from one operation to the next.

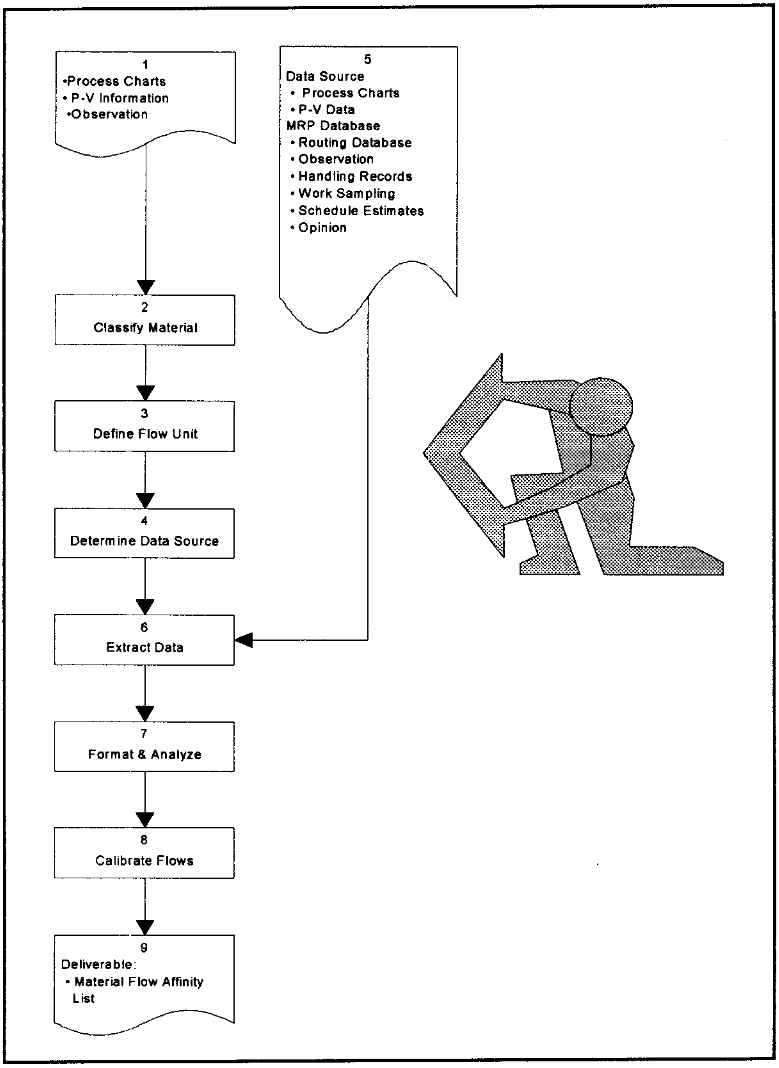


Figure 3.24 - Task 3.12, Analyze Material Flow

The source of data is determined in Block 4 of Fig. 3.24. For simple flow situations, the P-V analysis and process charts provide all the necessary information. In complex situations, the process charts may be too many or too complex; sometimes moves take place that are not in the official process. These must be identified from other data sources such as the MRP database, material handling records, direct

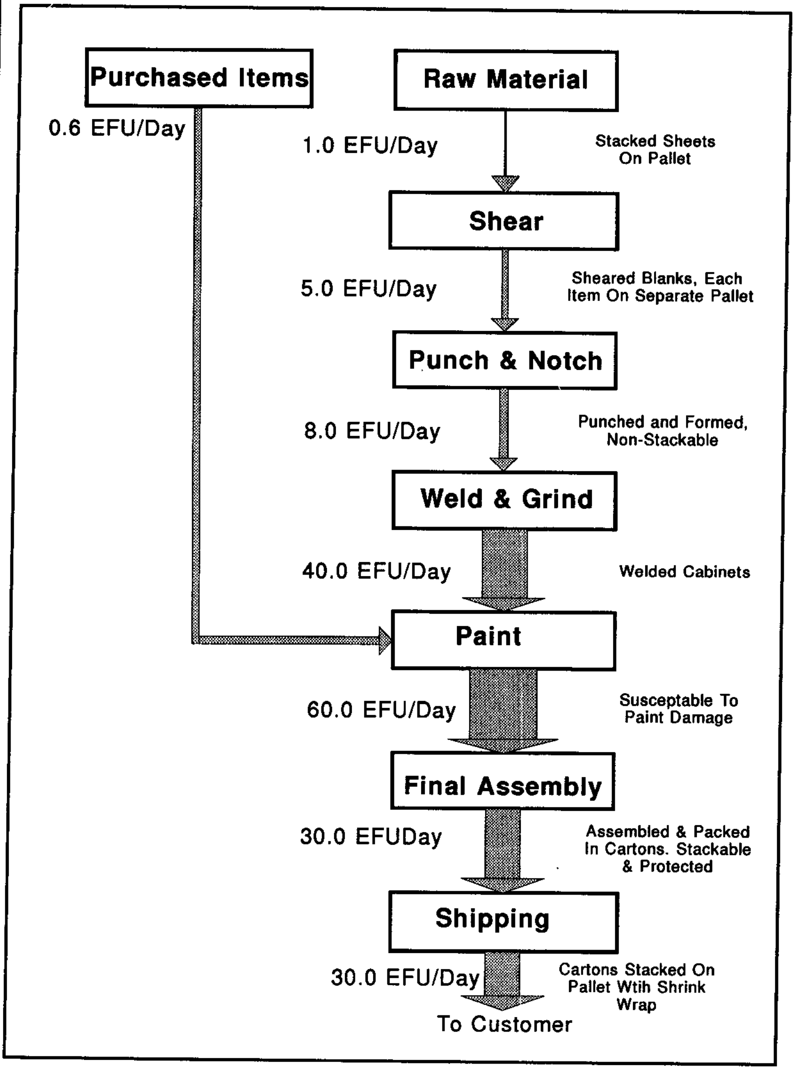


Figure 3.25 - Changes In Material Flow

observation, or random sampling as outlined in Block 5.

Block 6 marks the extraction of data. Again, for simple situations, only the process charts and the P-V information are necessary. For each move on the process chart, the planner determines if a similar move will exist when the new SPUs are used. He or she then determines the flow unit and the number of flow units per day required to meet the sales forecast.

Other data sources may need significant manipulation. Each space plan project is unique with respect to flow data. Experience and common sense are the main guides.

Block 7 formats the data, usually on a computer spreadsheet or database. In Block 8, the flow is calibrated using the AEIOUX conventions (see fig. 2.9). This is done on a ranked bar graph with the SPU pairs along one axis and flow rates on the other. The rating should be done manually. The affinity distribution in figure 2.10 should be used only as a guide, because other factors also are involved. For example, discontinuities in the curve naturally divide one rating from another. Affinity pairs that have zero flow between them get a "U" rating.

The procedure for Task 03.12 is illustrated by the Cosmos project. Based on the information from Block 1, the materials were classified as follows:

Log Rolls-These vinyl stock rolls are 36 inches long and about 12 inches in diameter. They weigh about 200 pounds.

Slit Rolls—Vinyl stock rolls are rolls that have been slit and rewound on smaller cores. They range from 6 to 20 inches in length and less than 5 inches in diameter. Weights are less than 40 pounds.

Roll Packages—These are packed roll products similar to cellophane tape or masking tape. The largest are about 5 inches in diameter and 4 inches in length. Most are much smaller.

Sheets—These large sheets of vinyl stock or decal material average 24 inches by 60 inches and remain flat throughout the process and shipping.

Packaged Sheets—These are decal sheets packaged in corrugated boxes. The boxes and packing significantly increase their volume but reduce the delicacy required in handling.

Much of the material handling in the plant is done using handcarts with four-wheel castors, so a handcart was used as an EFU. This offered several advantages. It was easy to visualize the handcart being used for all materials and to develop conversion factors from that vision. In the new layout, handcarts undoubtedly would remain the primary means of movement.

Table 3.1 is the output of Block 7 and the deliverable for Block 9 on the procedure diagram. This table shows the material flow analysis for Cosmos Products. The material classes are at the top left. Next to

EFU=Equivalent Hand Carts
Log Rolls 0.500
Slit Rolls 0.071
Roll Packages 0.004
Sheets 0.167
Packaged Sheets 0.250

(A) From -To	(B) Units	(C) Fwd Units /Day	(D) Rev Units /Day	(E) EFU Fact	(F) Tot EFUs /Day	(G) Flo Vow Rtg	(H) Flo Num Rtg	(I) Flo/ N-F Ratio	(J) N-F Vow Rtg	(K) N-F NumNum Rtg	(L) Tot Num Scr	(M) Tot Vow Rtg
01-02						U	0	1.25	A	4	2.00	E
01-04	SHTS	69.0		0.17	11.5	I	2	1.25	A	4	3.25	A
01-05	SHTS		69.0	0.17	11.5	I	2	1.25	E	3	2.75	E
01-08						U	0	1.25	O	1	0.50	O
01-12						U	0	1.25	I	2	1.00	I
01-13						U	0	1.25	I	2	1.00	I
01-14						U	0	1.25	I	2	1.00	
01-15						U	0	1.25	I	2	1.00	I
02-11						U	0	1.25	E	3	1.50	I
03-04						U	0	1.25	A	4	2.00	E
03-05	SLITS		46.0	0.11	5.1	O	1	1.25	E	3	2.13	E
03-06						U	0	1.25	O	1	0.50	O
03-08	PKGS	2134.0		0.01	19.2	A	4	1.25	I	2	3.50	A
03-10	PMAT		7.3	0.25	1.8	O	1	1.25	U	0	0.63	I
03-12						U	0	1.25	O	1	0.50	O
03-13						U	O	1.25	I	2	1.00	I
03-14						U	O	1.25	O	1	0.50	O
03-15						U	0	1.25	O	1	0.50	O
04-09	SHTS	69.0		0.25	17.3	E	3	1.25	E	3	3.38	A
04-11						U	0	1.25	I	2	1.00	I
04-12						U	0	1.25	O	1	0.50	O
04-13						U	0	1.25	O	1	0.50	O
04-14						U	0	1.25	O	1	0.50	O
04-15						U	0	1.25	O	1	0.50	O
05-06	SLITS	46.0	46.0	0.11	10.1	I	2	1.25	I	2	2.25	E
05-07	LOGS		23.4	0.50	11.7	I	2	1.25	I	2	2.25	E
05-09	LOGS	0.2		0.50	0.1	O	1	1.25	U	0	0.63	I
05-13						U	0	1.25	O	1	0.50	O
05-14						U	0	1.25	O	1	0.50	O
05-15						U	0	1.25	O	1	0.50	O
07-10	LOGS		23.4	0.50	11.7	I	2	1.25	O	1	1.75	E
07-12						U	0	1.25	O	1	0.50	O
08-09	PKGS	2134.0		0.01	19.2	A	4	1.25	I	2	3.50	A
08-12						U	0	1.25	O	1	0.50	O
08-13						U	0	1.25	O	1	0.50	O
09-10						U	0	1.25	O	1	0.50	O
09-12						U	0	1.25	O	1	0.50	O
10-14						U	0	1.25	E	3	1.50	I
11-12						U	0	1.25	I	2	1.00	I
11-13						U	0	1.25	O	1	0.50	O
12-13						U	0	1.25	O	1	0.50	O

TABLE 3.1

each class descriptor is the EFU conversion factor, which converts the material unit into an EFU. Each conversion factor is the inverse of the number of flow units that fit onto the cart. A cart usually carries two log rolls, for example, so its conversion factor is 0.5. The SPU pairs are in column A of table 3.1. Column B shows the flow units—slit rolls, sheets, etc. Columns C and D indicate the flow rate.

Paths should be specified using two numerical SPU identifiers. In the Cosmos example, 03 refers to roll operations, and 06 refers to intermediate storage. The flow path between them is 03 to 06. To avoid duplication and possible errors, planners should use only the forward path—the SPU with the lowest number followed by each SPU numbered above it. When material moves from a higher numbered SPU to a lower numbered SPU, it is called reverse flow. The total material flow is the sum of the forward and reverse flows. Column F in the Cosmos model is the flow totals multiplied by the EFU factor. This result is the average flow rate in EFUs per day. Column G shows the vowel rating for each flow path.

Figure 3.26 shows the flow calibration for Cosmos Products. This is Block 8 on the procedure chart and is typical of a product focused layout. It has a small number of high flow rates and many SPU pairs with zero flow. Process-focused layouts have a much broader distribution of flows commensurate with their complex natures.

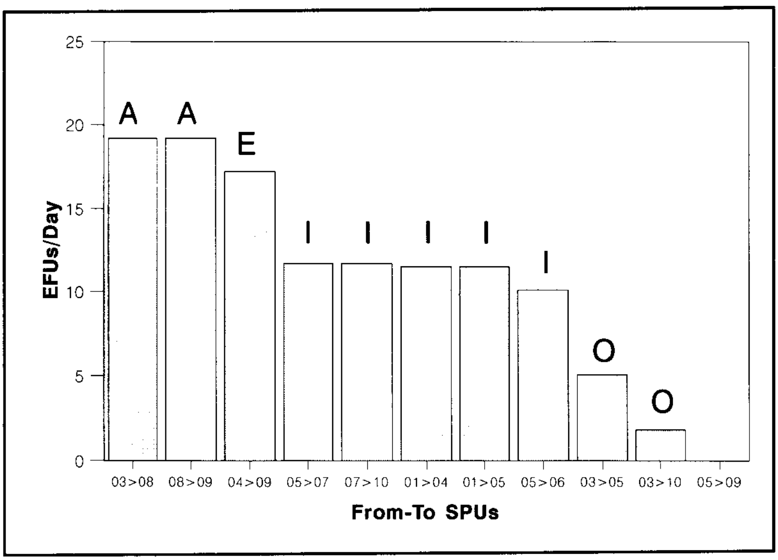


Figure 3.26 - Material Flow Calibration

Identifying non-flow affinities

Material flow is only one of many factors that give rise to affinities. Other factors are intangible and more difficult to quantify. Examples of these factors are: personal communication; the need to transfer personnel between cells or departments; movement to and from the cafeteria or rest rooms; quality feedback; joint teamwork communications; access by outside visitors; RF communications requirement; and other site-specific needs.

Figure 3.27 shows a chart for recording non-flow affinities that also may be used to document flow affinities or total affinities. Diagonals represent each SPU. When they cross, they form a diamond. In the upper half of the diamond, the affinity rating is recorded using the vowel or

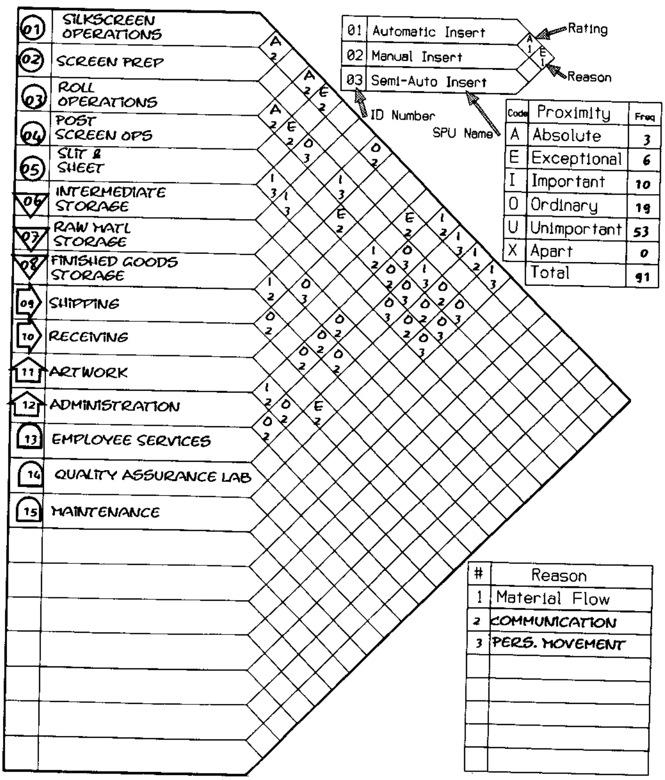


Figure 3.27 - Affinity Chart

number scale shown in figure 2.9. The lower half of the diamond is the place to record the primary factor(s) that gave rise to the affinity.

These non-flow affinities are independent of material flow requirements. The problem lies in capturing them. In Task 03.14 they are merged with affinities for an overall or total affinity rating. A survey, consensus meeting, or personal evaluation may also be used.

A consensus meeting that assembles representatives from each department or SPU is usually the best approach for accomplishing Task 03.13. The analyst acts as facilitator. Using the affinity chart of figure 3.27, he or she explains the need for affinity ratings, the chart, and the desired distribution. The group considers each pair of SPUs, one at a time, and discusses the relationships.

Using the conventions in figure 2.9, they decide on a rating. Initially, these discussions are rather long. After five to ten ratings, however, the group will begin to agree readily. A scribe records the ratings and keeps the group focused by displaying the current SPU pair on cards. Frequently, corollary issues arise. These may result in constraints or even revisions of the SPU definition.

Participants in a consensus meeting emerge feeling that they have been part of the overall project. This is important. When they see how their input led directly to a space plan, they will have increased commitment to the space plans that finally emerge.

Another method of identifying non-flow affinities involves sending questionnaires to representatives in each department. The questionnaire asks them to list other departments, areas, and people that must be near each other. The results are then assembled, interpreted, and ratings developed using the scale and conventions in figure 2.9. This method is effective for large projects with fifty or more SPUs and many affinities. However, it does not allow the participants to develop a common understanding through discussion. The participants may not trust the judgment of the person who interprets the surveys and corollary issues may not be brought out.

A third method is personal evaluation, which uses a single judge to determine affinities. He or she must have intimate knowledge of the operations. This often is the analyst, but he or she may also be a strong leader, perhaps the plant manager or CEO. This is a quick method and may be effective for small projects. This, however, does not build consensus and may be divisive. Corollary issues may remain hidden.

Merging affinities

Two sets of affinities now exist. The development of flow affinities used a quantitative approach. Non-flow affinities by their nature preclude a quantitative approach and were identified by a consensus or some other non-quantitative approach. These must now be merged into a single set of affinities (fig. 3.28). This is Task 03.14.

A spreadsheet created by hand or computer is usually the most straightforward method of merging. Table 3.2 is an extension of the spreadsheet in table 3.1. These columns are put in after columns A through D.

Column E: Vowel Non-Flow Rating (Enter Manually)
Column F: Numeric Non-Flow Rating (Enter Manually)
Column G: Flow/Non-Flow Ratio(Enter Manually)
Column H: Merged Score: Col. A x Col. F + Col. E x (1 - Col. F)
Column I: Merged Vowel Rating (Enter Manually)

Planners should add rows for all remaining combinations of SPUs, sort the rows in the merged score column (Col. H) in descending order, and plot the merged scores on a ranked bar chart. From the chart,

EFU=Equivalent Hand Carts

Log Rolls	0.500
Slit Rolls	0.071
Roll Packages	0.004
Sheets	0.167
Packaged Sheets	0.250

(A) From —To	(B) Units	(C) Fwd Units/ Day	(D) Rev Units/ Day	(E) EFU Fact	(F) Tot EFUs/ Day	(G) Flo Vow Rtg	(H) Flo Num Rtg
03-08	PKGS	2134.0		0.01	19.2	A	4
08-09	PKGS	21234.0		0.01	19.2	A	4
04-09	SHTS	69.0		0.25	17.3	E	3
05-07	LOGS		23.4	0.50	11.7	I	2
07-10	LOGS		23.4	0.50	11.7	I	2
01-04	SHTS	69.0		0.17	11.5	I	2
01-05	SHTS		69.0	0.17	11.5	I	2
05-06	SLITS	46.0	46.0	0.11	10.1	I	2
03-05	SLITS		46.0	0.11	5.1	O	1
03-10	PMAT		7.3	0.25	1.8	O	1
05-09	LOGS	0.2		0.50	0.1	O	1

TABLE 3.2

they should assign a merged vowel rating (Col. I).

Deciding the relative importance of flow and non-flow factors depends on the industry, process, and other influences. Heavy industries such as steel or shipbuilding warrant a flow/non-flow ratio up to 2.0. Office areas and industries that depend heavily on personal contact may have ratios as low as 0.5.

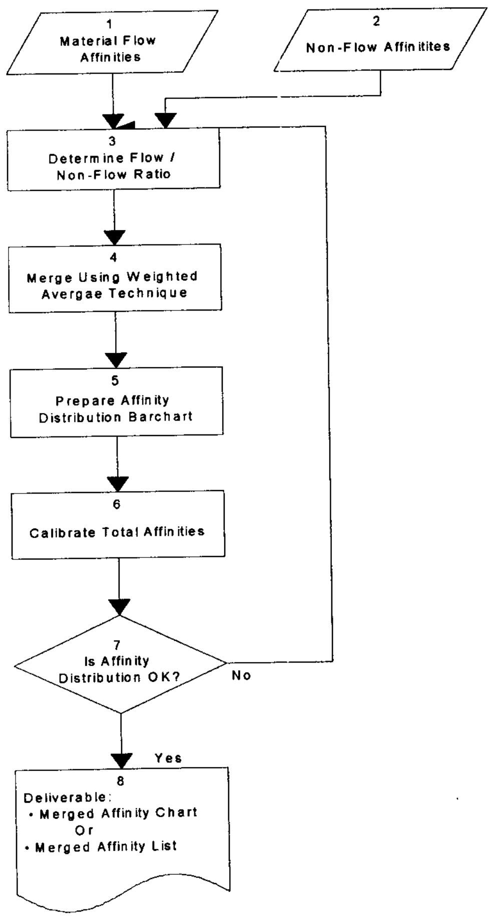


Figure 3.28 - Task 03.14, Merge Affinities

Generally, the same flow/non-flow ratio should be used for all the affinities on the space plan. Occasionally, however, specific affinities may have to be modified for special circumstances.

Next, the total affinities must be rated. When assigning the merged vowel rating, the analyst should consider two factors. First, he or she should strive for a workable distribution of ratings similar to those shown in figure 2.9. In addition, a search for natural breaks or discontinuities in the distribution avoids having nearly identical scores with different ratings. Accuracy is not paramount in this process.

Developing a configuration diagram

In Task 03.15, merged ratings are used to develop a configuration diagram. The configuration diagram is the first of the derived elements. It comes from cell definitions, affinities, and experience. The graphics work may be done on a CAD system or other software. However, manual development is straightforward and often quicker.

To develop the affinity diagram, the analyst places the A affinities and their associated SPU symbols first, then adds the E affinities. At this point, rearranging the diagram is desirable. Next, the I affinities are added and the diagram is rearranged again. He or she finishes with the O affinities, which usually will have little effect on the diagram..

Striving for short distances between the As and Es with minimal crossing is a worthwhile goal. Multiple crossings might create traffic congestion on the final space plan. Lower value affinities probably will have longer distances. The high value A and E affinities will have short distances. Attempting to fit this diagram into a building environment at this point is not advised. some excellent arrangements may be overlooked.

Figure 3.29 illustrates the diagram developed for the Cosmos project. Step 1 features the SPU symbols. Step 2 shows the A and E affinities in an undesirable arrangement. Step 3 shows the rearrangement of the A and E affinities and the addition of the I affinities. Another rearrangement is illustrated in Step 4. Finally, in Step 5, the affinities have been rearranged again, and the O affinities added.

The Cosmos configuration diagram in figure 3.29 is only one of many possible diagrams that uses this combination of SPUs and affinities. It can be mirrored or rotated. There may be other positions for the SPUs that give the same or better results. Some of these variations will fit the building better than others. However, it is best not to jump ahead and anticipate the shape of the building. It is worthwhile to ask several people to develop diagrams, thereby ensuring a wide selection of possibilities.

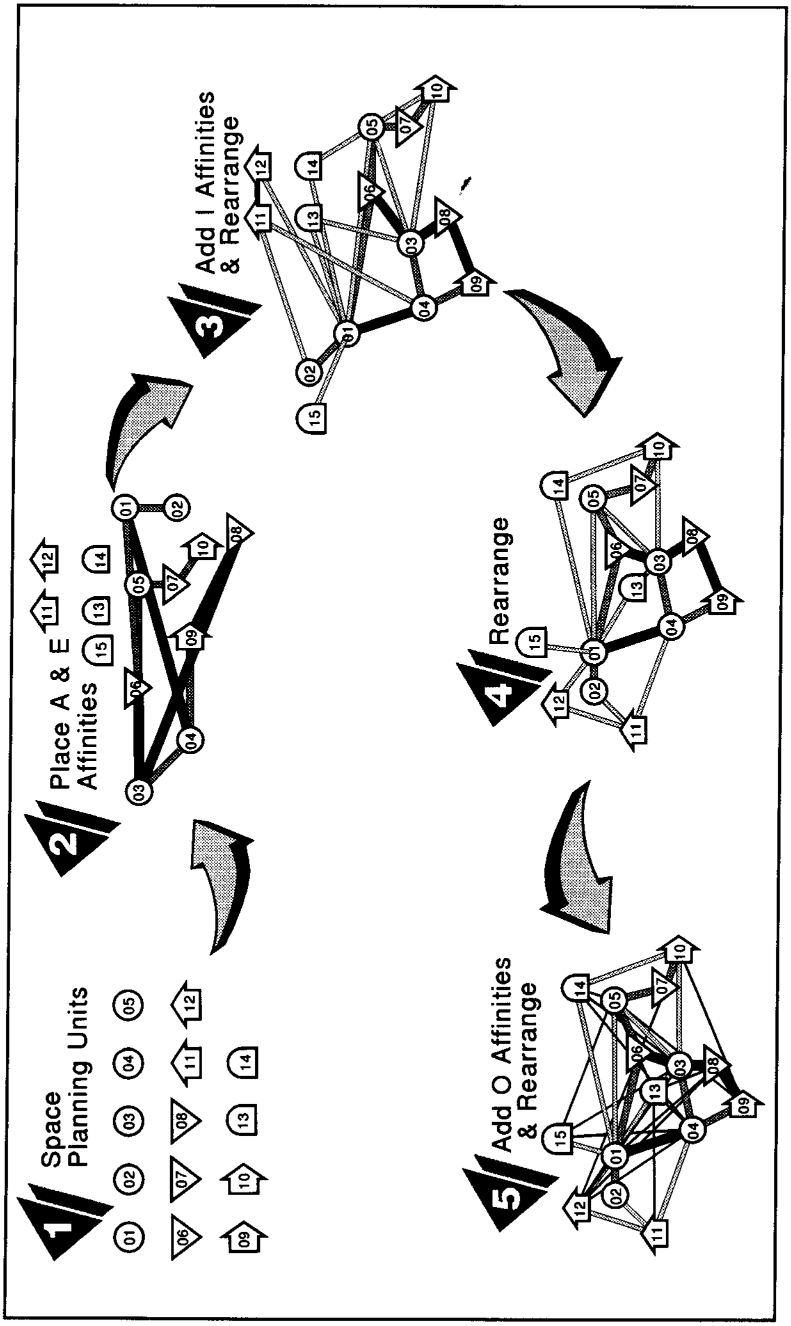


Figure 3.29 - Affinity Diagram

Space calculation

Space is the third fundamental element of a space plan. It is a limited resource; there is only so much space under a roof, on a site, or in a department. Whether the space is land on a site or space in a building, it is usually expensive

Although space is three-dimensional, most space plans ignore the vertical dimension. This is acceptable in all but a few situations.

Most layouts attempt to optimize the use of space as well as its arrangement. A complete space plan requires not only the location of SPUs, but their size and shape as well. The space occupied by SPUs usually prevents the designer from honoring all affinities

ID	Space Planning Unit	1994 Space	1998 Space	Calculation Method
01	Silkscreen Ops	16425	15580	Transform
02	Screen Preparation	1487	1500	Transform
03	Roll Operations	6123	8650	Transform
04	Post-Screen Ops	5460	7855	Elemental
05	Slit & Sheet	909	1000	Elemental
06	Intermediate Storage	3611	1600	Transform
07	Raw Mtl Storage	5151	4800	Transform
08	Finished Goods Stge	6789	4900	Transform
09	Shipping	874	1050	Transform
10	Receiving	1299	1500	Transform
11	Artwork	6320	6455	Standard
12	Administration	7320	8710	Standard
13	Employee Services	714	1500	Transform
14	Quality Assurance	480	745	Elemental
15	Maintenance	558	600	Transform
16	Aisles	2987	3700	Proportion
		62782	65845	

TABLE 3.3

simultaneously. Between them, it forces compromises above and beyond those arrived at in the configuration diagram. The space needs of SPUs may distort even a nearly perfect diagram.

Task 03.16 calculates size of the required space for each SPU, usually in square feet or square meters. Calculation of space requirements uses one or more of six methods. These methods are: *elemental calculation*, *visual estimating*, *transformation*, *space standards*, *proportioning*, or *ratio forecasting*. Table 3.3 shows Cosmos Products' space requirements and how the analysts used several methods for the calculation.

Elemental calculation

This method, illustrated in figure 3.30, starts at the most detailed level. Each piece of furniture or equipment assigned to an SPU is measured. These dimensions are then added together for the total amount of space. Space for aisles, miscellaneous storage, or other needs are also included in the sum. This added space often is a percentage of the basic equipment space.

Elemental calculation is simple and straightforward. However, it has its limitations. For one, it takes considerable time and effort. Uncertain forecasts can make it difficult to determine how much furniture or equipment will occupy the space. Elemental estimating is primarily a short-term methodology. Most industries use it for one to three years in the future. Beyond that, other methods are equally and perhaps more reliable.

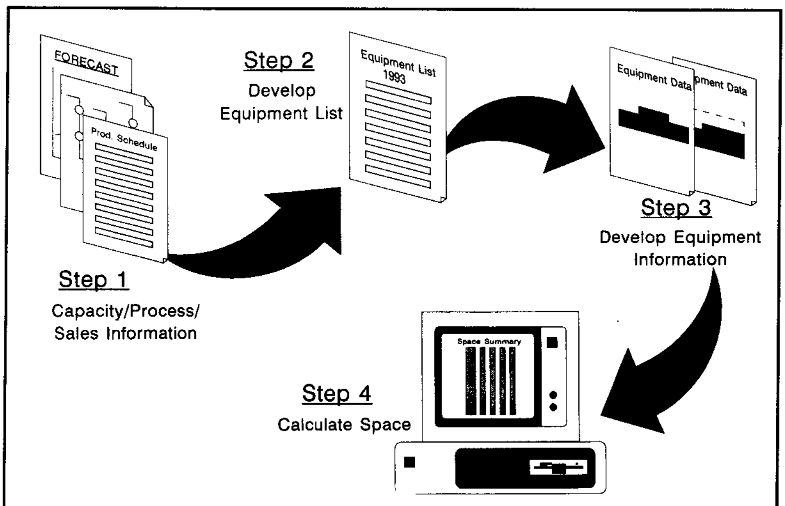


Figure 3.30 - Computing Space, Elemental Calculation

Visual estimating

Visual estimating uses templates to represent equipment and furniture—often this is only primary or large-scale equipment. The designer places the templates on a layout according to his or her judgment and knowledge of similar installations. The arrangement need not resemble the final configuration. The designer adjusts for aisles; maintenance access; and materials, storage, and minor equipment space requirements, and then measures the total space required for that SPU. Figure 3.31 illustrates.

Visual estimating is very useful for an SPU dominated by a few large items, but it can be laborious when many small items occupy the space. Forecast accuracy may become difficult. In the hands of an experienced planner, it can be accurate; however, inexperienced planners should be very cautious with this method.

Transformation

Figure 3.32 illustrates the transformation method: a designer takes a space requirement for an existing SPU and uses that as the basis for projecting future needs. Adjustments must be made for existing conditions such as overcrowding or wasted space. Changes in production and product mix are additional considerations, and new technologies that may need more or less space than current technology should be examined.

For example, suppose that current space for work in process storage is 3,400 square feet. Observation indicates that the area is crowded and congested. Ten percent is added to bring the space allocation up to present-day requirements. Then, if the planning

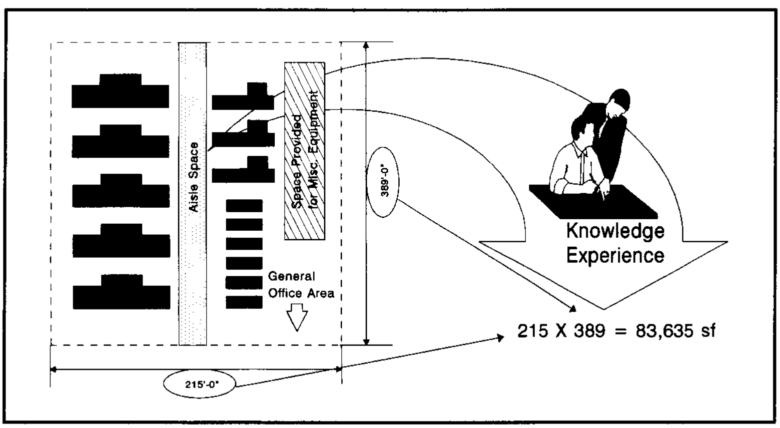


Figure 3.31 - Computing Space, Visual Estimation

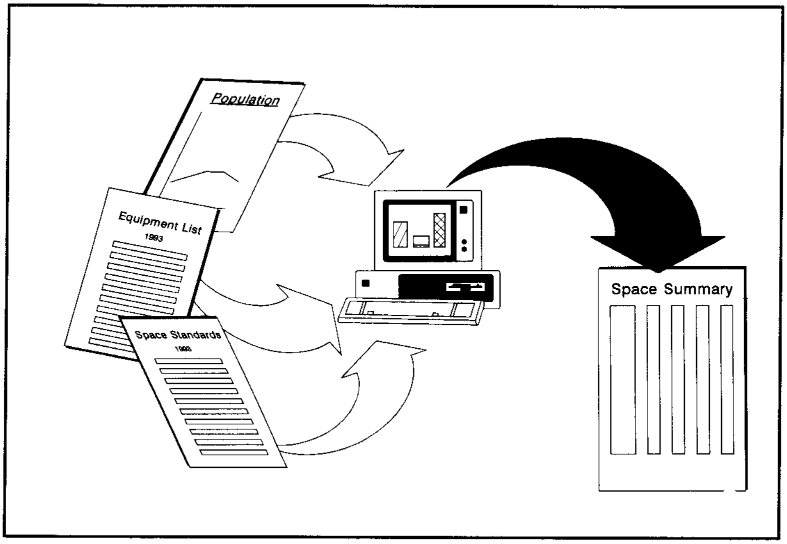


Figure 3.33 - Computing Space, Standard Data

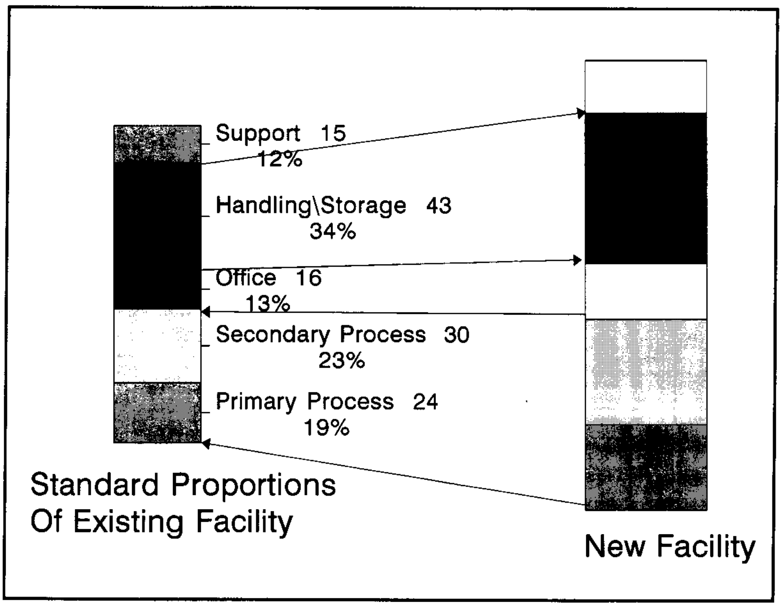


Figure 3.34 - Computing Space, Proportioning

Proportioning

Certain types of space calculation use proportions effectively. The space for a given SPU comes from the calculation of another space. For example, aisles might be a percentage of production space, or conference room space may be a portion of office space. Figure 3.34 illustrates.

Proportioning works well when the history to support it exists. It usually applies to only a few types of space, however. Proportioning requires little effort.

Ratio forecasting

Ratio forecasting uses historical trends to forecast space. In this method, business parameters and space are correlated over time. Such ratios may change gradually over the years. The analyst then projects the trend of this ratio into future years and uses that projection to calculate space.

Ratio forecasting, which is based on historical data, is most appropriate for long-term site plans. It has limited use for short-term space calculations.

The space plan primitive

The next step in the progression is the space plan primitive, which involves adding space to the configuration diagram(s). The space requirements come from the calculations and space summary (Task 03.16). The Cosmos Products space plan primitive is illustrated in figure 3.35.

The space plan primitive begins with a configuration diagram. Using an appropriate scale, designers place a square or rectangle with the SPUs calculated area near each SPU symbol. In step 2, designers either move each space block underneath the SPU symbol or move the SPU symbol over each space block. As the space plan primitive develops, it will have to be stretched to accommodate the space without overlaps. The result should be a compact arrangement that honors the affinities as closely as possible. Although designers should begin anticipating a building shape at this time, they should not strive for a final layout.

Constraints

Many factors that affect a macro-layout do not fit the concepts of SPUs, space, and affinities. These are constraints. Some examples are:

- Column spacing of 32 feet restricts the placement of aisles and some equipment.
- High electrical load restricts the placement of heat treat ovens to certain areas with adequate electrical service.
- A cold climate dictates that dock doors should not have

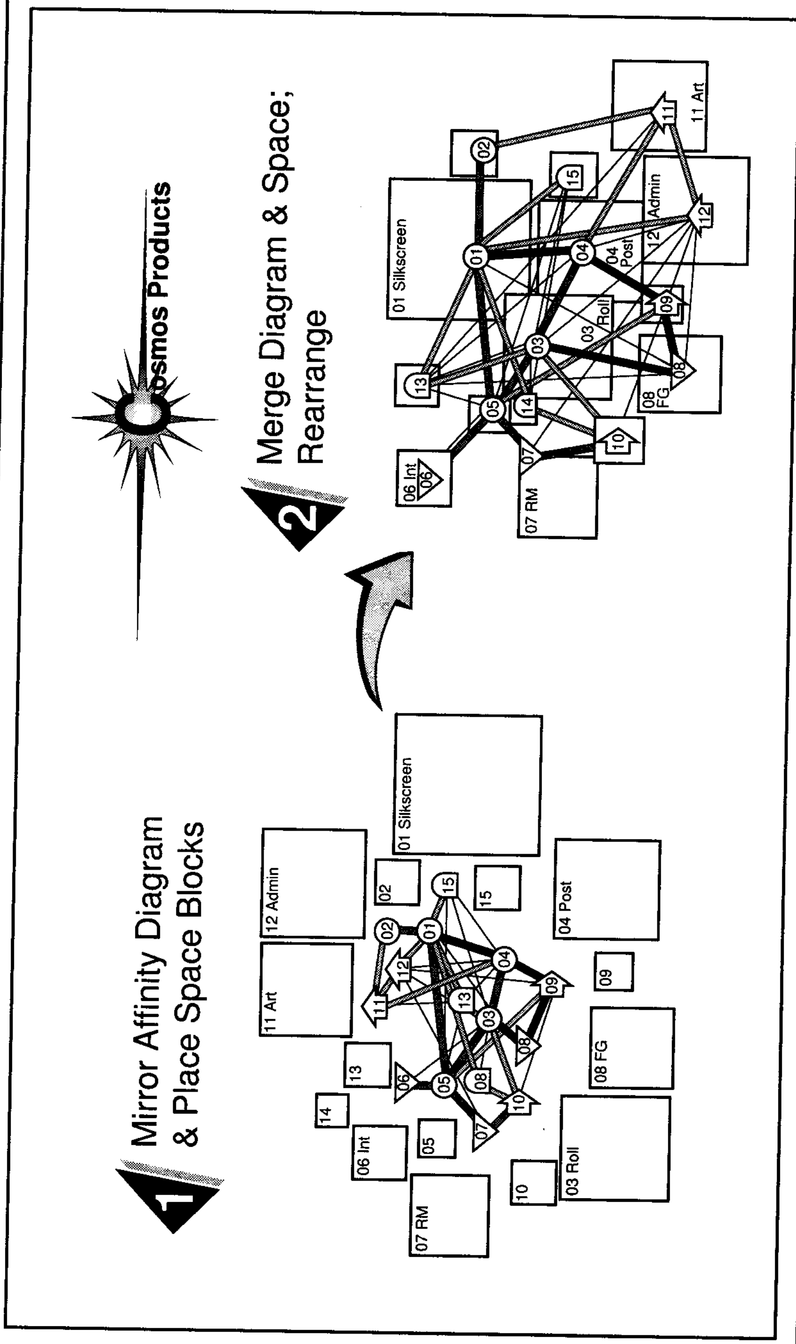


Figure 3.35 - Cosmos Spaceplan Primitive

northern exposure.

- zoning requirements specify that docks not face the street;
- floor loading restricts the placement of certain equipment;
- explosion hazard dictates that a hazardous chemical room have an explosion vent on an outside wall; and
- the company president requests a window for his office.

A form for identifying constraints (Task 03.19) is shown in figure 3.36. The SPUs are listed on the left and across the top, major categories are

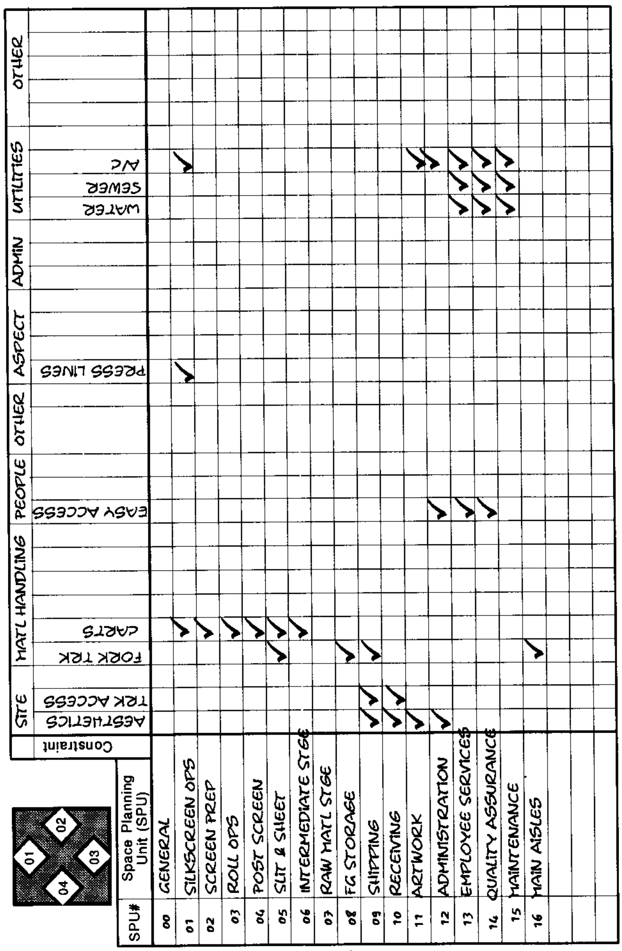


Figure 3.36 - Constraint Summary

identified. These include: site conditions, utilities, handling methods, personnel, procedures and controls, shape ratio, and others. The accumulated project documentation for each SPU and category are reviewed, and the constraints are listed. A bullet or check associates each constraint with a particular SPU. Some constraints apply to all SPUs. In this situation the bullet goes in the "general" row. The following is a description of Cosmos Products constraints:

Aesthetics—The nature of Cosmos products is artistic. Therefore, the aesthetics of the building and surroundings is important. Cosmos wants to present itself well to customers and other visitors. A pleasant surrounding will help attract the best commercial artists. The aesthetics issue applies to shipping and receiving areas, which are often unsightly. It also applies to the artwork, administration, and employee service areas.

Truck Access—This is another site condition. Trucks need access to both shipping and receiving. Cosmos is fortunate in this respect. The site has good access on both the north and south sides.

Fork Trucks—Handling in some areas uses forklift trucks. Adequate aisle widths on the main aisles and selected departmental aisles are necessary.

Carts—Small carts convey materials in many areas. Here, narrower aisles will suffice.

Easy Access—This is a personnel issue. Administration, employee services, and maintenance all require easy and inviting access for people.

Press Lines—Aspect ratio refers to the relative length and width of SPUs. Silk-screen printing operations require a minimum length to accommodate the long press lines.

Utilities—Certain SPUs require water, sewer, and air conditioning.

Next, this constraint summary and the space plan primitive will be used to prepare space plan options.

Designing macro-space-plans

The space plan primitive now must fit into a building outline. The building may exist or it may be a proposed structure.

Preparing space plan options begins with overlaying the building outline with a space plan primitive. The space blocks are shaped to fit building walls, columns, and other features. The constraints summary should be consulted during the placement of each SPU.

For each space plan primitive, there probably will be several viable layouts. All variations of the primitives, including mirror images and rotations, should be examined.

It may be difficult to match space, honor constraints, and design an orderly arrangement. In general, designers should strive for clean, rectangular areas. Space requirements may have to be compromised.

The original space calculations are usually flexible within a reasonable range—10 to 20 percent.

One of the macro-space-plan options (Option 1) from the Cosmos project is illustrated in figure 3.37. This option is based on the operations strategy, which called for a product-focused space plan using cellular manufacturing techniques and focused factories.

The space between the two original buildings is now enclosed to accommodate the increased space requirements and also to allow

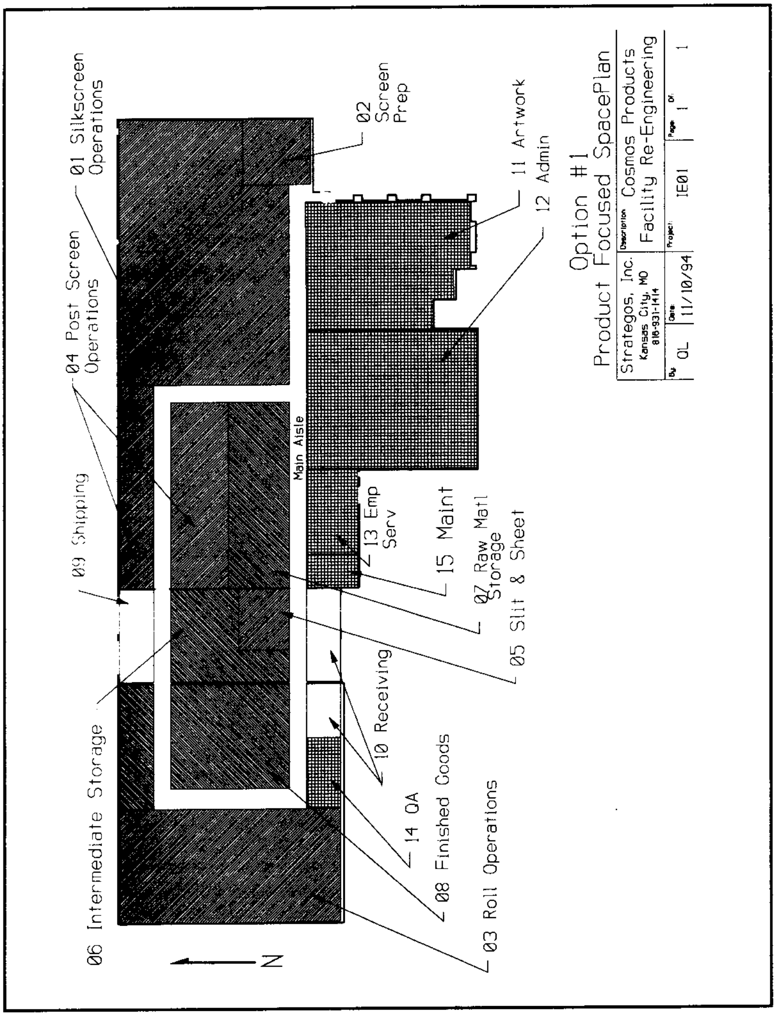


Figure 3.37 - Option I of the Macro-Spaceplans for the Cosmos Project

improved material flow between the buildings and to the shipping and receiving docks. Each of the old buildings has become a semi-focused factory, with roll products on the left and commercial products on the right. In the center are slit-and-sheet operations, which serve both focused factories. Service facilities such as quality assurance, employee services, and maintenance are also in a central location. Artwork, administration, and employee services face the street. This satisfies the aesthetic constraints.

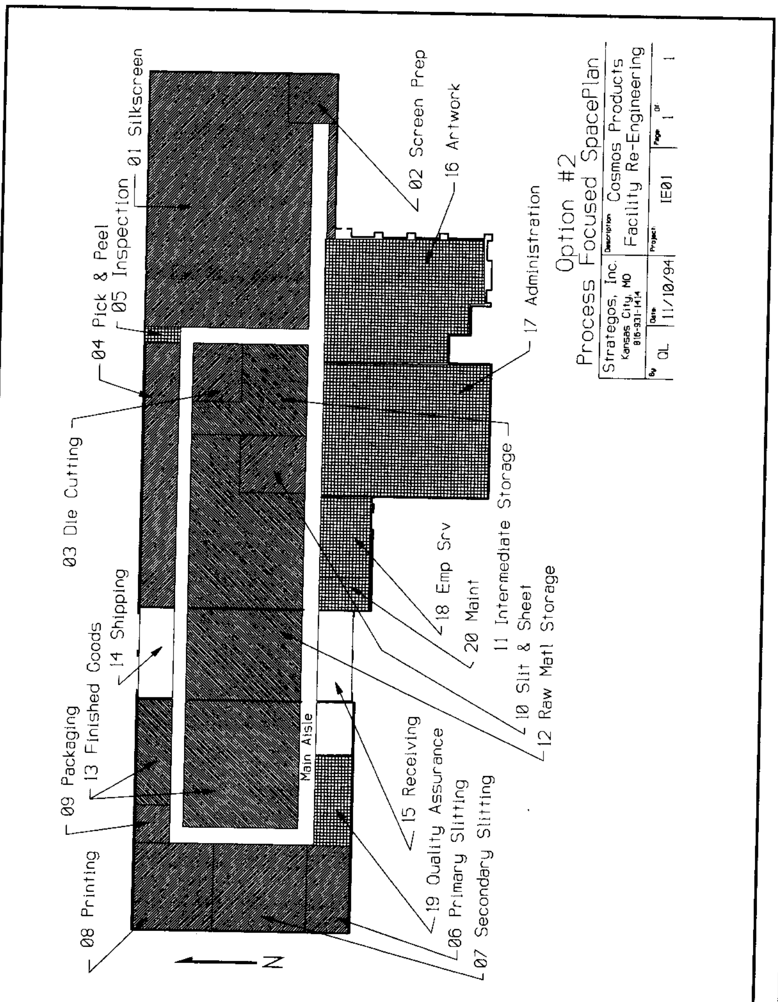


Figure 3.38 - Option 2 of the Macro-Spaceplans for the Cosmos Project

Some Cosmos managers had reservations about the product-focused strategy adopted in Task 03.10. Therefore, an additional macro-space-plan based on continuing the process-focused approach was prepared. The result was Option 2 (fig. 3.38), which mitigated their concerns and demonstrated the relative advantages and disadvantages of process and product focus. It was prepared as a second, parallel project starting from Task 03.10. The process-focused strategy statement produced a different set of SPUs, affinities, and space requirements.

Option 2 retains the aisle system and many of the good features of Option 1. Functional and semi-functional areas such as shipping, receiving, and artwork have many of the same characteristics. They are often in the same location. Some functional SPUs such as storage areas need significantly more space. Process areas change their names, characters, space requirements, and other characteristics. Option 2 needs about 10 percent more space than Option 1. This additional space is in a building expansion on the east side.

For most macro-space-planning projects, there will be three to six fundamentally different options and several variations. Using the existing layout—or simply doing nothing—is always an option. Even when the existing space plan is no longer viable, it makes a convenient baseline for gauging improvement. The Cosmos project team developed several other options, which are not included in this book.

Aisles

Aisles present special problems. They should be straight and wide enough for two-way traffic. Usually, the best approach identifies main aisles as a separate SPU. Designers then place them on the macro-space-plan. Departmental aisles, on the other hand, are within the space calculations for each SPU. Aisles adjacent to walls are often undesirable because they serve only one side.

An alternate approach includes all aisles as part of the SPUs. Designers then place SPUs on the plan, recognizing that those main aisles generally will follow the SPU boundaries.

The straightforward Cosmos space plans in figures 3.37 and 3.38 use the first method. Main aisles have a separate calculation and every SPU is adjacent to a main aisle. A central loop allows continuous traffic in both directions. A single dead-end aisle serves screen prep and part of the silk-screening operation. This aisle system will allow subsequent layout changes without disturbing the basic flow pattern.

Identifying key material handling issues

Material handling and layout are intertwined. The best handling system depends on the space plan and the best space plan may depend on handling methods. Often, a layout that does not work with manual handling becomes viable with automated or conveyorized handling.

This presents a chicken-or-the-egg problem. Are handling equipment and containers selected before the layout? Is the layout designed first and the handling system then selected? Usually, the best approach is to design the layout assuming conventional, perhaps manual handling. This optimizes material flow and often eliminates the need for complex and expensive handling systems.

However, particular handling issues that drastically affect space plan selection must be identified. For example, a pneumatic transport system has different requirements than a system that uses forktrucks for conveying bulk material. One space plan might be the best for fork truck handling, while another might be best for the pneumatic system.

A space plan should be designed and selected before the handling system is finalized. To do this, however, may mean assuming a general type of handling system prior to layout design.

To accomplish Task 03.20, examine each of the proposed layout options and ask the following questions:

- What types of handling systems are viable for each option?
- Would a particular handling system affect one layout option more than another?
- Would a different handling system allow new layout options?

If a particular handling system affects all layout options equally, selection of that system is not a key issue. In such a case, the evaluation of the options is the next step in the space plan. If a particular handling system would give one option a significant advantage over the others, such selection is a key issue. In such a case, further investigation is recommended, perhaps accompanied by a preliminary design and cost estimate for the handling system. This approach allows management to select the best layout at the macro-level without completely designing handling systems for all the options.

Deciding on the best space plan

Several viable options now exist for the macro-space-plan. Many others probably have already been screened out during earlier parts of the design process. The designer should narrow the choice to three to six significantly different options. Each option may have several minor variations. Management and others involved in the project then decide which to use. This is done for several reasons:

- management often criticizes the engineering staff for tunnel vision. Engineers may lock onto an idea early in a project. A wide variety of options shows that the designer or design team has considered a wide range of possibilities;

- asking for a selection from among options is usually more palatable than asking for approval of a preordained design;
- the process of decision-making builds consensus, support, and confidence. This prevents later attempts at redesign by those who felt left out of the process; and
- the decision process may generate hybrid plans, which are often superior to the original designs.

Figure 3.39 shows the procedure for evaluation. The space plan options are the "input" listed in Block 1. Block 2 assembles a decision team.

In Block 4, the team reviews the project's original objectives. These original objectives may be specific, directly measurable, and

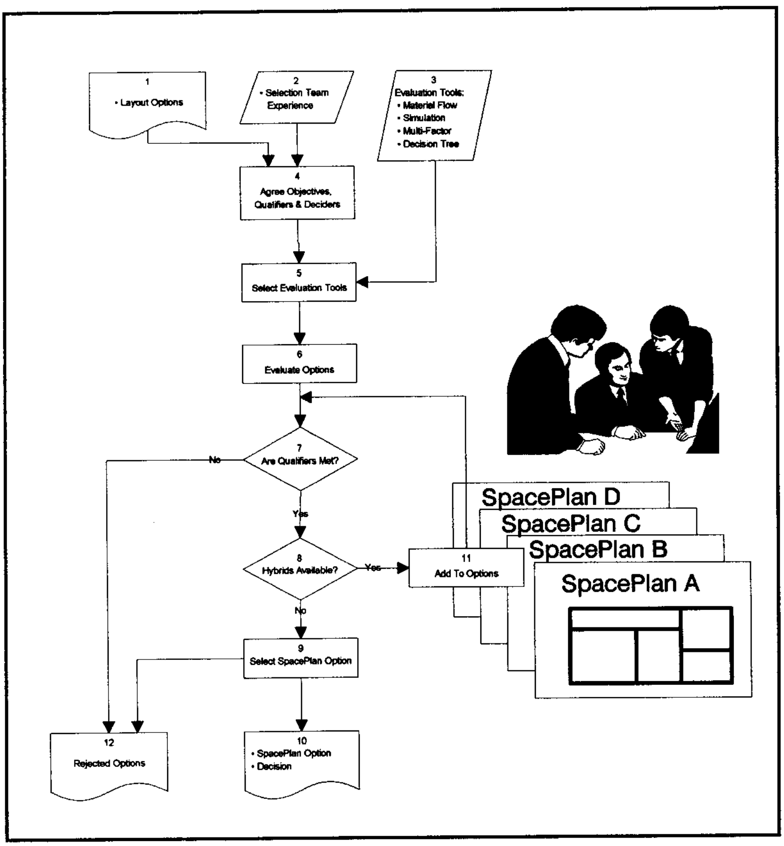


Figure 3.39 - Computing Space, Visual Estimation

applicable to the evaluation, or they may be global and difficult to measure. They may require sub-objectives for a good evaluation. The information developed during information gathering may have modified the objectives. The debates during the strategy development also may have changed objectives. The decision team adopts the original objectives or revises them as appropriate.

Flowing from the objectives are decision criteria. These are factors that the team can evaluate directly-either qualitatively or quantitatively. They are the basis for the decision. Examples of decision factors are: material handling savings, improved communication, OSHA compliance, improved teamwork, initial cost, operating cost, quality enhancement, improved delivery reliability, improved delivery speed, and ability to use a particular technology.

A decision criterion may be a decider or a qualifier. Qualifiers are go/no-go criteria: a space plan meets the minimum requirements or not. Performance beyond the minimum creates no additional benefits. Performance below the minimum disqualifies the space plan from consideration. For example, OSHA compliance might be a qualifier. Layouts that meet the requirements are acceptable. Layouts that go beyond OSHA requirements bring no perceived additional benefit.

Deciders bring additional benefits for each increment of performance. Improved cost, for example, is usually a decider. Option B may have an operating cost advantage over Option A. Although both space plans meet the budgeted cost improvement objectives, Option B is the preferred space plan on that dimension.

Block 3 contains the tools for evaluation. In addition to macro-space-planning, these tools apply to other levels of facility planning. Among the common tools for evaluation are: material flow analysis (MFA), financial analysis, ranking, instinct, positive-negative-interesting (PNI), decision tree analysis, and weighted factor analysis.

MFA examines the large-scale material movement between SPUs. It develops a measure of associated cost and difficulty. Improved communication and coordination are corollary benefits of improved material flow. Specific techniques in this category include transport work, flow diagrams, and D-F plots. For the most part, these are quantitative methods.

Financial analysis includes cost estimating, return on investment (ROI), and payback. These methods are quantitative; however, they often involve qualitative judgments as well.

A simple *ranking*, from most preferred to least preferred, is often an effective tool. The ranking can use qualitative factors, quantitative factors, or both.

The gut-level reaction or *instinct* of knowledgeable people has value. Although it should rarely be used as a primary evaluation tool, it may uncover unseen opportunities or problems.

PNI analysis is a variation of the brainstorming technique. It examines each space plan factor, focusing first on the positive features and then on negative features. Finally, it focuses on those that are neither positive or negative—things that are interesting or unique. This analysis, was developed by Edward DeBono, an expert on thinking processes. It is simple but effective. It often brings out hidden features and builds teamwork and consensus.

Decision tree analysis is useful when a series of probable events can affect the decision. For example, which space plan is best if a particular contract is won and, afterward, the overall market contracts? It helps evaluate the cumulative probability of each of the four possible outcomes. Combined with financial analysis, it is a quantitative tool.

Weighted factor analysis bases a decision on a combination of the various factors, both qualitative and quantitative. It is best if the factors are independent, but this is not always possible. Some compromising of this principle is acceptable. Judges first identify the factors, then decide a weight for each, and, lastly, rate each option.

In addition to the tangible and intangible categories, strategic issues may arise. These are usually qualitative. The consequences of strategic issues are often so far-reaching and so important they overshadow all other factors. For example, Option A might use a new technology. This technology shows no immediate cost benefit yet the introduction potentially could revolutionize the industry and place a firm far ahead of others. Should Option A be selected? This is a decision for top managers and cannot be made lightly.

In weighted factor analysis, the judges that weigh the factors may be different from those who rate the options. For example, top management may weigh the factors but leave ratings to specialists or operating people.

In physics, Heisenberg's uncertainty principle states that both the position and state of certain sub-atomic particles cannot be known. This is because the process of measurement distorts either the position or state. A parallel phenomenon occurs in space planning. The process of judging and evaluation often leads to other options. Thus, some or all of the space plans may change as a result of the evaluation process. Or, a hybrid space plan that features the best parts of several original options may emerge.

Block 5 of the procedure diagram examines the decision criteria and available tools. Two to four tools appropriate for the evaluation should be selected.

Block 6 evaluates all options with respect to the identified qualifiers. Any option that fails to meet a qualifying criterion drops from consideration.

Block 7 evaluates the options with respect to the decider criteria. New or hybrid options go on the list of available options.

After evaluation, one option is selected for development. A decision summary recapping the decision process should be prepared. The summary and decision make up Block 10.

Evaluating the Cosmos space plans

The Cosmos design team and steering committee met to evaluate the proposed space plans. They decided that both the steering committee and design team should participate in the evaluation. They first reviewed the original project objectives. These came from Task 03.01, "Plan Project":

- reduce material handling cost;
- reduce operating costs;
- deliver project under budget of $800,000;
- improve delivery performance;
- improve teamwork, communication, and quality;
- allow for new products; and
- accommodate 1998 production.

From the original objectives, they derived these decision criteria:

D	Material flow
D	Direct operating cost
Q/D	Initial cost
D	Delivery
D	Communication
D	Teamwork
D	Quality
D	New product adaptability
Q	Meets 1998 production requirement
Q	OSHA/EPA Compliance

A "Q" notation designates the qualifiers. OSHA/EPA compliance is necessary for any space plan. Those that fail to meet this qualification are no longer considered. Similarly, the 1998 production requirement is a qualifier. Initial cost is both a decider and qualifier. A space plan must meet the $800,000 budget limitation to be considered; this is the qualification. Initial cost below $800,000 is a benefit; this is the decider. All the other criteria are deciders, denoted by a "D."

The Cosmos team chose PNI, MFA, cost estimating, payback, and weighted factor analysis as the tools for evaluation.

They analyzed material flow first and then used the results to assist with the cost estimating. In Step 1 of the MFA, they developed the flow diagrams illustrated in figure 3.40.

These diagrams show where the flow complexity for the existing

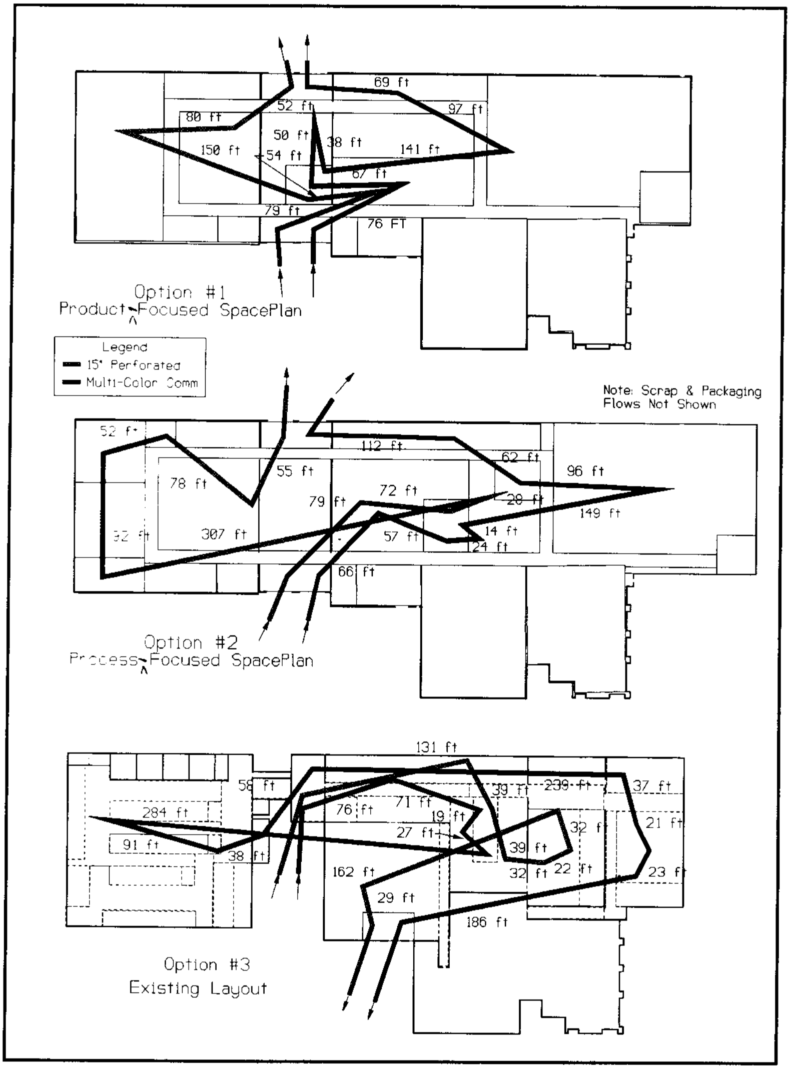


Figure 3.40 - Material Flow Evaluation

layout is greatest. Option 2, a revised functional layout, improves the flow complexity and shortens flow distance. Option 1 improves complexity and further shortens the total distance. The flow complexity index (FCI) counts the frequency of flow crossings on the diagram. Option 1 has an index of 0, Option 2 has an FCI of 4, and Option 3 has an FCI of 6. Visual examination of these material flow charts confirms the increasing material flow complexity from Option 1 through Option 3.

Transport work is the summation of each flow distance multiplied by the flow rate. The units for Cosmos are EFUs per day. Table 3.4 is the spreadsheet used by the team to calculate distance and transport

Option #1

(A) From -To	(B) From	(C) To	(D) Units	(E) Fwd Units /Day	(F) Rev Units /Day	(G) EFU Fact	(H) Tot EFUs /Day	(I) Dist Ft	(J) Trans Work
01-04	Silkscrn	Post	Scrn	SHTS	69.0	0.17	12	97	1118
01-05	Silkscrn	Slit	SHTS	69.0	0.17	12	141	1625	
03-05	Roll	Ops	Slit	SLITS	46.0	0.11	5	150	759
03-08	Roll	Ops	FG Stge	PKGS	2134.0	0.01	19	80	1536
03-10	Ops	Receiving	PMAT	7.3	0.25	2	156	285	
04-09	Post	Scrn Shipping	SHTS	69.0	0.25	17	69	1190	
05-06	Slit	Int Stge	SLITS	46.0	46.0	0.11	10	43	435
05-07	Slit	RM Stge	LOGS	23.4	0.50	12	67	784	
05-09	Slit	Shipping	LOGS	0.2	0.50	0	93	9	
07-10	RM	Stge	Receiving	LOGS	23.4	0.50	12	78	907
08-09	FG	Stge	Shipping	PKGS	2134.0	0.01	19	52	999
							119	**1026**	**9647**

TABLE 3.4

work for Option 1. The other options have similar spreadsheets. The three options have transport work of 9,647, 18,669, and 28,131 EFU-feet per day respectively.

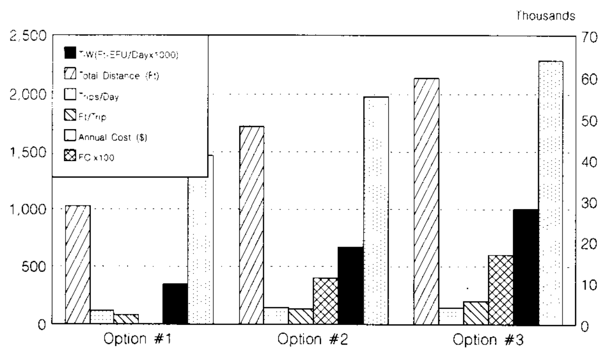
Another measure of material flow is the frequency count for material moves. Option 1 has 11 internal moves, Option 2 has 14, and Option 3 has 21. The total distance traveled for the two representative products is another measure. Options 1 through 3 have distances of 1,026, 1,723, and 2,135 feet, respectively. The average number of trips per day is 119, 132, and 198.

This analysis assumes that all trips use the EFU, an equivalent handcart, as the means. When implemented, the layout actually will use several methods of handling. However, for estimating, the EFU assumption is a reasonable approximation.

Figure 3.41 is a graphic display of the MFA results. Based on every material flow measure, Option 1 is significantly better than Option 2. Option 2 is significantly better than Option 3.

Financial analysis

Table 3.5 summarizes the financial results for the three options. Option 3—the existing layout—maintains the status quo. For this reason, there is no change in either savings or costs. Option 3 thus provides the baseline for the financial analysis.



	Option #1	Option #2	Option #3
T-W(Ft-EFU/Dayx1000)	9,647	18,669	28,131
Total Distance (Ft)	1,026	1,723	2,135
Trips/Day	119	142	142
Ft/Trip	81	132	198
Annual Cost ($)	41,071	55,399	63,957
FCIx100	0	400	600

Figure 3.41 - Material Handling Summary

The center building is the new construction between the two existing buildings. The team estimated the cost at $35 per square foot. The east extension for Option 2 will cost about $30 per square foot because it does not have loading docks.

Option 2 will need new equipment, valued at about $23,000, which will cost $21,000 for installation. Option 3 requires more equipment because of its cellular nature. Rearrangement costs are $45,000 and $28,000, respectively, for Options 1 and 2.

The cellular approach of Option 1 will require significant training and additional consulting fees when compared to Option 2. The team also anticipated a more difficult start-up.

A contingency of 15 percent that allows for unplanned costs is applied to the implementation of both new options. Either Option 1 or

Initial Cash Outflows Description	**Option 1 Amount**	**Option 2 Amount**	**Option 3 Amount**
Center Building	$161,000	$161,000	$0
East Extension	$0	$307,800	$0
Equipment	$176,000	$23,000	$0
Installation	$49,500	$7,800	$0
Rearrangement	$45,000	$28,000	$0
Training	$32,000	$0	$0
Consulting	$43,500	$20,000	$0
Startup	$100,000	$45,000	$0
Contingencies	$91,050	$88,890	$0
Total	$698,050	$681,490	$0

Annual Inflows Description	**Option 1 Amount**	**Option 2 Amount**	**Option 3 Amount**
Increased Sales	$750,000	$750,000	$0
Material Handling	$22,885	$8,558	$0
Direct Labor	$132,000	$10,000	$0
Other Indirect	$75,000	$37,500	$0
Working Capital	$140,000	$0	$0
Quality	$230,000	$20,000	$0
Total	$1,349,885	$826,058	$0
Initial Inflow Inventory	$1,750,000	$0	$0
Years-To-Payout	0.23	0.82	n/a

TABLE 3.5

Option 2 will bring increased sales and production. The net profit for this is estimated at $750,000.

Material handling savings come from the decrease in handling and transport work. Using the data from the material flow analysis, the team estimated cost savings of $22,885 per year for Option 1 and $8,558 dollars per year for Option 2. This assumes four minutes of loading and unloading for each trip. It assumes an average transport speed of 150 feet per minute and an $18.50 hourly labor cost. It also assumes that each move has an empty return trip.

Calculations for direct labor, quality, and other indirect labor savings are less rigorous, but the team developed conservative estimates from their experiences.

Option 1 has a significant inventory reduction of $1.75 million. This is a one-time savings and lessens the working capital required. The interest on this, at 8 percent, amounts to $140,000 per year.

The payout for Option 1 is 0.23 years. The payout for option 2 is 0.82 years. Both payouts are quick. There is no payout for Option 3 because there is no initial investment.

An ROI analysis would be more rigorous than the payout method. However, the fast paybacks for Options 1 and 2 indicate that the increased complexity and effort required for an ROI analysis is unnecessary.

The team reviewed the decision criteria to see if the options met all qualifiers. All three options met the regulatory qualifiers. All three options met the budgetary qualifier. Only Options 1 and 2 will satisfy 1998 production requirements. This signifies that doing nothing, Option 3, is not a viable course of action. Option 3, however, has been useful as a baseline for improvement estimates.

Positive-negative-interesting

Having completed the quantitative analyses, the evaluation group then turned to PNI analysis. Meeting with a facilitator, they focused on each option and each aspect in turn. They used brainstorming techniques to develop the positive, negative, and interesting points for each option. The results are in table 3.6.

Weighted factor analysis

With the quantitative and qualitative analysis complete, the team turned to weighted factor analysis, where analysis and opinion are merged into a single decision.

Figure 3.42 summarizes the weighted factor results. The team first reviewed each factor and confirmed the definition. Through discussion, the members reached a consensus on the weights. Each factor had a weight between one and ten.

Operating cost, quality, and delivery received high weights (ten and nine). These factors have the most direct effect in the marketplace. The group believed they had the highest strategic importance.

Material flow, communication, and teamwork received weights in the seven to eight range. These factors are somewhat related. Good material

PNI Analysis Summary

Option 1 Positive	Option 2 Negative	Option 3 Interesting
Best Material Handling Simplification Neat & Clean Geometry Less Inventory Better Teamwork Fits W/TQM Faster Throughput Faster Response Less Space Less Cost Faster Payout Best Annual Cost Easier Supervision Employee Involvement Nice Aisle System Uses Current Software w/Kanban Production Control	High Training Required It Might Not Work Difficult Adjustment Higher Risk	

Option 1 Positive	Option 2 Negative	Option 3 Interesting
Reduced Material Handling Nice Aisle System Neat & Clean Geometry Easy Personal Adjustment Lots of Space	Low Risk High Cost Allows Cellular Procrastination No Throughput Improvement More Space Required Lower Payout Higher Annual Cost Less Employee Involvement Does Not Assit TQM Less Teamwork	Allows Cellular Transition Later

TABLE 3.6

flow improves communication and simplifies operations. It also reduces interdepartmental problems. Better flow and better communication enhance teamwork. Material flow also ties to operating cost.

The team then examined material flow and compared the three options. With quantitative data from the MFA, they quickly achieved consensus on the ratings. Option 1 received an A for material flow,

Weighted Factor Analysis

Project: FACILITY RE-ENGINEERING			Prj #: IE01
Company: COSMOS PRODUCTS	By: QL		Date: 12/12/94
Note: COMBINED SCORES			

ID	Factor	Wght	Option #1		Option #2		Option #3		Option #4		Option #5		Notes
			Rate	Score	Rate	Score	Rate	Score	Rate	Score	Rate	Score	
F1	MATERIAL FLOW	8	A	32	I	24	U	0					
F2	COMMUNICATION	7	I	14	O	7	U	0					
F3	TEAMWORK	7	A	28	U	0	U	0					
F3	NEW PRODUCTS	2	O	2	E	6	E	6					
F4	INITIAL COST	3	I	12	E	9	A	12					
F5	DIRECT OPER COST	10	E	30	I	20	U	0					
F6	QUALITY	9	A	36	I	18	U	0					
F7	DELIVERY	10	A	40	O	10	U	0					
		Totals	194		94		18						

#	Option Description
1	CELLULAR
2	FUNCTIONAL
3	EXISTING
4	
5	

Notes:
JUDGES:
O. W. HOLMES F. TAYLOR
J. MARSHALL H. FORD
W. BURGER
E. WARREN

Figure 3.42 - Weighted Factor Analysis

Option 2 received an I, and Option 3, the baseline, received a U. The team repeated this process for the other factors.

Delivery had some quantitative basis. The number and length of moves from the MFA indicated that delivery would improve under Option 3, whereas delivery perhaps would see slight improvement under Option 2.

Quality, new products, teamwork, and communication had no quantitative analysis. Nevertheless, discussion and a review of the PNI analysis brought a consensus among the team members.

They then multiplied each factor weight by each rating and totaled the score for each option. Option 1 received 194 points, Option 2 received 94 points, and Option 3 received 18 points. From those scores, the group concluded that Option 1 was best by a large margin.

The team could have begun the weighted factor analysis by weighing each factor individually and rating each option. They could then average and compare their results as a basis for discussion. This is a useful technique when it appears that individuals have widely differing views. Several computer programs are available for this type of multifactor decision making, but the most important results derive from the discussions. In most situations, a manual compilation like that in figure 3.42 is sufficient.

Conclusion

This completes the discussion of macro-space-planning. Many of the methods apply to other levels of space plan design. Material flow analysis, for example, is an important tool for Level 2, "Site Planning." Weighted factor analysis applies at all levels.

For most facility planning, the macro-space-plan is the most important planning level. It is where strategy is defined and the first steps toward implementation are taken. It is the level that usually has the greatest impact on a firm's competitive position. For these reasons it has been the subject of the most substantial discussion in this book.