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FORMAL TECHNIQUES FOR ORGANIZATION ANALYSIS: TASK AND RESOURCE MANAGEMENT

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This report presents a method of modelling human organizations by means of a relational model. The model is described and several hypothetical examples show how the model can be used to design an organization specifically to carry out an explicit mission. Features of the model are also used to guide the assignment of personnel to specific jobs, basing the job assignments on a match of skills required by the procedures that will be performed by the job (role) incumbents and the skills possessed by job (role) candidates. Other features of the model are used to simulate (in a very elementary sense) the behavior of the designed

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organization under expected external stimuli. All the examples are explained in detail by use of graphic displays of the consequences of each step of the development.

Specific applications in the military context for the modelling techniques are discussed. The research program, its long-range goals and completed work, with references, are presented.

The report concludes with a set of recommendations for development of a computer software system to bring the benefits of the modelling methodology to a wide audience within the Department of Defense, and for application of the technique to some pressing organizational problems, in order to (1) refine the methodology, and to (2) gain insight into the mechanisms of organizational pathology.

The relational modelling technique presented herein has applications in designing new organizational structures to meet the requirements of unprecedented mission assignments; in diagnosing the sources of ills or troubled organizations; in training military managers; and in developing computer-based management information systems which themselves are founded upon an analog of the very organizations they are intended to help control.

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Formal Techniques for Organization Analysis:

Task and Resource Management

FINAL REPORT

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Foreword

This study was conducted for the U. S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, Virginia, under Contract #MDA903-81-C-0402, dated 1 July 1981. Contracting Officer's Technical Representative was T. Owen Jacobs, Ph.D., Leadership and Management Technical Area, ARI. The research was done at the School of Architecture, University of Illinois, Urbana-Champaign.

It is the fourth in a series of studies addressing the development of a comprehensive organization modeling tool, to be used in organization design and analysis. Interested readers may obtain more information about the research program and its publications by contacting the authors at the School of Architecture, UIUC, telephone (217) 333-1330.

1. Summary

This report presents a method of modelling human organizations by means of a relational model. The model is described and several hypothetical examples show how the model can be used to design an organization specifically to carry out an explicit mission. Features of the model are also used to guide the assignment of personnel to specific jobs, basing the job assignments on a match of skills required by the procedures that will be performed by the job (role) incumbents and the skills possessed by job (role) candidates. Other features of the model are used to simulate (in a very elementary sense) the behavior of the designed organization under expected external stimuli. All the examples are explained in detail by use of graphic displays of the consequences of each step of the development.

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computer-based management information systems which themselves are founded upon an analog of the very organizations they are intended to help control.

2. Introduction

2.1. Background

A ubiquitous human activity is the design of organizations to accommodate to organizational purpose; the legal, economic, social, and political environments; and human and other resources. There is no body of formal procedures for the design of human organizations and the task therefore is done subjectively, drawing heavily on experience. Organizational structures of the past suggest those of the future. The typical approach has been to base new entities on stereotypical structures and make changes as problems are recognized. Clearly, this is not an optimal approach to bringing a viable organization into being. A design methodology supported by formal procedures and generalized models holds the potential for saving significant amounts of time and money. The development of such an objective design methodology is the focus of the research program described here.

Research to date on organization design has followed, for the most part, a descriptive path, that is, the reporting on structural patterns that have proved successful in various contexts. Little has emerged thus far in the way of prescriptive techniques. On the other hand, an impressive literature has evolved which deals with design of highly complex computer and communications systems. Important analogies exist between control systems for industrial robots, artificial intelligence systems, multi-user interactive computer operating systems, translators for programming languages and the like on one hand, and complex human organizations on the other. This wealth of systems knowledge has not been systematically exploited for that most complex of human enterprises, the design of purposive human organizations.

The successful application of developments from other fields, however, requires first that a basic framework for the formal description of organizational structures be articulated and shown to be sufficiently comprehensive to incorporate the important structures found in existing viable organizations. The second step is to devise operational techniques which can exercise the structural model in time. These two primary constructs, the structural model and its operational techniques, constitute the foundation of a comprehensive, integrated design and analysis system. The present research program has been aimed at producing such a basic working model, as a first major step toward a sophisticated yet practical design system for complex human organizations. A second goal has been to gain insight into the real workings of modern organizations sufficient to guide the development of diagnostic tools for treating ailing organizations.

The long-range objective is to produce a formal system for design which allows people to describe the organization they have or want to have, and test its probable performance by simulating its behavior in terms of the purposes to be achieved. The goals along the way to the long-range objective are described in the next section.

2.2. Long Range Goals

1. A general purpose simulation model for human organizations which will allow the formal description of the essential elements of the organization, e.g., resources; tasks; relationships; information flows; task sequencing and scheduling; resource assignment and status; factors influencing the character of tasks and the performance of resources; procedures for task accomplishment; future plans; record of past performance of resources and sets of resources, i.e., an institutional memory; and versions of the conceptual organization as possessed by the various human resources; and provide the means to change and track all

these parameters as they interact with each other and respond to external stimuli in time.

2. A formal language that will allow one to

   a. describe explicitly a hypothetical organization to carry out a set of interrelated tasks representing an assigned mission; and

   b. describe an existing organization in order to examine its present functioning and to predict its functioning under internal and external change.

3. Data gathering techniques to allow one to efficiently collect reliable modeling parameters from organization participants or the organization designer, if in a synthesis mode.

4. A multi-level simulation methodology from pencil-and-paper through computer processing, to make it practicable to answer "what if" questions about the organizational response to internal and external stimuli such as change in mission, loss of resources, cutback in strength, and the like. The highest level of processing would be through an interactive computer processor.

5. An integrated and flexible organization design methodology to guide one in using effectively the collected data, the formal language, and the processor to develop an organization design with a high probability of success, and to respond rapidly with structural and operational modifications when confronted with material changes in internal and external conditions.

2.3. Military Applications

The long range goals of this research are to produce practical management tools which are applicable in the entire spectrum of human organization, from infantry squad to DA level. Based largely on information flows and cybernetics, the technology can improve the vertical integration of policies and their implementation by emphasizing task decomposition and specialization from broad statements of intent to the concrete steps ultimately required to accomplish the purpose. It can improve the horizontal integration of system requirements (e.g., manpower planning, training, operational requirements, new weapons system acquisition) through the provision of a structural framework for coordinating information flows within agencies and between agencies. Following are some typical uses of the technology, in the context of military organizations. They are suggestive, and not exhaustive.

1. Policy Level
   a. Models to show Army personnel system functioning with respect to new weapons system acquisition.
   b. Models to show relationships of materiel systems to relevant force structures, doctrine, and training.
2. Operational Planning
   a. Integrated men/materiel models simulating force effectiveness, including the impact of human issues such as morale, leadership, unit cohesiveness, turbulence, and fatigue. Current combat models do not consider these factors, but many military leaders believe they have a large impact on combat effectiveness. Current models concentrate on sub-elemental features, e.g., fire power and other hardware

considerations, of a system and use these as substitutes for the system-as-a-whole for estimating total system effectiveness.

b. Comprehensive models to determine and/or predict force composition and structure, including such variables as personnel characteristics, vital statistics, force number limits, etc. Current force structure models are mostly either small, limited purpose models, not designed to interact with others, or they are broader in scope than would be usable by small, operational units.

3. Weapon System Planning, Procurement and Deployment

   a. Models to integrate operational planning with weapon system planning, procurement and deployment, showing the functional requirements of the process and the associated assigned responsibilities, mapped onto a time dimension.

   b. Models to show how soldier and weapon can be joined to make an effective combat system.

   c. Models to promote the understanding of how the human dimension contributes to the effectiveness of the total system, and to allow the quantification of that contribution.

4. Manpower Planning, Recruitment, Training and Retention

   a. Models to integrate weapon system planning and Army doctrine with long range personnel policies and manpower operation, including recruitment and training to provide personnel with the personal qualities and skills required to effectively man the weapons systems.

b. Models to forecast the manpower requirements under various scenarios of combat, explicitly taking into consideration the cumulative effects on force effectiveness of such human issues factors as fa 'gue, morale, turbulence, level of training, unit cohesiveness, attrition, confidence in leadership and weapon systems, and the like.

5. Command, Communications and Control

a. Models that integrate the structure and organization of operational units with their human and technological resources to simulate force performance under a variety of combat scenarios.

b. Models that form the framework for communications and decision-making systems for the battlefield, capable of simulating probable outcomes of real-time decisions taking into consideration actual force attrition and changes on the battlefield.

c. Models that examine the micro-structure of military units, simulating reaction by commanders to external stimuli, such as:

(1) Reduction in force

A commander, confronted with an impending reduction in force with no change in assigned mission, is required to alter his organization structure and task-processing functions to adapt to a reduction in resource availability. The methodology may be used to pose hypothetical organizational changes, note effects on productivity, revise the modifications, and repeat the process until the results are satisfactory or until it is clear that mission effectiveness or efficiency will be unacceptably degraded if the proposed reduction in force is implemented.

(2) Change in mission

The model will simulate the results of various alterations to an existing organization to determine the optimum reorganization. Alternatively, the model organization may be restructured to simulate response to changes in task sets and connectivities to accommodate the new mission.

(3) Change in resource responsiveness

Tasks may be redesigned to respond to changes in human resource motivation, skill level, fatigue, etc.

(4) Decrease in budget, mission unchanged

The system can be used to assess the effects of lowered financial resources on influencing factors or task elimination/modification (e.g., training exercises) on force readiness, effectiveness, and efficiency.

d. Models that examine effects on force readiness or performance due to various kinds of internal stimuli changes. A commander may use the methodology to study:

(1) effects on productivity and force readiness of variations in leave policy, retention policy, training,

(2) hypothetical response to variations in internal perception of external threats,

(3) degradation of response with internal psychological and/or physical attrition, i.e., organizational vulnerability/ survivability studies.

2.4. The Research Program

The Research Program is directed at completing the conceptual design of the structural model and mechanisms to make it operational, and developing a methodology for designing and simulating future organizations. The Program, which is now in its second phase, is logically arranged into four phases.

1. Phase I consisted of developing the basic structural model and verifying the validity of its major features, specifically the nature of the relationships between resources and tasks and pairs of tasks, by on-site observation of an existing organization. Patterns representing authority structure, ordering of basic tasks toward goals, and association of resources to tasks have been documented. A second objective of Phase I was to identify and document information flows for task accomplishment and for resource control.

2. Phase II has provided for sequencing of tasks and assigning of resources to tasks, detecting task failures and modifying plans, and integrating individual job plans into a continually evolving long range operational plan for the entire organization.

3. Phase III will identify the influencing factors for resources and tasks and integrate them into the evolving model. It is this phase which promises to transform the basically mechanistic model into a sophisticated management tool which considers such factors as morale, health, fatigue, boredom, skill level and motivation and their impact on the effectiveness of the organization.

4. Phase IV extends the structural model to a single dynamic model, able to simulate parametric changes over time while maintaining structural integrity. At this point, the model becomes a true simulator.

2.5. Current Status

The basic building block for a generalized structural model and an associated organization-building scheme were articulated and documented in a symposium paper in 1978.[3] This elementary model is general enough to accommodate much of existing organization theory, yet is rich enough to support the structural definitions of complex organizations.

With funding from the U. S. Air Force Office of Scientific Research (AFOSR), an expanded model was developed and used to describe certain aspects of an existing organization. This work focussed on resource-resource relational patterns representing authority, groupings of resources, and interpersonal relationships; task-task relational patterns representing precedence, independence, information flow, and task decomposition; and resource-task patterns representing responsibility for task accomplishment. These results were published in 1981.[4]

With funding from the U. S. Army Research Institute for the Behavioral and Social Sciences (ARI), work was undertaken to compare the structural model with the model implicit in socio-technical theory. This was published in 1982.[5] Also with funding from ARI, a pilot study of use of the model for diagnostics of existing organizations was performed. This report was also published in 1982.[6]

2.6. Relationship to Work by Others

No work directly related to the research has been identified. Ansoff and Brandenburg[1] in their description of a language for organization design have defined a basic vocabulary and the general structure of a variety of purposeful informally designed organizations, but have not prescribed a procedure for synthesizing organizational structure by formal means.

Galbraith[7] has summarized the state-of-the-art in organization synthesis, but stops short of formal design methods. Dinnat and Murphree[3] have described the basic elements of a formal organization model based on information flow theory, and have shown how such a model can serve as the basis for certain kinds of organization evaluation. Additional work by Dinnat and Murphree, et al., has verified the basic model and extended it.[4,5,6]

3. Objective of this Study

The research described in this report was aimed at developing methods for using the model to depict the following major activities performed by the management of any formal organization, military or non-military:

1. selection and organization of tasks as components of complete jobs,
2. selection and organization of resources to accomplish assigned tasks,
3. planning at the organizational level, and
4. detection of failure to complete a task.

4. Approach

4.1. The Relational Model

All operating organizations consist of a collection of resources performing an ordered set of tasks using selected procedures. Associated with each task and procedure are informational (or product) inputs and outputs, resources applied to the task, and internal and external factors influencing the performances of the resources (e.g., humans, weapon systems, communications equipment) and the nature of the tasks. All are in some way time-dependent. The tasks are, in general, interdependent because the output of one is the input of another. Figure 4.1 shows diagrammatically the basic building block of the structural model.

The structural integration of the basic building blocks into an organization model can be graphically portrayed by means of a matrix wherein the diagonal elements represent resources and tasks, as in Figure 4.2.

The off-diagonal elements represent relationships, and in the general case, constitute vectors. Element A in the Resource-Resource (R-R) submatrix represents a directional relationship from resource 1 to resource 4, for example, "has authority over"; element B represents a directional relationship from R4 to R2, for example, "serves on a committee chaired by." Element D in the Resource-Task (R-T) submatrix represents a directional relationship from resource 2 to task 5, for example, "performs." Element C represents a directional relationship from task 3 to task 6, say, "produces input for." Each element is a vector; hence, large numbers of complex relationships can be accounted for and they can be tracked as they change with time. Adding an additional vector to each resource and task element allows factors affecting performance of resource and character of task to be accounted for, again as they change in time. This latter

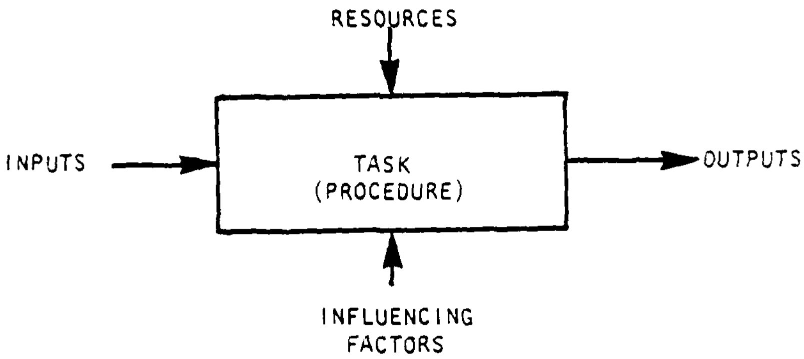

Figure 4.1. Basic Building Block

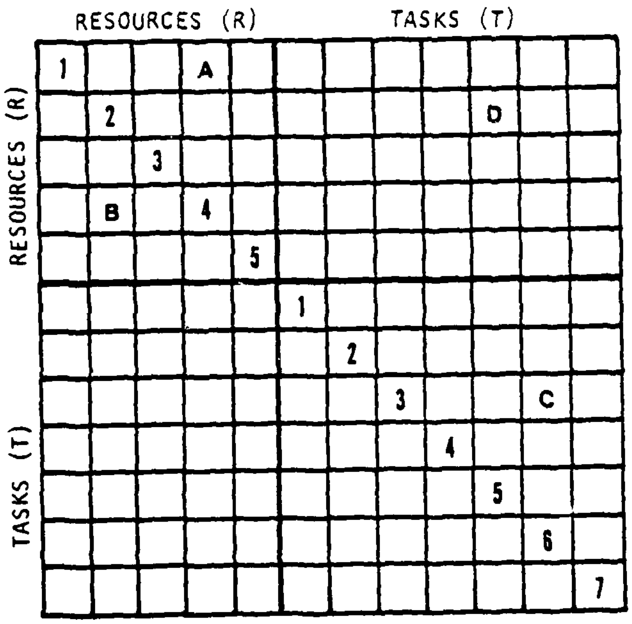

Figure 4.2. Structural Matrix

facility holds the key to investigating the effects of individual human factors, such as fatigue, morale, skill level, motivation and the like on the performance of the organization as a whole.

4.2. Model Components

4.2.1. Goals

Goals are the end products of the organization's efforts. They are the tangible artifacts or the intangible services provided to the customer. They are not the work that must be performed to produce the product or service, nor do they relate directly to the means of producing them, the processes and resources required. They are the bridges and landing fields, not the men and machinery nor the knowledge and skills used to produce them. Goals are stated as nouns, never verbs.

Conceptual goals are those which are stated at an abstract level: a report, a building design, a new weapons system, a new product developed. They are the kinds of things an entire organization would set as a goal, but not something an individual might set out to accomplish. Conceptual goals imply many steps, or subgoals (each perhaps a conceptual goal itself), in its accomplishment, down to the lowest level in a hierarchy of goals, to a set of goals which are reachable by, say, a single worker.

Simple goals lie at the bottom of the hierarchy of goals, and are the real stepping stones to the accomplishment of the conceptual goals. The successful completion of all the simple goals in a conceptual goal implies the successful completion of the conceptual goal of which the simple goals are the components.

The tree of goals, the lowest branches of which are the simple goals, form the basis of the organization's directed, or purposeful, behavior. The accomplishment of explicit goals requires that tasks be done, each in the pursuit of a single goal, at the simple goal level or conceptual level. The next Section discusses the place of task in the model.

4.2.2. Tasks

Conceptual tasks constitute work sequences which typically require collections of resources, more than a single worker can perform personally, for example. A specific conceptual task is associated with a corresponding conceptual goal, and constitutes the work to be done to reach the goal. The actual procedure to perform the task is a separate issue. For example, let a conceptual goal be "a geographical area clear of mine fields"; the corresponding conceptual task might be "clear the area of mine fields". The relationship of goals to tasks may be best understood in terms of the inputs and outputs of goals. In the present example, the input to the task "clear the area of mine fields" is "an uncleared area", while the output (if the task is successfully performed!) is "a cleared area." The associated goal is, then, equivalent to the output of the task. The actual means to clear the area of mine fields, the procedures and the resources required by the chosen procedures, are matters independent of either the goal or the task. The concept of procedure and its impact on organization are discussed in a later Section.

Simple tasks are those tasks which can actually be carried out by a single resource, say, a single worker. A simple task corresponds to a single goal. In the example in the paragraph above, clearing an area of mines is not normally a job for one person, but even if only one person is available, then there is a multitude of separate operations (tasks) that he must perform, so during a single clearing operation, he will perform the jobs of several different people. The entire clearing task is, then, a conceptual task, while any one of several different operations would constitute a simple task.

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Task structures parallel those of goals in that for every goal there is a corresponding task. The general structure is, then, a tree of conceptual tasks, each branch terminating in a simple task. Since task is rooted in action, and action in time, there is another, time-related, dimension to task structure. Time is experienced as one-dimensional. The performance of an uninterrupted task has a beginning point in global, universally experienced time, proceeds through time, and has a termination point in time. It has, in other words, a duration, a "length" of time for its accomplishment. For a task which requires no input from another task nor resources sought by other tasks, this duration can occur at any interval of the proper "length" on the time continuum. If, on the other hand, a task, B, requires input which is the output from another task, A, or shares resources with task A, then a precedence relationship between A and B exists. That is, A and B cannot occur, even in part, during the same time interval: task A must precede, in its entirety, task B. The concept of flows from task A to task B is a useful one, which accommodates to the notion of information or products moving from one process to the next. In the general case, in a single set of related tasks, there will be subsets in precedence relationships and subsets which are not, the resulting structure being a partially ordered set. In a practical sense, this means that more than one task can be going on at any given time interval, provided that those simultaneously occurring tasks cannot be in precedence relationships with each other. A considerable amount of useful work has been done on the properties of these sets, in Graph Theory, and practical applications include network modelling and some aspects of simulation. The well-known CPM (Critical Path Method) and

PERT (Program Evaluation and Review Technique) methodologies are based on the mathematics of partially-ordered sets. There is a wealth of theoretical and practical information on this subject in the literature of mathematics, operations research, and management science.[2,8,9,10]

4.2.3. Resources

Conceptual resources are those resources of all kinds — men, equipment, funding, space, skill, knowledge, time are typical examples — which are required to perform the associated conceptual tasks. Simple resources are associated with simple tasks, and represent resources which are single units, such as a single worker or a single room, resources which are normally indivisible.

Procedures are the methods by which the tasks are done; and to the extent that knowledge and skill, as well as more obvious examples of resources, are required on the part of the organization, procedures are themselves resources belonging to the organization. Successful competition in the electronics industry is, for instance, rooted not only in design knowledge, but also in knowledge and skills in manufacturing, possessions guarded more jealously than are plant and machinery.

Skills are the knowledge and abilities that resources must possess in order to perform the procedures. If the procedure is to "build a platform from dimension lumber," then a required resource, in addition to the materials for the platform, will be a package of skills including "reading plans and specifications," "measuring lumber," "sawing," and "nailing," among others. These skills commonly are used together, and along with other similar skills have come to be associated with the role of "carpenter." It is convenient to use this concept of role in the model as a packaging of skills which are closely related as a group to a particular procedure or group of procedures.

The basic objects of the model have now been covered. In the next Section, we turn to the relationships between pairs of the basic objects, and consider the ways in which objects and diadic relationships are combined to model human organization.

4.2.4. Relationships

4.2.4.1. Goals and Tasks

Goals are accomplished by tasks, and are, in effect, the outputs of tasks. But we have seen that tasks are more often than not linked together in strings of tasks, so the goal that is the output of one task becomes the input to its successor. The goal states what is required, while the associated task states what must be done to produce it.

4.2.4.2. Tasks and Tasks

There are two relationship categories for task pairs. The first is the hierarchical tree-structured breakdown of high-level conceptual tasks into subtasks at many levels, ending finally in the simple tasks, which allow no further subdivision. The second is the precedence relationships between pairs of tasks on the same level, which serve to link tasks together in pursuit of associated goals and subgoals.

4.2.4.3. Tasks and Procedures

The accomplishment of a task requires that an appropriate procedure be implemented. In any given situation, there may be a multitude of available procedures any one of which is capable of performing the task. For example, if the task is to "excavate for a building foundation," procedures such as "excavate with a back-hoe," "excavate with a clam-shell," or even "excavate with laborers using hand tools," are all feasible means of performing the task. The choice is influenced by such considerations as procedure duration (task duration), location within the site (it may be quite constrained), and cost, but most importantly, the availability of the required resources. Perhaps neither a back-hoe nor a clam-shell is available, or perhaps the economics or politics of the situation dictate that local human labor be used if at all possible.

4.2.4.4. Procedures and Resources

Associated with every procedure possessed by the organization is a reference to every resource required by it. By implication, if the procedure is possessed by the organization, then every resource required by the procedure is also possessed by the organization. Some resources can be requisitioned in a word, such as office, typewriter, computer terminal, truck, and so on, while others require more detail. The following Sections describe the packaging of certain human resources in abstract, but useful, ways.

4.2.4.5. Resources and Roles

Humans are complex resources, and it is usually insufficient for a certain procedure to require as a resource a "human"; more information about exactly what "kind" of human is required, what particular attributes this human must have. In the present context, these attributes are termed skills, and neat packages, i.e., sets of skills which are useful in conjunction with each other, are termed roles. A single human may perform in many roles on the job and off, and unless a procedure can be shown to require only standard, well established, sets of skills that are already associated with established roles, then the organization designer is well advised to define procedures directly in terms of specific skills required, and perform the packaging of skills into roles as a second step. The relationship of skills and roles is covered in the next Section.

4.2.4.6. Skills and Roles

Associated with each role are one or more skills, which serve to explicitly define the role in terms of the actions the role incumbent must be able to perform. Roles are, then, sets of skills, and are in a sense conceptual skills, following the pattern already set for goals, tasks, and resources. It does not follow, however, that every skill is associated with a collection of other skills or a role. It is permissible, if in a given situation it is useful, for a role to be defined by a single skill. For an arbitrary procedure, it may be that some of its required skills can be packaged into roles, while others are not. Some procedures will require more than one human resource, even though the skills required may be possessed by all of them. The organization of required skills into roles is a difficult one for the organization designer, and will tax the creativity of the conscientious practitioner. Role creation is equivalent to job design, and is properly done with one eye on the goal-task-procedure chain and the other on the human worker. It is here that the philosophy of organization is crucial, and much work remains to be done to understand the impact of role on the ultimate success of the organization. This is the interface of human and work, and we can go from one end of the job design spectrum to the other — from the traditional mass-production, assembly line model to the autonomous work group model, all within the concept of assigning skills to roles, with the background of procedures to fulfill tasks, and within the context of the present relational model.

4.2.4.7. Resources and Resources

As in the case of tasks, there are two kinds of relationships which can exist between pairs of resources. In the first kind, there is a hierarchy of conceptual resources, such as divisions comprised of departments, which in turn are composed of sections, in which there are workers. In the second case, there are relationships between pairs of resources on the same level of abstraction, such as interpersonal relationships between pairs of workers.

4.3. Model Exercise

4.3.1. Planning

4.3.1.1. Introduction

The last Section, 4.2, defined the basic objects and the diadic relationships which serve as the building blocks for relational models of organization. The machinery thus developed is sufficient to describe the principal mechanisms by which organizations can perform, but is insufficient to allow such fundamental organizational activities as planning and control. It is the intent of this Section to extend the use of the matrix-based relational model, using the machinery just described, to project the work of the organization onto a time dimension, so that the organization designer can display some of the consequences of elemental choices. We can view what has been done to this point as the construction of a potential capability of the designed organization. We must now develop the means of exercising the organization on "real" work.

4.3.1.2. Replication of Tasks

By extending the matrix, we can replicate those tasks which are required to accomplish specific goals, such as the repair of a particular car or several particular cars. This is altogether different from building into the matrix the capability to repair cars in general, if any were to appear to be repaired. The replicated tasks bring along references to all their associated procedures, skills and resources, so a complete inventory of requirements, including time, is always available. The entire process is demonstrated in Chapter 7, using an auto repair facility as an example.

4.3.1.3. Simulation

Ideally, we would be able to exercise the model dynamically, simulating the operation of the organization in response to a scenario of inputs from the environment, and making judgements about the efficacy of various organizational structures. The model as now constituted has the potential of development as a true dynamic simulator, and can be used as a simple simulator in its present form. Chapter 7 discusses its use as a simulator, in the context of the auto repair facility model.

4.3.1.4. Conclusions

This Section has presented the elements and structure of the relational model, and has described its application in two of management's perennial problems, designing the potential of the organization, and making plans for the actual use of that potential.

4.3.2. Errors and Control

Error detection and correction lie at the roots of organization control. Both are tasks at various levels, assigned to resources at appropriate levels, but ultimately they are simple tasks assigned to simple resources. In the context of the relational model, error detection can only be done at the boundaries (i.e., the beginning or ending) of a task, where there is an opportunity to compare the associated goal with the delivered product. If there is a discrepancy outside established tolerances, then an error exists at that point. If input to the task was not in error (it came from somewhere, and is therefore output from another task, where it was in error, or it came from the external world and should have been tested for acceptance at its entry point), then the error has occurred within the task. The action within a task is centered in the procedure employed, which in turn references the resources used. Ideally, then, every potential source of the error is identified as soon as the error is detected. When the detected error is of such magnitude as to constitute a failure, i.e., a following task cannot proceed, then the source of the error may, indeed, be thus isolated. In the more general case, however, where there is a pattern of increasing error in a string of tasks, then the real source of error must lie on the chain of tasks preceding the one where the final error condition is detected. The relational model provides a chain of pointers to exactly those tasks wherein the trouble must lie.

A principal duty of management is control of the organization. Much of control is dependent upon the detection of error and re-design of the organization, from changing procedures to re-allocating resources. The major contribution of the relational model in this regard is providing a framework for a true management information system, explicitly designed to aid the manager in detecting and pin-pointing the sources of errors.

4.4. Conclusion

The foregoing Sections have presented in narrative form the essential elements of the relational model. The implications of the technique are more easily understood through the study of fairly comprehensive examples. The remaining Chapters of this report present, with both narrative and diagrams, the use of the relational model in the development of a simple organization and the examination of some consequences of the design.

5. Organization Design

5.1. Introduction

The concepts of designing an organization and simulating its behavior under typically anticipated circumstances are comfortably explained through the development of a model for an example situation. The particular situation chosen is an auto dealership; some of the figures here have appeared elsewhere in a different context.[5] The idea for the example came from Pasmore, et al.[11]

The Dealership will, among other things, service cars needing repairs. We will focus our attention on a step-by-step process of using the matrix model to design an organization for the Dealership's repair operation.

In the figures which follow, the organizational matrix is constructed. The narrative is keyed to the figures, and the appropriate figure should be viewed as the narrative is read.

5.2. Building the Basic Model

Figure 5.1 Identification and Structure of the Conceptual Tasks

No organization exists, and only the general idea is known of what kinds of work will be performed by the organization when it exists. In this step, we identify the Conceptual Tasks (or functions) of the future organization as Dealership Tasks, Service Tasks, Shop Tasks, Parts Tasks, and Office Tasks, in rows 44-48. The marks in the matrix at 44-48 document an "included in" relationship on the Conceptual Tasks. The marks at (44, 45) and (44, 48) show that Dealership Tasks include Service Tasks and Office Tasks, and no others. Service Tasks are further subdivided into Shop Tasks (45, 46) and Parts Tasks (45, 47). It is important to note here that while the names of tasks resemble those typically employed

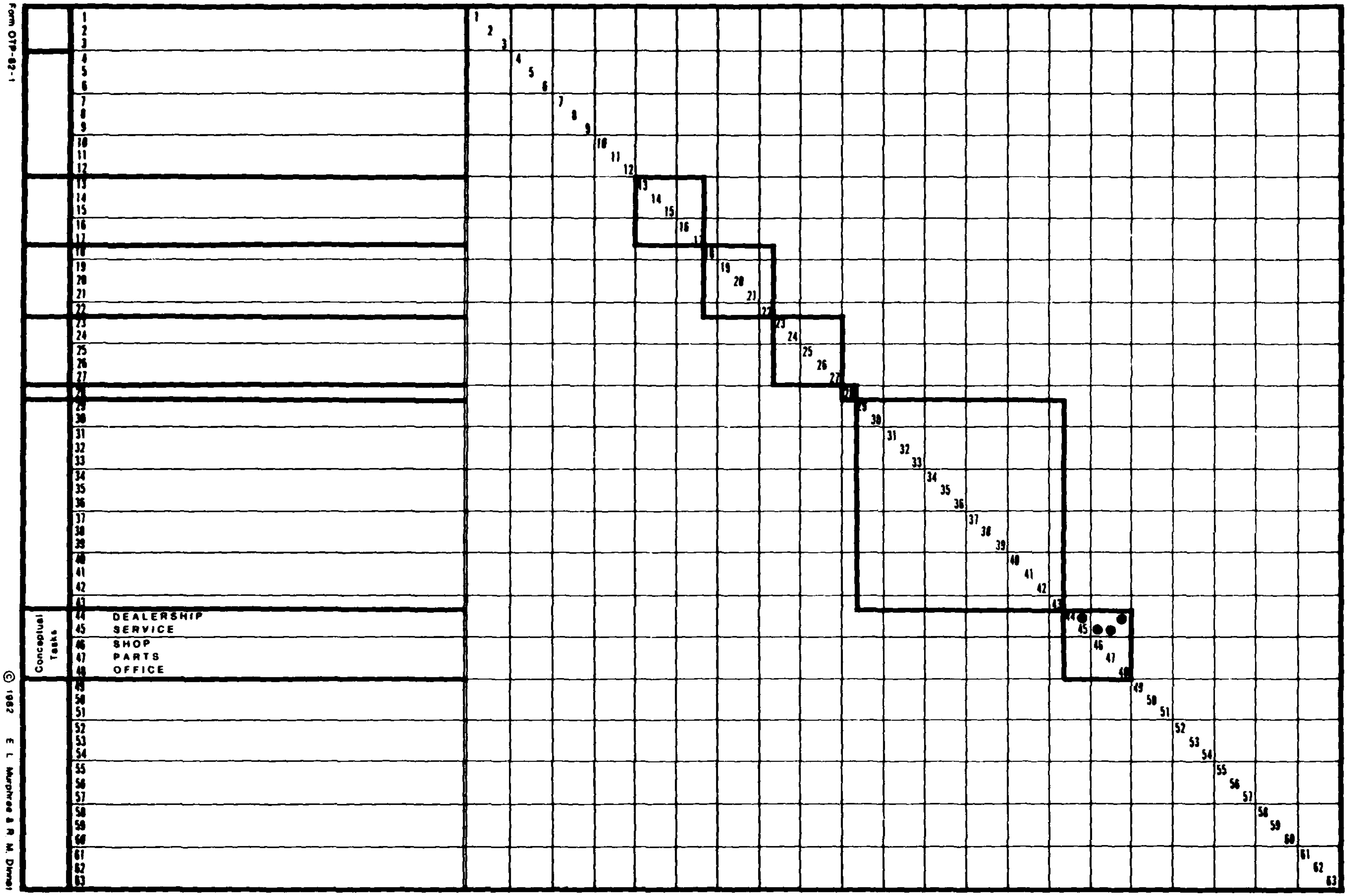

Figure 5.1. Identification and Structure of the Conceptual Tasks

for auto dealership organizational units, the similarity is due solely to a lapse of imagination; we are dealing here with a structure of <u>tasks</u> or <u>functions</u>, not the resources that will perform them.

<u>Figure 5.2</u> Identification and Structure of the Conceptual Resources

Having blocked out the function categories of the future organization, we now turn our attention to a parallel grouping of Conceptual Resources, shown in rows 23-27, and the "included in" relationship on the Conceptual Resources. The matrix at 23-27 documents a hierarchical structuring with the Dealership including the Service Department (23, 24) and the Office (23, 25), and the Service Department including the Shop (24, 26) and the Parts Room (24, 27).

At this point, we have a structure for identified functions and a structure for identified organizational groups. No assignments have been made relating resource group to function category.

<u>Figure 5.3</u> Assignment of Responsibility to Conceptual Resources for Conceptual Tasks

The marks at the sub-matrix (23-27, 44-48) assign responsibility to Conceptual Resources for Conceptual Tasks. The mark at (23,44) assigns Dealership Tasks to Dealership, the mark at (27, 47) assigns Parts Tasks to the Parts Room, and so on through each Conceptual Task and each Conceptual Resource.

<u>Figure 5.4</u> Identification of Roles

Conceptual Resources are just that: conceptual. They have no real resources, no flesh and blood workers, no machines, no offices and workrooms. We must now look into the details of both Conceptual Resources and Conceptual Tasks, to examine the <u>content</u> of both in terms of real work and workers.

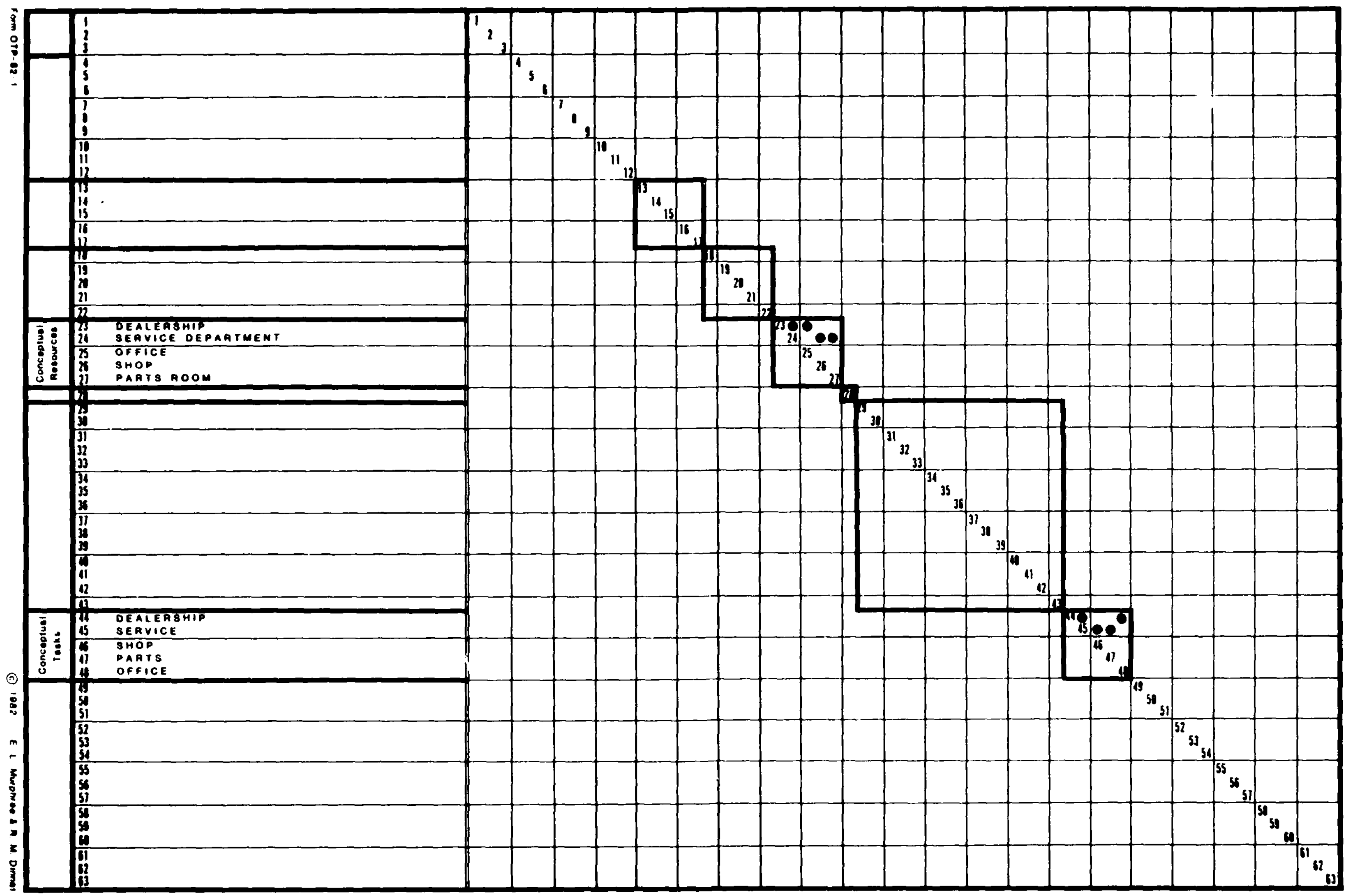

Figure 5.2. Identification and Structure of the Conceptual Resources

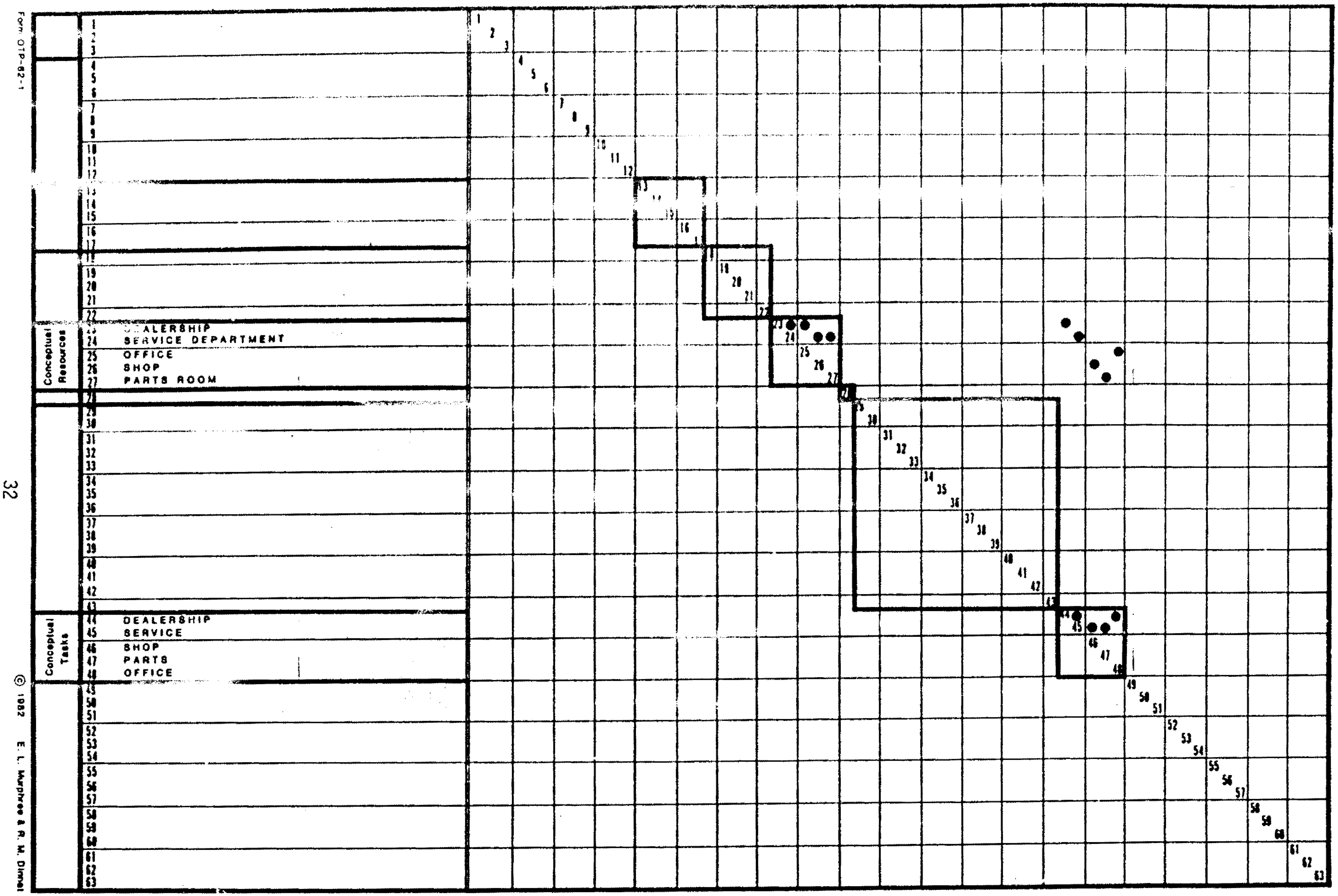

Figure 5.3. Assignment of Responsibility to Conceptual Resources for Conceptual Tasks

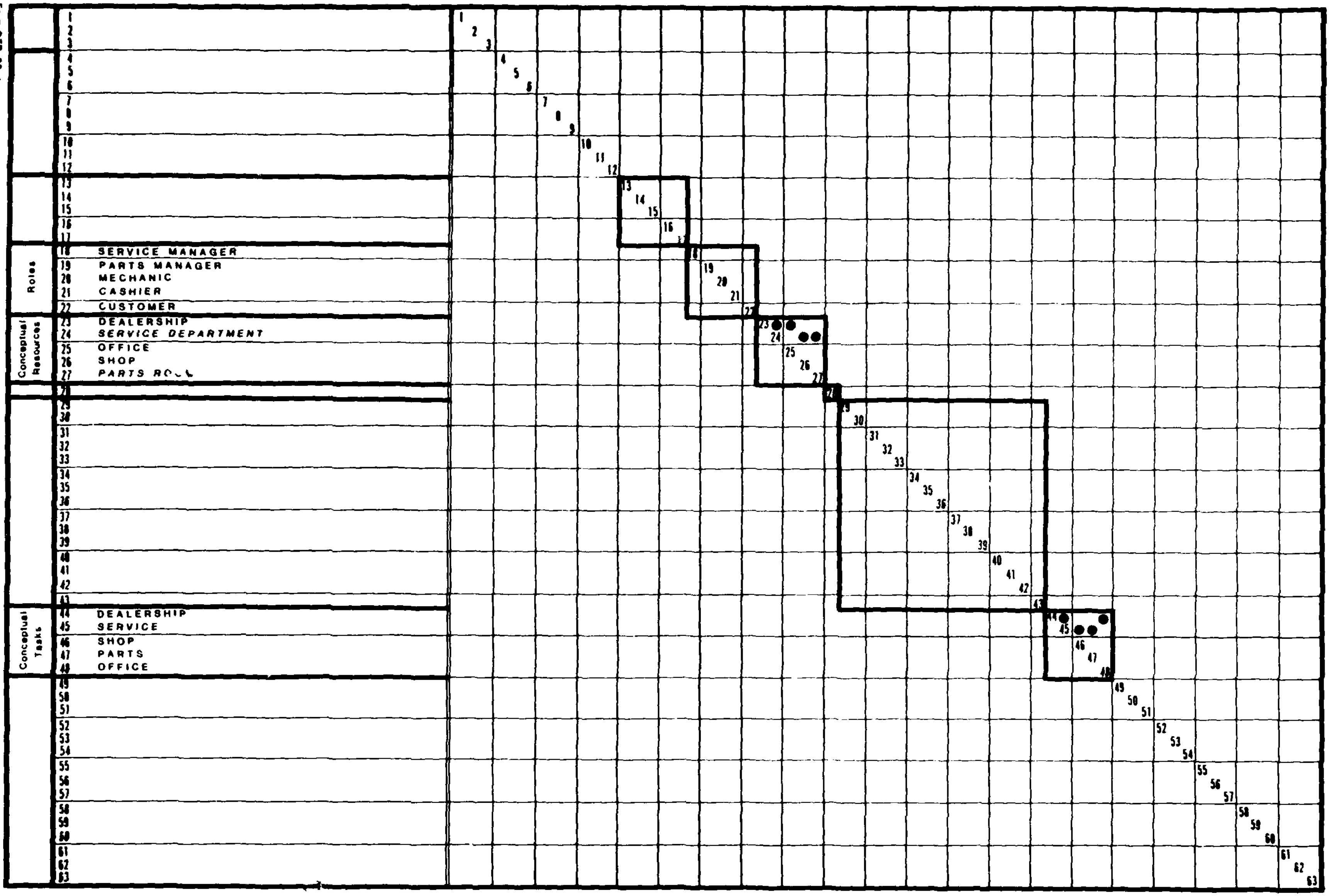

Figure 5.4. Identification of Roles

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We can, with equal logic, go either way, and break down first the content of the Conceptual Tasks and then devise roles to perform the tasks, or vice versa, first devising roles and then arranging and assigning tasks accordingly. We choose to follow the former pattern, and do so arbitrarily. Roles are identified by label, but not content, in 18-22.

Figure 5.5 Assignment of Roles to Organizational Units (Conceptual Resources)

The Roles are assigned to organizational units (Conceptual Resources) in sub-matrix (18-22, 23-27). Note that we have simply assigned Roles to groups: Service Manager to Service Department, Cashier to Office, etc. Nothing has been stated about the content of the Roles, and we know little about what real tasks are to be performed. The Customer is not identified with any organizational group, since at this point we have only considered the internal *structure of the organization*. The Customer on the other hand is of the world external to the organization, the Environment in which the organization as a whole exists. The Customer and the Environment will be integrated into the model shortly.

Figure 5.6 Identification of Real Resources (Persons)

Roles must be played by real resources, in the present example by human resources. Rows 13-17 list the names of persons who are candidates for the Roles, the Resources of the Dealership organization.

Figure 5.7 Assignment of Real Resources to Roles

The sub-matrix (13-17, 18-22) makes Role assignments: Jenner to Service Manager (13, 18), Cannon to Parts Manager, etc. At least one customer, Stahl, has been identified (14, 22).

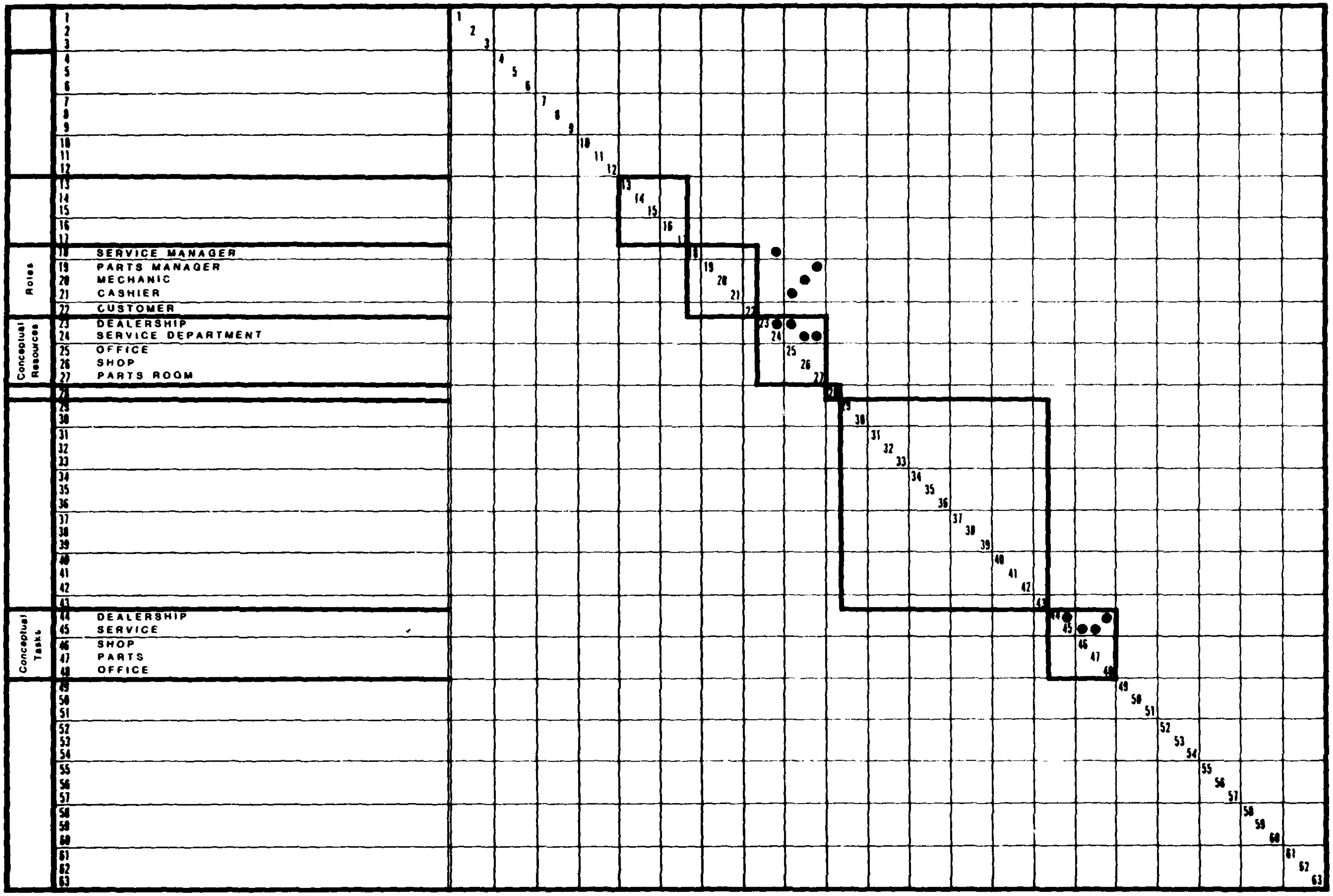

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Figure 5.5. Assignment of Roles to Organizational Units (Conceptual Resources)

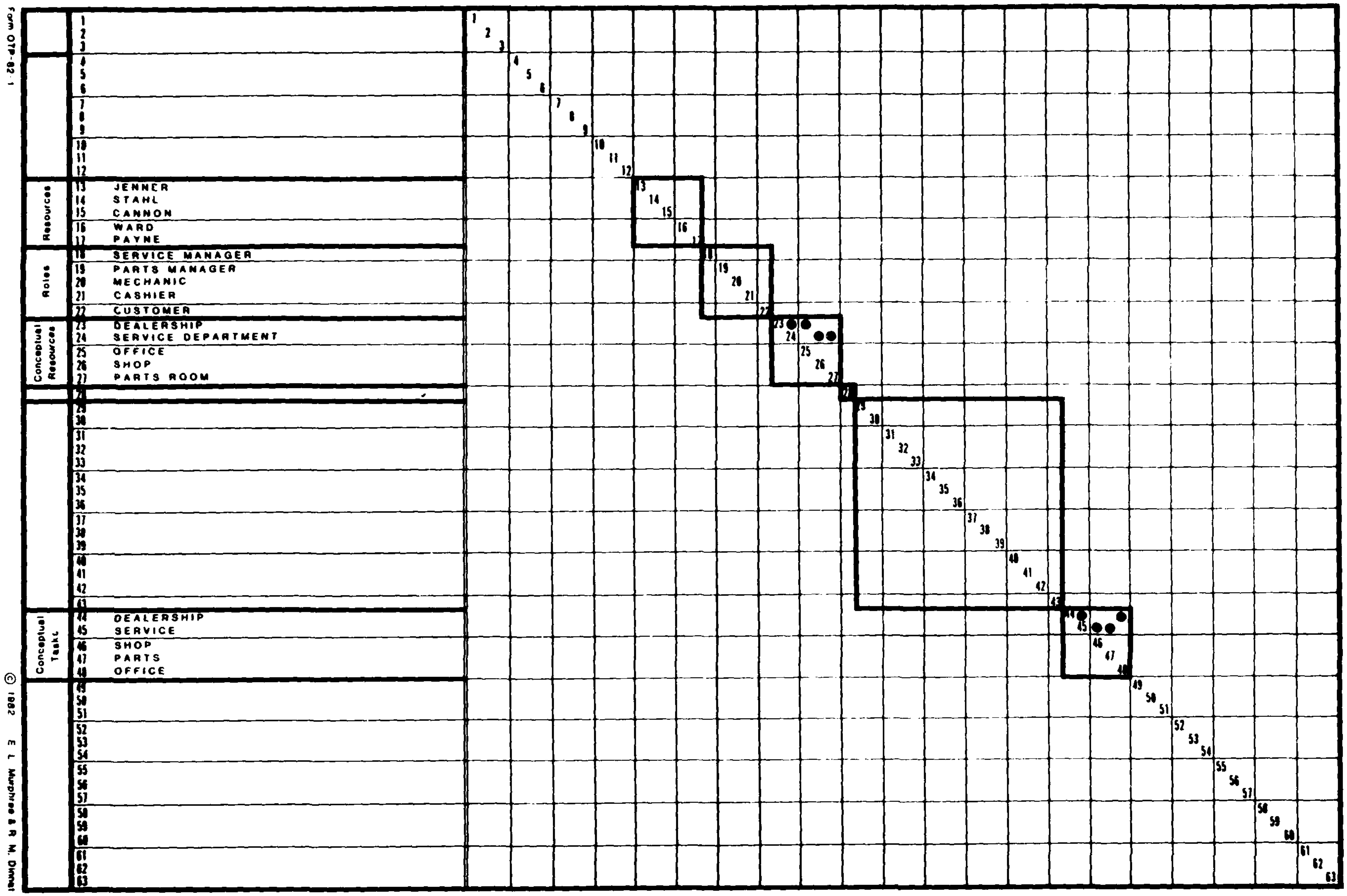

Figure 5.6. Identification of Real Resources (Persons)

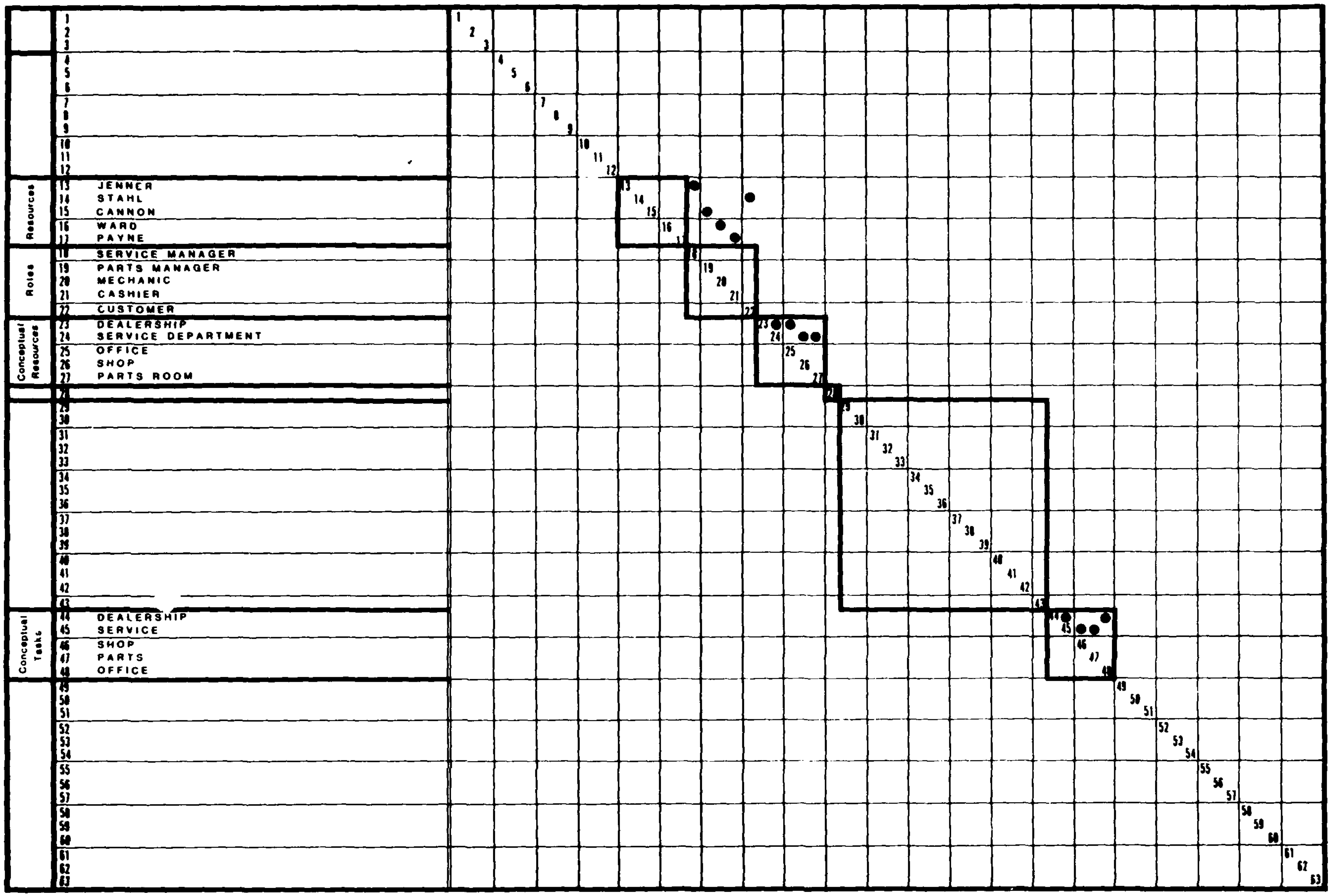

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Figure 5.7. Assignment of Real Resources to Roles

We now have an organization, with real people assigned to play roles, assigned to organizational units, themselves arranged in hierarchical order in the manner of traditional organization structure. Beyond the labels attached to the assigned Conceptual Tasks, however, nothing is documented about the real work of the Dealership, how it is to be carried out, by whom, or when.

Figure 5.8 Identification of Tasks or Functions of the Organization

The detailed list of Tasks or functions which must be performable, that is, the knowledge and skills and resources to perform them must be possessed by the organization, appears in rows 29-43. With each is an estimate of the average time required to perform that Task.

This set of Tasks represents a master set of Tasks which can be performed by the organization. Each project, or job, which the Dealership is capable of performing is constituted of a subset of these Tasks. Replication of Tasks in a single job is permitted, in general. The sequencing of Tasks in a particular job depends upon the nature of the job.

Figure 5.9 Precedence Relationships of Tasks for Repairs

In the sub-matrix at 29-43 is shown the sequencing of Tasks for the repair of an automobile. The relationship represented is precedence: the mark at (29, 30) states that Make Appointment, row 19, precedes Deliver Car, row 20, and so on. The open mark at (31, 29) implies that when the result of the decision task Verify Appointment, at row 31 is NO, then Make Appointment, row 29, follows Verify Appointment. The solid mark at (31, 32) corresponds to a YES result, sending the process next to Describe Symptoms, row 32.

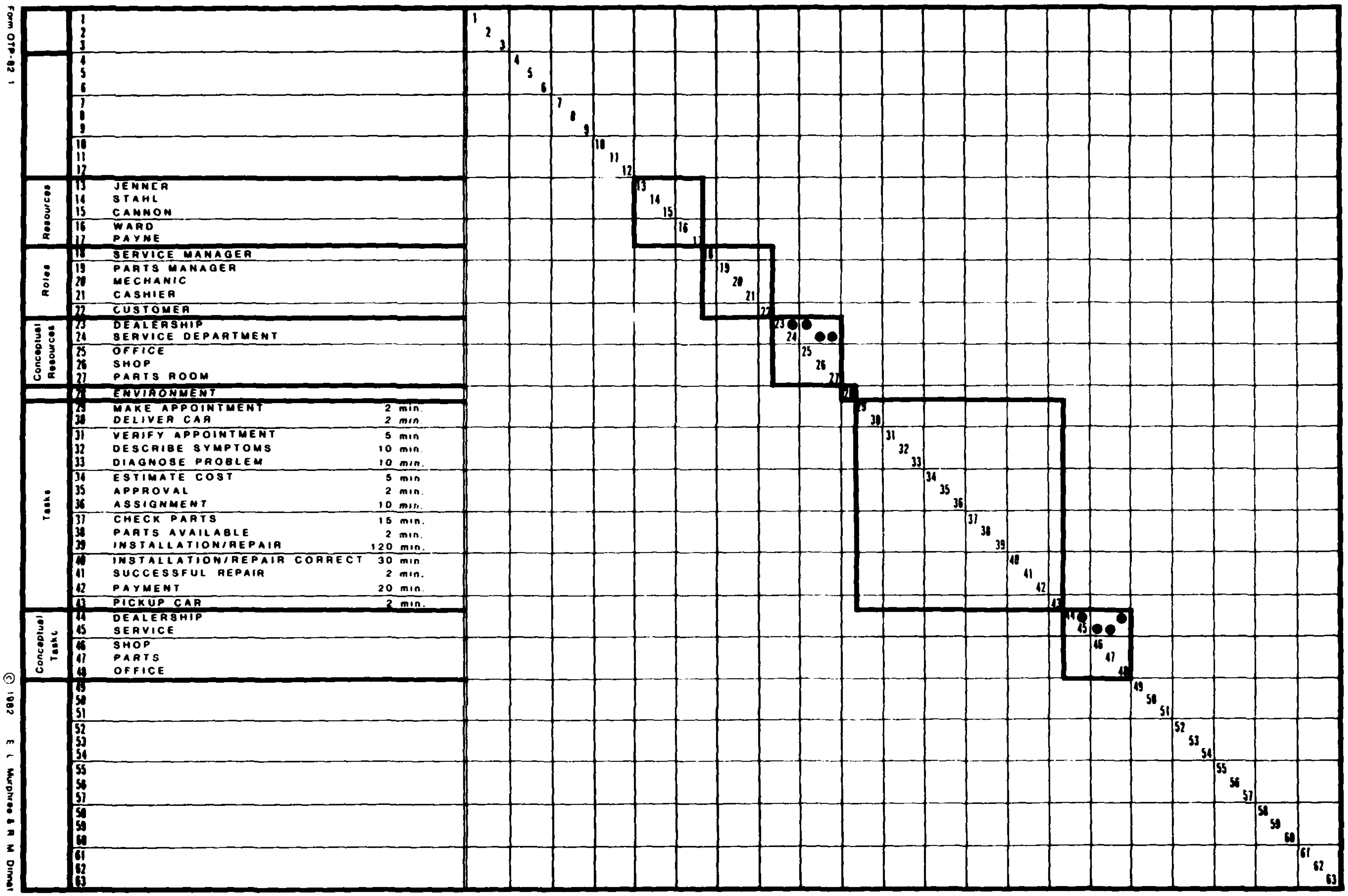

Figure 5.8. Identification of Tasks or Functions of the Organization

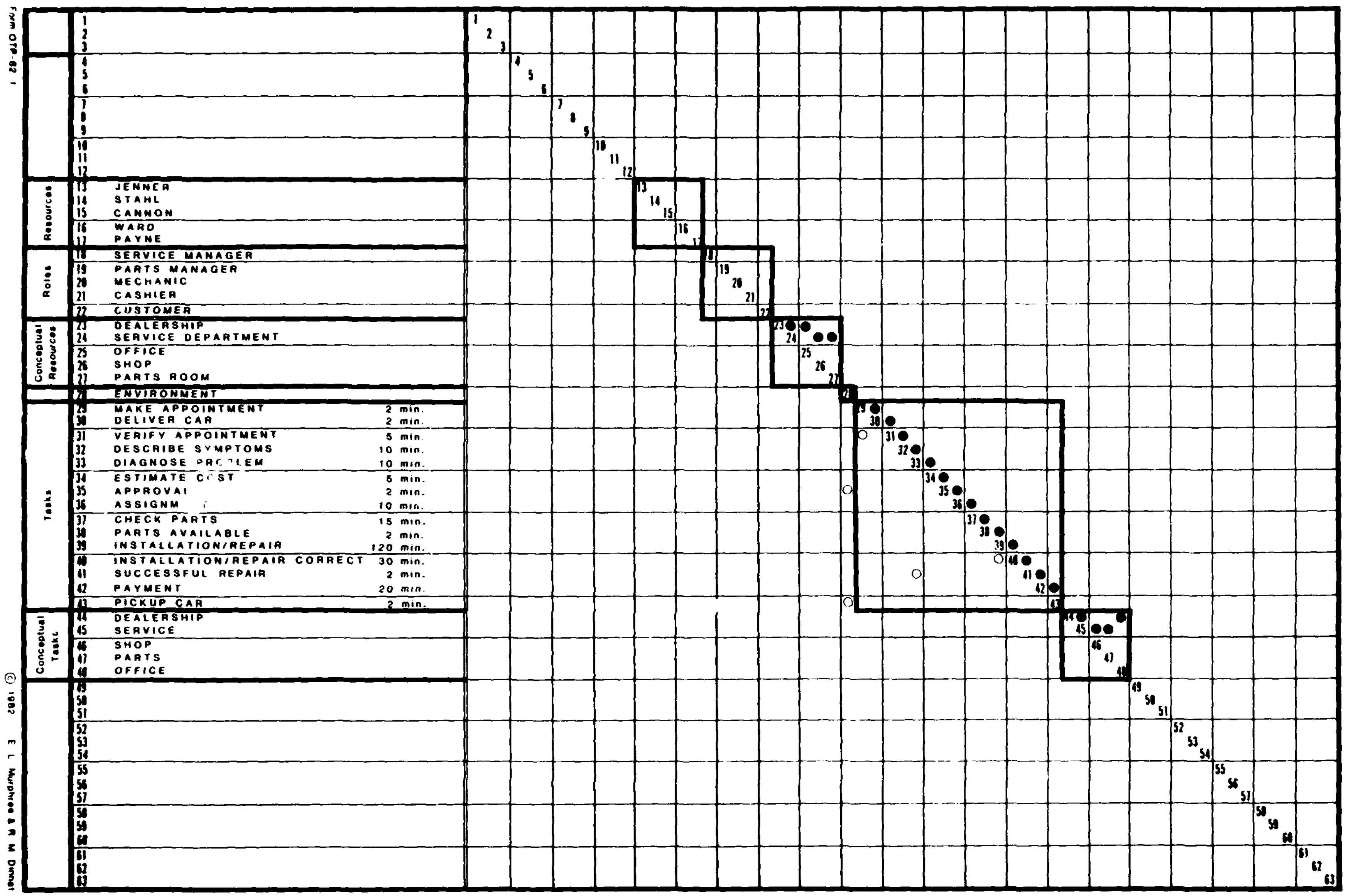

Figure 5.9. Precedence Relationships of Tasks for Repairs

This pattern of time-sequenced Tasks is a template, which would be replicated for each actual car-repair job presented to the Dealership by a Customer. Before we can deal with actual repair jobs, however, we must articulate the resource requirements for each Task, and, by extension, to each repair job. And, to keep the assignment of resources orderly, we must first coordinate Tasks and Conceptual Tasks.

Figure 5.10 Assignment of Tasks to Conceptual Tasks

The sub-matrix at (44-48, 29-43) assigns Tasks to Conceptual Tasks, to form a tree of tasks with Dealership Conceptual Tasks as the root, when the sub-matrix at 44-48 is considered. Thus, Service Tasks (row 44) include Make Appointment (29) through Assignment (36) and Pick Up Car (43), while Office Tasks include only Payment (42).

Figure 5.11 Assignment of Roles to Tasks

The sub-matrix at (18-22, 29-43) documents the Roles which must perform the Tasks at 29-43. The marks at (18, 29) and (22, 29) mean that Make Appointment (29) requires a Service Manager (18) and a Customer (22).

Now that we have an Environment, the Customer can be assigned to it by (22, 28).

Figure 5.12 Assembly of Sub-Elements to Represent the Organization

The sub-elements thus far developed are reassembled to present the entire organization, ready to perform repair jobs on incoming cars.

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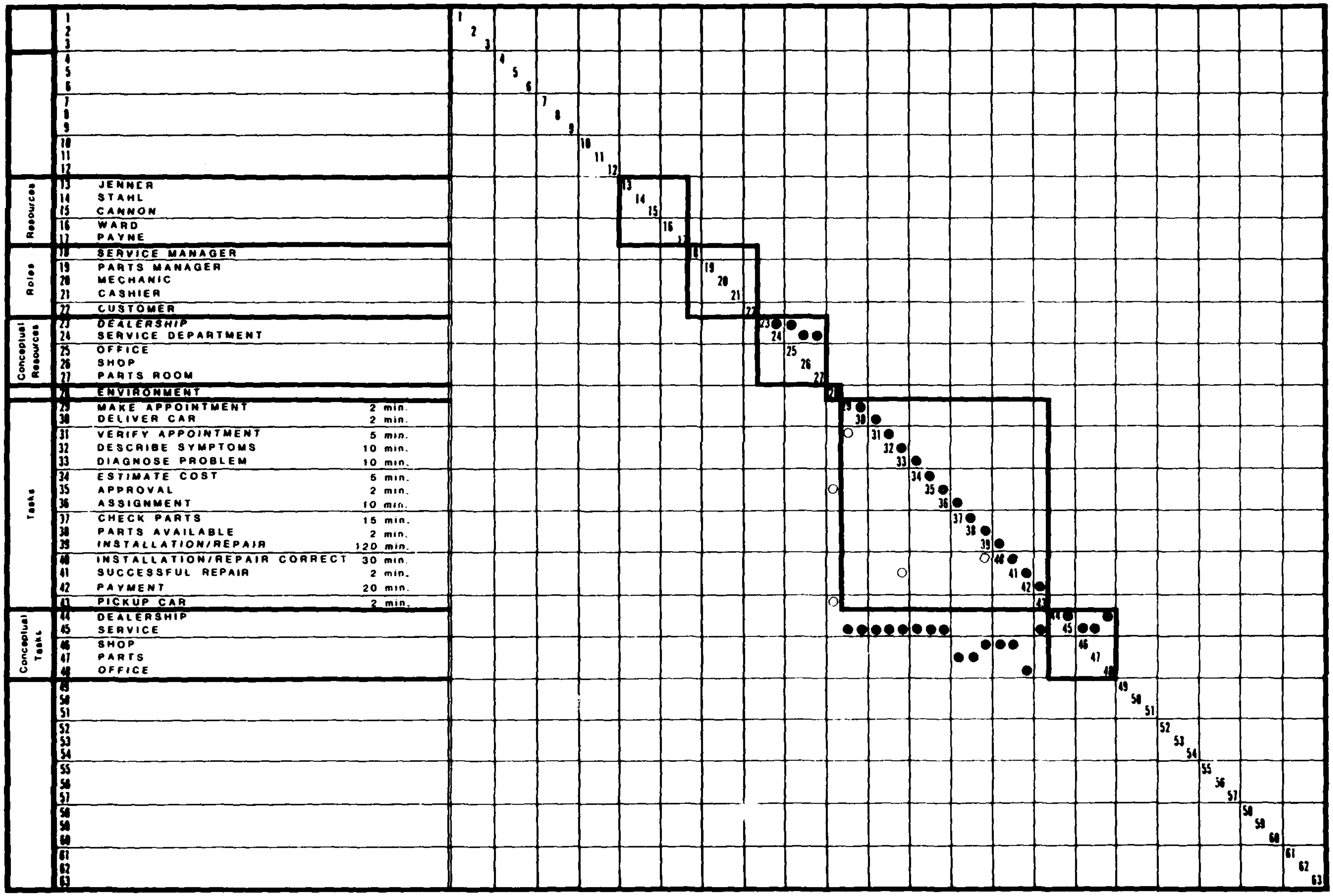

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Figure 5.10. Assignment of Tasks to Conceptual Tasks

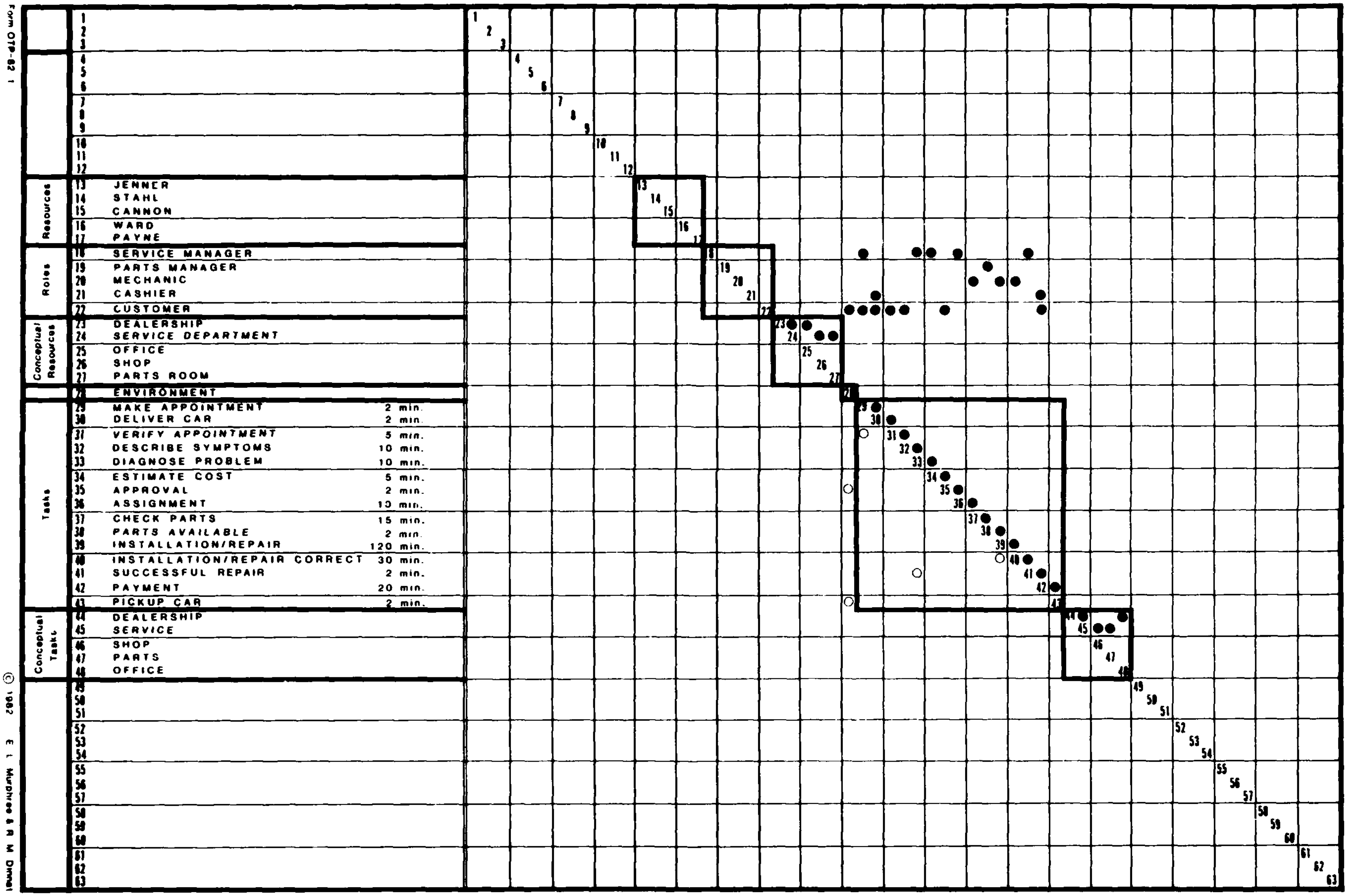

Figure 5.11. Assignment of Roles to Tasks

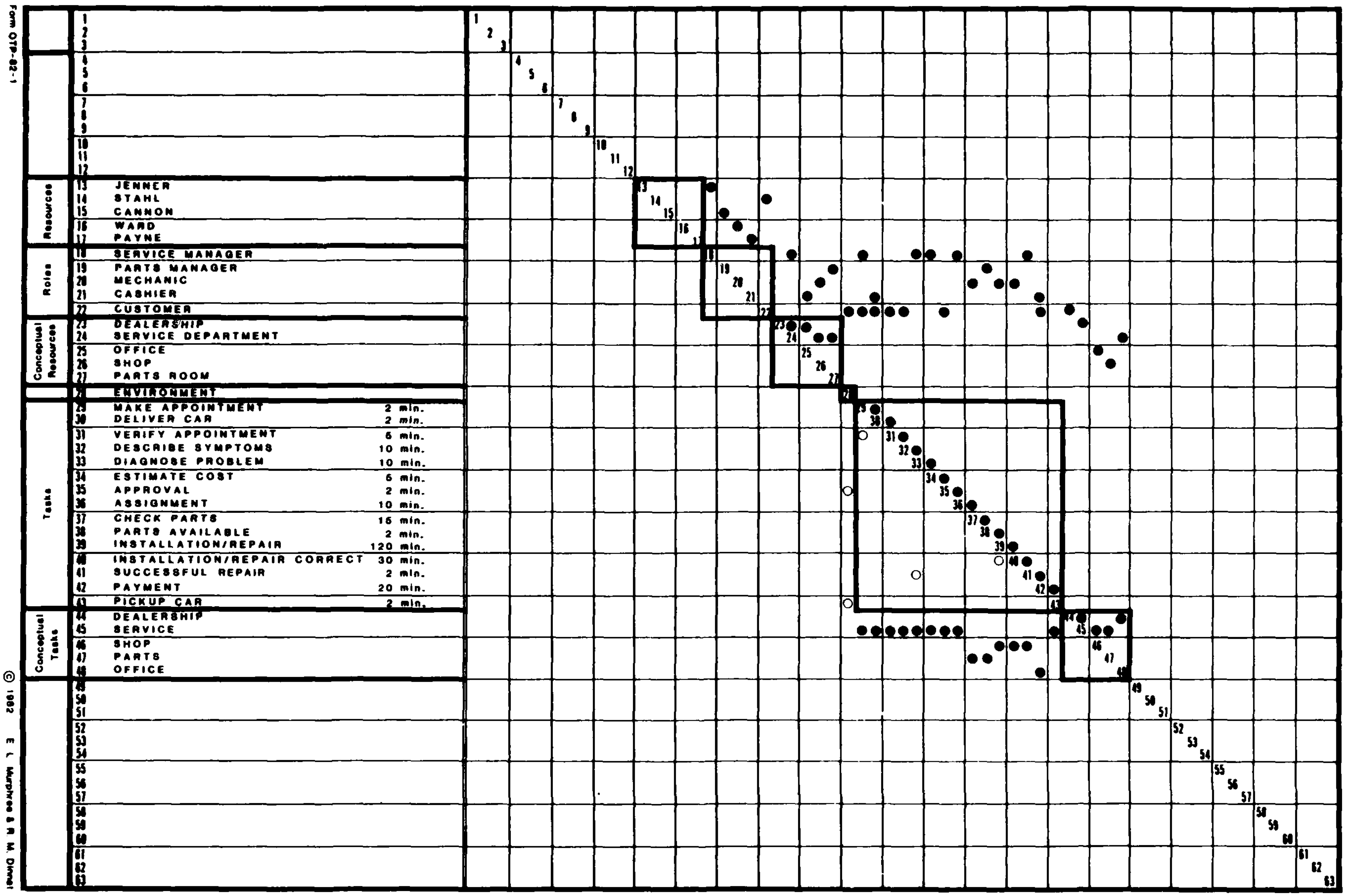

Figure 5.12. Assembly of Sub-Elements to Represent the Organization

6. Coordination of Task, Procedure, Skills, Roles, and Resources

6.1. One Approach

In the example of building the Dealership organization, no attention was paid directly to

1. selection of a specific procedure to accomplish a given task,
2. the set of skills required by the selected procedure,
3. the packaging of the required skills into roles,
4. the sets of skills possessed by the resources available for the roles, or
5. the assignment of resources to roles by matching skills required by roles to those possessed by resources.

The example presented here takes us through a process of matching task and resource by the steps cited above. The general situation of the earlier example, the Dealership, maintains in the following. The numbers in the matrix of the figures do not relate to those of the figures in Section 6.

Figure 6.1 Choice of Task for Detailed Analysis

A specific Task, Check parts availability, is chosen for scrutiny (row 20).

Figure 6.2 Procedures for Accomplishing Task

Three Procedures are presented as alternatives for accomplishing the Task, Check parts availability:

row	
16	Face to face conversation
17	Telephone call
18	Shouted query

	1		1																				
	2			2																			
	3				3																		
	4					4																	
	5						5																
	6							6															
	7								7														
	8									8													
	9										9												
	10											10											
	11												11										
	12													12									
	13														13								
	14															14							
	15																15						
	16																	16					
	17																		17				
	18																			18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.1. Choice of Task for Detailed Analysis

	1	1																				
	2		2																			
	3			3																		
	4				4																	
	5					5																
	6						6															
	7							7														
	8								8													
	9									9												
	10										10											
	11											11										
	12												12									
	13													13								
	14														14							
	15															15						
PROC	16 Face to face conversation																16				●	
	17 Telephone call																	17				
	18 Shouted query																		18			
TASKS	19																			19		
	20 Check parts availability																				20	
	21																					21

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Figure 6.2. Procedures for Accomplishing Task

For further examination, we have chosen Face to face conversation (row 16), as indicated by the mark at (16, 20).

Figure 6.3 Master List of Skills Required by Roles

The master list of Skills, sub-sets of which represent the skill requirements of each of the Procedures in 16-18, is entered next, rows 8-15.

Figure 6.4 Roles Defined in Terms of Required Skills

The Roles of Parts Manager (6) and Mechanic (7) which are to perform the Procedure, Face to face conversation (16), are now placed on the form. The specific skills from the master list in 8-15, which each Role requires for this Procedure, are marked in the appropriate matrix cells. Thus, marks in (6, 8) and (7, 8) indicate that both Parts Manager (6) and Mechanic (7) must possess the skill Know parts numbers (8). The Mechanic must Recognize defective parts, but the Parts Manager need not possess this skill (but is, of course, not prohibited from having it). For this Procedure, neither is required to Use telephone (15); on the other hand, Procedure 17 would likely impose this Skill requirement on both parties. It is important to understand though, that we must have an entirely new set of Role-Skill relationships for a new Procedure.

Figure 6.5 Resources and Skills Possessed

We now add to the growing matrix the three Resources, by name, who are candidates for the Roles of Parts Manager and Mechanic, and the inventory of pertinent Skills possessed by each Resource. For example, Cannon, Ward, and Payne all know parts numbers, as shown by marks in (3, 8), (4, 8) and (5,8); while only Ward and Payne can Recognize defective parts, as shown in (4, 10) and (5, 10). Absence of a mark

	1		1																				
	2			2																			
	3				3																		
	4					4																	
	5						5																
	6							6															
	7								7														
SKILLS	8	Know parts numbers								8													
	9	Know identity of parts									9												
	10	Recognize defective parts										10											
	11	Speak English											11										
	12	Understand spoken English												12									
	13	Walk to and from parts room													13								
	14	*Read parts, inventory books*														14							
	15	Use telephone															15						
PROC	16	Face to face conversation																16				●	
	17	Telephone call																	17				
	18	Shouted query																		18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.3. Master List of Skills Required by Roles

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	1	1																				
	2		2																			
	3			3																		
	4				4																	
	5					5																
ROLES	6 Parts Manager						6		●	●		●	●		●		●					
	7 Mechanic							7	●	●	●	●	●	●			●					
SKILLS	8 Know parts numbers								8													
	9 Know identity of parts									9												
	10 Recognize defective parts										10											
	11 Speak English											11										
	12 Understand spoken English												12									
	13 Walk to and from parts room													13								
	14 Read parts, inventory books														14							
	15 Use telephone															15						
PROC	16 Face to face conversation																16				●	
	17 Telephone call																	17				
	18 Shouted query																		18			
TASKS	19																			19		
	20 Check parts availability																				20	
	21																					21

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Figure 6.4. Roles Defined in Terms of Required Skills

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
RESOURCES	1		1																				
	2			2																			
	3	Cannon			3					●	●		●	●	●	●							
	4	Ward				4				●	●	●	●	●	●	●	●						
	5	Payne					5			●	●	●	●	●	●	●	●						
ROLES	6	Parts Manager						6		●	●		●	●		●		●					
	7	Mechanic							7	●	●	●	●	●	●			●					
SKILLS	8	Know parts numbers								8													
	9	Know identity of parts									9												
	10	Recognize defective parts										10											
	11	Speak English											11										
	12	Understand spoken English												12									
	13	Walk to and from parts room													13								
	14	Read parts, inventory books														14							
	15	Use telephone															15						
PROC	16	Face to face conversation																16				●	
	17	Telephone call																	17				
	18	Shouted query																		18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.5. Resources and Skills Possessed

in (3, 10) indicates that Cannon does not possess the Skill, Recognize defective parts.

It is at this point where a choice must be made of which Resource (Cannon, Ward, Payne) will be assigned to which Role (Parts Manager, Mechanic). This requires a matching of Skills required for each Role and Skills possessed by each candidate (Resource). Matching the marks in row 3 (Cannon) with those in row 6 (Parts Manager), we find that Cannon possesses Skills 8, 9, 11, 12, 13 and 14, while the Parts Manager Role requires Skills 8, 9, 11, 12 and 14. Cannon possesses more skills than are required for Parts Manager and is clearly a candidate for that Role. When we match Cannon's skills against those required for the Role of Mechanic (row 7), however, we find that he cannot Recognize defective parts, as required by (7, 10), since there is no mark in (3, 10). Cannon, then, is not a candidate for the Role of Mechanic. Matching skills for Ward and Payne in the same manner, we find that both are sufficiently skilled to fill either Role.

<u>Figure 6.6</u> Assignment of Resources to Roles

Cannon and Ward have been selected to fill the Roles of Parts Manager and Mechanic, respectively, as indicated by marks in (3, 6) and (4, 7). Note that, given the Skill matches, other choices could have been made.

6.2. An Alternative Approach

In the foregoing Section, an approach was presented to coordinating Tasks, Procedures, Skills, Roles and Resources. The sequence of steps presented there is, of course, not the only viable approach. Another approach might be more appropriate if, say, individual Resources were

RESOURCES	1		1																				
	2			2																			
	3	Cannon			3			●															
	4	Ward				4			●														
	5	Payne					5																
ROLES	6	Parts Manager						6		●	●		●	●		●		●					
	7	Mechanic							7	●	●	●	●	●	●			●					
SKILLS	8	Know parts numbers								8													
	9	Know identity of parts									9												
	10	Recognize defective parts										10											
	11	Speak English											11										
	12	Understand spoken English												12									
	13	Walk to and from parts room													13								
	14	Read parts, inventory books														14							
	15	Use telephone															15						
PROC	16	Face to face conversation																16				●	
	17	Telephone call																	17				
	18	Shouted query																		18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.6. Assignment of Resources to Roles

already incumbent in Roles and we, as organization designers, are confronted with the need for assigning a new Task to the Roles. The problem, then, becomes one of determining which of the alternative Procedures can be handled by the incumbent Resources.

<u>Figure 6.7</u> Identification of Task for Assignment

Task (20), Check parts availability, has been selected for assignment of Procedure and Resources.

<u>Figure 6.8</u> Assignment of Roles to Perform Task

Roles of Parts Manager (6) and Mechanic (7) have been identified to perform the task selected.

<u>Figure 6.9</u> Identification of Incumbents in Roles

Cannon (3) and Ward (4) are identified as the incumbents in the roles of Parts Manager (mark in (3, 6)) and Mechanic (mark in (4, 7)).

<u>Figure 6.10</u> Master List of Skills

The master list of Skills possessed by Cannon and Ward, and those Skills required by the Roles of Parts Manager and Mechanic are added. Note that this list tells us nothing about <u>specific</u> matches of Resources, Roles, and Skills. The list shown is the union of all Skills that must be involved.

<u>Figure 6.11</u> Skills Required for the Roles

The Skills required for each of the two Roles are identified. Nothing here indicates the Skills possessed by Cannon or Ward; however, since we know from Figure 7.9 that Cannon is Parts Manager and Ward is Mechanic, each must possess at the minimum the Skills required for the Role he fills.

	1		1																				
	2			2																			
	3				3																		
	4					4																	
	5						5																
	6							6															
	7								7														
	8									8													
	9										9												
	10											10											
	11												11										
	12													12									
	13														13								
	14															14							
	15																15						
	16																	16					
	17																		17				
	18																			18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.7. Identification of Task for Assignment

	1		1																				
	2			2																			
	3				3																		
	4					4																	
	5						5																
ROLES	6	Parts Manager						6															
	7	Mechanic							7														
	8									8													
	9										9												
	10											10											
	11												11										
	12													12									
	13														13								
	14															14							
	15																15						
	16																	16					
	17																		17				
	18																			18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.8. Assignment of Roles to Perform Task

RESOURCES	1		1																				
	2			2																			
	3	Cannon			3			●															
	4	Ward				4			●														
	5	Payne					5																
ROLES	6	Parts Manager						6															
	7	Mechanic							7														
	8									8													
	9										9												
	10											10											
	11												11										
	12													12									
	13														13								
	14															14							
	15																15						
	16																	16					
	17																		17				
	18																			18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.9. Identification of Incumbents in Roles

RESOURCES	1		1																				
	2			2																			
	3	Cannon			3																		
	4	Ward				4																	
	5	Payne					5																
ROLES	6	Parts Manager						6															
	7	Mechanic							7														
SKILLS	8	Know parts numbers								8													
	9	Know identity of parts									9												
	10	Recognize defective parts										10											
	11	Speak English											11										
	12	Understand spoken English												12									
	13	*Walk to and from parts room*													13								
	14	Read parts, inventory books														14							
	15	Use telephone															15						
	16																	16					
	17																		17				
	18																			18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.10. Master List of Skills

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
RESOURCES	1		1																				
	2			2																			
	3	Cannon			3																		
	4	Ward				4																	
	5	Payne					5																
ROLES	6	Parts Manager						6		●	●		●	●		●							
	7	Mechanic							7	●	●	●	●	●	●								
SKILLS	8	Know parts numbers								8													
	9	Know identity of parts									9												
	10	Recognize defective parts										10											
	11	Speak English											11										
	12	Understand spoken English												12									
	13	Walk to and from parts room													13								
	14	Read parts, inventory books														14							
	15	Use telephone															15						
	16																	16					
	17																		17				
	18																			18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.11. Skills Required for the Roles

Figure 6.12 Skills Possessed by Resources

The foregoing speculation is confirmed with the addition of the spectrum of skills possessed by not only the Role incumbents Cannon and Ward, but also the third potential Resource, Payne.

Figure 6.13 Skills and Resources Required for Telephone Call Procedure

The marks in rows 6 and 7 identify those Skills from the master skill list needed by each of the two Roles required (marks in (6, 17) and (7, 17)) for the Procedure Telephone Call (17) to accomplish Task 20, Check Parts Availability. Comparison of row 6, column 8-15, with the marks in rows 3, 4, and 5, Figure 6-12, clearly shows that Ward and Payne have the skills to perform the new Procedure, while Cannon (row 3) does not, since the absence of a mark in (3, 15) indicates that he does not have the skill Use Telephone.

Figure 6.14 Skills and Resources Required for Face to Face Conversation Procedure

The marks in rows 6 and 7 identify those Skills from the master skill list needed by each of the two identified Roles for the Procedure Face to Face Conversation to accomplish Task 20. Comparison of the patterns as above shows that Ward and Payne have the requisite skills for both Parts Manager and Mechanic. It also reveals that Cannon, while not qualified for Mechanic, does qualify for Parts Manager, if the Face to Face Conversation Procedure is used for Task 20.

6.3. Conclusion

The following examples serve to illuminate some basic problems facing the organization designer and approaches to their solution by means of the

RESOURCES	1		1																				
	2			2																			
	3	Cannon			3					●	●		●	●	●	●							
	4	Ward				4				●	●	●	●	●	●	●	●						
	5	Payne					5			●	●	●	●	●	●	●	●						
ROLES	6	Parts Manager						6															
	7	Mechanic							7														
SKILLS	8	Know parts numbers								8													
	9	Know identity of parts									9												
	10	Recognize defective parts										10											
	11	Speak English											11										
	12	Understand spoken English												12									
	13	Walk to and from parts room													13								
	14	Read parts, inventory books														14							
	15	Use telephone															15						
	16																	16					
	17																		17				
	18																			18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.12. Skills Possessed by Resources

RESOURCES	1		1																				
	2			2																			
	3	Cannon			3																		
	4	Ward				4																	
	5	Payne					5																
ROLES	6	Parts Manager						6		●	●		●	●		●	●		●				
	7	Mechanic							7	●	●	●	●	●			●		●				
SKILLS	8	Know parts numbers								8													
	9	Know identity of parts									9												
	10	Recognize defective parts										10											
	11	Speak English											11										
	12	Understand spoken English												12									
	13	Walk to and from parts room													13								
	14	Read parts, inventory books														14							
	15	Use telephone															15						
PROC	16	Face to face conversation																16					
	17	Telephone call																	17			●	
	18	Shouted query																		18			
TASKS	19																				19		
	20	Check parts availability																				20	
	21																						21

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Figure 6.13. Skills and Resources Required for Telephone Call Procedure

RESOURCES	1	1																				
	2		2																			
	3 Cannon			3																		
	4 Ward				4																	
	5 Payne					5																
ROLES	6 Parts Manager						6		●	●		●	●		●		●					
	7 Mechanic							7	●	●	●	●	●	●			●					
SKILLS	8 Know parts numbers								8													
	9 Know identity of parts									9												
	10 Recognize defective parts										10											
	11 Speak English											11										
	12 Understand spoken English												12									
	13 Walk to and from parts room													13								
	14 Read parts, inventory books														14							
	15 Use telephone															15						
PROC	16 Face to face conversation																16				●	
	17 Telephone call																	17				
	18 Shouted query																		18			
TASKS	19																			19		
	20 Check parts availability																				20	
	21																					21

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Figure 6.14. Skills and Resources Required for Face to Face Conversation Procedure

relational model. While the entire process, in both situations examined, can be carried out manually, in reality, an interactive computer program would likely be preferred to pencil and paper.

Nevertheless, all the basic elements for coordination of Task, Procedure, Skills, Roles, and Resources within the context of the relational model have been described.

7. Planning at the Organizational Level

7.1. The Organization in Action

The model of the Dealership developed in the previous Section does not go beyond establishing the relationships necessary to process car-repair jobs, <u>if such jobs appeared</u>. The model then represents <u>potential capability</u>, only. We now wish to extend the model so that it has the capacity to represent what could occur, on a time scale, if multiple car-repair opportunities presented themselves.

Figure 7.1 is an enlarged view of the Tasks the Dealership is organized to perform. The Tasks are organized in an appropriate sequence for repairing cars in a general sense, but not necessarily with reference to any particular car.

Suppose, now, that three cars, A, B, and C, are expected to appear for repairs tomorrow. The repairs on all are not identical, but the general sequence of tasks is similar for all three.

Figure 7.2, then, shows an extension of the matrix, with three replications of the Task-Task sub-matrix, one for each of the three cars. Each Task-Task sub-matrix, (13-27), (28-42), and (43-57), represents the pattern of Task performance for a single car. Note that each car is sequenced through the process independently of the others.

In rows 5-12, we see the familiar Roles, now augmented by three new ones, Cars A, B, and C. In the sub-matrix (5-12, 13-57) are replications of the Role-Task patterns developed in the previous Section, one pattern for each Car, and the added marks in the car rows for those Tasks requiring the presence of a car. The marks in (5, 14), (11, 14), and (12, 14), then imply that Car A, the Cashier, and the Customer must be present for the

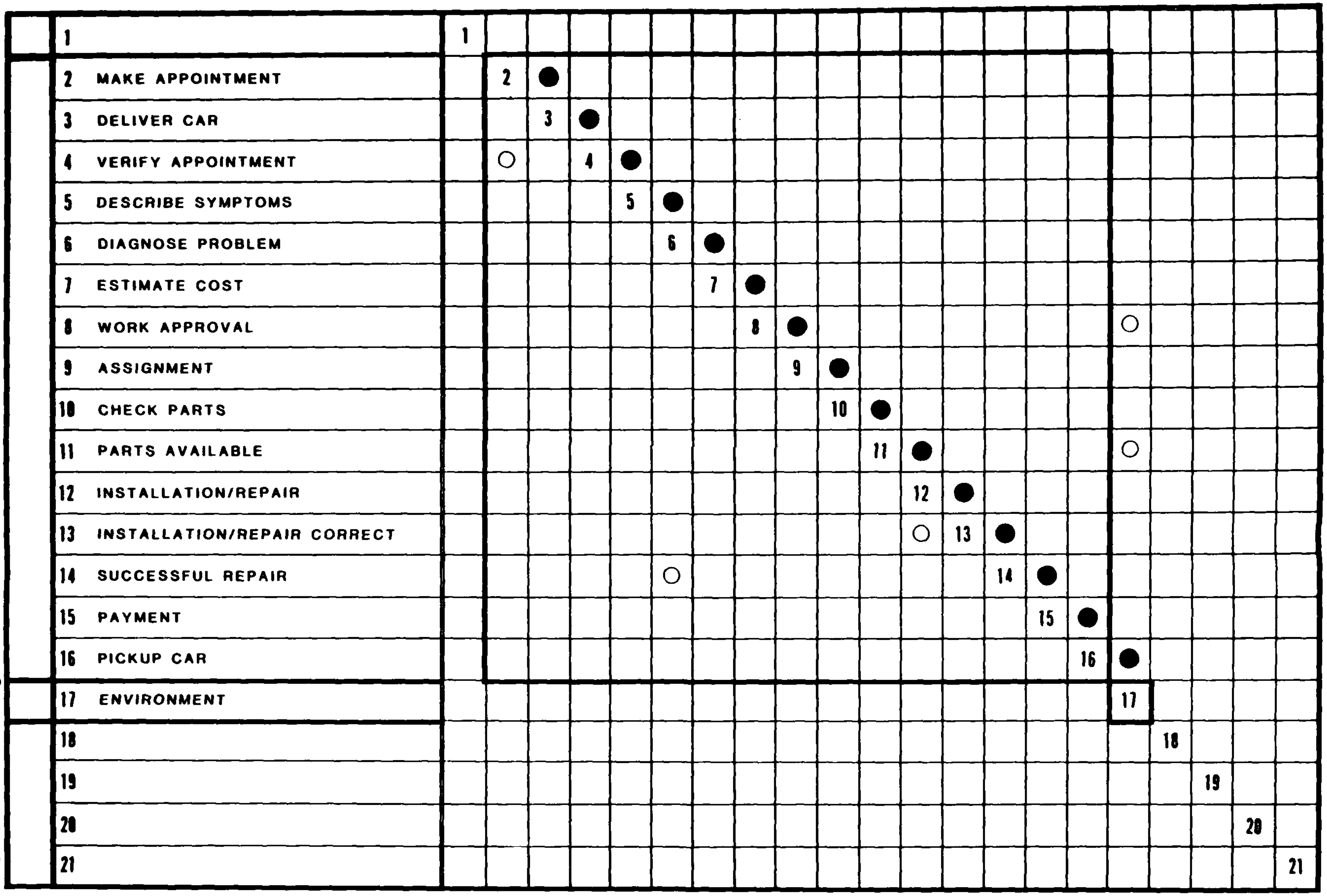

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Figure 7.1. Enlargement of Task-Task Submatrix Showing Precedence Relationships Between Task Pairs

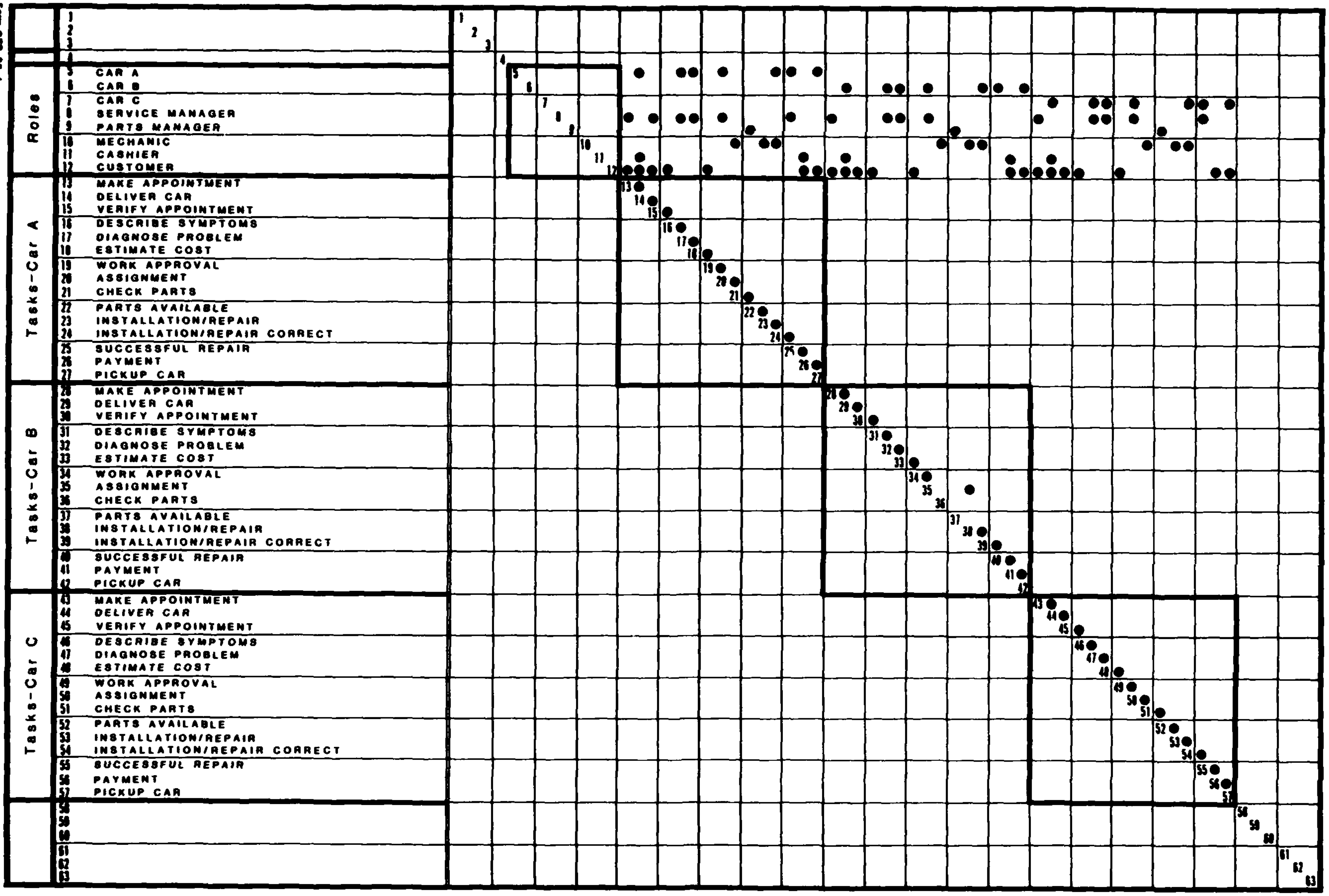

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Figure 7.2. Organizational Plan for Repairing Three Cars

Task Deliver Car (14) to be performed. The marks in each column in 5-12 have this meaning.

Figure 7.2 represents, then, a complete logical plan for the processing of the three cars through the repair shop. The resources required and the sequencing of tasks are completely defined by the matrix. Procedures for the tasks are implied by the Role sets specified. The average duration of each Task is known and documented on the matrix of the previous Section. Only the time of arrival of each Car at the Dealership is needed to determine the whereabouts of every Role player at any time t during the work period. For this example, we assume arrival times of +0, +5, and +85 minutes for Cars A, B, and C, respectively. Time of beginning is assumed to be 0.

7.2. Simple Simulation

From the data on the matrices and the assumed Car arrival times, we can, with CPM-type[2] calculations, prepare several displays of varying usefulness. Figure 7.3 shows the path taken by the Service Manager as he goes from Task to Task and Car to Car, as each Car arrives and requires his attention. The display is busy, and gives the impression that the Service Manager, too, is very busy. We must keep in mind, however, that the durations of the tasks do not appear in this display, and we cannot assess his true busyness without that dimension.

A more generally useful display appears in Figure 8.4, which is a timing chart for the entire operation. Shaded bars represent times when a *Role player is actually involved* with a Task. Non-shaded bars represent times when the Role player is idle. Idleness need not result from sloth. Waiting for Resources to finish other Tasks can also compel idleness on

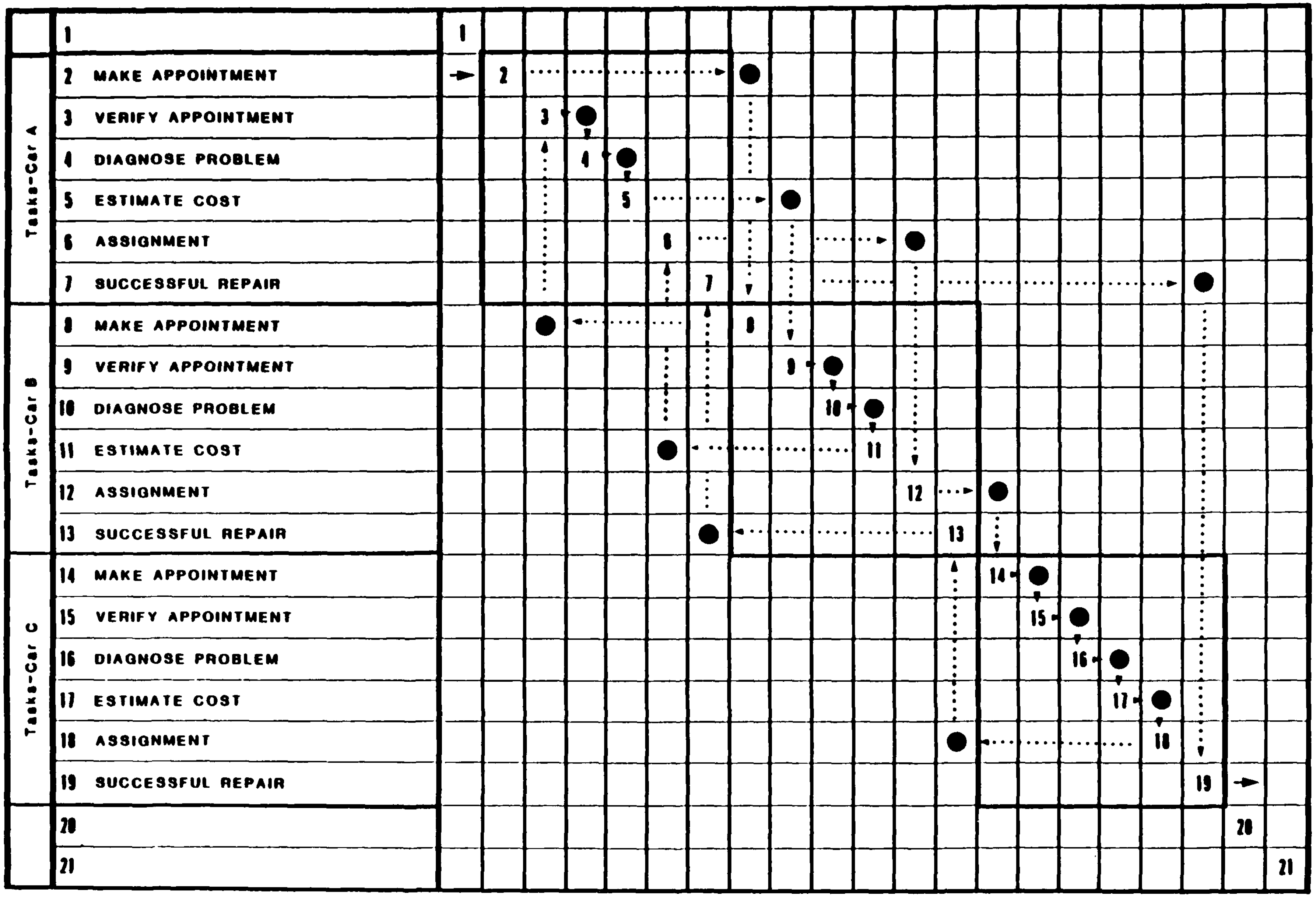

Figure 7.3. Path of Service Manager from Task to Task

the part of a Role player. Inspection of the display clearly shows the Service Manager to be relatively busy during the first 120 minutes and idle for virtually the entire remainder of the day. The Parts Manager and Cashier are also not over-worked. Mechanic #1 is substantially busier than Mechanic #2.

From a timing chart such as that of Figure 7.4, it is an easy matter to see that efficiencies might be realized by combining Roles, notably those of Service Manager, Parts Manager, and Cashier. It must be understood, however, that this display represents a very simple simulation, and changes should be made cautiously, and with the benefit of other scenarios.

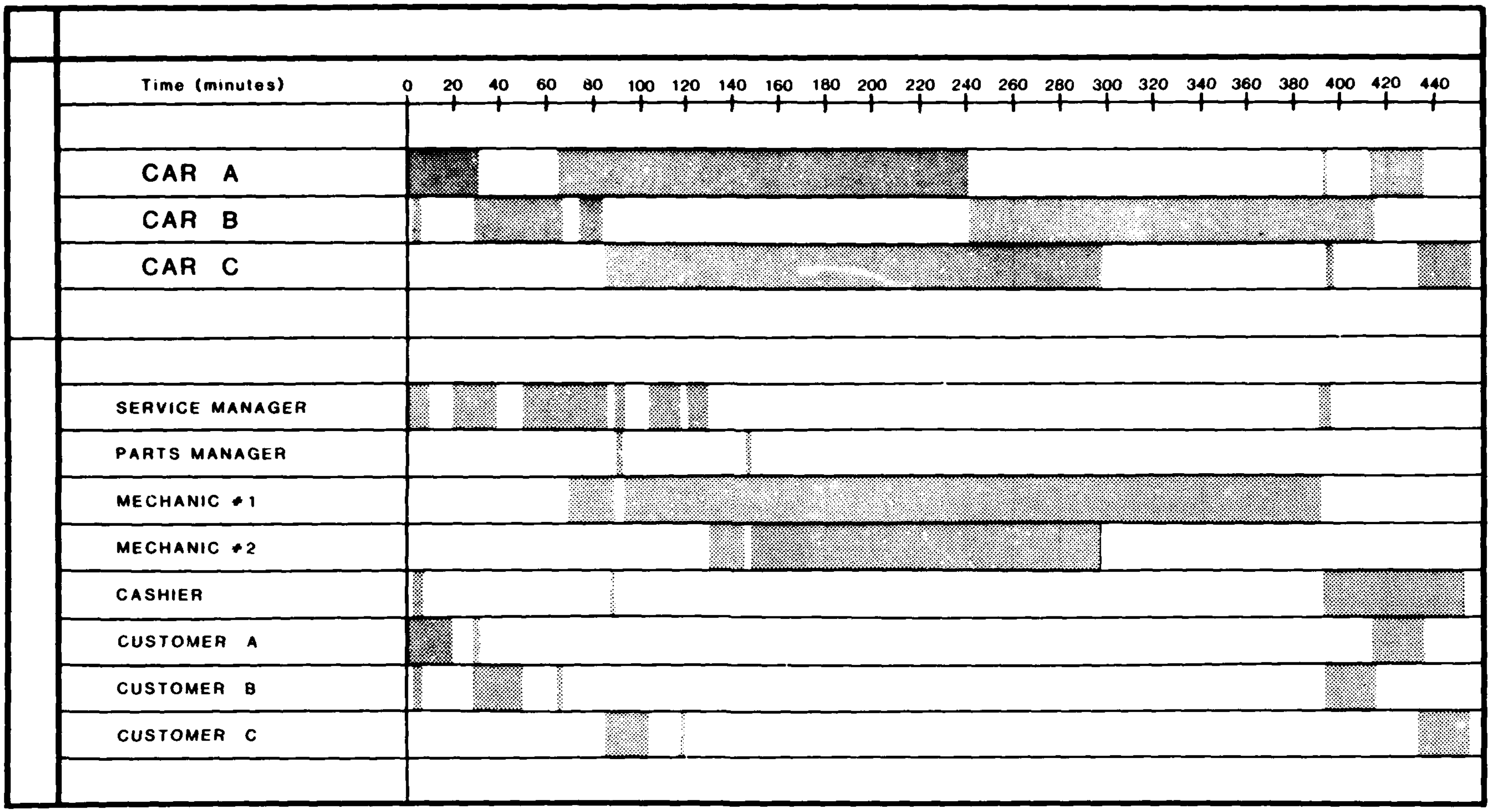

Figure 7.4. Timing Chart for Roles in Auto Repair Shop

8. Recommendations

This report has presented a method of modelling purposive human organizations which holds enormous potential for improving organizational performance. The rudiments of using the methodology have been presented, but it is clear from the elementary examples here, that a useful relational model of a "real" organization, whether an existing one or one being designed, involves a very large amount of information. The model will not likely reach its potential without computer processing of the data. The first recommendation emerging from the effort reported herein, then, is that a computer software system be developed to manage the organizational data and to present it to users in graphical format.

The second recommendation is that the model in its present form be used in several situations where organizations are malfunctioning to assess its value in uncovering sources of organizational troubles. Such a use will unquestionably contribute to our understanding of the relationship between organizational structure and organizational performance.

9. References

1. Ansoff, H. I., and Brandenburg, R. R., "A Language for Organization Design: Parts I and II," Management Science, Vol. 17, No. 12, August, 1971.

2. Berge, C., The Theory of Graphs and Its Applications, John Wiley & Sons, Inc., 1962.

3. Dinnat, R. M., and Murphree, E. L., "A Technique for Modelling Building Organizations," Proceedings of the International Symposium on Construction Organization and Management, Haifa, September, 1978.

4. Murphree, E. L., Dinnat, R. M., Clickener, P. A., and Matthews, R. S., Formal Techniques for Analysis and Design of Purposive Organizations, Department of Architecture, University of Illinois, Urbana-Champaign, Final Report, Contract No. AFOSR-80-0900, U. S. Air Force Office of Scientific Research, Bolling AFB, Washington, D. C., September, 1981.

5. Murphree, E. L., Dinnat, R. M., Carreon, N. S., Elliott, B. W., Harless, M. W., and Matthews, R. S., Models of Purposive Human Organization: A Comparative Study, School of Architecture, University of Illinois, Urbana-Champaign, Final Report, Contract No. MDA-903-81-M-4200, U. S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA, May, 1982.

6. Murphree, E. L., Dinnat, R. M., Carreon, N. S., Elliott, B. W., Harless, M. W., Diagnostic Procedures for Organization Systems, School of Architecture, University of Illinois, Urbana-Champaign, Final Report, Contract No. MDA-903-81-M-7255, U. S. Army Research Institute for the Behavorial and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA, May, 1982.

7. Galbraith, J. R., Organization Design, Addison-Wesley Publishing Co., 1977.

8. Knuth, D. E., The Art of Computer Programming: Fundamental Algorithms, Vol. 1, 2nd Edition, Addison-Wesley Publishing Co., 1973.

9. Perlis, S., Theory of Matrices, Addison-Wesley Publishing Co., 1952.

10. Van der Waerden, B. L., Modern Algebra, Frederick Ungar Publishing Co., 1953.

11. Pasmore, W. A., Francis, C., Haldeman, J., and Shani, A. B., Sociotechnical Approaches to Organizational Change in USAREUR, U. S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA, September, 1980.