DIVISION OF ENGINEERING RESEARCH

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REPORT

A CONCEPTUAL FRAMEWORK

FOR

TRANSPORTATION RESEARCH

AT

THE MISSISSIPPI TEST FACILITY

OF

NASA

LOUISIANA
STATE
UNIVERSITY

A Conceptual Framework
for
Transportation Research
at
The Mississippi Test Facility
of
NASA

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

FIGURE		PAGE

ABSTRACT

In 1968 a preliminary study was made, by the authors of this report, to determine the utility of the Mississippi Test Facility from the standpoint of transportation research. As a result of that study it was concluded that the facility have potentials far beyond the transportation research facilities already established in the United States. It was also concluded, at that time, that the potential research areas should be delineated, organized in an efficient and logical manner, and be presented to interested parties for further consideration. However, a logical organization such as this requires, in turn, a logical regimentation of research problems.

Many research centers around the country have performed excellent research and produced very useful results, thus the question, also, arose whether a "center" in the magnitude of Mississippi Test Facility would be effective or not, or should a fresh approach be taken in solving the present and future transportation problems.

With the above ideas and the long range objectives of the Department of Transportation in mind it was decided to attempt to reach the overall goals of the initial study by using a systems approach.

A thorough study of the literature showed that most studies made up to date did not present the total system of transportation in a model where it could be separated into components and studied individually and then assembled into the total system for application.

Therefore, to achieve the stated goals, it was found necessary to develop a model of the transportation system. Since neither the

time nor monies allocated for this project would allow the development of the total transportation system, it was concluded that, initially a model for the ground transportation would be developed.

This model can serve multiple purposes such as it can be used to determine the various components of the system, the problems associated with each component and the relationship of these problems with the other components of the system, thus presenting a map from which research areas and proposals can be formulated and facilities and personnel needed can be determined. The model, if valid, can also be used for transportation systems planning and design.

This report presents the development of the system, the model and its use, in addition a description of the facilities and their potentials are also discussed.

CHAPTER I

INTRODUCTION

1.1 An Unbalanced Effort/Results Situation

The Transportation Department was established by the Department of Transportation Act of October 15, 1966. It "was created for the purpose of developing national transportation policies and programs conducive to the provision of fast, safe, efficient, and convenient transportation at the lowest cost consistent therewith."* Transportation requirements and problems have attracted an impressive level and scope of interest across the nation. Huge sums are spent annually on transportation research. For example, the estimated cost of federal-aid highway research and development studies in progress as of July 1, 1969 was $36,777,000.** The question is why, with so much effort being put forth, has relatively little progress been made toward problem solution? There are, of course, several possible reasons. One basic cause may be due to an unconscious omission of the study of structure in the application of a time-tested research strategy.

1.2 An Unconscious Omission--The Study of Structure

Transportation research, along with many other areas of science has long been under the strong influence of the doctrine that the best scientific research strategy is first to discover

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*United States Organization Manual 1969-70 (Washington, D. C.: G.P.O., 1969), p. 376.

**Highway Research and Development Studies (Washington, D.C.: G.P.O., 1969), p. 1.

the most basic, i.e., comparatively microscopic, set of relations, and once the discovery is made, then to set forth constructing less elementary, i.e., comparatively macroscopic (and therefore generally more complex) relations from the basic relations. This strategy has met with amazing success in physical sciences such as physics and chemistry but with relatively limited success in the field of transportation.

It is proposed that one basic cause may be due to an omission in the application of the research strategy rather than an error in the strategy itself. Consider the chemist asked to explain the behavior of a given compound. It is not surprising that the chemist, as a first step, begins to break down the compound into its component parts. It is not surprising because it is a foregone conclusion that he will try to explain the behavior of the compound in terms of the properties of its elementary parts.

Now consider the researcher asked to explain some particular aspect of transportation. Again, it is not surprising that he identifies the component parts, studies them, and then attempts to explain the behavior of the aggregate in terms of the behavior of the component parts.

The procedures seem to be the same but there is a difference. The chemist is required, because of a difference in observation points, to study the structure* of his compound while the transportation researcher is not required to study the structure of the transportation system and consequently does not.

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*Knowledge of structure implies knowledge of the relationships between components and their relation to the whole.

From the chemist's observation point (see Figure 1), he can view the macroscopic system under study. The identification of the component parts of the compound necessitates a detailed breakdown and analysis of compound structure. On the other hand, the

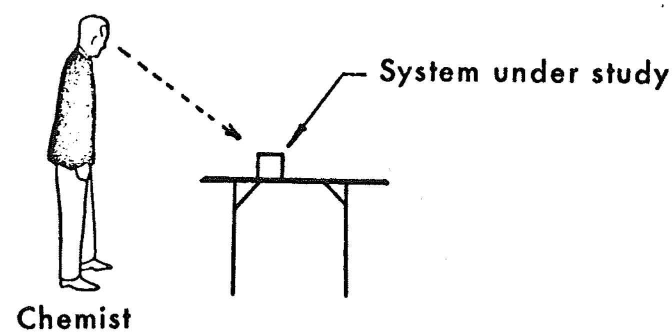

Fig. 1. The chemist's observation point.

transportation researcher, due to his observation point (see Figure 2), is able to observe the component parts (automobiles, highways,

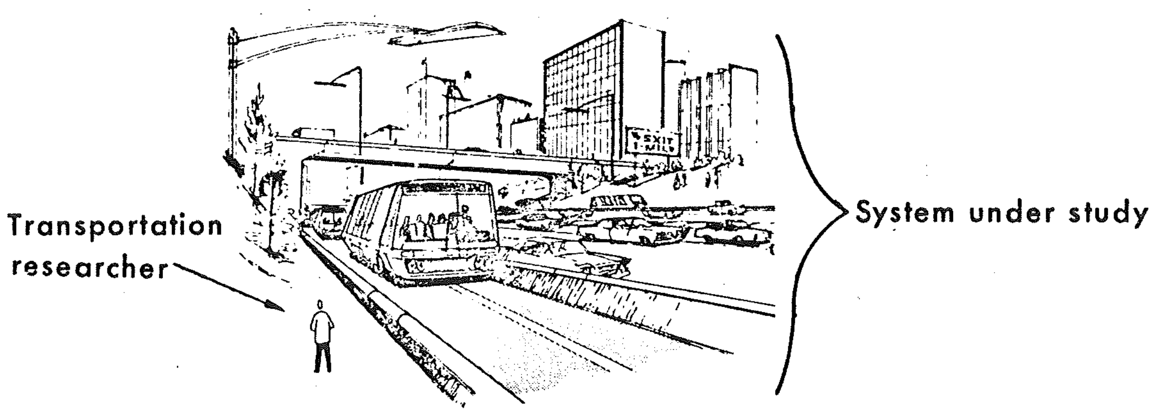

Fig. 2. The transportation researcher's observation point.

etc.) directly. The study of structure is not necssary to identify the component parts and is therefore usually omitted.

There is no way to prove that the amazing success of the physical sciences in going from the microscopic to the macroscopic is due to the study of structure. The implication is strong, however, since the study of structure in the physical sciences or lack of it in the transportation field seems to be the only real difference in the two research efforts. There is simply no law that ensures that once an understanding of the component parts of a system is acquired that an understanding of the aggregate will follow.

1.3 Purpose of the Study

The purpose of this study is to provide a general conceptual framework for the transportation system which would relate the various components of the system to a logical whole. (This is, in effect, determining the basic structure of the system.) The framework should allow those concerned with transportation not only to view the system as a whole, but also to view at the same time each component with reference to the whole and with reference to man.

The efforts will be directed primarily along the lines of cognition within a general systems approach.

CHAPTER II

THE SYSTEMS APPROACH

2.1 Systems Thinking

> "The needs of our actual life are so imperative, that the sense of vision becomes highly specialized in their service. With an admirable economy we see only so much as is needful for our purposes; but this is in fact very little, just enough to recognize and identify each object or person; that done they go into our mental catalogue and are no more really seen. In actual life the normal person really only reads the labels as it were on the object around him and troubles no further. Almost all the things which are useful in any way put on more or less this cap of invisibility."*
>
> --Roger Fry, 1866-1934

The systems approach is not new. It is simply the name given to the thinking process that attempts to throw away the "cap of invisibility" and to see things with reference to the whole and with reference to man. Aristotle warned his students about how they might fall into logical traps when confronted by various types of sophistry. Thomas Hobbes in the Leviathan, 1651, warned against incorrect definitions as starting points:

> "...For the errours of Definitions multiply themselves, according as the recokoning proceeds; and lead men into absurbities, which at last they see, but cannot avoyd, without reckoning anew from the beginning; in which lyes the foundation of their errours."**

In a more recent book entitled The Systems Approach, Churchman (1)*** writes:

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*As quoted by Ralph Borsodi in The Definition of Definition (Boston: Porter Sargent, 1967), p. 4.

**Ibid., unnumbered page opposite page 1.

***Numbers in parentheses refer to references given in the bibliography.

"We ought not to approach the world blindly, letting our observations and what other people tell us be the basis of our description. We shouldn't say that the world is made up of problems like poverty, health, education, and so on simply because these are the problems that everybody is talking about. We ought to ask ourselves at the very outset how to think about a large system, and our manner of thinking will dictate how we will describe the system. There are ways of describing systems that would not occur to most people who tend to look at the world in one way, namely, the way that is most familar to them. The systems approach will have to disturb typical mental processes and suggest some radical approaches to thinking. It may in fact be already quite radical for somebody to think first of all about the overall objective and then to begin to describe the system in terms of this overall objective.

"For example, if I ask you to describe an automobile, you may immediately switch off your thinking process and simply blurt out the things you recall about your own automobile--its wheels, engine, and shape. You start by saying, 'Well, an automobile is something that has four wheels and is driven by an engine.' I (in an attempt to switch on your thinking process) ask whether a three-wheel automobile is a possibility. You have seen one and will readily admit this change in your description, still without thinking much about the meaning of the change. I, becoming more belligerent, pursue the matter further and ask you whether a two-wheeled automobile is a possibility. You begin to look puzzled, thus indicating that your thinking has been turned on at a low voltage. I go on, being cheerfully disagreeable, and ask you whether an automobile without any wheels whatsoever is also a possibility. You become more puzzled and think not about automobiles but about silly question posers. Yet to consider the wheelless automobile is a creative way of looking at this system we call the automobile. It may be that the need for wheels is one of the major producers of traffic congestion and the inconvenience of the current automobile. An automobile that can float a few feet off the surface of the earth might provide a far more comfortable ride and produce far fewer problems of traffic congestion and even of accidents. And floating automobiles may be technically feasible in the future.

"The way to describe an automobile is <u>first</u> by thinking about what it is for, about its <u>function</u>, and not the list of items that make up its structure. If you begin by thinking about the function of the

> automobile, that is, what it is for, then you won't describe the automobile by talking about its four wheels, its engine, size, and so on. You will begin by thinking that an automobile is a mechanical means of transporting a few people from one place to another, at certain prescribed cost. As soon as you begin to think in this manner, then your 'description' of the automobile begins to take on new and often quite radical aspects. That's the systems approach to automotive transportation."*

There is of course, more to applying the systems approach to transportation than is revealed by Churchman's example. His comments do illustrate, however, the "free" thinking process required.

In applying the systems approach to transportation, it is necessary to first heed Hobbes' warning and establish a solid base in definitions. What is a problem? What is the transportation problem? What is a system? What is the transportation system? The remaining part of this chapter will be concerned with answering these questions.

2.2 A Problem

> Dr. Pell was want to say that in the Solution of Questions, the Maine Matter was the well-stating of them; which requires mother-witt & Logick....for Let the question be but well stated....it will work almost of itself: as for example, the most Difficult Problem, being thus stated; the working of it become very easie.**
>
> --John Aubrey, 1626-1697

A problem can be defined as a situation in which there are two states: One is characterized by the present state, the other by a proposed state. The present state is exemplified by the existing system; the proposed state is exemplified by the system that is hypothesized (desired) or proposed. In both states, there is a set

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*C. West Churchman, The Systems Approach, (New York: Delacorte Press, 1968) pp. 12-13.

**As quoted by Ralph Borsodi in the Definition of Definition (Boston: Porter Sargent, 1967), p. 1.

of objects, attributes, and relationships interlocked in a process. Each state may be considered a system.

The present state (existing system), as in all other systems, may contain both knowns and unknowns; that is, the existence of an unknown may not hamper the ability of a system to function. The existing system may be rational but incapable of meeting a restriction. Thus, system performance alone is not the ultimate criterion of excellence, since some ideally performing systems (from a technological standpoint) may not meet objectives. Objectives are definable only in terms of systems requirements.

Systems requirements are the means of fixing unambiguous statements of objective. Since systems requirements are stated in terms of objects, attributes, and relationships, objectives may be identified in terms of a desired state. The objective and the desired state for a given set of systems requirements may be one and the same.

The difference between existing and desired systems creates what is loosely identified as a problem. Thus, formulation of a problem involves identification of both the existing state and the desired state and then recognizing the difference between the two.

Successful formulation of a problem is tantamount to "partially solving" the problem. For this reason, the analyst places emphasis on the early appraisal of parameters, properties, and relationships of a given problem. It is not always possible to bring to a problem a "ready-made" objective, for example, the objective expressed may prove insufficient. "Partially solving" problems does not mean that the problem is truly solved, but that the fundamental elements of the problem are properly identified and related.

The formulation of a problem is also called its definition. The goal is to state the nature of the problem in terms that are known, as opposed to terms that are unknown. For example, consider the problem: The transportation system is too expensive. The analyst must first examine each facet of the problem statement to determine the parts of the problem that are known and the parts that are unknown. The term "transportation system" means different things to different people: To a mass transit user, the transportation system may be the subway system; to the city planner, the term has a much broader meaning. Likewise, "too expensive" is also ambiguous. Too expensive for whom, the user or the state? Unless the terms are known, the problem solver's task may be made more complex by the statement of the problem.

Problem statements should also be free of built-in potential solutions. For example: An administrator may ask how many routes must be discontinued to reduce mass transit cost by one-half. The goal of reducing mass transit cost by one-half may be accomplished in several ways. Some combination of changes in equipment, personnel and routes may be more advantageous than the built-in solution of a reduction of routes.

Problems can be classified as either "structured" or "ill-structured." Problems of long range, problems whose solutions depend upon hardware as yet undeveloped, and problems that hypothesize the integration of systems as yet undentifiable in the existing scene are ill-structured. Ill-structured problems are generally "solved" by postulating relative values rather than absolute values.

When an ill-structured problem is recognized, a preliminary study effort may be required. By starting a complex problem analysis with a preliminary study, a natural, convenient stopping place at which to assess the position is provided. A preliminary study to define the problem may provide a middle ground to which all parties to a dispute may agree. In any case, the initial step in problem analysis is to formulate the problem.

2.3 A System

> Make for thyself a definition or description of the thing which is presented to thee, so as to see distinctly what kind of thing it is in its substance, in its nudity, in its complete entirity, and tell thyself its proper name, and the names of the things of which it is compounded, and unto which it will be resolved. For nothing is so productive of elevation of mind as to be able to examine methodically and truly every object which is presented to thee in life, and always to look at things so as to see at the same time what kind of universe this is, and what kind of use everything has with reference to the whole, and what with reference to man.*
>
> --Marcus Aurelius, 121-180

The word "system" has been defined in many different ways. The definition formulated by Hall and Fagen (2) seems to be the most complete and useful to date. It is presented below:

> "A system is a set of objects together with relationships between the objects and between their attributes."**

In order to reduce the vagueness inherent in the definition, the terms objects, relationships, and attributes will be considered separately.

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*As quoted by Ralph Borsodi in The Definition of Definition (Boston: Porter Sargent, 1967), p. 3.

**A. D. Hall and R. E. Fagen, "Definition of System," General Systems Yearbook, I (1956) p. 18.

Objects

Objects are the parts or components of a system. The variety of these parts is unlimited. Most systems consist of physical parts: atoms, stars, switches, masses, springs, wires, etc. Abstract objects such as mathematical variables, equations, rules and laws, processes, etc., may also be considered objects of a system.

Attributes

Attributes are properties of objects. For example, the objects listed in the preceeding section have among others, the following attributes:

Atoms - The number of planetary electrons, the energy states of the atoms, the number of atomic particles in the nucleus, the atomic weight

Stars - temperature, distances from other stars, relative velocity

Switches - speed of operation, state

Masses - displacement, moments of inertia, momentum, velocity, kinematic energy, mass

Springs - spring tension, displacement

Wires - tensile strength, electrical resistance, diameter length

Relationships

The relationships are what "tie the system together." It is, in fact, these relationships that make the notion of "system" useful.

For any given set of objects it is impossible to say that no interrelationships exist since, for example, one could always consider as relationships the distances between pairs of the objects. Relationships to be considered in the context of a given set of objects depend on the problem at hand, important or interesting relationships being included, trivial or unessential relationships excluded.

2.4 Example of a Physical System

First, suppose the parts are a spring, a mass, and a solid ceiling. Without the obvious connections, these components are unrelated (except for some logical relationships that might be thought of, such as being in the same room, etc.). But hang the spring from the ceiling and attach the mass to it and the relationships (of physical connectedness) thus introduced give rise to a more interesting system. In particular, new relationships are introduced between certain attributes of the parts as well. The length of the spring, the distance of the mass from the ceiling, the spring tension and the size of the mass are all related. The system so determined is static; that is the attributes do not change with time. Given an initial displacement from its rest position however, the mass will have a certain velocity depending on the size of the mass and the spring tension; its position changes with time, and in this case the system is dynamic.

2.5 Definition of Environment

Hall and Fagen (2) also provide a useful definition of environment. They define environment in a manner quite similar to that used to define system.

> "For a given system, the environment is the set of all objects a change in whose attributes affect the system and also those objects whose attributes are changed by the behavior of the system."*

The statement invites the natural question of when an object belongs to a system and when it belongs to the environment; for if an object

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*A. D. Hall and R. E. Fagen, "Definition of System," General Systems Yearbook, I (1956) p. 20.

reacts with a system in the way described above should it not be considered a part of the system? The answer is by no means definite. In a sense, a system together with its environment makes up the universe of all things of interest in a given context. Subdivision of this universe into two sets, system and environment, can be done in many ways which are in fact quite arbitrary. Ultimately it depends on the intentions of the one who is studying the particular universe as to which of the possible configurations of objects is to be taken as the system.

2.6 Defining a Particular System

In order to define completely a particular system, it is necessary to identify the objects that make up the system, and to delineate their attributes and the relationships between objects and between attributes of particular objects. Complex systems, such as socio-economic systems, which are made up of a large number of parts with complex relationships, may never be completely defined in this sense. The degree to which the definition is carried depends upon the benefits to be derived. It may be enough to simply identify the objects of one system while it may prove beneficial to formulate complex mathematical models of the relationships of another. Regardless of the degree to which the definitions may eventually be carried, the first step in defining any one particular system is the identification of the objects of which it is composed.

2.7 Formulating the Problem - Concept of the System

Formulating the transportation problem along the guidelines set down in Section 2.2 involves the identification of both the existing state and a desired state of the transportation system. Using blocks to represent these two states, the situation can be depicted as shown in Figure 3.

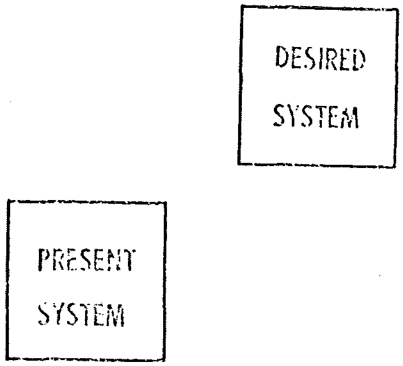

Fig. 3. The present state and a desired state of the transportation system.

The block labeled "PRESENT SYSTEM" represents the transportation system at the current point in time. Its complete description (definition) would involve the identification of elements, their attributes, and the connecting relationships in the sense discussed in Section 2.6. The block labeled "DESIRED SYSTEM" represents a "better" system than the present system. The most desirable transportation system will be called the "IDEAL SYSTEM". The ideal system may be described only in general, though absolute terms, according to current ideals in transportation. It may be described as the least expensive, safest, most convenient, etc. This ideal system is considered to be at the end of a long progression of "more desirable" systems (see Figure 4) stemming from the present system.

This allows the transportation system to be viewed as a large evolving system. Whenever there is a change in any of the major components of the system, the system evolves to a new state. The state of the system at a given moment is now defined as the total set of measurable characteristics that the system exhibits at that moment.

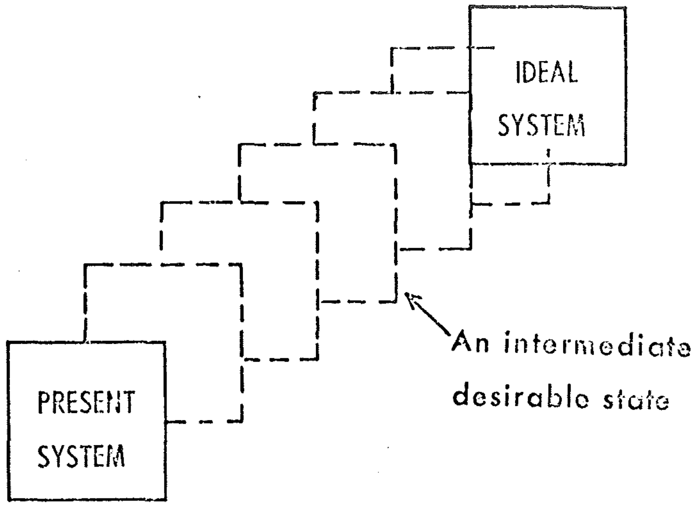

Fig. 4. The progression of states toward the ideal state.

Each state can be considered a separate system. The present transportation system is considered to have evolved from a feeble horse-and-buggy beginning. The system is constantly changing and it is assumed that each new state will be closer to the ideal state although there is no assurance, at present, against a "backward" evolutionary change (a change to a less desirable state). This concept of the transportation system (see Figure 5) provides a perspective from which all past and present "occurrences" in transportation can be viewed, analyzed, and explained.

2.8 Statement of the Transportation Problem

The above concept of the transportation system allows for a relatively simple statement of the general problem:

THE PRESENT TRANSPORTATION SYSTEM IS NOT PERFORMING EXACTLY AS DESIRED

In other words, the present system and the ideal system are not one and the same. The statement is free of built-in potential solutions and so meets one of the requirements of Section 2.2. However, it is not free of unkonwns. Neither the present state nor the ideal state have been defined to a useful degree.

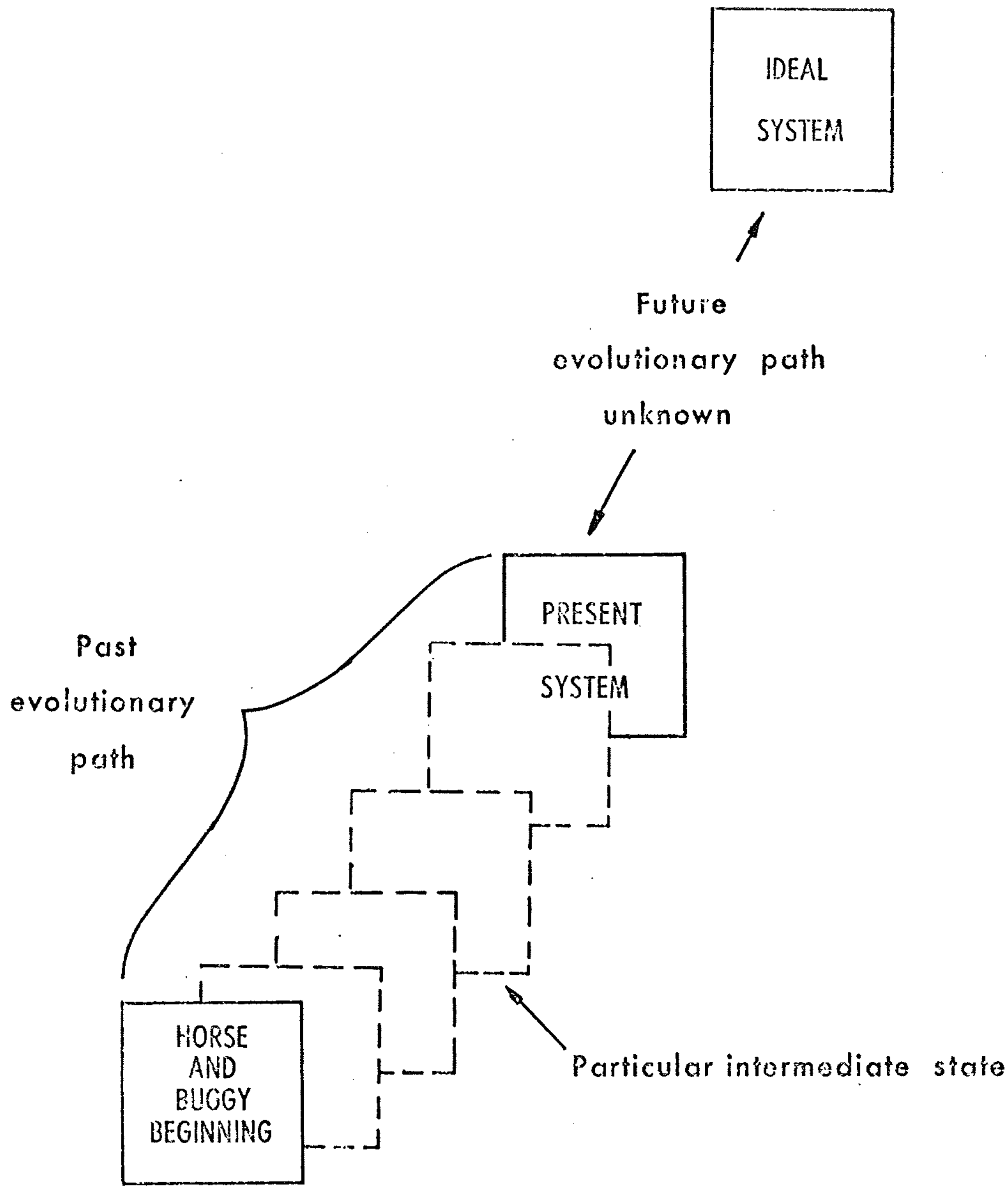

Fig. 5. The evolving transportation system.

CHAPTER III

DEFINING THE TRANSPORTATION SYSTEM

3.1 A Starting Point

The first step in defining any system is the identification of its elements. It has been recognized that the various elements employed to produce transportation often display marked similarity. Statements of general groupings of elements along functional guidelines have appeared occasionally in the literature. As early as 1870, in an article entitled "The Science of Transportation", Potts (3) proposed two general groupings, way facilities and vehicles. Way facilities included links, intersections of routes, and terminals. Vehicles included locomotives, freight cars, etc. reflecting the importance of rail transportation to that era.

In 1894 Cooley (4) wrote on "The Theory of Transportation" in which he divided a modal system into a number of elements--the way facilities, vehicles, and motive force. It is interesting to note that like Potts, he makes no mention of any control system, apparently indicating the infantile state of transportation.

More recent statements as to the elements of a transportation system include those by Hay (5), Manheim (6), and Morlok (7). The elements proposed by Hay and Morlok are essentially the same, being: (a) the way links, (b) the way interchanges (or intersections), (c) the terminals, (d) the vehicles, and (e) the control system. Manheim's elements are, (a) the persons and things being transported, (b) the vehicles in which they are conveyed, and (c) the networks through which the vehicles move.

All of the authors mentioned above proposed general groupings of elements as part of their definition of the transportation system. Their primary purpose was to define the transportation system from a semantics standpoint. Manheim realized that definitions of this type have "several important implications for analysis" but, by his own words, his purpose in naming the elements was "to establish what we mean by a transportation system." Although semantics is important, and it will be discussed further in this report, whenever elements are identified for the express purpose of defining the system, there are certain "finality" implications. The underlying purpose in formulating a definition of the transportation system should be to provide a starting point for problem solution. Thus, future utility must be considered paramount in the identification of elements.

3.2 The Trip Concept

Efforts to avoid the "finality" trap led to the formulation of the "trip concept."* In much the same way that an atom can be considered the basic building block of matter, a "trip" will be considered the basic building block of the transportation system.

A "trip" is defined as any combination of seven elements, at least one element from each general group.

The general groupings of elements are:

1. ORIGIN - The location of the object to be transported at the beginning of the trip.

2. OBJECT-TO-BE-TRANSPORTED - The person or thing to be transported.

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*The Trip Concept, and its relation to the system as a whole, will be discussed in more detail in Chapter VI.

3. CONVEYANCE - The device which is the interface between the object-to-be-transported, (OTBT) and the way system. An OTBT may serve as its own conveyance.

4. CONVEYANCE CONTROLLER - The device that regulates the degrees of freedom in the province of the conveyance. An automobile (the conveyance) normally has two degrees of freedom; its lateral direction and speed. The device which regulates its direction and speed (normally a man) is the conveyance controller.

5. THE WAY - The path traversed by the OTBT in moving from its origin to its destination.

6. REGULATING SYSTEM - The set of devices (laws, traffic signs, police, etc.) which provide for the efficient and rational operation of the system.

7. DESTINATION - The location of the OTBT at the end of the trip.

To illustrate, consider the trip made by John Doe in driving to work. This trip is one particular combination of basic elements which fit under the general groupings as follows:

1. ORIGIN - John Doe's home.

2. OTBT - John Doe himself.

3. CONVEYANCE - John Doe's car.

4. CONVEYANCE CONTROLLER - John Doe himself.

5. THE WAY - The particular combination of links and intersections traversed by John Doe in going from his home to his work location.

6. REGULATING SYSTEM - The laws, traffic signals, police, etc. which have bearing on John Doe's particular trip.

7. DESTINATION - John Doe's work location.

Any trip can be broken down and its elements fitted into the general groupings. The term origin contains all locations where a trip can originate; OTBT contains all objects that can be transported; conveyance includes all objects that can act as a conveyance; etc. Thus, all the objects (with their attributes) from the seven general groupings make up the static transportation system. The conglomeration of all trips make up the dynamic system.

Even though the general groupings contain all the objects of the transportation system, the objects themselves have not been identified to any useful degree. This can best be done by decomposing the system by making use of the hierarchical nature of complex systems.

3.3 Hierarchic Nature of Transportation System

General systems theorists, H. A. Simon (8), Masanao Toda (9), and Emir H. Shuford, Jr. (9) being prominent among them, have recognized that complex systems (social, biological, physical, etc.) display a common property, i.e., a hierarchical structure. A hierarchic system is composed of interrelated subsystems, each of the latter being, in turn, heirarchic in structure until some lowest level of elementary subsystem is reached. In most systems in nature, it is somewhat arbitrary as to where to stop partitioning, and what subsystems to take as elementary. Physics makes use of the concept of "elementary particle." For certain purposes of astronomy, whole stars, or even galaxies, can be regarded as elementary subsystems. In one kind of biological research, a cell may be treated as an elementary subsystem; in another, a protein molecule; in still another, an amino acid residue. Simon (8) takes up the question as to why a scientist has a right to treat as elementary a subsystem that is in fact exceedingly complex. For the purpose of this study, however, it is sufficient to say that the level of analysis determine the level of decomposition to be taken as elementary. For city-wide transportation planning or analysis, an entire school may be considered an elementary origin. Within the school itself, however, individual buildings may be the elementary origins and within a specific building, the classrooms may be the origins. Thus, a decomposition of the general term origin can always be carried to the desired degree and it is neither necessary nor desirable to identify any particular level as being the most elementary.

Almost all systems can be decomposed so one need not worry about the possibility of decomposing the transportation system. In fact, the first level in a decomposition has already been specified (see Figure 6). An important point to bear in mind is that, as a rule,

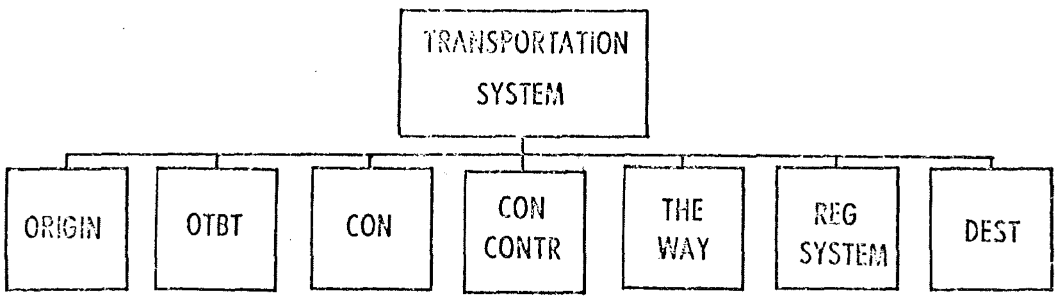

Fig. 6. The first level of decomposition of the transportation system.

there is more than one way of decomposing a given system. For example, a computer system may be decomposed into its major physical components, e.g. the central processor unit, card read-punch unit, and high-speed printer. Or it may be decomposed into operational subsystems, e.g. input, arithmetic unit, control unit, memory, and output. Each decomposition produces a different set of parts with a specific degree of utility for a given purpose. For example, the element "trucks" is likely to appear at some level in the decomposition of conveyance (see Figury 7). "Trucks" can be decomposed according to color, e.g. all

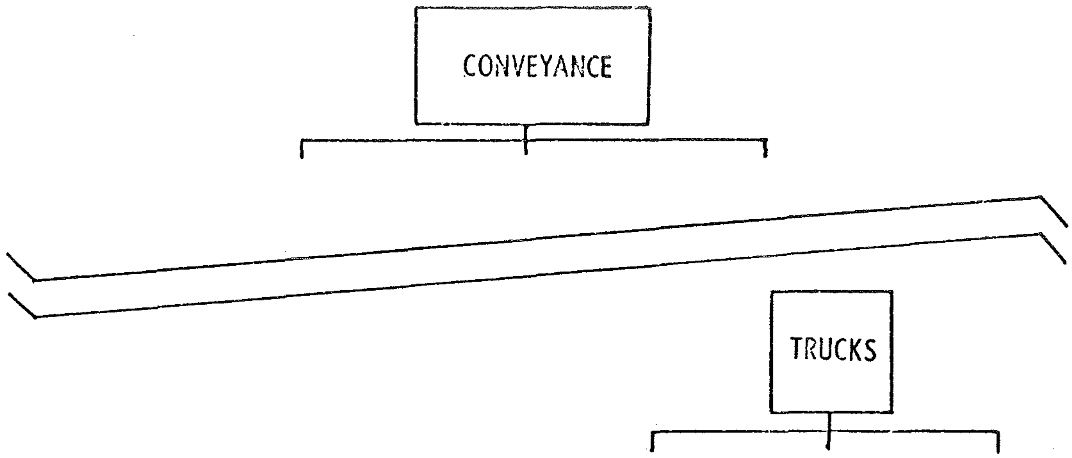

Fig. 7. The element 'trucks' is likely to appear at some level in the decomposition of CONVEYANCE.

green trucks grouped together, all red trucks grouped together, etc. If the primary concern is with aesthetics then such a breakdown may be the most useful. If, however, the primary concern is with trucks as functioning conveyances, a breakdown by type (van, wrecker, etc.) will have much greater utility. This fact provides the first basic guideline for a meaningful decomposition of the objects of the transportation system.

GUIDELINE I:

The decomposition of the objects of the transportation system should be along the lines of greatest overall utility. Such a policy involves considerable compromise. Any one breakdown will have a different degree of usefulness to planners, manufacturers, traffic analyst, etc. The best breakdown is the one that optimizes the overall utility.

GUIDELINE II:

The decomposition must be such that the subsystems generated are mutually either locationally disjunct or functionally disjunct

(9). This means that each element or subsystem must have a separate function or function in a separate space. Consider the decomposition shown in Figure 8. A further breakdown would reveal that the "pick-

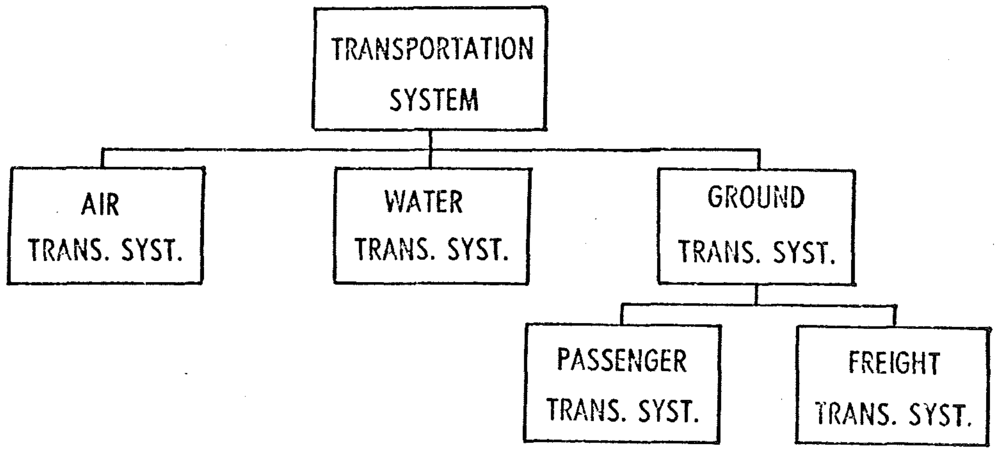

Fig. 8. An invalid decomposition.

up truck" appears below "Passenger System" and below "Freight System" in the same context, that is, functioning as a conveyance in the same space. This is a violation of the disjunctness requirement and invalidates the breakdown.

CHAPTER IV

IDENTIFYING THE ELEMENTS OF THE PRESENT AND IDEAL STATES OF THE TRANSPORTATION SYSTEM

4.1 The Present System

In order to demonstrate the feasibility of identifying objects of the present transportation system along the guidelines set down in the previous chapter, a partial decomposition was made. Since the major area of interest is with ground transportation, the decomposition centers around the common trip of a human being being transported over land by common land conveyances. The elements of any trip, however, be it by land, sea, or air could be located on the complete breakdown.

Whenever possible, classifications (sub-groupings) were adopted in line with the highest, and normally the most general, agency. This was, in most cases, the United States Government. In several instances where no previous classifications could be found, original groupings were made with the two guidelines of utility and disjunctness in mind. Formulating new groupings often involved formulating new "names" as well. Whenever a new name is used, it will be defined. Definitions or explanations of the remaining terms can be found by referring to the referenced sources.

It should be kept in mind that the partial decomposition is presented to demonstrate feasibility. Decompositions of greater utility can no doubt be realized. All anticipated users should be consulted and compromises made where necessary. This exercise, which is in effect deciding which attributes of an object are most important from an overall system standpoint, is extremely rewarding.

In fact, a decomposition of the type presented has several useful features other than just the identification of objects. This follows naturally, of course, if a starting point, as discussed in Chapter III, is actually provided. The added features will be discussed in Chapter VI.

4.2 The Decomposition

The first level of the hierarchic decomposition, already discussed, is presented again in Figure 9. For ease of presentation,

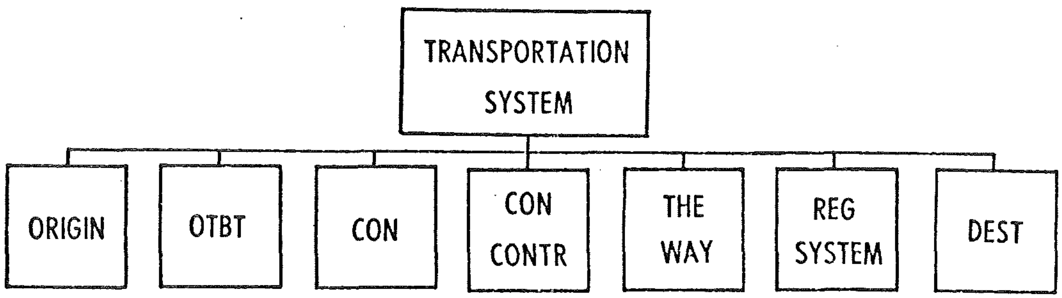

Fig. 9. The first level of the hierarchic decomposition.

all groupings, regardless of level, will be referred to as elements. The seven general groupings will be called the major elements. All elements lower on the hierarchic decomposition "tree" and stemming from a particular element will be called subordinate elements to the particular element.

For the identification of particular elements, a numerical labeling scheme has been devised. The seven major elements are numbered by increments of ten from 10 to 70. All subordinate elements of any particular element are numbered from 01 up to 99. Any element may have up to 99 subordinate elements (see Figure 10). The numerical designation of a particular element is the sequence of two digit numbers obtained by tracing the path from the major element down to the particular element. For example, the numerical designator of element "D" in Figure 10 is 100301.

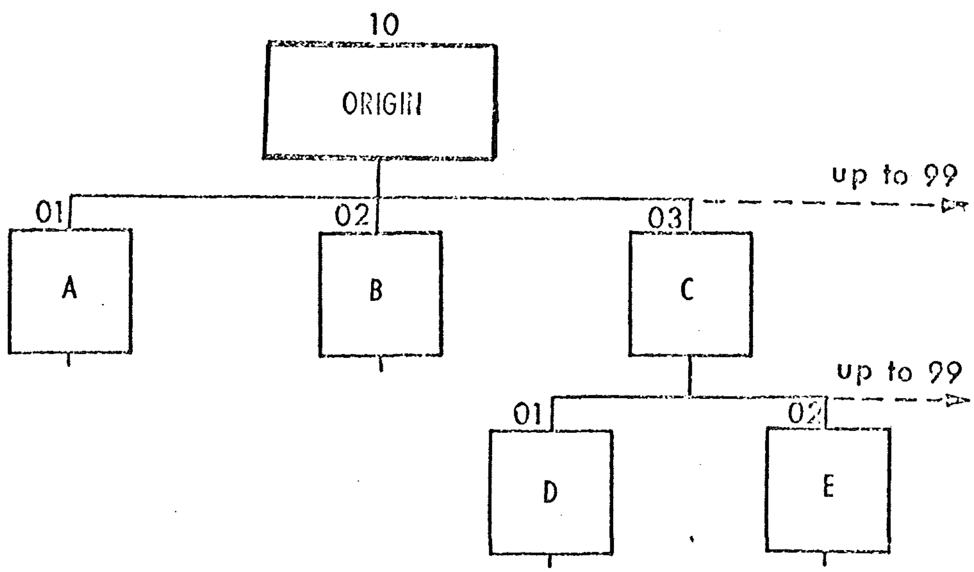

Fig. 10. The numerical designator scheme.

The system is not restrictive as it permits one to select the level of detail considered most appropriate. Also, it permits the use of additional subdivisions in adopting a standard decomposition*, while still retaining the basic framework.

4.2.1 Origin

Figure 11 shows, in chart form, a partial decomposition of the major element, ORIGIN. A more complete decomposition is given in outline form in Appendix II. The reference numbers given in Figure 11 (REF. 10040101, for example) refer to the element on the outline

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*The advantages of a standard decomposition will be discussed in chapter VI.

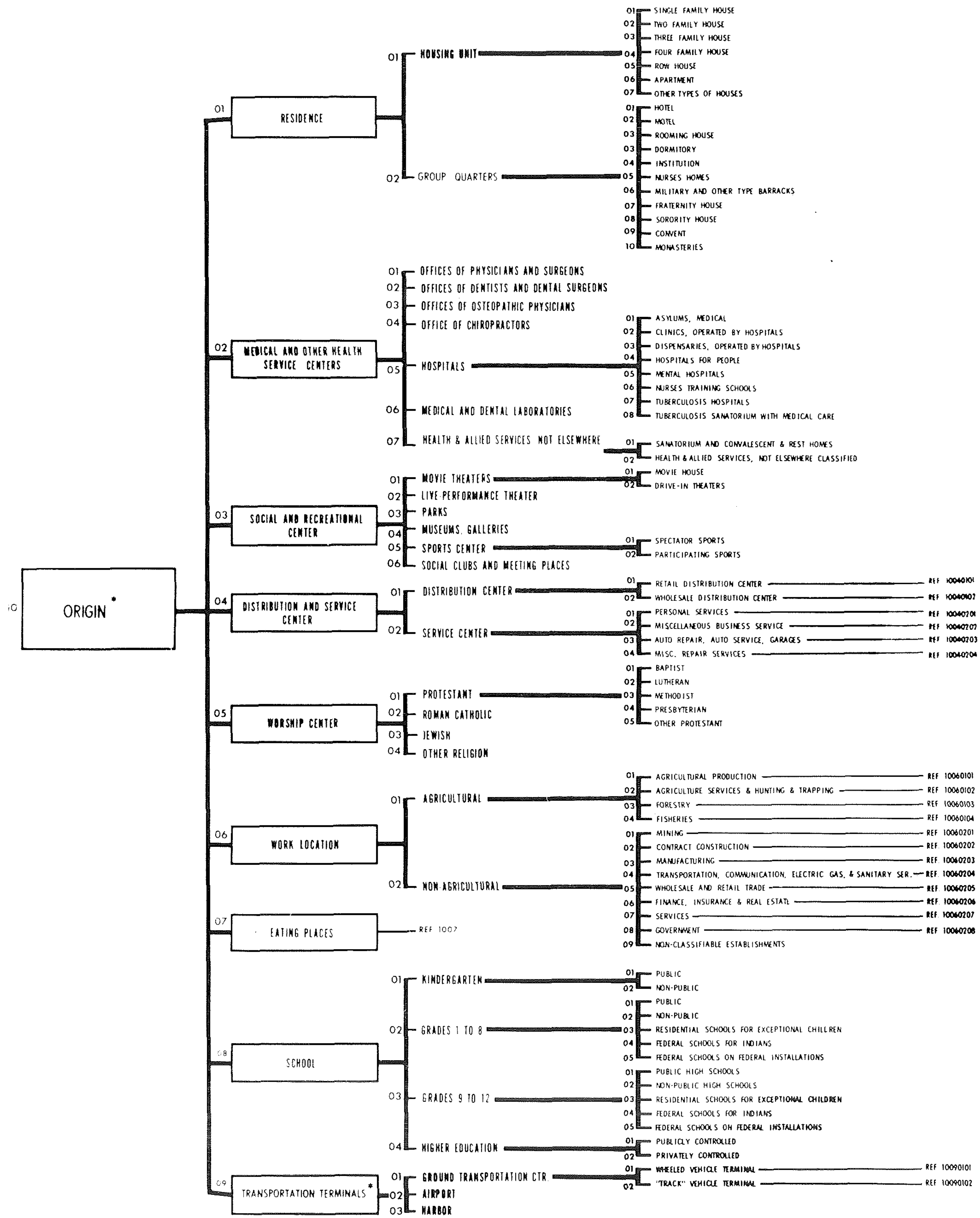

Fig. 11. A partial decomposition of the major element, origin.

*Elements defined in Appendix I.

where the decomposition is continued.

Several levels of decomposition could be included between the major element and the first level of decomposition shown in Figure 11. It may be useful to start with the United States and go down through regions, states, cities, and neighborhoods before getting to the Residence [1001]*, ..., Transportation Terminals [1009], level. Each level will have a different degree of usefulness depending on the level of analysis.

The major references for this decomposition were the <u>1967 Standard Industrial Classification Manual</u> (10), the <u>1968 Statistical Abstract of the United States</u> (11), and the <u>1960 U. S. Census of Housing</u> (12).

4.2.2 Object to be Transported (OTBT)

No references could be located to aid in the decomposition of the OTBT. The decomposition (Figure 12) is, therefore, limited but sufficient to demonstrate the considerations for making such a breakdown. All objects that can be transported were divided into two major groups; live cargo and goods. Several other classification are possible. However, when considering all things in light of their characteristics as objects to be transported, the presence or absence of life was deemed most important. All live cargo requires some life sustaining environment and this fact has considerable bearing on the design of other elements of the system, the conveyance in particular.

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*Numbers in brackets refer to the numerical designator of element

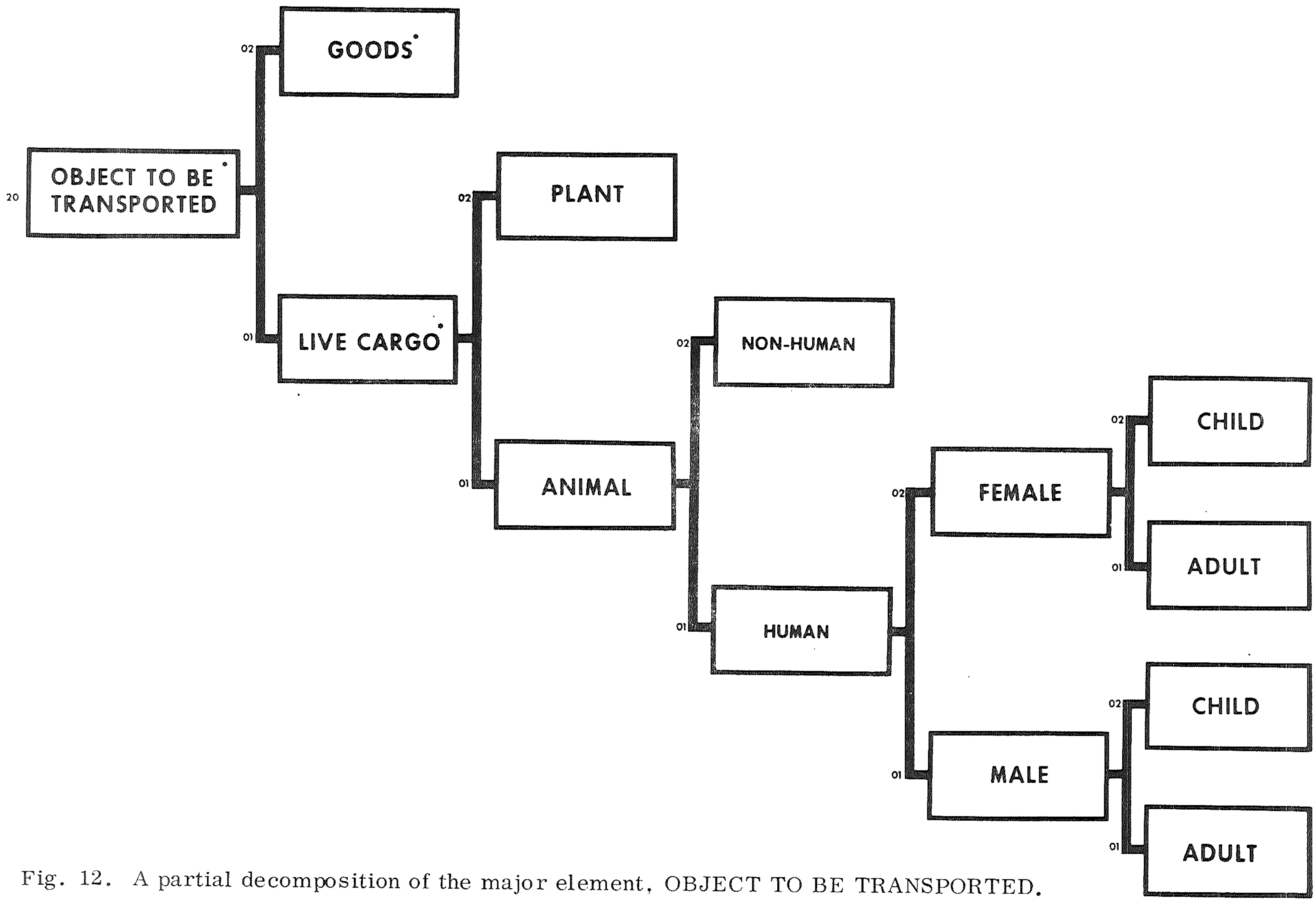

Fig. 12. A partial decomposition of the major element, OBJECT TO BE TRANSPORTED.

Because attention is directed toward the transportation of human beings, only the "live cargo" branch is developed. However, the transportation of goods is also important. A large percentage of all conveyances are designed around the transporting characteristics of goods (i.e., size, weight, value, etc). Subordinate elements for goods are suggested by the conveyances used to transport them: refrigerated vans are used to transport "perishable" goods; lowbeds are used to transport "heavy" equipment; etc. Decisions as to major subdivision of goods should not be made, however, without first making a comprehensive study of all facets (goods themselves, conveyances, laws, etc.) of the goods transportation system.

Under "live cargo" the subordinate elements are "animal" and "plants"; under "animal", they are "human', and "non-human". The breakdown under "human" is for demonstration only as deciding among the many transporting characteristics of human beings (size, state of health, etc.) would also require a comprehensive study.

4.2.3 Conveyance

The partial decomposition of the major element conveyance is given in Figure 13. The decomposition of Landcraft [300102] involved formulating two new terms, "Free" conveyance [300101] and "Guilded" Conveyance [300103]. A "free" conveyance is a conveyance which has "direction" as a degree of freedom. A "guided" conveyance is a conveyance which does not have "direction" as a degree of freedom. Automobiles and airplanes are "free" conveyances while railway trains, whose direction is determined by the way on which they travel,

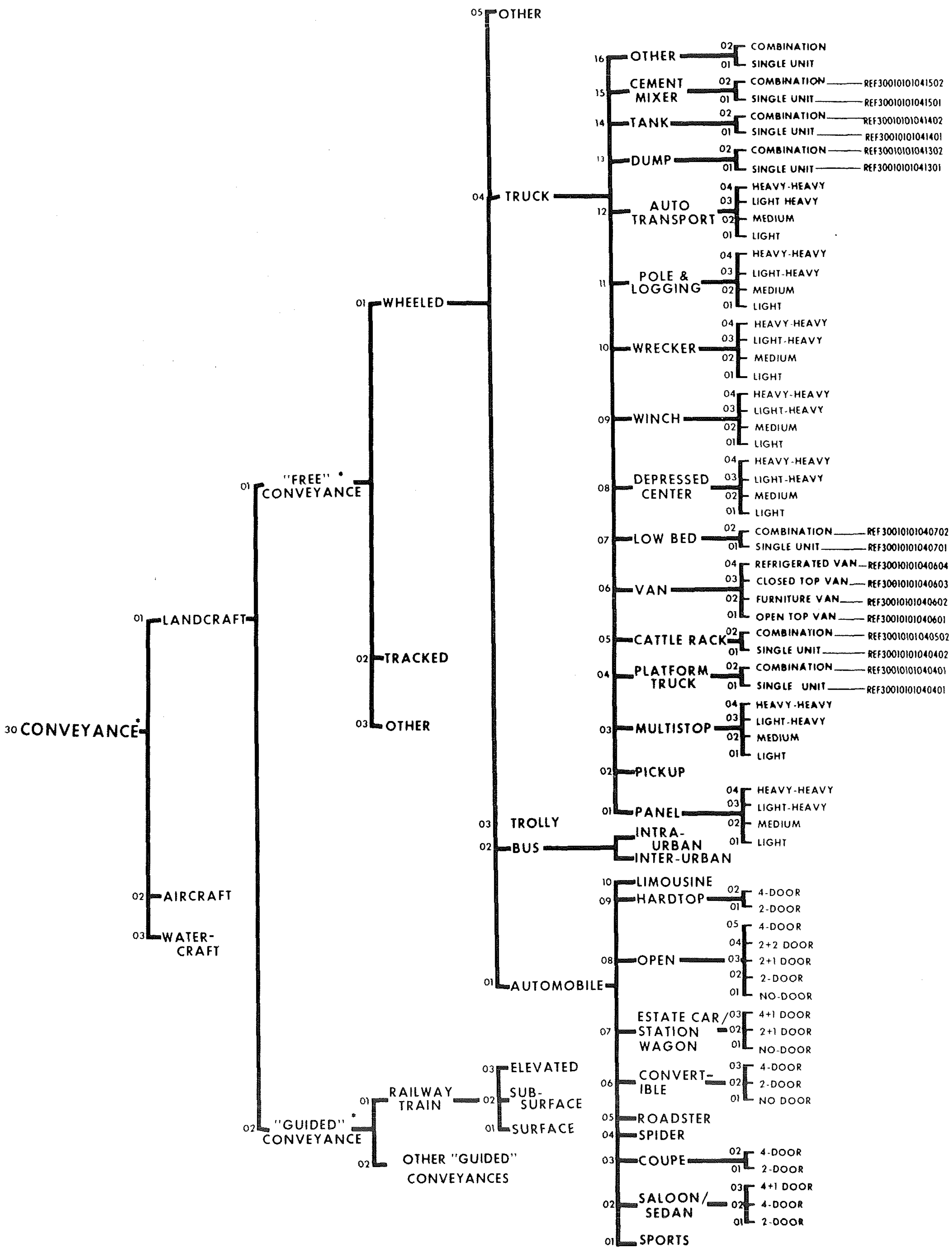

Fig. 13. A partial decomposition of the major elements, CONVEYANCE.

are "guided" conveyances. Under "free" conveyance, the term Tracked [30010102] refers to track-laying vehicles such as combat tanks, bulldozers, etc.

It is interesting to note that for the decomposition of Automobile [3001010101] no breakdown of high utility could be located. Automobiles could be grouped by manufacturer (Ford, Chevrolet, etc.), by price range (economy, medium priced, etc.), or by several other criteria. However, knowing the manufacturer reveals little about the automobile as a conveyance. Also, it reveals very little about the other elements of the system with which the particular automobile is likely to combine to form a trip. Grouping automobiles by price range was rejected because of the anticipated difficulty of actually classifying automobiles by these criterion. A luxury car may have an "economy" price tag once it is considered used.

The breakdown by body type according to the Automobile Club d'Italia World Car Catalogue (13) had the highest utility of classifications considered. Knowing that the conveyance is a sports car implies something about its size and handling characteristics. It also gives considerable information about the probable conveyance controller. Insurance companies have recognized these facts.

The 1963 Census of Transportation (14) along with the World Car Catalogue were the major references for the decomposition of Conveyance.

4.2.4 Conveyance Controller

The partial decomposition of the major element Conveyance Controller is given in Figure 14. All conveyance controllers were

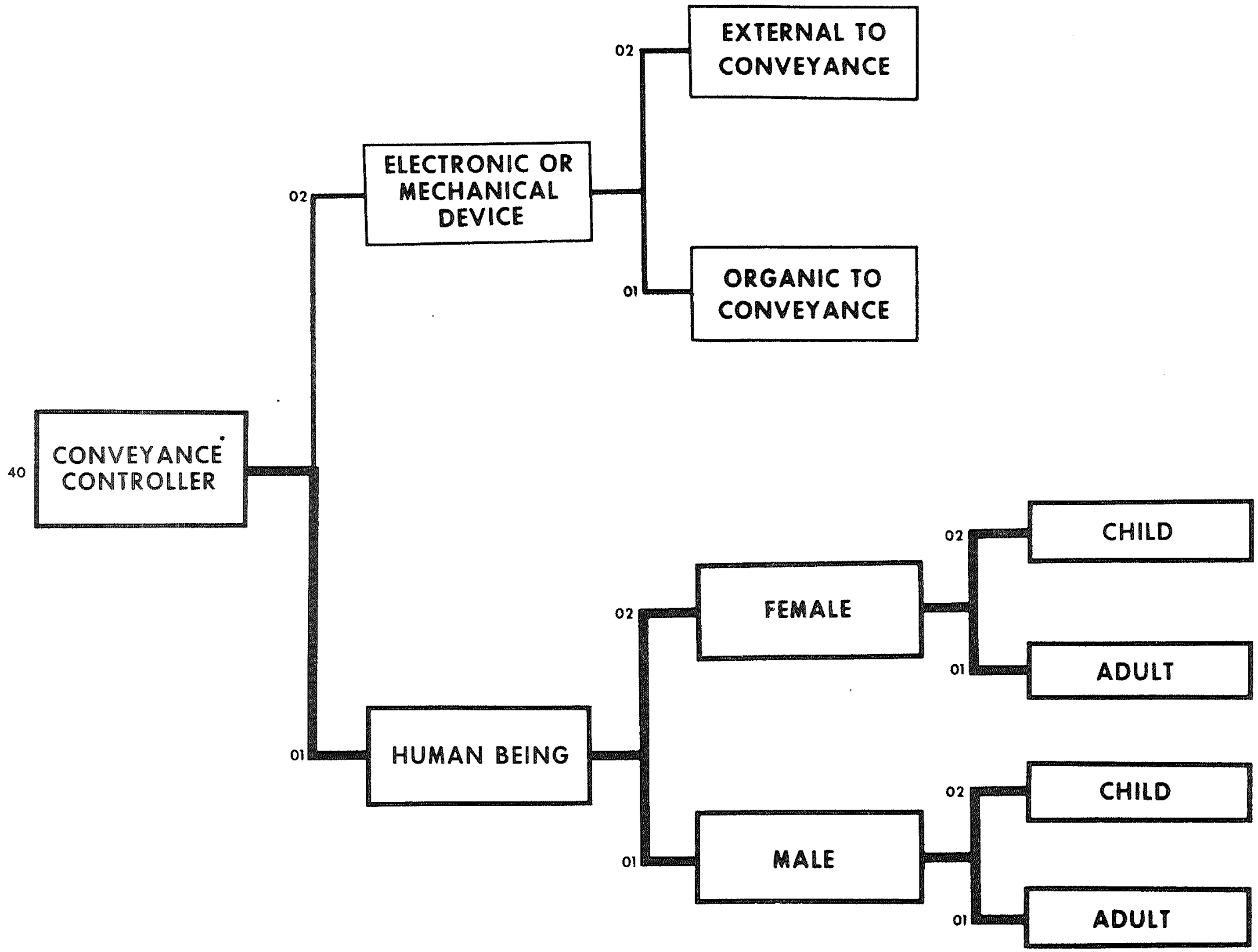

Fig. 14. A partial decomposition of the major element, CONVEYANCE CONTROLLER.

divided into two groups, Human Being [4001] and Electronic or Mechanical device [4002]. An automatic pilot is an example of an electronic device serving as a conveyance controller.

The decomposition of Human Being is for demonstration as a comprehensive study would be required to formulate a decomposition of high utility. A human being has many attributes which effect his ability to function as a conveyance controller. Some, such as vision, hearing, and reaction time, are easily quantifiable while others, such as judgement are not. Several indicators (age, sex, marital status) are used to reflect on a person's ability to operate an automobile "successfully". Because of ease of classification and relatively high utility, decomposition according to such "indicators" may prove most advantageous. However, further research is needed.

4.2.5 The Way

The partial decomposition of The Way is shown in Figures 15, 16, and 17. The two major subordinate elements are The Way Links [5001] and The Way Intersections [5002]. Most terms are self

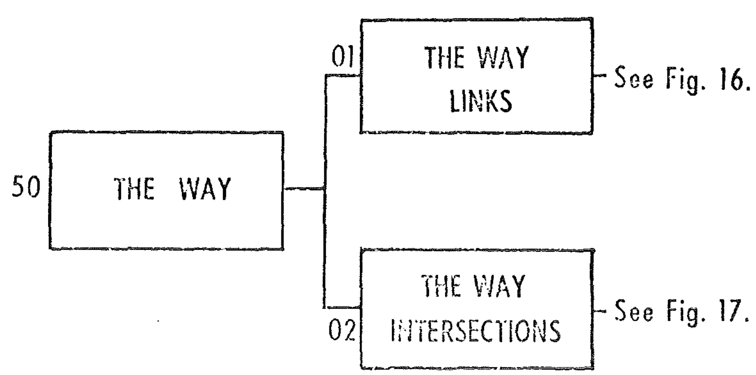

Fig. 15. The two major subordinate elements of THE WAY.

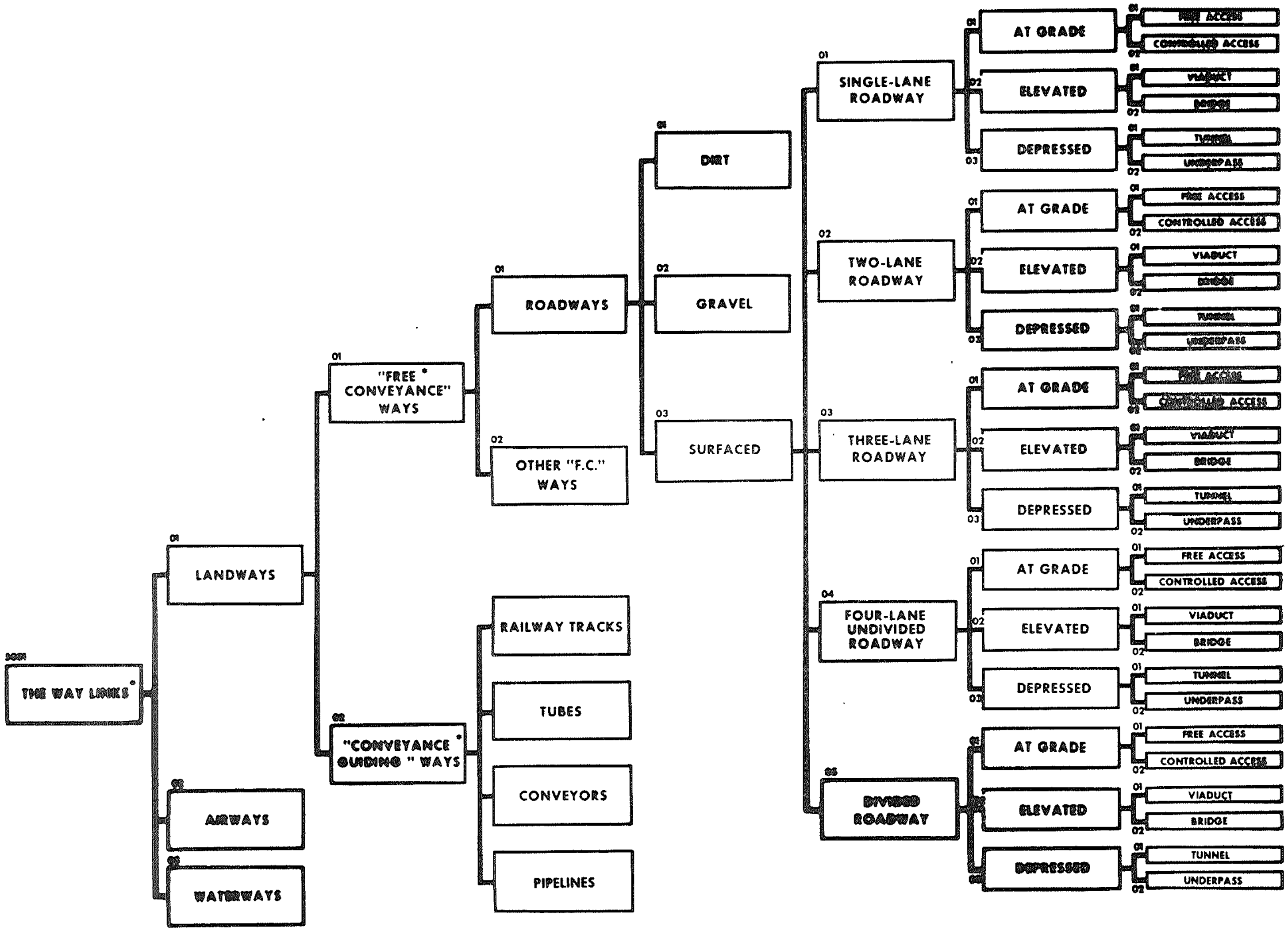

Fig. 16. A partial decomposition of THE WAY LINKS.

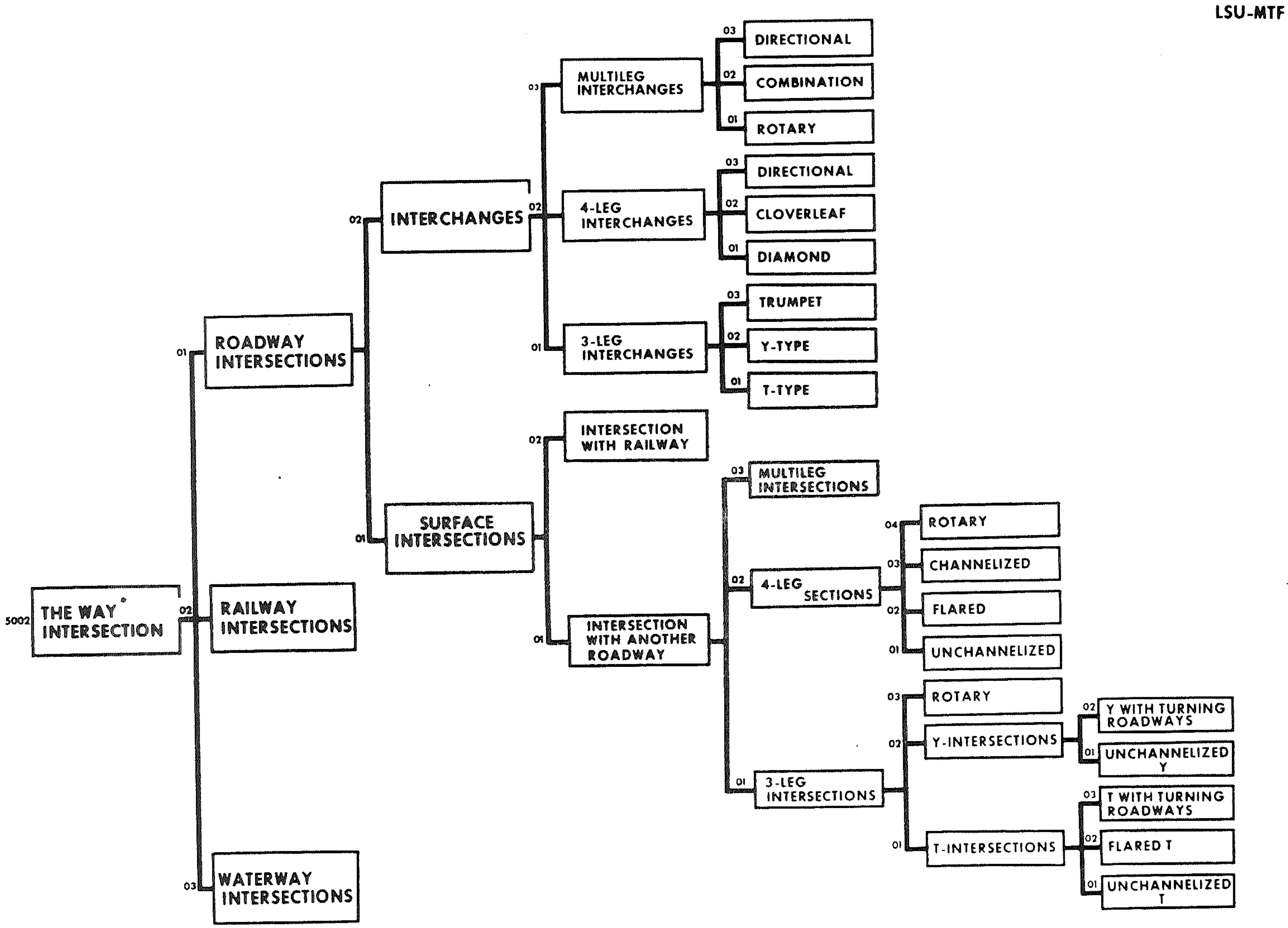

Fig. 17. A partial decomposition of THE WAY INTERSECTIONS.

explanatory. A "free conveyance" way link [50010101] is a way link normally traversed by a "free" conveyance. A "conveyance guiding" way link [50010102] is a way link which guides the conveyance along a predetermined course.

The major references for this decomposition were A Policy on Arterial Highways in Urban Areas (15) and A Policy on Geometric Design of Rural Highways (16), both published by the American Association of State Highway Officials.

4.2.6 Regulating System

The decomposition of the Regulating System is shown in Figure 18. The major subordinate elements are Laws [6001], Law enforcement element [6002] and "Information communication to conveyance controller [6003]. The decomposition of laws is for demonstration as no previous classifications were located. The Law Enforcement element includes, not only the police charged with regulating traffic, but also the agents charged with enforcing manufacturing standards, road construction standards, etc. The "Information communication to conveyance controller element includes all devices (stop signs, directional signs, traffic signals, etc.) which transmit information about the system (which is often some requirement of the law) to the conveyance controller.

4.2.7 Destination

The decomposition of the major element Destination (Figure 19) is the same as the decomposition of Origin. This follows, as any location that can serve as an origin can also serve as a destination. Each is retained as a major element, however, because it is highly probable that different characteristics will be important

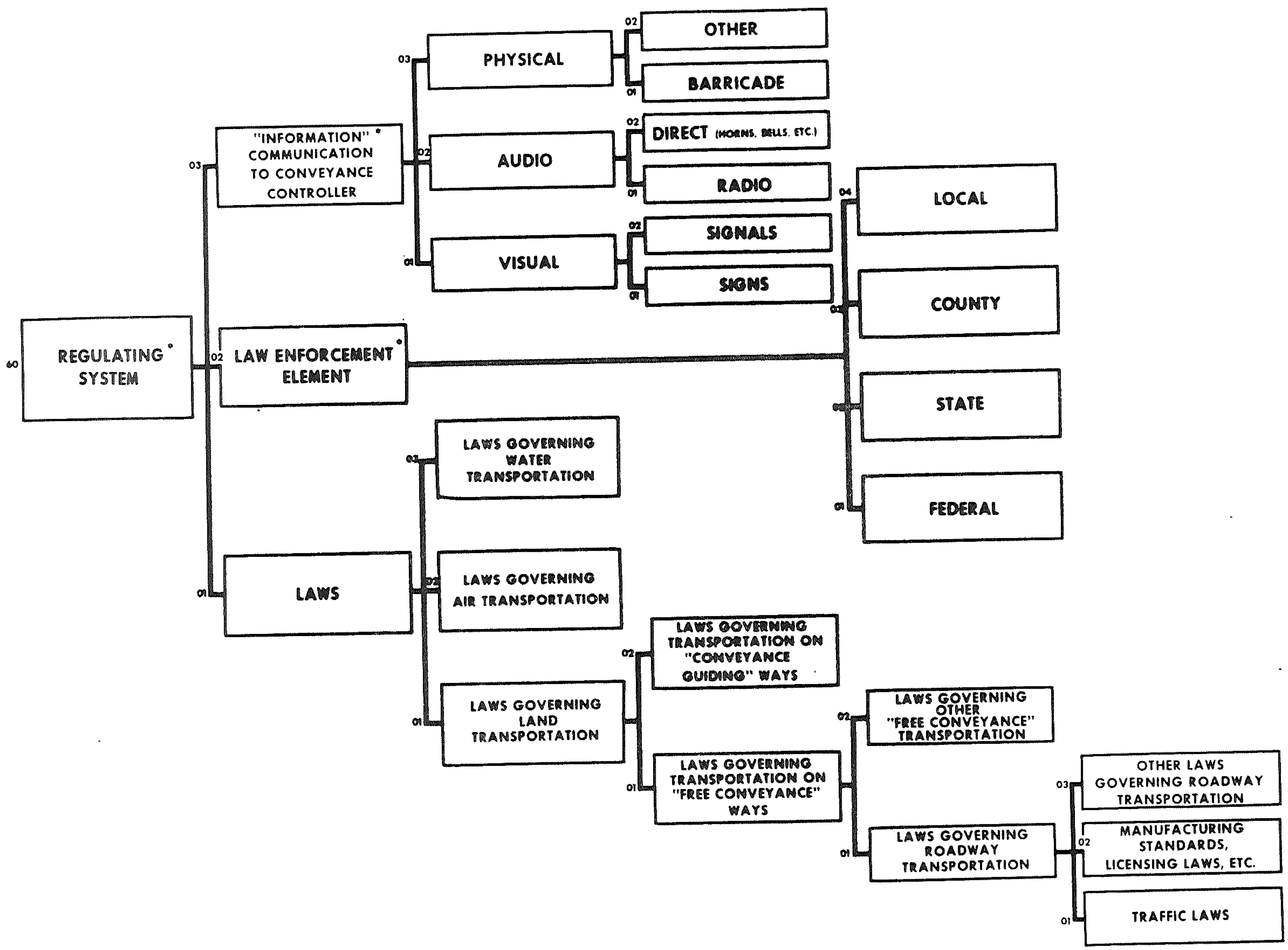

Fig. 18. A partial decomposition of the major element, REGULATING SYSTEM.

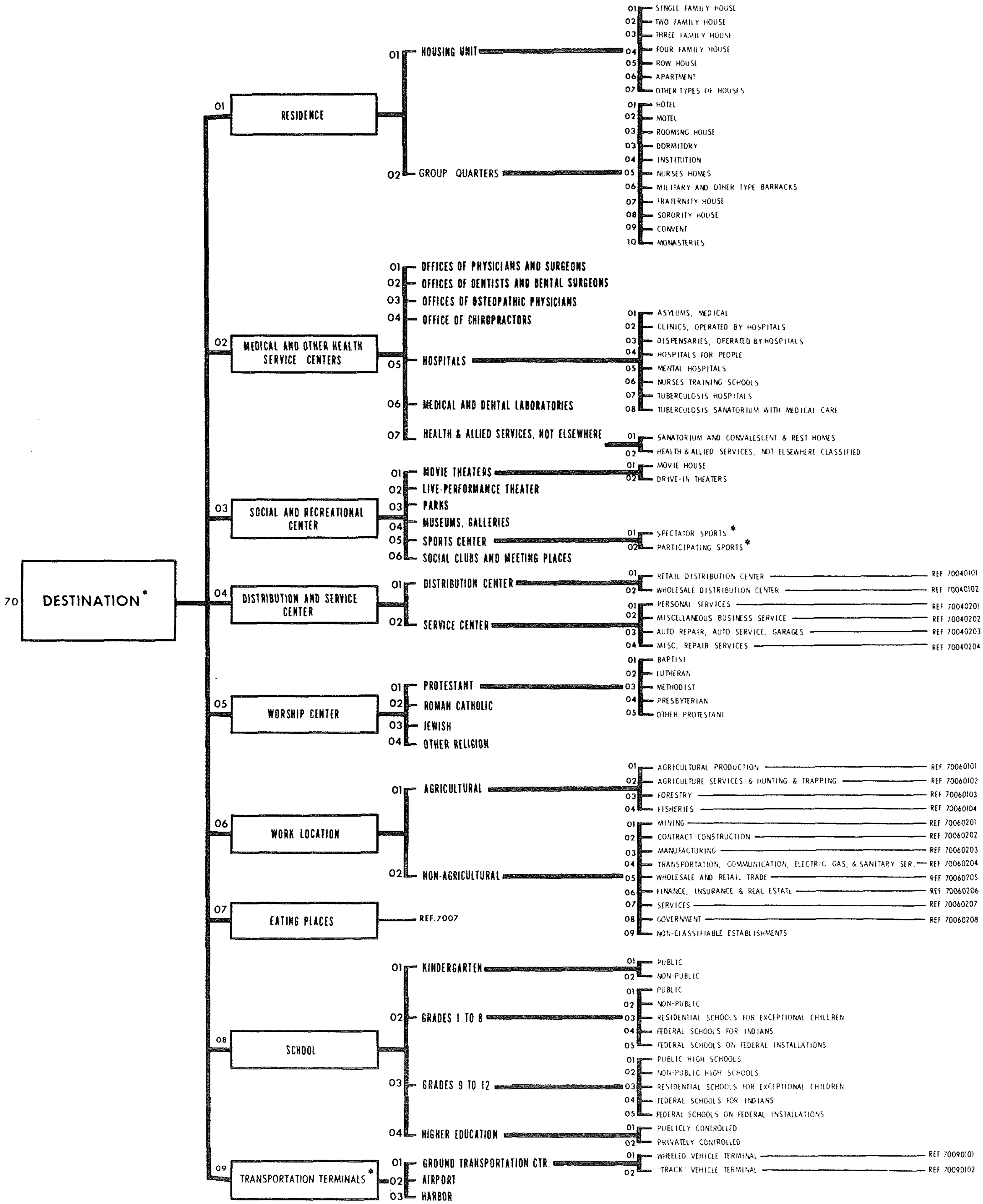

Fig. 19. A partial decomposition of the major elements, DESTINATION.

depending on whether the location under consideration is serving as an origin or destination.

4.3 The Ideal System

The particular objects of the ideal system cannot be identified as this would require an ability to "see" the future. However, because the "trip concept" holds for all states of the system, the objects of the ideal system can be grouped under the seven major elements (see Figure 20). From this point, the ideal system must be described in terms of objectives.

The ideal system is not "fixed" because ideas as to

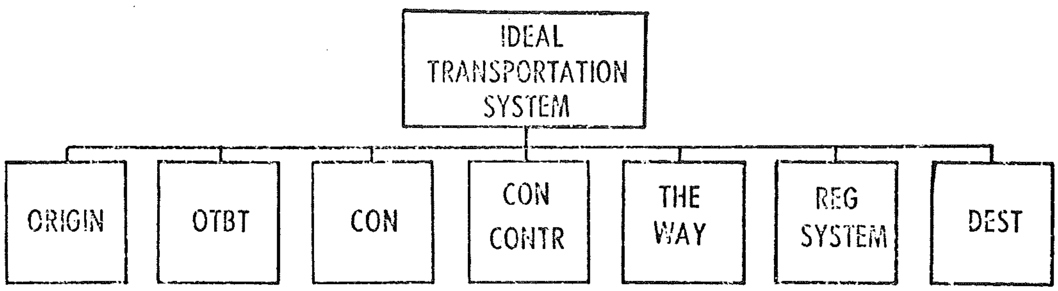

Fig. 20. The major elements of the ideal transportation system.

what is desired in a transportation system may vary with time. This does not present a problem, however, because picturing the transportation system as a large evolving system allows for evolution toward the ideal system whatever the current ideals may be. To date, the most general statement of objectives is contained in the Department of Transportation Act of October 15, 1966. In it, the Transportation Department is directed to work toward "provision of fast, safe, efficient, and convenient transportation at the lowest cost consistent therewith."* Thus, the current ideal system is the one that provides the fastest, safest, most efficient, and most convenient transportation at the lowest cost consistent therewith.

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*United States Government Organization Manual 1969-70 (Washington: G.P.O., 1969), p. 376.

CHAPTER V

EVOLUTION TOWARD THE IDEAL STATE

5.1 Problem Solving: The Cognitive Approach

"The solving of problems is accomplished by a process of learning. Learning is defined as a cognitive action resulting from stimuli. Cognition is the broad range of intelligent acts in which the discernment of a pattern, present or future, takes place. Discernment is among the principal functions of the intermediary. Other principal learning functions are formulation of the means by which the transformation between systems states will be implemented, and formulation of the concept that *a priori* indicates how the desired state may be obtained through changes in existing objects, attributes, and relationships."*

Thus, one of the primary requirements in solving the transportation problem is the discernment of a pattern. This is, in effect, determining what is actually happening. Before tackling the problem of cognition at the total system level, a more limited problem, that of improving the performance of a human being acting as the conveyance controller for an automobile, will be considered.

5.2 General Conception of Problem

Given sufficient information, a distribution of all men according to their ability to drive an automobile, could be formulated. This distribution will be called the "raw" distribution. At present, this "raw" distribution is fed into a Black Box system where it is

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*Stanford L. Optner, Systems Analysis for Business and Industrial Problem Solving. (Englewood Cliffs, New Jersey: Prentice-Hall, 1965), p. 75.

processed. The desired output is a driver performance distribution that is within acceptable performance limits (see Figure 21). This is the desired case. The actual situation is depicted in Figure 22. When the "raw" distributuion is fed into the Black Box a portion of the output performance distribution falls outside acceptable limits. This portion represents unacceptable driver performance. Any driver performance which causes undue delays in traffic flow is considered unacceptable.

In problem formulation terminology, the actual situation is the present system and the desired case is the desired system. The objective is to modify the output distribution of the actual situation until it falls entirely within acceptable limits.

5.3 General Conception of Black Box

The input "raw" distribution and the Black Box processing system are the determinants of the "shape" of the output performance distribution. However, the rate of change of the "raw" distribution is such that it is normally considered constant. Therefore, if the performance of a human being acting as a conveyance controller is to be improved, the Black Box must be improved.

For discussion purposes, only a major contributor of man's ability to drive will be considered as his total ability is not currently quantifiable. Visual acuity, a contributor which is quantifiable, will be taken though hearing or reaction time would serve just as well.

The "raw" distribution is now considered to be a distribution of men according to their visual acuity (Figure 23). This distribution is fed into the Black Box. The Black Box is perceived as a

PERFORMANCE OF CONVEYANCE CONTROLLER

THE DESIRED CASE

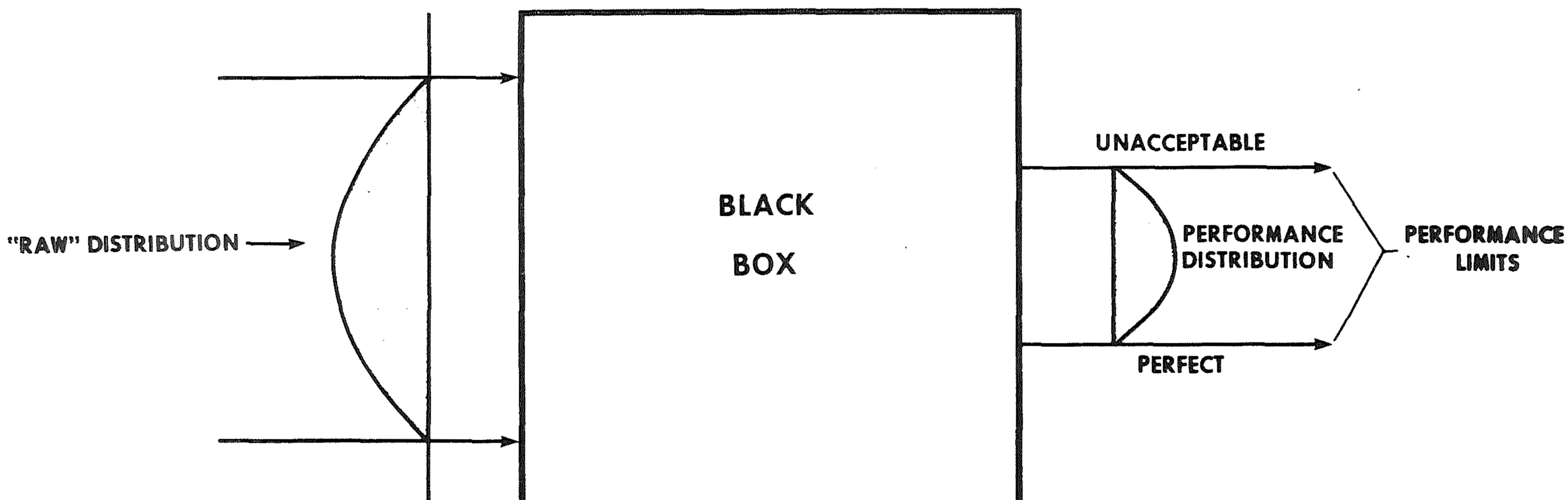

Fig. 21.

PERFORMANCE OF CONVEYANCE CONTROLLER

THE ACTUAL SITUATION

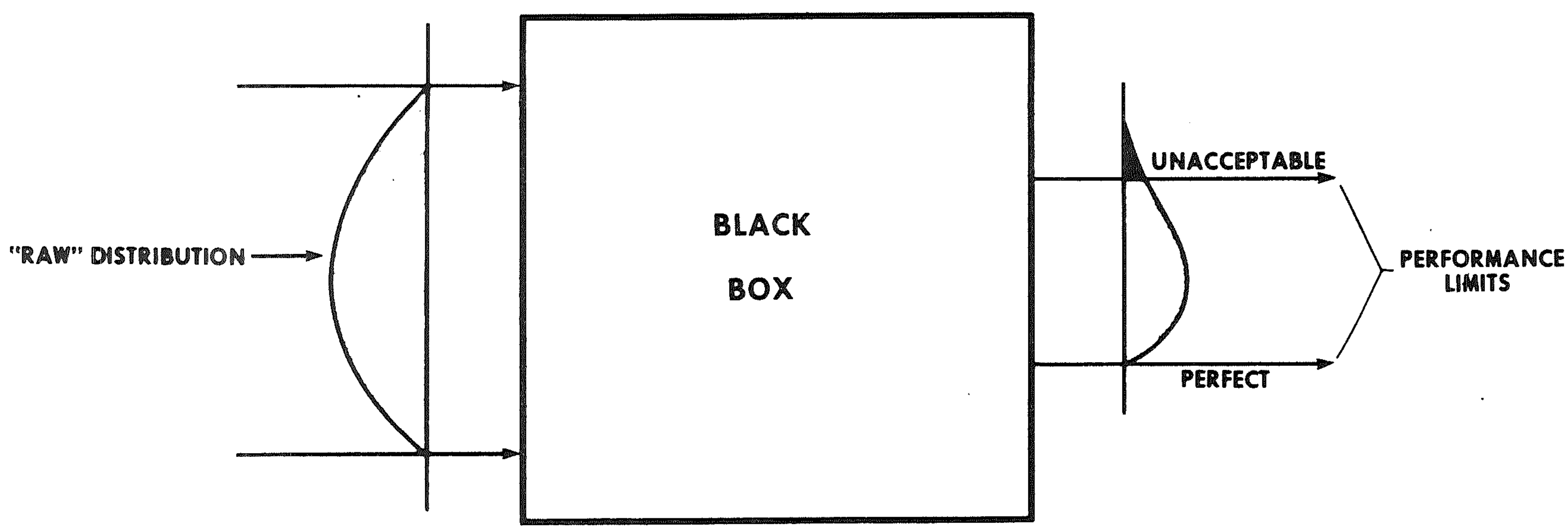

Fig. 22

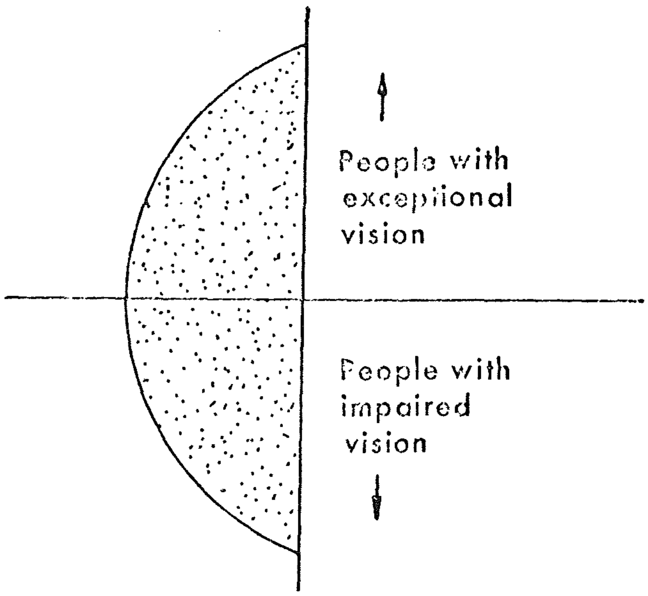

Fig. 23. A 'raw' distribution of men according to visual acuity.

transportation system made up of elements which have been "designed" to compensate for inadequacies in other elements of the same system. For the particular case under study, man's performance as a conveyance controller is the output of a transportation system that has been designed to compensate for his visual inadequacies (17) thru (59). For example, men do not have the ability to see to the rear, so this "inadequacy" is compensated for in the design of the automobile (a conveyance) by providing rearview mirrors. Similarly, men traveling 60 m.p.h. at night have difficulty in decerning the edge of the road so the way is designed to assist him, i.e., a more distinct white line is painted along the edge. Suppose, now, that an individuals' vision is 20-400. Socio-economic considerations deem it infeasible to design the other elements of the system to compensate for such a great inadequacy so the man (a conveyance controller) is modified by providing him with eyeglasses. If his vision cannot be sufficiently corrected, then the regulating system is designed, through licensing requirements, to prohibit him from driving.

After processing, the effectiveness of the Black Box can be evaluated by inspection of the performance distribution output. Any unacceptable performance by a conveyance controller due to a visual inadequacy indicates that the system has not been sufficiently designed to compensate for all inadequacies. To improve the performance distribution, the Black Box, which is, in effect, the present transportation system, must be improved.

5.4 The Evolutionary Process

The analysis of the Black Box provides some insight as to how the transportation system evolves. The process discussed in the preceding section can be restated in more general terms as follows:

1. An element of the system was selected (a conveyance controller).
2. A particular characteristic (vision) of the element was chosen.
3. The characteristics required of other elements of the system to make the system harmonious to the element under study were determined (automobile should have rearview mirror, highways should have edgemarkings, etc.)
4. The characteristics determined in step 3 were considered characteristics of ideal elements with respect to element under study. An ideal element is an element that functions in complete harmony in the existing system. At any state of the system other than the ideal state, the system may

prescribe infeasible characteristics for an ideal element. The significance of this will be discussed in section 5.5)

5. The characteristics necessary for an ideal element were evaluated in the light of socio-economic considerations and a decision was made as to the current feasibility of incorporating these characteristics into the actual design of elements of the system. (The installation of rearview mirrors was deemed feasible as was the use of edgemarkings for highways. However, it was deemed infeasible to design the system to compensate for the visual inadequacies of a man with 20-400 vision).

The process outlined above is applicable to all elements of the system. Suppose the element under study is the automobile, a conveyance. Its width and length are characteristics which affect the design of other elements of the system, i.e., the size of parking slots in the design of origins and destinations and the width of traffic lanes in the design of the way. Similarly, if a man is being considered as an object to be transported, his physical dimensions and "loading" and "unloading" characteristics are important in the design of the conveyance. As another example, if a truck is the element under study, its weight will place certain strength requirements on the way. In the same manner the "strength" of existing ways, place weight restrictions on conveyances.

The above examples may be oversimplifications but they do illustrate how element characteristics are determined. In the examples, several requirements were placed on the way: A conveyance controller required that the way have edgemarkings; one conveyance required a certain lane width; and still another conveyance placed certain strength requirements on the way. The collection of requirments placed on the way by all other elements of the system constitutes the characteristics of the ideal way. The same is true for each element. A man, an object to be transported, requires that his automobile, a conveyance, be comfortable. A man, a conveyance controller, requires that the automobile have a rearview mirror. He also dictates other characteristics of the automobile, such as the force required to activate the brake pedal, the force required to turn the steering wheel, the position of the controls, etc. Existing origins and destinations restrict the size of the automobile and the regulating system requires safety glass and many other features. The collection of these requirements constitutes the characteristics of the ideal conveyance.

If the characteristics of the horse-and-buggy as a conveyance are compared with the characteristics of the ideal conveyance, the horse-and-buggy is quickly classified as "unfit". As the "unfit" element is phased out, the system evolves to a new state. The new state has the gasoline powered automobile as the primary conveyance. This system dictates characteristics for the way which "dirt" roads do not possess so they become "unfit". As the "dirt" roads are surfaced, the system evolves to a new state. As the number of surfaced ways increases, the feasibility of hauling freight over them (as compared to rail) increases. Thus, the system evolves to a new state by the addition of trucks as conveyances.

It can be seen that the evolutionary process of the transportation system is not so unlike the process found in nature where conditions of fitness govern selectivity. The existing system dictates the characteristics of the most fit elements. Existing elements which do not have these characteristics "die out". Adaptive elements "change" to fit the system, and more fit elements are "born" into the system. The transportation system, therefore, evolves to a new state by the modification or removal of existing elements or by the addition of new elements into the system.

5.5 The Direction of Evolutionary Change

Cognition of the evolutionary process invites questions of controlled evolution. However, before the evolution can be controlled, it is necessary to understand how the "direction" of evolution is determined.

Figure 24 depicts the evolutionary process of the transportation system. The characteristics of each element in the system place requirements on the system (Item 1). The collection of these requirements (Item 2) define the characteristics of the ideal element. The characteristics of the ideal element are evaluated in the light of socio-economic considerations and divided into two groups: (a) those characteristics currently infeasible or undesirable (Item 4). The elements produced with the characteristics of Item 3 become members of the system while the infeasible or undesirable characteristics are "fed back" to be compensated for in the design of some other element.

As an example of the process, suppose trucks as conveyances were under study. The weights of pickup trucks and heavy-equipment transporters place strength requirements on the way. These requirements could be found in Item 1, under conveynaces, in the block

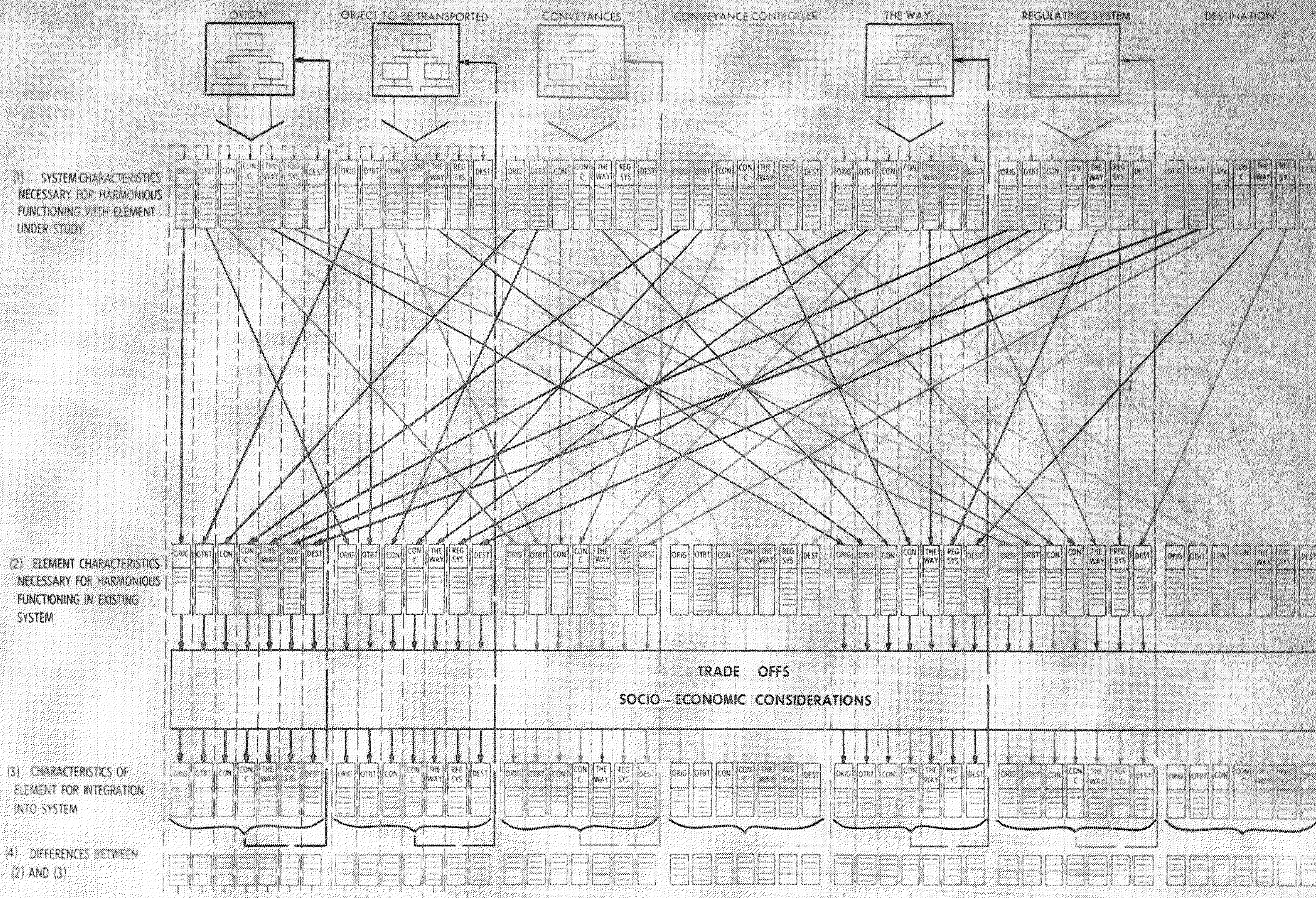

Figure 24. The Evolutionary Process of the Transportation System

labelled WAY. The colored line from the bottom of the block shows that these requirements become characteristics of the ideal way (Item 2) as specified by conveyances. When the characteristics are evaluated in the light of socio-economic considerations, it may prove feasible and desirable (Item 3) to design a new way to meet the strength requirements specified by pickup trucks. However, it may prove infeasible or undesirable (Item 4) to meet the strength requirements specified by heavy-equipment transporters. When this unsatisfied requirement is fed back (dotted line), it is changed into a requirement placed on the conveyance by the way, i.e., the strength of existing ways restrict the weight of conveyances.

The only decision made was in the socio-economic considerations block. It is in this block, therefore, that the direction of the evolutionary process is determined. Suppose, that in the preceeding example, it had been deemed both feasible and desirable to build new ways to meet the strength requirements of the heavy-equipment transporters. As the new ways are bult, heavy conveyances become more "fit" and low strength ways become less "fit". Thus, in time, the system evolves to a state in which heavy conveyances function harmoniously.

Whenever elements are changed, the new state redefines the ideal elements. If the characteristics of existing elements do not match the characteristics of the ideal elements, the system will not function in complete harmony. At the ideal state, the characteristics of functioning elements and the characteristics of the ideal elements as defined by the system are one and the same. Therefore, in evolving toward the ideal state, effort should be concentrated on matching the characteristics of existing and ideal elements. This can be done in two ways. Elements can be designed with the characteristics of the ideal elements or if a particular element is considered desirable, the system can be changed to redefine the ideal element to match the existing element. Either action will assure evolution toward the ideal state.

5.6 Controlled Evolution

It has been shown how cognition of the evolutionary process allows one to rationally set the direction of evolution. However, setting the direction does not mean that the evolution of the system will be controlled. As stated in section 5.4, the transportation system evolves to a new state by the modification or removal of existing elements or by the addition of new elements into the systems. Controlling the evolution then means controlling the addition, deletion, and modification of elements.

To some extent, government manufacturing standards regulate the changing of the system from the "addition of element" standpoint. Mandatory vehicle safety inspections do regulate, somewhat, the modification and removal of at least one major component of the system. However, cognition of the evolutionary process and of how the direction of evolution is determined, allows for more positive control. The suitability of a proposed new element can be determined by comparing its characteristics with the charactersitics of an ideal element. Existing elements can also be compared with ideal elements and decisions as to modification or removal can be made.

Control by this method would ensure that new elements introduced into the system will not change or reverse the desired direction of evolution. It would also ensure that the evolution not be allowed to proceed at a rate which is detrimental (to an unnecessary degree) to some other element of the system. (An evolution toward heavy conveyances may prove extremely costly in highway repairs, unless the regulating system is modified to restrict the routes of heavy conveyances.)

The more thoroughly the evolutionary process of the transportation system is understood, the more closely it can be directed and controlled. In consequence, the transition to more desirable states will be faster and smoother.

CHAPTER VI

RECAPITULATION AND CONCLUSION

6.1 Recapitulation

Although the discussion thus far has focused primarily on the ground transportation system, the basic concepts are applicable to any mode of transportation, be it by land, sea, or air. The transportation system is preceived to be a large evolving system that changes state by the addition, deletion, or modification of the elements which make up the system. At any point in time, system users can envision a state which is more desirable than the present state. The difference between the present state and the most desirable state (the ideal state) defines the transportation problem.

Formulating the transportation problem in this manner involves defining both the present and ideal states of the system. The first step in defining any system is the identification of its elements. The identification of the elements by the use of the hierarchical nature of complex systems resulted in a "picture" of the present system which will now be called a descriptive model. (More accurately, it is a descriptive model resulting from element identification through a hierarchical decomposition along functional guidelines.) This type of model has especially high utility as it has several useful feature. These features are enumerated below.

6.1.1 An Evolving Model

Because the transportation system is constantly changing state, a model that is applicable only to one specific state would have very low utility. The descriptive model presented is capable of accepting element additions, deletions, or modifications without losing its original integrity, i.e., a new element can be fitted unto the model or present elements can be deleted or modified without substantially altering the decomposition "tree" or in any way altering the decomposition principle. Thus, the model can be "carried along" the evolutionary path toward the ideal state.

6.1.2 A Standard Decomposition

A model of this type can provide standard groupings for compiling statistical data and also for cataloguing research information. For example, reports containing information pertaining to elevated four-lane undivided surfaced roadways could be listed under its numerical designator, 5001010101030402.

The adoption of a standard decomposition, along with the associated standard definitions of elements, would greatly assist in alleviating the transportation semantics problem. For instance, is it primary, secondary, and tertiary roads, or parkways, thoroughfares, arterials and connectors, or is it freeways, major streets, collector streets, and local streets (60)? Standard definitions would not only aid communications within the field of transportation, but would also aid communication with other disciplines as the interdisciplinary nature of transportation is fast being recognized. Here is an ancient fable to illustrate the importance of communications.

> "And it came to pass...that...they said to one another let us build us a city, and a tower, whose top may reach unto Heaven... And the Lord came down to see the city and tower which the children of man had builded, and the Lord said: 'Behold, they are one people and they have all one language, and this is what they begin to do; and now nothing will be withholden from them, which they purpose to

> do....Let us go down, and there confound their language, that they may not understand one another's speech."
>
> So...they left off building the city.*

Another important feature is the systematic method with which a hierarchical standard decomposition could be adopted. The first step would be to gain general acceptance for the definitions of the major elements. Definitions for subordinate elements would then have to be proposed and evaluated from a utility standpoint. This procedure could be continued until all elements, to whatever degree of decomposition desired, are defined.

6.1.3 Applicable at All Levels

The descriptive model as well as the general concept can be adopted at any level: national, regional, state, city, etc. Adoption or non-adoption at any level does not preclude adoption at any other level. However, the greatest benefits would be obtained if the order of adoption would be from high to lower levels, i.e., from national down.

6.1.4 Suggested Organization for Research

The adoption of a standard decomposition, along with cognition of the evolutionary process, would aid in organizing and directing the transportation research effort. Research areas and responsibilities could be assigned according to the standard decomposition. A total research effort could be organized to evolve the system toward the ideal state. The suggested organization, in the form of a functional process diagram for the section concerned with

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*As quoted by Ralph Borsodi in The Definition of Definition (Boston: Porter Sargent, 1967), p. 1.

conveyances, is depicted in Figure 25. The total organization consists of seven similar sections, one for each major element, and a coordinating section. The functional process for each section would be the same as shown for conveyances.

6.2 Further Comments on the Trip Concept: Traffic Flow and Element Behavior

The trip concept, though important in the development of the conceptual framework, finds its greatest usefulness in the analysis and understanding of traffic flow and element behavior. A trip has been defined as any combination of elements, at least one element from each general grouping. As there are, theoretically, and infinite number of elements in the system, the number of trips is also infinite. However, there are relatively few trips of importance. Certain elements are "more likely" to combine to form a trip than are other elements. What type of home does a blue collar worker live in? What type of car does he drive? Where is his most likely work location? Where does he go for entertainment? Each element has a varying degree of "affinity" for other elements for combining to form a trip. This "affinity" is highly dependent on such variables as the day of the week, the time of the day, the weather conditions, etc. The elements of a Monday morning work trip have little "affinity" for each other at 2:00 p.m. on a Sunday afternoon.

The above speculations are primarily in the disciplines of sociology and social psychology. Their relation to traffic flow analysis and traffic volume prediction is a good indicator of the interdisciplinary nature of transportation. Although the subject is interesting, further investigation is outside the scope of this paper.

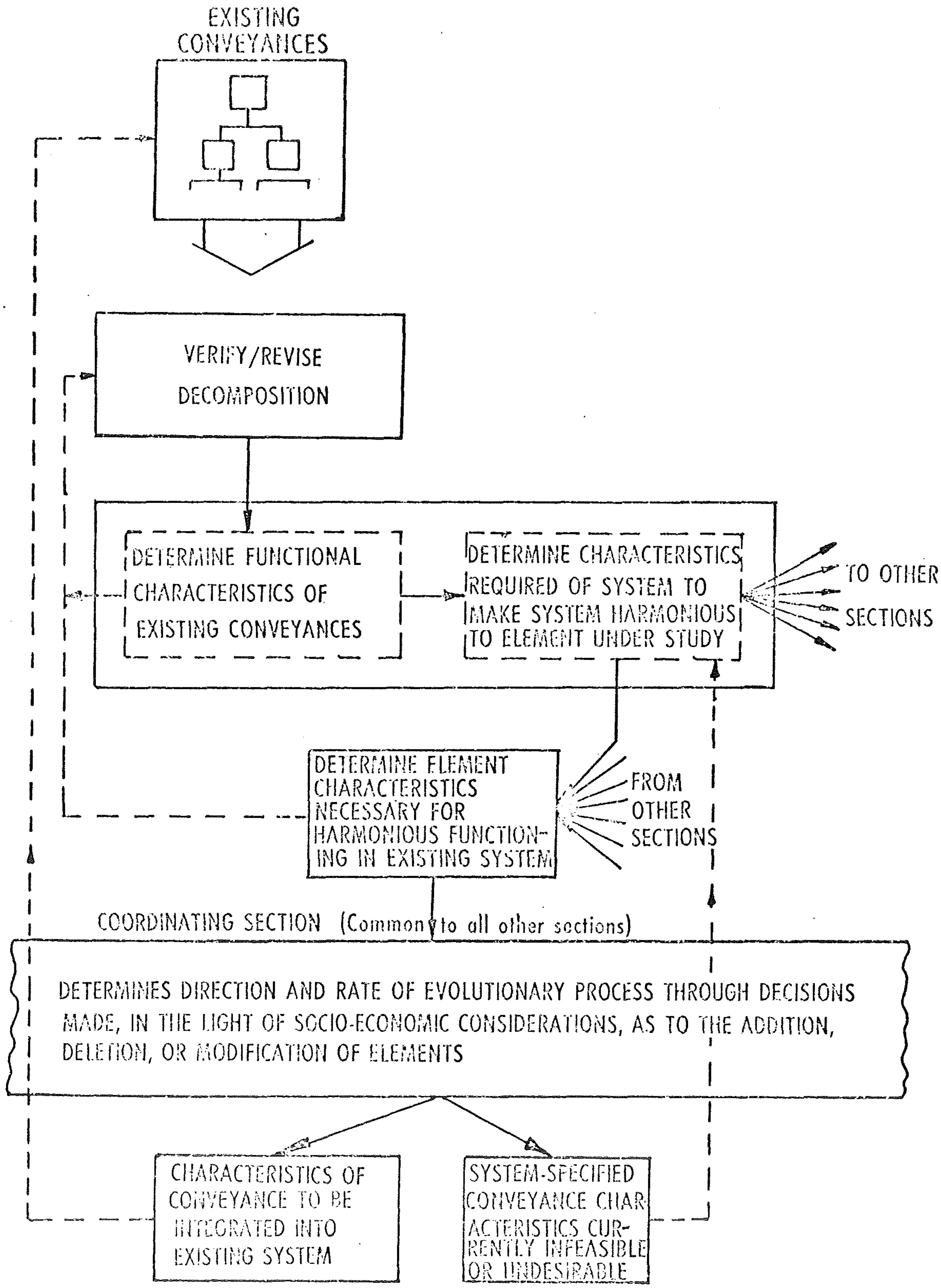

Fig. 25. Functional process diagram for research section concerned with conveyances.

6.3 Concept of the Journey

A trip begins when the Object to be Transported moves and ends when it reaches a recognized destination. A recognized destination is any location identified as an element in the decomposition of the major element, destination. A journey is defined as a series of trips which results in the movement of the OTBT from its "home" back to its original "home" or to its new "home". Only the "permanent location" connotation of "home" is applicable here.

The purpose of defining a journey in this manner is to help alleviate the problems of interface by avoiding the creation of new ones. For example, under this concept, the common business "trip" becomes a business journey. The businessman makes a trip from his home to airport "A", a trip from airport "A" to airport "B", a trip from airport "B" to a hotel, a trip from the hotel back to airport "B", a trip from airport "B" back to airport "A", and finally a trip from airport "A" back to his home. This journey contains five interfaces (the connecting link between trips) which must be considered in any attempt to reduce the businessman's total travel time. Past experience has shown that decreasing the air travel time may in fact increase the total journey time if the interfaces are not considered. Trip interfaces any important components of any journey and must be considered in any analysis.

6.4 Conclusion

The general framework proposed was developed primarily through a cognitive process. The approach has been more along the lines of discovering the framework rather than developing a framework. The transportation system does exist, its components are related, and socio-economic considerations do play an important role.

The framework allows men to view the system as a logical whole and at the same time view its components with reference to the whole and with reference to man. All disciplines with any relation to transportation are equally "at home" under the concept. The effect of relatively minor occurrences, such as the modification of one particular element, can now be logically related to the whole. The significance of relative limited research efforts (e.g., the determination of stopping distances, a characteristic of a conveyance) can now be evaluated in view of a total effort to evolve the system to a more desirable state.

The features discussed above establish the utility of the proposed general framework for the transportation system.

CHAPTER VII

CAPABILITIES OF THE MISSISSIPPI TEST FACILITY AND SUGGESTED RESEARCH TOPICS

7.1 The Capabilities of the Mississippi Test Facility

Mississippi Test Facility is particularly well suited for transportation research. The in-place, on-site capabilities provide an impressive physical plant encompassing the entire spectrum of support activities which are readily available for (and applicable to) transportation research needs. Available services range from modern data acquisition systems through complex data handling systems, numerous processing equipment, safety systems, medical services, massive cranes, to pollution measurement and analysis equipment. NASA report entitled, Transportation Systems Testing at NASA-MTF*, provides a synoptic discussion of those facilities and services of interest.

The discussion includes:

> Instrumentation and Other Technical Support - A comprehensive, tabular presentation of in-place equipment and service.
>
> Operation Support - A narrative of facility-wide, base type integrating services available.
>
> Utilities - A narrative of the in-place and operating utilities including the railroad and waterway.
>
> Management Approach - A narrative of MTF's operational techniques.
>
> Safety, Health, and Quality Control Programs - A narrative of these vatal, site-wide support functions.

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*NASA, Transportation Systems Testing at NASA-MTF, (Bay Saint Louis, Miss.: MTF, 1969)

Technical Personnel and Services - A statement of MTF's human resources.

Mississippi Test Facilities's capabilities make it especially well suited for research studies on five (Object to be Transported, Conveyance, Conveyance Controller, The Way, and The Regulating System) of the seven major elements of the ground transportation system. Under the research concept presented in this report, the major areas of research would be in (a) verifying and revising the decomposition already presented, (b) determining the functional characteristics of existing elements, and (c) determining the interaction between different elements of the system. Of special interest is the Conveyance Controller/Conveyance (man-machine) interactions.

7.2 Research Objectives and Relate Research Topics

This section presents, in outline from, suggested research which could be accomplished at Mississippi Test Facility. The research topics are listed under objectives subordinate to the major objectives discussed in section 7.1. For completeness, all seven major elements are included. Two-element interactions are also included to demonstrate how the decomposition of the elements facilitates the consideration of all possible interactions.

For reference to the research topic outline, a labeling scheme has been employed. Each element is identified by its numerical designator; research objectives under each element are identified by capital letters; and specific research topics are numbered in sequence under each research objective. For example, 30A2, refers to the second topic under the first objective in the study of conveyances. The term (30-40), refers to a Conveyance/Conveyance Controller interaction.

10 Origin

A. Verify/Revise decomposition

1. Analysis of Literature

2. Contact with location-classification agencies at all levels (federal, state, local).

B. Determine functional characteristics of each element of Origin

1. Lighting characteristics.

2. Surface weight limitations.

10-10 Origin/Origin interaction

A. Evolutionary: Determine characteristics required of elements of Origin by other elements of Origin if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Origin and other elements of Origin.

10-20 Origin/OBTB interaction

A. Evolutionary: Determine characteristics required of elements of Origin by other elements of Origin if the system is to function harmoniously.

B. Functional Traffic Analysis: Determine correlation between elements of Origin and elements of OTBT.

10-30 Origin/Conveyance interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance by elements of Origin if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Origin and elements of Conveyance.

1. Optimal use of parking space.

2. Optimal entrance and exit characteristics of Origins.

10-40 Origin/Conveyance Controller interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller by elements of Origin if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Origin and elements of Conveyance Controller.

10-50 Origin/The Way interactions

A. Evolutionary: Determine characteristics required of elements of The Way by elements of Origin if the system is to function harmoniously.

1. Land use studies.

B. Functional/Traffic Analysis: Determine correlations between elements of Origin and elements of The Way.

10-60 Origin/Regulating System interactions

A. Evolutionary: Determine characteristics required of elements of the Regulating System by elements of Origin if the system is to function harmoniously.

1. Construction standards.

2. Inspection procedures

3. Zoning

4. Parking laws

B. Functional/Traffic Analysis: Determine correlations between elements of Ofigin and elements of Regulating System.

10-70 Origin/Destination interactions

A. Evolutionary: Determine characteristics required of elements of Destination by elements of Origin if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Origin and elements of Destination.

20 Object to be Transported (OTBT)

A. Verify/Revise decomposition

1. Use statistical techniques to determine groupings. All human beings to be transported may be grouped by such variables as age, sex, physical dimensions, state of health, etc.

2. Analysis of accident reports.

B. Determine functional characteristics of each element of OTBT.

1. Limb movement.

2. Limb positioning.

20-10 OTBT/Origin interaction

A. Evolutionary: Determine characteristics required of elements of Origin by elements of OTBT if the system is to function harmoniously.

B. Functional/Traffic Analysis: see (10-20)B

20-20 OTBT/OTBT interaction

A. Evolutionary: Determine characteristics required of elements of OTBT by other elements of OTBT if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of OTBT and other elements of OTBT.

20-30 OTBT/Conveyance interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance by elements of OTBT if the system is to function harmoniously.

1. Development and evaluation of "safety" components for ground vehicles when submerged.

2. OTBT restraining devices (seat belts, etc.).

3. OTBT - Conveyance impact studies.

4. Location of comfort/conveyance features.

a. Position of seats.

b. Location of arm rest.

c. Location of ash trays, etc.

5. Design of conveyance to prevent injury to OTBT in crash.

6. Entering and exiting characteristics.

B. Functional/Traffic Analysis: Determine correlations between elements of OTBT and elements of Conveyance.

20-40 OTBT/Conveyance Controller interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller by elements of OTBT if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of OTBT and elements of Conveyance Controller.

20-50 OTBT/The Way interactions

A. Evolutionary: Determine characteristics required of elements of The Way by elements of OTBT if the system is to function harmoniously.

1. Aesthetics.

B. Functional/Traffic Analysis: Determine correlations between elements of OTBT and elements of The Way.

1. Special routes for OTBT.

20-60 OTBT/Regulating System interaction

A. Evolutionary: Determine characteristics required of elements of Regulating System by elements of OTBT if system is to function harmoniously.

1. Safety laws.

2. Route laws.

B. Functional/Traffic Analysis: Determine correlation between elements of the Regulating System.

20-70 OTBT/Destination interaction

A. Evolutionary: Determine characteristics required of elements of Destination by elements of OTBT if the system is to function harmoniously.

1. Shelter requirements.

2. Lighting requirements.

B. Functional/Traffic Analysis: Determine correlations between elements of OTBT and elements of Destination.

30 Conveyance

A. Verify/Revise decomposition

1. Analysis of vehicle registration information.

2. Analysis of accident reports

3. Census of vehicles.

4. Manufacturers classifications.

5. Classifications by vehicle servicing facilities.

6. Classifications by vehicle regulating laws.

B. Determine functional characteristics of each element of Conveyance.

1. Analysis of manufacturer's data, past research, and new research.

a. Braking - all phases.

b. Steering.

c. Lighting.

d. Crash characteristics

(1) Vehicle to vehicle.

(2) Vehicle to static object.

2. Development of analytical methods to determine the most effective means of vehicle test.

3. Development of numerical analysis methods for stress distribution in vehicle shells.

4. Verification of the above with full scale crash test.

5. Full scale testing to analyze safety of vehicle geometrics.

6. Full scale testing of vehicle controls (steering, brakes, etc.)

7. Tire testing, standardization and evaluation.

8. Survival in "Submerged" ground vehicles, the performance of vital components of vehicles such as windows, doors, etc. when submerged.

9. Study of hydroplanning.

10. Evaluation, development, and alalysis of shock absorption devices.

11. Ambulance safety studies.

30-10 Conveyance/Origin interaction

A. Evolutionary: Determine characteristics required of elements of Origin by elements of Conveyance if the system is to function harmoniously.

1. Physical dimensions.

2. Surface strength requirements.

B. Functional/Traffic Analysis: see (10-30)B.

30-20 Conveyance/OTBT interaction

A. Evolutionary: Determine characteristics required of elements of OTBT by elements of Conveyance if the system is to function harmoniously.

B. Functional/Traffic Analysis: see (20-30)B.

30-30 Conveyance/Conveyance interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance by other elements of Conveyance if the system is to function harmoniously.

1. Power requirements.

2. Speed requirements.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance and other elements of Conveyance.

30-40 Conveyance/Conveyance Controller interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller by elements of Conveyance if the system is to function harmoniously.

1. Driving skill.

2. Visual requirements.

3. Audio requirements.

4. Physical dimensions

5. Strength.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance and elements of Conveyance Controller.

30-50 Conveyance/The Way interactions

A. Evolutionary: Determine characteristics required of elements of The Way by elements of Conveyance if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance and elements of The Way.

30-60 Conveyance/Regulating System interaction

A. Evolutionary: Determine characteristics required of elements of Regulating System by elements of Conveyance if the system is to function harmoniously.

1. Placement of signs and signals.

2. Manufacturing standards.

3. Speed limits.

4. Routing laws.

5. Speed detection devices.

B. Functional/Traffic Analysis: Determine correlations between elements of conveyance and elements of Regulating System.

1. Effectiveness of guardrails in preventing damage to vehicles other than the one crashing against them (see also 60B).

2. Effectiveness of guardrails in preventing damage to crashing vehicles and its contents.

30-70 Conveyance/Destination interaction

A. Evolutionary: Determine characteristics required of elements of Destination by elements of Conveyance if the system is to function harmoniously.

1. Loading and unloading characteristics.

2. Physical dimensions.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance and elements of Destination.

40 Conveyance Controller

A. Verify/Revise decomposition

1. Analysis of driver registration information.

2. Analysis of accident reports.

3. Consultation with professionals in the social disciplines.

4. U. S. Census.

B. Determine functional characteristics of each element of Conveyance Controller.

1. Use of alcoholic beverages by driver.

2. Use of drugs by driver.

3. Driver education.

4. The effect of socio-economical environments of a driver on his capabilities as a vehicle controller.

5. The effect of air pollution on the driver performance.

6. The effect of noise pollution on the driver performance.

7. The effect of "sound effects" transmitted through car radios on the performance of the driver.

40-10 Conveyance Controller/Origin interaction

A. Evolutionary: Determine characteristics required of elements of Origin by elements of Conveyance Controller if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (10-40)B.

40-20 Conveyance Controller/OTBT interaction

A. Evolutionary: Determine characteristics required of elements of OTBT by elements of Conveyance if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (20-40)B.

40-30 Conveyance Controller/Conveyance interaction

A. Evolutionary: Determine characteristics required of elements of conveyance by elements of Conveyance Controller if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (30-40)B.

40-40 Conveyance Controller/Conveyance Controller interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller by other elements of Conveyance Controller if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance Controller and other elements of Conveyance Controller.

40-50 Conveyance Controller/The Way interactions

A. Evolutionary: Determine characteristics required of elements of The Way by elements of Conveyance Controller if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance Controller and elements of The Way.

40-60 Conveyance Controller/Regulating System interaction

A. Evolutionary: Determine characteristics required of elements of Regulating System by elements of Conveyance Controller if the system is to function harmoniously.

1. Drivers' licensing.

2. Laws pertaining to the use of drugs by drivers.

3. Laws pertaining to the use of alcohol by drivers.

4. Sign location and height.

5. Sign language.

6. Signal location and height.

7. Signal language.

8. Visual and physiological effects of the design of guardrails on the performance of the driver (the shape, location and the size of guardrails in relation to the driver).

9. Identification of the alcoholics and DWI.

10. Medical verification of the above.

11. Development of legislation to enable the law enforcement officers to collect evidence of DWI.

12. The treatment of roadside stores, bars, etc. dispensing alcohol to drivers.

13. Placement standards of reflectorized markers.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance Controller and elements of Regulating System.

1. Analysis of traffic laws.

2. Analysis of enforcement of traffic laws.

50-70 Conveyance Controller/Destination interaction

A. Evolutionary: Determine characteristics required of elements of Destination by elements of Conveyance Controller if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Conveyance Controller and elements of Destination.

50 The Way

A. Verify/Revise decomposition

1. Analysis of accident reports.

2. Consultation with highway officials.

B. Determine functional characteristics of each element of The Way.

1. Studies of Way geometrics.

2. Studies of structural integrity.

50-10 The Way/Origin interactions

A. Evolutionary: Determine characteristics required of elements of Origin by elements of The Way if the system is to function harmoniously.

B. Functional/Traffic analysis: See (10-50)B.

50-20 The Way/OTBT interaction

A. Evolutionary: Determine characteristics required of elements of OTBT by elements of The Way if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (20-50)B.

50-30 The Way/Conveyance interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance by elements of The Way if the system is to function harmoniously.

1. Size restrictions.

2. Weight restrictions.

3. Turning characteristics.

4. Tire characteristics.

5. Power requirements.

B. Functional/Traffic Analysis: See (30-50)B.

50-40 The Way/Conveyance Controller interaction.

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller, by elements of The Way if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (50-50)B.

50-50 The Way/The Way interaction

A. Evolutionary: Determine characteristics required of elements of The Way by other elements of The Way if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of The Way and other elements of The Way.

50-60 The Way/Regulating System interaction

A. Evolutionary: Determine characteristics required of elements of the Regulating System by elements of The Way if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of The Way and elements of the Regulating System.

50-70 The Way/Destination interaction

A. Evolutionary: Determine characteristics required of elements of Destination by elements of The Way if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of The Way and elements of Destination.

60-10 Regulating System/Origin interaction

A. Evolutionary: Determine characteristics required of elements of Origin by elements of Regulating System if system is to function harmoniously.

B. Functional/Traffic Analysis: See (10-60)B.

60-20 Regulating System/OTBT interaction

A. Evolutionary: Determine characteristics required of elements of Regulating System if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (30-60)B.

60-30 Regulating System/Conveyance interaction

A. Determine characteristics required of elements of Conveyance by elements of Regulating System if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (30-60)B.

60-40 Regulating System/Conveyance Controller interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller by elements of Regulating System if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (40-60)B.

60-50 Regulating System/The Way interaction

A. Evolutionary: Determine characteristics required of elements of The Way by elements of REgulating System if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (50-60)B.

60-60 Regulating System/Regulating System interaction

A. Evolutionary: Determine characteristics required of elements of Regulating System by other elements of Regulating System if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Regulating System and other elements of Regulating System.

60 Regulating System

A. Verify/Revise decomposition

1. Study of existing laws.

2. Study of law enforcement organizations.

3. Study of various types of signs, signals, etc.

B. Determine functional characteristics of each element of Regulating System.

1. Effectiveness of guardrails in preventing damage to vehicles other than one crashing against them (see also (30-60)B.

2. Effectiveness of guardrails in preventing damage to crashing vehicle and its contents (see also (30-60)B.

3. Energy absorption characteristics of guardrails and other types of barricades.

4. Visibility of signs under various environmental conditions.

5. Effectiveness of reflective signs.

6. Effectiveness of lighted signs and various lighting schemes.

7. Sign structures, their structural integrity, and their relation to roadway safety.

8. Visibility of signals under various environmental conditions.

9. Effectiveness of reflective signals.

10. Effectiveness of lighted signals and various lighting schemes.

11. Signal structures, their structural integrity, and their relation to roadway safety.

12. Effectiveness of reflectorized markers under various weather conditions.

13. Durability of reflectorized markers.

60-70 Regulating System/Destination interaction

A. Evolutionary: Determine characteristics required of elements of Destination by elements of Regulating System if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Regulating System and elements of Destination.

70 Destination

A. Verify/Revise decomposition

1. See 70A

B. Determine functional characteristics of each element of Destination.

70-10 Destination/Origin interaction

A. Evolutionary: Determine characteristics required of elements of Destination by elements of Origin if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (10-70)B.

70-20 Destination/OTBT interaction

A. Evolutionary: Determine characteristics required of elements of OTBT by elements of Destination if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (20-70)B.

70-30 Destination/Conveyance Controller interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller by elements of Destination if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (40-70)B.

70-40 Destination/Conveyance Controller interaction

A. Evolutionary: Determine characteristics required of elements of Conveyance Controller by elements of Destination if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (40-70)B.

70-50 Destination/The Way interaction

A. Evolutionary: Determine characteristics required of elements of The Way by elements of Destination if the system is to function harmoniously.

B. Functional/Traffic Analysis: See (50-70)B.

70-60 Destination/Regulating System interaction

A. Evolutionary: Determine characteristics required of elements of Regulating System by elements of Destination if the system is to function harmoniously.

B. Functional/Traffic Analysis; See (60-70)B.

70-70 Destination/Destination interaction

A. Evolutionary: Determine characteristics required of elements of Destination by other elements of Destination if the system is to function harmoniously.

B. Functional/Traffic Analysis: Determine correlations between elements of Destination and other elements of Destination.

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APPENDIX I

GLOSSARY

CONVEYANCE- The device which is the interface between the object-to-be-transported (OTBT) and the way system. An OTBT may serve as its own conveyance.

CONVEYANCE CONTROLLER- The device that regulates the degrees of freedom in the province of the conveyance. An automobile (the conveyance) normally has two degrees of freedom; its lateral direction and speed. The device which regulates its direction and speed (normally a man) is the conveyance controller.

"CONVEYANCE GUIDING" WAY LINK - A way link which guides the conveyance along a predetermined course.

DESTINATION- The location of the OTBT at the end of the trip.

ELEMENT- Any grouping of components of the transportation system. Conveyances, collectively, constitute an element as do automobiles.

"FREE" CONVEYANCE- A conveyance which has "direction" as a degree of freedom. Automobiles and airplanes are "free" conveyances while railway trains are not because their direction is determined by the way on which they travel.

"FREE CONVEYANCE" WAY LINK- A way link normally traversed by "free" conveyances.

GOODS- All objects, other then live cargo, which can be transported.

"GUIDED" CONVEYANCE- A conveyance which does not have "direction" as a degree of freedom. A railway train whose direction is determined by the way on which it travels is a "guided" conveyance.

IDEAL ELEMENT- An ideal element is an element that functions in complete harmony with existing system.

"INFORMATION" COMMUNICATION TO CONVEYANCE CONTROLLER- All devices (stop signs, directional signs, traffic signals, etc.) which transmit information about the system to the conveyance controller.

JOURNEY- A series of trips which results in the movement of the OTBT from its "home" back to its original home or to its new home. Only the "permanent location" connotation of "home" is applicable here.

LAW ENFORCEMENT ELEMENT- All individuals and agencies charged with inforcing transportation related laws. This includes, not only traffic police, but inspectors ensuring compliance with manufacturing standards, road construction standards, etc.

LIVE CARGO- An object ot be transported which is alive (or has recently been alive) and of which the maintenance of life is a major transporting characteristic. Under this definition, a human corpse would be included in live cargo while an apple (a seed which is technically alive) would not be.

OBJECT TO BE TRANSPORTED- The person or thing to be transported.

ORIGIN- The location of the object to be transported at the beginning of the trip.

PARTICIPATING SPORTS CENTER- A facility whose primary function is to provide for the active participation of individuals in a sports event (e.g. a swimming pool, bowling alley, etc).

<u>REGULATING SYSTEM</u>- The set of devices (laws, traffic signs, police, etc.) which provide for the efficient and rational operation of the system.

<u>SPECTATOR SPORTS CENTER</u>- A facility whose primary function is to provide housing for the viewing of a sports event (e.g. a football stadium).

<u>TRANSPORTATION SYSTEM</u>- All objects (with their attributes) from the seven general groupings make up the <u>static</u> transportation system. The conglomeration of all trips make up the <u>dynamic</u> system.

<u>TRANSPORTATION TERMINAL</u>- A transportation terminal may function as a boarding terminal and/or an alighting terminal. A boarding terminal is a facility whose primary function is to provide for the placing of the object to be transported on the appropriate conveyance. An alighting terminal is a facility whose primary function is to provide for the removal of the object to be transported from a conveyance.

<u>TRIP</u>- Any combination of elements, at least one from each general grouping. A trip begins when the OTBT moves and ends when it reaches a recognized destination.

<u>WAY</u>- The path traversed by the OTBT in moving from its origin to its destination.

<u>WAY INTERSECTION</u>- A facility which permits a conveyance to move from one way link to another.

<u>WAY LINK</u>- A path on which a conveyance moves between way intersections.

APPENDIX II

A PARTIAL DECOMPOSITION OF THE TRANSPORTATION SYSTEM

ORIGIN

10 Origin

01 Residence

01 Housing Unit

01 Single family house

02 Two family house

03 Three family house

04 Four family house

05 Row house

06 Apartment

07 Other types

02 Group Quarters

01 Hotel

02 Motel

03 Rooming house

04 Dormitory

05 Institution

06 Nurses homes

07 Military and other type baricks

08 Fraternity house

09 Sorority house

10 Convent

11 Monasteries

02 Medical and other health services centers

01 Offices of physicians and surgeons

02 Offices of dentists and dental surgeons

03 Offices of osteopathic physicians

04 Offices of chiropractors

05 Hospitals

01 Asylums, medical

02 Clinics, operated by hospitals

03 Dispensaries, operated by hospitals

04 General Hospitals

05 Mental hospitals

06 Nurses' training schools

07 Tuberculosis sanitoria with medical care

06 Medical and dental laboratories

07 Health and allied services, not elsewhere classified

01 Sanitoria and convalescent and rest homes

02 Health and applied services, not elsewhere classified

03 Social and recreational center

01 Movie theaters

01 Movie house

02 Drive-in theaters

02 Live-performance theater

03 Parks

04 Museums, galleries

05 Sports center

01 Spectator sports

02 Participating sports

06 Social clubs and meeting places

04 Distribution and service center

01 Distribution center

01 Retail distribution center

01 Lumber, building materials, hardware, fram equipment dealers

01 Lumber yards, building materials dealers

02 Heating plumbing, electrical stores

03 Paint, glass, wallpaper stores

04 Hardware stores

05 Farm equipment dealers

02 General merchandise group stores

01 Department stores

02 Limited price variety stores

03 Food Stores

01 Grocery stores, including delicatessens

02 Meat markets

03 Fish (seafood) markets

04 Fruit stores, vegetable markets

05 Candy, nut, confectionery stores

06 Retail bakeries

04 Automotive dealers

01 Passenger cars dealers, franchised

02 Passenger car dealers, non-franchised

03 Tire, battery, accessory dealers

04 Misc. aircraft, marine, automotive

05 Gasoline service stations

06 Apparel, accessory stores

01 Men's boy's clothing and furnishings

02 Women's clothing, specialty stores

03 Family clothing stores

04 Shoe stores

05 Children's infants' wear stores

07 Furniture, home furnishing, equipment

01 Furniture, home furnishings stores

02 Household appliance stores

03 Radio, television stores

04 Music stores

08 Drug stores, proprietary

01 Drug stores

02 Proprietary stores

09 Other retail stores

01 liquor stores

02 Book, stationary stores

03 Sporting goods stores, bicycle shops

04 Hay, grain, feed stores

05 Farm, garden supply stores

06 Jewelry stores

07 Fuel, ice dealers

08 Florists

09 Cigar stores, stands

10 News dealers, news stands

11 Camera, photographic supply stores

12 Gift, novelty, souvenior shops

13 Optical goods stores

14 Typewriter stores

15 Luggage, leather goods stores

02 Wholesale distribution center

01 Durable goods

01 Motor vehicles, automotive equipment

02 Electrical goods

03 Furniture, home furnishings

04 Hardware, plumbing, heating equipment supplies

05 Lumber, construction materials

06 Machinery, equipment, supplies

07 Metals, metal work (except scrap)

08 Scrap, waste materials

09 Jewelry

02 Non-durable goods

01 Groceries and related products

02 Beer, wine, distilled alcoholic beverages

03 Drugs, chemicals, allied products

04 Tobacco, tobacco products

05 Dry goods, apparel

06 Paper, paper products (excluding wallpaper)

07 Farm products (raw materials)

08 Other non-durable goods

01 Service Center

01 Personal services

01 Laundries, laundry service, cleaning, dyeing plants

02 Beauty shops

03 Barber shops

04 Photo studios, incl. commerical photography

05 Shoe repair, shoeshine, hat cleaning

06 Funeral service, crematories

07 Pressing, alterations, garment repair, fur repair, storage

08 Miscellaneous business services

- 01 Advertising
- 02 Credit bureaus, collection agencies
- 03 Direct mail advertizing, duplication, copy, steno. services
- 04 Services to dwellings, other bldgs.
- 05 News syndicates
- 06 Private employment agencies
- 07 Research, development laboratories
- 08 Testing laboratories
- 09 Business, mgt. consulting services
- 10 Public relations services
- 11 Detective agencies, protective services
- 12 Armored car services
- 13 Equipment rental
- 14 Coin-operated machine, rental, repair service
- 15 Photofinishing laboratories
- 16 Trading stamp establishments
- 17 Interior decorating
- 18 Sign painting shops
- 19 Auctioneer's estab. (serv. only)

20 Telephone answering

21 Window display services

22 Water softing services

23 Other

03 Auto repair, auto service, garages

01 **Auto repair shops**

02 Auto parking

03 Auto truck rentals, without drivers lease service

04 Auto services, except repair

04 Misc. repair services

01 Electrical repair shops

02 Watch, clock, jewelry repair

03 Re-upholstery, furniture repair

04 Misc. repair shops, related services

05 Worship center

01 Protestant

01 Baptist

02 Luthern

03 Methodist

04 Presbyterian

05 Other Protestant

02 Roman Catholic

03 Jewish

04 Other religion

06 Work location

01 Agricultural production

01 Field crops

02 Fruits, tree nuts, and vegetables

03 Livestock

04 General farms

05 Miscellaneous agriculture

02 Agriculture services and hunting and training

01 Agricultural services, except animal husbandry and horticultural services

02 Animal husbandry services

03 Horticultural services

04 Hunting and trapping, and game propagation

03 Forestry

01 Timber tracts

02 Forest nurseries and tree gathering and extracting

03 Gathering of gums and barks

04 Forestry services

05 Gathering of forest products, not elsewhere classified

04 Fisheries

01 Fisheries, except fish hatcheries, farms, and preserves

02 Fish hatcheries, farms, and preserves

02 Non-agricultural

01 Mining

01 Metal mining

02 Anthracite mining

03 Bituminous coal and lignite mining

04 Crude petroleum and natural gas

05 Mining and quarrying of non-metallic minerals except

fuels

02 Contract construction

01 Building construction - general contractors

02 Construction other than building construction-general contractors

03 Construction - special trade contractors

03 Manufacutring

01 Durable Goods

01 Ordnance and accessories

02 Lumber and wood products, except furniture

01 Logging camps and logging contractors

02 Sawmills and planning mills

03 Millwork, veneer, plywood, and prefabricated structural wood products

04 Wooden containers

05 Misc. wood products

03 Furniture and fixtures

01 Household furniture

02 Office furniture

03 Public building and related furniture

04 Partitions, shelving, lockers, and office store fixtures

05 Misc. furniture and fixtures

04 Stone, clay, and glass products

01 Flat glass

02 Glass and glassware, pressed or blown

03 Glass products, made or purchased glass

04 Cement, hydraulic

05 Structural clay products

06 Pottery and related products

07 Concrete, gypsum, and plaster products

08 Cutstone and stone products

09 Abrasive, asbestos, and miscellaneous non-metallic mineral products

05 Primary metal industries

01 Blast furnace, steel works, and rolling and finishing mills

02 Iron and steel foundries

03 Primary smelting and refining of non-ferrous metals

04 Secondary smelting and refining of non-ferrous metals

05 Rolling, drawing, and extruding of non-ferrous metals

06 Non-ferrous foundries

07 Miscellaneous primary metal products

06 Fabricated metal products except ordinance, machinery, and transportation equipment

01 Metal cans

02 Cutlery, hand tools, and hardware

03 Plumbing and heating, except electric

04 Fabricated structural metal products

05 Screw mathine products, bolts, etc

06 Metal stamping

07 Coating, engraving, and allied services

08 Miscellaneous fabricated wire products

09 Miscellaneous fabricated metal products

07 Machinery, except electrical

01 Engines and turbines

02 Farm machinery and equipment

03 Construction, mining, and material handling machinery and equipment

04 Metal working machinery and equipment

05 Special industrial machinery, except metal-working machinery

06 General industrial machinery and equipment

07 Office, computing, and accounting machines

08 Service industry machines

09 Misc. machinery, except electrical

08 Electrical, machinery, equipment and supplies.

01 Electric transmission and distribution equipment

02 Electrical industrial apparatus

03 Household, appliances

04 Electric lighting and wiring equipment

05 Radio and TV receiving sets, except commo. types.

06 Communication equipment

07 Electronic components and assessories

08 Misc. electrical machinery, equipment, and supplies

09 Transportation equipment

01 Motor vehicles and motor vehicle equipment

02 Aircraft and parts

03 Ship and boat building and repairing

04 Railroad equipment

05 Motorcycles, bicycles, and parts

06 Miscellaneous transportation equipment

10 Professional, scientific, and controlling instruments; photographic and optical goods; watches and clocks

01 Engineering, laboratory, and scientific and research instruments and associated equipment

02 Instruments for measuring, controlling, and indicating physical characteristics

03 Optical instruments and lenses

04 Surgical, medical, and dental instruments and supplies

05 Ophtalmic goods

06 Photographic equipment and supplies

07 Watches, clocks, clockwork operated devices, and parts

11 Misc. manufacturing industries

01 Jewelry, silverware, and plated ware

02 Toys, amusements, sporting and athletic goods

03 Pens, pencils, and other office and artistic materials

04 Costume jewelry, costume novelties, buttons, and miscellaneous notions, except precious metal

05 Miscellaneous manufacturing industries

02 Non-durable goods

01 Food and kindred products

01 Meat products

02 Dairy products

03 Canned and preserved fruits, vegetables and sea food

04 Grain mill products

05 Bakery products

06 Sugar

07 Confectionery and related products

08 Beverages

09 Miscellaneous food preparations and kindred products

02 Tobacco manufacturs

01 Cigarettes

02 Cigars

03 Textile mill products

01 Broad woven fabric mills, cotton

02 Broad woven fabric, man-made fabric and silk

03 Broad woven fabric mills, wool:
incl dyeing and finishing

04 Narrow fabric and other small wares mills: Cotton, wool, silk, and man-made fiber

05 Knitting mills

06 Dyeing and finishing textiles, except wool fabrics and knit goods

07 Floor covering mills

08 Yarn and thread mills

09 Miscellaneous textile goods

04 Apparel and other finished products made from fabrics and similar materials

- 01 Men's, youths', and boys' suits, coats, and overcoats
- 02 Men's, youths; and boys' furnishings work clothing and allied garments
- 03 Women's, misses', and juniors' outerwear
- 04 Women's, misses', children's and infants' undergarments
- 05 Hats, caps, and millinery
- 06 Girls, children's and infants' outerwear
- 07 Miscellaneous apparel and accessories
- 08 Miscellaneous fabricated textile products

05 Paper and allied products

- 01 Pulp mills
- 02 Paper mills, except building paper mills
- 03 Paperboard mills
- 04 Converted paper and paper board products, except containers and boxes
- 05 Paperboard containers and boxes
- 06 Building paper and building board mills

06 Printing, publishing, and allied industries

- 01 Newspapers: Publishing, publishing and printing
- 02 Periodicals: Publishing, publishing and printing
- 03 Books
- 04 Miscellaneous prublishing
- 05 Commercial printing
- 06 Manifold business forms

07 Greeting card publishing

08 Blank books, loose leaf binders, and book binding and related work

09 Service industries for the printing trade

07 Chemicals and allied products

01 Industrial inorganic and organic chemicals

02 Plastics materials and synthetic resins, synthetic rubber, synthetic and other man-made fibers, except glass

03 Drugs

04 Soap, detergents, and cleaning preparations, perfumes, cosmetics, and, other toilet preparations

05 Paints, varnishes, lacquers, enamels, and allied products

06 Agricultural chemicals

07 Miscellaneous chemical products

08 Petroleum refining and related industries

01 Petroleum refining

02 Paving and roofing materials

03 Miscellaneous products of petroleum and coal

09 Rubber and miscellaneous plastics products

01 Tires and inner tubes

02 Rubber footwear

03 Reclaimed rubber

04 Fabricated rubber products, not elsewhere classified

05 Miscellaneous plastics products

10 Leather and leather products

02 Industrial leather belting and packing

03 Boot and shoe cut stock and findings

04 Footwear, except rubber

05 Leather gloves and mittens

06 Luggage

07 Handbags and other personal leather goods

08 Leather goods, not elsewhere classified

04 Transportation, communication, electric, gas, and sanitrary services.

01 Railroad transportation

02 Local and suburban transit and interurban passenger trans.

03 Motor freight transportation and warehousing

04 Water transportation

05 Transportation by air

06 pipeline transportation

07 Transportation services

08 Communication

01 Telephone communication (wire and radio)

02 Telegraph communication (wire and radio)

03 Radio broadcasting and television

04 Communication services, not elsewhere classified

09 Electric, gas, and sanitary services

01 Electric companies and systems

02 Gas companies and systems

03 Combination companies and systems

04 Water supply

05 Sanitary services

06 Steam supply

07 Irrigation systems

05 Wholesale and retail trade

01 Wholesale trade

01 Motor vehicles and automotive equipment

02 Drugs, chemicals, and allied products

03 Piece goods, notions, apparel

04 Groceries and related products

05 Farm product - Raw Materials

06 Electrical goods

07 Hardward and plumbing and heating equipment and supplies

08 Machinery, equipment, and supplies

09 Miscellaneous wholesalers

02 Retail trade

01 Building materials, hardward, and farm equipment dealers

02 Retail trade-general merchandise

03 Food stores

04 Automotive dealers and gasoline service stations

05 Apparel and assessory stores

06 Furniture, home furnishings and equipment stores

07 Eating and drinking places

08 Miscellaneous retail stores

06 Finance, insurance, and real estate

01 Banking

02 Credit agencies other than banks

03 Security, commodity brokers, dealers, exchanges and services

04 Insurance carriers

05 Cafes

06 Cafeterias

07 Carry-out restaurants-retail

08 Caterers

09 Commissary restaurants

10 Dairy bars - retail

11 Diners (lunch stands)

12 Drive in restaurants

13 Frozen custard stands

14 Grills (eating places)

15 Hot dog (frankfurter) stands

16 Ice cream stands

17 Lunch bars

18 Lunch counters

19 Lunch rooms

20 Luncheonettes

21 Oyster bars

22 Pizzeria

23 Refreshment stands

24 Restaurants

25 Sandwich bars or shops- regail

26 Soda fountains

27 Soft drink stands-retail

28 Tea rooms

08 School

01 Kindergarten

01 Public

02 Non-public

02 Grades 1 to 8

01 Public

02 Non-public

03 Residential schools for exceptional children

04 Federal schools for Indians

05 Federal schools on federal instalations

03 Grades 9 to 12

01 Public high schools

02 Non-public high schools

03 Residential schools for execptional children

04 Federal schools for Indians

05 Federal schools on federal installations

04 Higher education

01 Publicly controlled

02 Privately controlled

09 Transportation terminals

01 Ground transportation terminal

01 Whelled vehicle terminal

01 Automobile

02 Bus

02 Track vehicle terminal

01 Railroad station

02 Mono-rail station

02 Airport

03 Harbor

OBJECT TO BE TRANSPORTED

20 Object to be transported

- 01 Live Cargo
  - 01 Animal
    - 01 Human
      - 01 Male
        - 01 Adult
        - 02 Child
    - 02 Non-human
  - 02 Plant
- 02 Goods

CONVEYANCE

30 Conveyance

01 Landcraft

01 "Free" conveyance

01 Wheeled

01 Automobile

02 Saloon/sedan

01 2-door

02 4-door

03 4 + 1 door

03 Copue'

01 2-door

02 4-door

04 Spider

05 Roadster

06 convertible

01 no doors

02 2-door

03 4-door

07 Estate car/station wagon

01 no door

02 2 + 1 door

03 4 + 1 door

08 Open

01 No doors

02 2-door

03 2 + 1 door

04 2 + 2 door

05 4 - Door

09 Hard top

01 2-door

02 2-door

10 Limousine

02 Bus

01 Inter-urban

02 Intra-urban

03 Trolley

04 Truck

01 Panel

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

02 Pickup

03 Multistop

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

04 Platform truck

01 Single unit

01 Light

02 Medium

03 light-heavy

04 Heavy-heavy

02 Combination

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

05 Cattle rack

01 Single unit

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

02 Combination

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

06 Van

01 Open top van

01 Single unit

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

02 Combination

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

03 Closed top van

01 Single unit

01 light

02 Medium

03 Light-heavy

04 Heavy-heavy

02 Combination

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

04 Refrigerated van

01 Single unit

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

02 Combination

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

07 Low bed

01 Single unit

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

02 Combination

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

08 Depressed center

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

09 Wench

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

10 Wrecker

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

11 Pole and logging

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

12 Auto transport

- 01 Light
- 02 Medium
- 03 Light-heavy
- 04 Heavy-heavy

13 Dump

- 01 Single unit
    - 01 Light
    - 02 Medium
    - 03 Light-heavy
    - 04 Heavy-heavy
- 02 Combination
    - 01 Light
    - 02 Medium
    - 03 Light-heavy
    - 04 Heavy-heavy

14 Tank

- 01 Single unit
    - 01 Light
    - 02 Medium
    - 03 Light-heavy
    - 04 Heavy-heavy
- 02 Combination
    - 01 Light
    - 02 Medium
    - 03 Light-heavy
    - 04 Heavy-heavy

15 Cement mixer

01 Single unit

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

02 Combination

01 Light

02 Medium

03 Light-heavy

04 Heavy-heavy

16 Other

01 Single unit

02 Combination

05 Other

02 Tracked

03 Other

02 "Guided" conveyance

01 Railway train

01 Surface

02 Sub-surface

03 Elevated

02 Other "Guided" conveyances

02 Watercraft

03 Aircraft

CONVEYANCE CONTROLLER

40 Conveyance controller

- 01 Human being
  - 01 Male
    - 01 Adult
    - 02 Child
  - 02 Female
    - 01 Adult
    - 02 Child
- 02 Electronic or mechanical device
  - 01 Organic to conveyance
  - 02 External to conveyance

THE WAY

50 The way

- 01 The way links
  - 01 Landways
    - 01 "Free conveyance" ways
      - 01 Roadways
        - 01 Dirt
        - 02 Surfaced
          - 01 Single-lane roadway
            - 01 At grade
              - 01 Free access
              - 02 Controlled access
            - 02 Elevated
              - 01 Viaduct
              - 02 Bridge
            - 03 Depressed
              - 01 Tunnel
              - 02 Underpass
          - 02 2-lane roadway
            - 01 At grade
              - 01 Free access
              - 02 Controlled access
            - 02 Elevated
              - 01 Viaduct
              - 02 Bridge
            - 03 Depressed

- 01 Tunnel
- 02 Underpass

04 4-lane undivided roadway

- 01 At grade
  - 01 Free access
  - 02 Controlled access
- 02 Elevated
  - 01 Viaduct
  - 02 Bridge
- 03 Depressed
  - 01 Tunnel
  - 02 Underpass

05 Divided roadway

- 01 At grade
  - 01 Free access
  - 02 Controlled access
- 02 Elevated
  - 01 Viaduct
  - 02 Bridge
- 03 Depressed
  - 01 Tunnel
  - 02 Underpass

02 Other "F.C." ways

02 "Conveyance guiding" ways

- 01 Railroad tracks
- 02 Tubes
- 03 Conveyors

REGULATING SYSTEM

60 Regulating system

- 01 Laws
  - 01 Laws governing land transportation
    - 01 Laws governing transportation on "Free Conveyance" ways
      - 01 Laws governing roadway transportation
        - 01 Traffic laws
        - 02 Manufacturing standards, licensing laws, etc.
        - 03 Other laws governing roadway transportation
      - 02 Laws governing transportation on "conveyance guiding" ways
    - 02 Laws governing air transportation
    - 03 Laws governing water transportation
  - 02 Enforcement element
    - 01 Federal
    - 02 State
    - 03 County
    - 04 Local
  - 03 "Information" communications to conveyance controller
    - 01 Visual
      - 01 Signs
      - 02 Signals
    - 02 Audio
      - 01 Radio
      - 02 Direct (horns, bells, etc.)

03 Physical

01 Barricade

02 Other

DESTINATION

70 Destination

(decomposition is the same as for <u>origin</u>)