Anhydrous sodium acetate will serve as the catalyst with maleic, chloro-maleic, and methylglutaconic anhydrides, giving yields of 0.54, 0.22, and 1.02 moles CO₂ per mole of anhydride.

The products of all these reactions are black and brown-black, are soluble in acetone, acetoephonone, dioxane, and aqueous alkali and are insoluble in benzene, toluene, ether, chloroform and carbon tetrachloride, and aqueous acid. The reaction can be carried on in solution in acetic anhydride, diphenylmethane, acetone, and acetoephonone.

The product is heterogeneous since it can be fractionated by solution in acetone and precipitation by ether. The most soluble fraction is brown; the least soluble one tends to be black.

Cyclopentylmaleic, dodecenylsuccinic, 1,2-cyclohexanedicarboxylic, and cyclohexene-1,2-dicarboxylic anhydrides do not produce CO₂ on treatment with tertiary amines.

Summary.—Many cyclic aliphatic anhydrides on treatment with catalytic amounts of a tertiary amine undergo a reaction with the evolution of CO₂. The evolution of CO₂ is preceded by the appearance of a red to purple intermediate. The products are brittle and amorphous, soluble in polar solvents and in alkali, insoluble in nonpolar solvents and acid.

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† Part of the work described here was carried out while one of us (D. R.) was a guest at the Weizmann Institute of Science at Rehovoth, Israel. We are indebted to Dr. E. Katchalsky for many helpful discussions.

1 Pfeiffer, P., and T. Böttler, Ber., 51, 1819 (1918).
4 We are indebted to Dr. W. R. Vaughn of the University of Michigan for a sample of this anhydride.
5 Obtained from Allied Chemical and Dye Corp., Buffalo, N. Y. Used without further purification.
6 Obtained from Brothers Chemical Co., Orange, N. J. Used without further purification.

URBAN PLANNING, TRANSPORTATION, AND SYSTEMS ANALYSIS*

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As a consequence of established trends in our contemporary society, more planning is required and practiced in the United States with each passing year. Planning is applied in many forms and areas of activity. It is therefore of growing importance that the American people have the opportunity to choose among the
basic objectives implicit in such plans, and between alternative methods of effec-
tuation. Without the presentation of this choice, the people will find themselves
increasingly committed to ends and means established without their awareness by a
host of separate governmental, business, and professional decisions and actions.
A procedure of conscious selection will not require techniques of prediction which
produce precise answers. What is essential in the American system is the oppor-
tunity for an enlightened choice based on the facts and best judgments available.

Although this discussion focuses on the physical environment, the human being
is central in comprehensive planning, transportation, and related systems analysis.
Techniques from which man is excluded in the basic study, and only appended
to the solution later, are clearly unsound but by no means uncommon. Sociological
material to be used in planning must be based on the needs and expressed desires
of man, as interpreted by persons of wisdom and good will who are informed of the
present, knowledgeable of the past, and can reason logically concerning the future.
Current data obtained by scientific sampling provides neither reliable extrapolation
nor the types of evaluative and projective judgment required in planning. Rela-
tively few people have the requisite information or experience for considered judg-
ments concerning complex problems and the longer-range future. We cannot yet
sample basic or unconscious motivations which might permit the prediction of
future opinions. And as expressed by one scientist: humans are a highly unlinear
device.

Planning and Systems Engineering.—The methods of analysis and synthesis now
available or under development within mathematics, science, engineering, and other
disciplines are adequate for the formulation of alternative plans for communities
and regions—including their transport systems. The techniques of the newer
fields called operations analysis, operations research, and systems synthesis, when
combined with the methodologies of engineering, comprise systems engineering.

Systems engineering deals with a production process, complex of activities, or
functioning organism of several or many parts. It treats these parts as interde-
pendent, using mathematical and other expressions which permit the quantifica-
tion and intercomparison of components. It evaluates the process or activity
with reference to stated objectives or specific results, often expressed as cost, time,
resources consumed, or impact on man. It derives alternative ways of achieving
these objectives. The basic intent and the measure of its success is an optimum
relationship between the combined inputs into the system and the outputs of the
system, which satisfies the established purposes and various limiting criteria.
Systems engineering seeks to measure not only the performance reliability of parts
of the organism, but predict its probable life as an entity as designed. It is applied
from initial conception to the termination of the system. It includes man as well as
machines and other inanimate phenomena in its formulation and treatment of the
problem.

Systems optimization with respect to man involves more than his average physio-
logical and psychological requirements. It must account for the important indi-
vidual differences among men, and include the needs of the whole emotional-
intellectual being. At least for some time to come, determination of human ob-
jectives for planning will remain essentially a matter of value judgment. But there
is much we can do to improve our techniques of achieving sound value judgments,
and to fulfill the democratic purpose of fundamental betterment in the condition of man.

Systems engineering, or its equivalent in the different descriptive words which some prefer, is a core methodology of coordinative planning. Because it is directed toward constructive guidance and the prevention of mistakes, rather than toward static diagnosis, it incorporates the basic intent of planning. To be sure, many more data than are now recorded and available will be needed to design systems with predictive characteristics, but the electronic computer is at hand to correlate, store, and otherwise process the information. In their treatment of all elements of an organism as interdependent, planning and systems engineering contrast with the artifice of treating each component separately. Unfortunately, this artifice is still in common use: witness as a single example the separate handling of the different utilities installed in the city street, with the usual result that its over-all design and functioning suffer from this lack of integration, and total costs over time are increased.

Mobility.—The extension of man's senses and physical capabilities is a development as old as man. First, he transferred certain of his activities to domestic animals, and later to machines. He is now extending his control of repetitive-deterministic processes through automation. Man has also collectivized his activities, in that he has made it possible for one person to perform or control the work tasks of many others. But man's innate needs, mode of life, social mores, and drives are such that he refuses intuitively for his own well-being to delegate certain of his individual functions to machines or other men. Should he ever choose to do so, the nature of our society would change radically. Theoretically, a human society could evolve like those of the social insects, with a group of queens performing the significant control and a mass of human drones following a pattern of prescribed action.

It is possible to collectivize the transport of goods and people to a much greater extent than is now the case, but certain of these movements must remain subject to individual choice. Some maintain the best balance has already been disturbed. Man sits too much, an unnatural position for prolonged periods. He appears overly enamored of the many personal control tasks now possible through widespread mechanization. The availability of power which the individual can manipulate to effect his own movements is both a significant step forward and a great temptation for misuse; the automobile, of course, is the prime example. Parenthetically, individual transportation does not extend man's senses, unless the rear view mirror is an exception. In general, the acceleration of mechanization, materialism, and organizational-social conformity suggest we at least pause and consider to what extent these trends coincide with our desired objectives.

The means of extending individual surface mobility to a larger and larger proportion of the population are at hand, with new horizons of air transport in the making. But the direct and indirect costs of unplanned expansion—in space, manpower, dollars, time, natural resources, and human wear and tear—are being largely ignored. In an expanding and profligate society, failure to evaluate present and future costs in the broadest sense of the term is a serious omission.

Such an evaluation requires theoretical advances. Only so much is accomplished by the accumulation of masses of transportation data, unless they are transformed into meaningful generalizations or specific formulations which can be employed
in system design and control. It might be added that such data-gathering can be made more efficient by a more extensive use of models. These are helpful in determining initially what data are needed and in what form, or as a check during the earlier stages of collection. In certain situations, their use may eliminate the need for elaborate survey. Under the auspices of the U.S. Office of Naval Research, Air Force, and the National Academy of Sciences—National Research Council, some progress has been made in studying the air and ocean transport of goods. But further study is needed to evaluate the complete sequence of movement and related effort from beginning to end: shipment, storage, loading, unloading, transportation, communication, organizations, and the use of material resources, time, money, and people. Theories of mobility are needed applicable to goods, wastes, and the many materials produced and transported in discrete form. And there is more to be learned about the methods of moving continuous media or energy such as water, electric power, gas, or oil—especially with reference to their location on, below, or above ground. Time and motion studies, hydraulics, queueing theory, mathematical and logical simulation, and the various theories of traffic flow will be among the techniques applied.

Finally, the total transportation function of moving goods and people within a city, region, or nation must be examined as a single complex of many interrelated subsystems and parts. Only in this way will we learn how the different modes of transportation might be used to complement each other and optimize the functioning of the total system. Such analysis is best conducted by a neutral organization, for among the problems which cannot be ignored is the role of regulatory agencies, of government and private ownership. Although traditions and established positions are strong on this score, they will have to be resolved gradually in terms of the general public interest.

Transportation Systems and Urban Variables.—It is an axiom confirmed by settlements throughout history that transportation routes for men and materials are primary determinants of the physical arrangement of human habitats. The use of land other than for transportation also shapes the form of communities and rural regions. Because of the significance of accessibility in the employment of land, transportation and land use are, of course, closely interrelated—an age-old interdependence highlighted by mass transportation and the private automobile. But land use is also influenced by topography, geology, climate, religion, and many other factors. In particular situations, any one of the many elements constituting the human habitat may be dominant. There are today only a few elements in planning which are treated as absolutes: climate, seismic conditions, atmospheric radiation, tides, or other natural phenomena beyond human influence. And the effects of even these are subject to increasing modification by man at a cost in time, money, and other resources: climate by heating, air conditioning, or cloud seeding; seismic effects by preventive engineering; or atmospheric radiation by atomic fallout. Since we possess the capability of atomic explosion, atmospheric pollution, or affecting our biological development, it can be argued there are no immutables in planning.

But the successful conduct of the affairs of men normally requires a conceptual and procedural dominant. Plans are formulated and effectuated in terms of primary and secondary elements. The primary elements can be considered relatively
independent variables. Their selection is vital to the substance of the plan on paper and its outcome in physical space. To the extent one can generalize, transportation, land use, and utilities are the dominants of urban planning in the United States today. Unfortunately, however, it is often assumed that these dominants which shape the community for many years should follow current preferences and self-interest.

It would be better if the people concerned decided what fundamental characteristics they want in the city in the future, the functions they believe paramount. These choices would establish parameters of land use and population density, which in turn determine the network of transport conforming to the selected urban functions. A series of progressive steps or transformations in the transportation system would be undertaken to bring about the desired city of the future. To be sure, our concept of the desirable city changes, but not so continuously or radically that the process of planning does not produce in the long run results more satisfying and closer to our total wishes than would occur by chance. Furthermore, there is actually no choice, for planning has always been an essential aspect of human action. In the complex technological world of today, it is more than ever necessary.

Because a city rebuilds itself gradually by discrete increments, change is inevitable and directed rearrangement entirely feasible. The American community today renews itself for the most part in seventy-five to one hundred years. Its primary productive facilities are replaced at shorter intervals, and many residential structures are becoming less permanent. Also, we can now tear down and rebuild more quickly than we could not too many years ago, and moving entire buildings is often feasible. These observations underline the fundamental nature of cities and ruralities as subtle systems of many interrelated parts. These systems are evolving continuously, and are subject to directed change by the selection and progressive modification of primary elements. Chaos will result, however, especially in the economic realm, if development is the consequence of independent planning by separate agencies responsible for a particular resource or those responsible for different forms of transportation.

Analytic Models.—A community can be conceptualized in two parts. The first consists of the sum total of the historical, legal, traditional, psychological, and other human forces which influence decisions involving change. The second part comprises the physical content of the city.

The physical portion includes three types of nodes, places of "rest" or storage: the domicile, place of work, and service node. The abode may be house, apartment, trailer, and possibly cemetery for permanent residence. The locus of work may be office, factory, field, or elsewhere. The service node includes schools, churches, hospitals, markets, government, recreation, and the like. Normally, these nodes merge into one another without sharp demarcation. In some cases, they coincide at the same point in space. Between these nodal concentrations there are fluxes, many forms of movement and communication. The metropolitan region in all its complexity could be expressed and examined in terms of such nodes and the transport functions between them.

The purpose here is not to formulate a specific model, but only to suggest the type of construct which can now be programmed on an electronic computer to reveal relationships hitherto indeterminate or even unrecognized because of the
time and cost of processing masses of data by office machine. Clearly, a first objective of rational planning will be to determine an optimal structure of the city from the viewpoint of costs over time, including those of transportation. To achieve this in meaningful form for planning will require some analytic simulation relating space, time, cost, and function.

The optimum pattern with reference to costs will not necessarily be the optimum pattern all things considered. There are the many human factors to be incorporated—the other half of our conceptual example. Nor is the optimum cost-pattern necessarily the most achievable, for some nodes are likely to be too deeply fixed even for gradual relocation. Purely rational analysis is limited by definition, and must always be adjusted to the forces of history, law, or cultural mores, and to the realities of emotional preference and prejudice. But such cost studies will undoubtedly tell us more about what we are doing, and perhaps give us pause to examine the consequences or best way of directing basic rearrangements now under way: the flood tide from country to city, the disappearance of agriculture from metropolitan regions, the migration from northern to southern climes, the growth of trailer living, or extreme concentrations of population as occurring in Southern California. One question must surely be asked: Do the designs of present communities reflect the increasing mobility of modern man, or will costs become unbearable when the provisions required for this mobility are superposed on the urban and suburban patterns as now conceived and executed?

_Dubious Philosophies of Urban Design._—One philosophy of engineering design assumes man is moving in completely wrong directions, and should look to the past for his ideas and urban forms. What is past is certainly prologue, but copying urban forms belonging to historical periods so different from ours in so many fundamental ways is hardly sound or practical.

Another philosophy of design considers the urban environment of today satisfactory because it necessarily reflects the socio-economic forces which brought it about. The future city can therefore be designed by the extension and duplication of what we now have. It is quite clear, however, that if certain urban variables are interdependent, but the laws of their interrelation are unknown, linear extrapolation can lead to absurd answers. As the population changes and its derivatives in time and space change, forces of unrecognized significance may become important determinants and entirely "new" factors may be introduced.

In general, man responds to gradual change, although he often causes and reacts positively to catastrophic change. There are those who maintain that the solution of the transportation problem will not be provided or accepted until conditions first become intolerable. This view assumes the nation and the community can tolerate the widespread consequences of transportation chaos. But San Francisco did not rebuild itself in more rational form after the disastrous fire of 1906, and the urban historian Pierre Lavedan has written convincingly of "La Loi de la Persistance du Plan." The experience of both world wars shows that when cities are damaged severely or destroyed, the emergency needs of shelter and any form of renewed urban life and functioning far outweigh the opportunity for the constructive reorganization of the urban pattern. Such times are surcharged with emotion and the basic instinctual drives of survival. There is a rush to identify in the rubble the boundaries of property which often represents a last remaining economic resource.
The cities which have used catastrophe or chaos to rebuild according to a rationally improved urban form can probably be counted on the fingers of one hand.

**Engineering Solutions.**—The engineer employs analytical and experimental methods to derive solutions to problems posed by society or conceived by him. In the analytical method, he constructs an ideal system based on his perception of the real, existing system. Until recent times, this ideal conceptualization was chosen conservatively because the engineer usually depended on classical examples for his logic of solution. The introduction of statistical methods has allowed the extension of the ideal system from the deterministic to the stochastic, and the advent of the electronic computer permits examination of a range of conceptual systems. Actual system behavior can thus be approximated from two directions—the actual and the ideal. Whatever the method of solution, the engineer must resort to judgments based on experience to fill the gap between the predicted behavior of the ideal formulation and the actual behavior of the system in being. This contribution is the art of engineering.

Analogy is, of course, one way of applying established solutions to a related domain of investigation. Simulation is an important engineering technique, whether digital or analog computers are used, or physical models. Experimental methods are employed to determine the behavior of a prototype, if one is available or is worth constructing because it will be repeated many times—as for example a test section of roadway or pipeline. Parenthetically, deciding what constitutes an adequate prototype is clearly important. But in this connection, it may be observed that millions of dollars are spent for research on the materials and exact construction of roadbeds, but little for research relating to the flow characteristics of the road when built. Experiment is also a powerful tool when applied to models which are comparable to the prototype because they conform to the same differential equations, exhibit similar boundary and initial conditions, or can be related by scale factors. Ordinarily, a combination of these techniques is most successful.

Promising predictive results are being attained in transportation by analytical methods and computers, using queueing theory, statistical mechanics similar to Boltzmann's approach to quantum theory and energy degradation, shock wave propagation, vehicle-following behavior as a dynamic control problem, and various simulation techniques. Certain traffic flow situations can be compared meaningfully to the flow system of compressible fluids, and a theory of the flow of discrete objects is being developed slowly from circuit and information theory.

The employment of the computer produces specific numerical results, but these can be generalized in several ways: through the generation of dimensionless moduli either by differential equations which may not be solvable; dimensional analysis; or by dimensionless variables similar to those of thermodynamics, or to those of electrical and hydraulic engineering where the ratio of the variable to the critical but general magnitude of the same variable is used.

An ideal system may be defined for a region, metropolitan city, its central core, or a community within the city. The computer allows the testing of many nodal arrangements in terms of transportation costs. Other concepts of the best spatial organization of cities can also be tested, such as those to be found in the literature of urban planning. In each instance, however, the system under examination must be defined accurately, and its boundary conditions established for all fluxes
and their variations in time. Communications and the movement of resources such as power, water, or air must be included as well as the transportation of goods and people.

Prototype-testing in the field with the consumer as the experimenter is an honored American method, but the performance data required for systems analysis are rarely obtained. Only in certain areas of urban development and design are truly scientific approaches under way. With the public deeply concerned with the rising costs of living and governmental services, the generalized techniques now available should be used to develop feasibility studies, functionally economic designs, and finally optimum systems of urban organization and operation over time from all essential points of view.

A Requirement of Further Progress.—To make significant progress along the lines suggested here, there is need for encouragement, leadership, and monetary support at a high level. In particular, an organizational mechanism must be formed to sponsor research permitting those most knowledgeable in planning, transportation, and urban analysis to apply themselves to the many questions still to be answered. Working groups are needed to advance specific techniques and the state of the art of systems engineering.

Since some two thirds of the American people live in metropolitan regions, there can be no question of the primary importance of our cities. The essential requirement is a more effective application at the national level of our best minds and most understanding personalities to the problems of urban planning and related decision-making.

* An invited presentation at the session on Transportation and Patterns of Living, during the Annual Meeting of the National Research Council, National Academy of Sciences, Washington, D.C., March 24–26, 1960.


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