Systems Analysis as a Tool for Urban Planning

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Abstract—New ways are becoming available for analyzing our social systems. These permit the design of revised policies to improve the behavior of the systems within which we live. Industrial dynamics relates system structure to behavior. Industrial dynamics belongs to the same general subject area as feedback systems, servomechanisms theory, and cybernetics. Industrial dynamics is the study of how the feedback loop structure of a system produces the dynamic behavior of that system. In managerial terms industrial dynamics makes possible the structuring of the components and policies of a system to show how the resulting dynamic behavior is produced. In terms of social systems it deals with the forces that arise within a system to cause changes through time. The structure of an urban area has been organized into a system model to show the life cycle dynamics of urban growth and decay. The results suggest that most of today's popular urban policies lie between neutral and detrimental in their effectiveness. Quite different policies are suggested when one comes to an understanding of why urban areas evolve as they do.

The city shows the general characteristics of a complex system. Complex systems are counterintuitive; they resist policy changes; they contain influence points from which changes can be made to radiate; they tend to counteract programs aimed at alleviating symptoms; their short-term response to a policy change is often in the opposite direction from the long-term response; they contain dynamic mechanisms that produce the observed undesirable behavior; and they generate pressures characteristic of each stable mode in which they might operate.

New ways are becoming available for analyzing our social systems. These permit the design of revised policies to improve the behavior of the systems within which we live. Many of the ideas discussed here are treated more fully in [1] which shows the city as an interacting system of industry, housing, and people. The book presents a theory, in the form of a computer model, that interrelates the components of a city. It shows how the interacting processes produce urban growth and cause growth to give way to stagnation. Various changes in policies are examined with the laboratory model to show their effect on an urban area. A number of presently popular proposals are tested: a job training program, job creation by bussing to suburban industries or by the government as employer of last resort, financial subsidies to the city, and low-cost housing programs. These are all shown to lie between neutral and detrimental in their effect on a depressed urban area. The evolution of an urban area from growth into stagnation creates a condition of excess housing. Housing is excess compared to the population and compared to the availability of income earning opportunities. To reestablish a healthy economic balance and a continuous process of internal renewal, it appears necessary to reduce the in-herent excess housing of depressed areas and to encourage the conversion of part of the land to industrial use. By so doing, a large enough wage and salary stream can be brought from the outside economy to make the area self sustaining.

As you can see, these results are controversial. If they are right, it shows that most of the traditional steps taken to alleviate the conditions of our cities may actually be making matters worse. This book [1] first appeared this last May; it is already in the second printing. Although it has so far received little public notice in this country, it has become the center of a political tempest in Canada. North of the border, newspaper headlines, editorials, and radio and television panel discussions are debating its merits.

It is based on methods for studying complex systems that form a bridge between engineering and the social sciences. Although we will present here some of those results, my principal emphasis will be on the importance of the methods to all social systems.

Over a decade ago at M.I.T., we began to examine the dynamic characteristics of managerial systems. The field known as industrial dynamics resulted [2]. Industrial dynamics belongs to the same general subject area as feedback systems, servomechanisms theory, and cybernetics. Industrial dynamics is the study of how the feedback loop structure of a system produces the dynamic behavior of that system. In managerial terms industrial dynamics makes possible the structuring of the components and policies of a system to show how the resulting dynamic behavior is produced. In terms of social systems it deals with the forces that arise within a system to cause changes through time.

A design study of a social system seeks changes in structure and policies that will improve the behavior of the system. Some people recoil at the thought of designing social systems. They feel that designing a society is immoral. But we have no choice about living in a system that has been designed. The laws, tax policies, and traditions of a society constitute the design of a social system. Our available choice is only between different designs. If we lament the functioning of our cities, or the persistence of inflation, or the changes in our environment, we mean that we prefer a social system of a different design.

The design process is first to observe the behavior modes of a system to identify the symptoms of trouble. Second, the system is searched for the feedback structures that might produce the observed behavior. Third, the level and rate variables making up that structure are identified and explicitly described in the equations of a computer simulation model. Fourth, the computer model is then used to simulate in the laboratory the dynamic behavior implicit in the identified structure. Fifth, the structure is modified until components of the structure and the resulting behavior

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agree with the observed conditions in the actual system. Sixth, modified policies can then be introduced into the simulation model in search of usable and acceptable policies that give improved behavior.

This design process brings the essential substance of a social system into the laboratory where the system can be studied. Laboratory representation of a social system can be far more effective than most people would expect. Anything that can be stated or described about a social system can be represented in such a laboratory model. The major difficulty is the rarity of skilled professional talent. There are very few men with a knowledge of the proper guiding principles and with experience in perceiving the pertinent feedback structure of complex poorly defined systems. Whatever one may say about the shortcomings of the process, there is no comparably effective substitute.

Surprising discoveries come from this combination of theory and laboratory experimentation. We observe that relatively simple structures produce much of the complex behavior of real-life systems. We find that people’s skills in perception are very different from those commonly supposed. It is often asserted in the social sciences that people are unreliable in analyzing their own actions, yet we find time and again that the policies and practices that people know they are following are the ones that interact to produce the most troublesome consequences. Conversely, it can be clearly demonstrated that the vaunted powers of judgment and intuition usually deceive the person who tries to guess the time-varying consequences that follow even from a completely known system structure. We find that the modes of behavior which are most conspicuous in managerial, urban, and economic systems are produced by nonlinearities within those systems. The linearized models which have been used in much of engineering and the social sciences cannot even approximate the important modes of behavior in our social systems. The most visible and troublesome modes are manifestations of nonlinear interactions. We find it relatively straightforward to include the so-called intangible factors relating to psychological variables, attitudes, and human reactions. Again, if the influences can be discussed and described, they can be inserted in the policy structure of a model. Any person who discusses why people act the way they do, or explains a past decision, or anticipates a future action is relating the surrounding circumstances to the corresponding human response. Any such discussion is a description of decision-making policy. Any such policy statement can be put into a system model.

A body of dynamic theory and principles of structure is emerging that allows us to organize and understand complex systems [3]. For example, the feedback loop becomes the basic building block of systems. Within the feedback loop there are two and only two kinds of variables. One is the level variable produced by integration; the other is the policy statement or rate variable which governs the changes in a system. The level variables are changed only by the rates of flow. The rate variables depend only on the levels. Any path through a system network encounters alternating level and rate variables. These and many other principles of structure are universal in the entire sweep of systems that change through time. Furthermore, the structure of a system determines its possible modes of behavior. Identical structures recur as one moves between apparently dissimilar fields. These identical structures behave in identical ways wherever they are found.

The same principles of structure and the same relationships between structure and behavior apply to a simple swinging pendulum, a chemical plant, the processes of management, internal medicine, economics, power politics, and psychiatry. A universal approach to time-varying systems is emerging which seems capable of dealing with systems of any complexity. We observe that students, as they master the principles and practice of dynamic analysis, develop a remarkable mobility between fields of endeavor. The same person can clarify the dynamics of how a transistor functions, organize the processes of a public health epidemic, design new management policies to avoid stagnation in product growth, discover the sensitive factors in ecological change, and show how government policies affect the growth and decline of a city.

Some diagrams showing urban behavior will illustrate these ideas. Fig. 1 shows the central structure of an urban area. The nine rectangles represent the selected level variables. The 22 valve symbols represent the rates of flow that cause the nine system levels to change. Engineers often refer to these level variables as the state variables of a system. The distinction between level and rate variables is also familiar to anyone who examines financial statements. Balance sheet variables are always separated from variables on the profit and loss statement. They are separate because they are conceptually quite different. The balance sheet variables are system levels. They are created by accumulating financial flows. The profit and loss variables are system rates. This sharp distinction is found in all systems.

In this figure one can begin to detect the reasons for urban decline. The age of a building tends to determine the character of its occupants. New commercial buildings are constructed through the rate of flow NEC in the upper left corner of Fig. 1. A new commercial building is occupied by a healthy successful commercial organization that uses
relatively more managers and skilled workers than those who are unskilled. As the building ages first into the mature business category and then into the declining industry category, it tends to be occupied by a progressively less successful enterprise with lower employment skills. In addition to the changing employment mix as the industrial building ages, there is a tendency for total employment per unit of floor space to decline. This means that as industrial buildings age the total employment declines and also the average wage paid declines. On the other hand, as residential buildings age, there is a tendency for occupancy to increase as well as to shift to a lower economic category of population. As housing in Fig. 1 moves from premium housing and worker housing into the older underemployed housing category, the housing is acceptable only to the lower income population. But the income of this group is not sufficient to use the buildings at the original population density. Lower incomes mean that the floor space must be used more intensively. As the building ages it attracts a lower income occupant and the building houses a higher population density. One perceives then a condition where the aging of buildings in an urban area simultaneously reduces the opportunities for employment and increases the population. The average income and standard of living decline.

Fig. 2 shows the same nine system levels and one of the 22 flow rates. The dotted lines are the information linkages from the system levels to control the one flow rate, here the arrival of underemployed population into the urban area. The various levels of the system combine to create a composite attractiveness which determines the inflow rate to the area. If the area is more attractive than those from which people might come, a net inward population flow occurs. If the area is less attractive, an outward flow dominates. Five components of attractiveness are shown in Fig. 2. In the upper right corner UJM relates the population to the available jobs and represents the income-earning attractiveness of the area. The circle UAMM generates the attractiveness created by upward economic mobility. In other words, an area with high upward economic mobility is more attractive than one offering no hope of advancement. The circle UHM relates the underemployed population to the available housing. The area becomes more attractive as housing becomes more available. UHPM represents the attractiveness of a low-cost housing program if such exists. And in the lower right corner PEM is the influence on attractiveness of the public expenditure per capita. As per capita expenditure arises, it means better public services, better schools, and higher welfare budgets.

The concept of attractiveness is fundamental to the population flows. Of all the characteristics of an area that make it attractive, these five and many more combine to influence migration. An attractive area draws people. But almost every component of attractiveness is driven down by an increase in population. If there is an excess of housing, the area is attractive, but a rising population crowds the housing. If there is an excess of jobs, the area is attractive, but the incoming flow of people fills those jobs. In other words, migration continues until the attractiveness of the area falls and becomes equal to all other places from which people might come.

An important idea follows from examining these components of attractiveness. In a condition of population equilibrium, all areas must be equally attractive to any given population class; otherwise net migration would occur. If one component of attractiveness is increased in an area, other components must necessarily fall to establish a new equilibrium. Compensating changes in the components of attractiveness explain many past failures in our cities wherein we attempt to improve one aspect of the city only to discover that other aspects have become worse.

In making a laboratory model of a social system one should not attempt straightaway to solve a problem. Instead one should generate a model which will create the trouble symptoms. Only if one fully understands the processes whereby difficulties are created can he hope to correct the causes. This means that we want a model of an urban area which can start with empty land, grow a city, and show the processes whereby economic health falters into stagnation and decay.

As another guide to modeling, one should start, not by building a model of a particular situation, but by modeling the general class of systems under study. This may seem surprising, but the general model is simpler and initially more informative than a model of a special case. Here we wish to model the general process of urban growth and stagnation. It should be a model which, with proper changes in parameters, is good for New York, Calcutta, a gold rush camp, or West Berlin. These all seem to have very different characteristics but they have certain elements in common which describe their urban processes. There are fewer concepts which are common to all than are to be found in any one. The general model can strip away the multitude of detail which confuses any one special situation. The general model identifies the central processes and is a statement of the theory for the entire class of systems.
Fig. 3 shows the behavior of the laboratory model of an urban area. It presents the nine system level variables over 250 years. The first 100 years is a period of exponential growth; however, when the land area becomes filled, growth ceases, and the aging process begins. At year 100, near the end of the growth phase, the labor population is almost double the underemployed population. This is a healthy mix which is well matched to the job distribution in the area and which gives a high upward economic mobility to the underemployed population. But by year 150, the labor population has fallen and the underemployed population has risen until these two groups are almost equal. Business activity has declined and the area has taken on the characteristics of a depressed city. This has occurred because of the way that the industry, housing, and populations in Fig. 1 have interacted with each other.

Fig. 4 shows other variables during the same 250 years. Notice especially the UR and UAR. During most of the first 100 years of growth these two ratios were almost constant. The URH was high (above the center of the figure) meaning that the population is large compared to the housing. In other words, during the first 100 years there was a housing shortage for the underemployed population. On the other hand, the UR was low, meaning that the population was below the job opportunities, jobs were readily available, economic opportunity was good, and upward economic mobility was high. During this early period of growth and high economic activity, the underemployed population was being effectively adjusted in relation to other activity by balancing good economic opportunity against a housing shortage.

But between 90 and 140 years, notice the sharp reversal of the curves for the UR and UAR. Within this 50-year span, the underemployed have increased while available jobs decreased; the result is a precipitous rise in unemployment. But in this same period, the housing that is aging and becoming available to the underemployed is rising even more rapidly than the underemployed population. Jobs have become scarce while housing has become surplus. The model is behaving the way our cities do.

Many people seem not to realize that the depressed areas of our cities are areas of excess housing. The economy of the area is not able to maintain all of the available housing. Because of low incomes, people crowd into some dwelling units while other buildings are abandoned, stand idle, and decay.

Recall the earlier comments about compensating movements in the components of attractiveness. Here, as housing becomes more available, jobs become more scarce. The stagnating urban area has become a social trap. Excess housing beckons people and causes inward migration until the rising population drives down the standard of living far enough to stop the population inflow. Anything which tends to raise the standard of living is defeated by a rise of population into the empty housing.

Fig. 5 shows 50 years beginning with the conditions found at the end of Fig. 3. At time 0, a low-cost housing program is introduced which each year builds low-cost housing for
2.5 percent of the underemployed population. Observe what happens. Underemployed housing, which is being actively constructed, rises 45 percent, but premium housing falls 35 per cent, and worker housing falls 30 percent. New enterprise declines 50 percent and mature business declines 45 percent, all in the 50-year period. Economic conditions become sufficiently worse that even the underemployed population, although it rises initially, eventually falls to slightly less than its beginning value. These changes are a result of the low-cost housing program.

In Fig. 6, the corresponding UR has risen 30 percent, indicating substantially higher unemployment, while the UHR ratio has fallen 30 percent indicating a still higher excess of housing. Again, the two components of attractiveness compensate for one another with better housing and a falling standard of living. In the long run, the low-cost housing program has not served the interests of the low-income residents. Instead, it has intensified the social trapping characteristic of the area. Over the period, the tax levies rise 35 percent. The area has become worse from almost all viewpoints.

In this same manner, job training programs, job creation programs, and financial subsidies were examined. All lie between ineffective and harmful. The low-cost housing program was the most powerful in depressing the condition of a stagnant urban area.

The depressed areas of our cities seem to be characterized by excess housing compared to jobs and by excessive concentration of low-income population. These conditions, created by aging industrial and dwelling buildings, interact to drive out the upper-income population and business activity, and to reduce the tax base. Once the decline starts, it tends to accelerate. Unless one can devise urban management policies that produce continuous renewal, difficulties are inherent.

Fig. 7 shows an urban condition that begins with stagnation and then changes toward revival. Here, 5 percent of the slum housing is removed each year, and the incentives for new enterprise construction are increased somewhat. The result is a cascading of mutual interactions which raise the economic activity of the area, increase upward economic mobility for the underemployed population, and shift the population internally from the underemployed to the labor class. This is done without driving the existing low-income population out of the area. Underemployed housing is reduced. Initially this reduction comes largely from the empty housing. The resulting housing shortage restrains the population inflow which would otherwise defeat the revival of the area.

Fig. 8 shows the same 50-year span as in the preceding figure. Here again, employment and housing move in opposite directions. The UR falls which means more jobs and lower unemployment. On the other hand, the UHR rises which means a tighter housing situation. If the economic circumstances are to be improved, we must accept some compensating change in other components of attractiveness. Here it is the increased tightness of housing which allows job opportunities to increase faster than
population until a good economic balance is reached. I stress economic revival as the first stage of rebuilding a depressed area because it appears that an economic base must precede social and cultural development.

It is simply not possible to increase all of the attractiveness components of an area simultaneously. Attractiveness is here defined in a very broad sense. For example, legal restrictions, like an immigration barrier into a country, can produce enough unattractiveness to inward migration so that other components might be maintained at a high level. But wherever one component of attractiveness is high, others will be found that are low.

Engineers, especially, should consider the compensating changes that will occur in the attractiveness components of an area, because engineers tend to deal with economic considerations and technology. Economic and technical factors are more concrete than the intangible quality of life variables. The economic and technical aspects of a city are the ones we most easily see how to improve. Our technological society tends, therefore, to observe, react to, and improve the economic and technical aspects of a city. Such improvements increase the technical and economic components of urban attractiveness. But, as a result, population density rises until the urban area once again reaches attractiveness equilibrium with its environment. The burden of forced reduction in other components of attractiveness falls on the quality of life variables: crowding, pollution, and psychological stress. These less tangible variables have been weak, hard to measure, and have been defenseless against the persuasiveness and the certainty of improvement shown by the technical and economic considerations. But we are entering a time when a reversal will occur between the formerly weak and strong variables. For a substantial fraction of our population, the standard of living is already high enough so that more gain in the economic and technical areas will come at too high a price in the quality-of-life components of our environment. The engineer, if he continues to serve society, must balance a greater number of social needs against one another. At one time his task was simply to balance financial cost against economic performance of his technology. Now the product and also the medium of payment are both expanding. Social value and quality of life become part of the product. Psychological stress, ugliness, and crowding become part of the cost. Engineers who fail to recognize this broadened role will be vilified and castigated by a society which perceives them as narrow and insensitive to the demands of the times.

When a system misbehaves, we should ask ourselves what policies within that system cause the undesirable characteristics. If we examine the laws under which a city operates, we see a structure of regulations which could hardly be better designed to create stagnation and decline. The aging and decay of buildings is central to the urban decline process; yet we see throughout our tax laws and regulations numerous incentives to keep old buildings in place. As the value of a building decreases, so do the assessed taxes. The reduced expense makes it possible to retain the old building longer. For income tax purposes under some circumstances the value of a building can be depreciated several times. This produces incentives to keep an old building in place. Here is not the place for detail, but it seems clear that a different set of tax laws and city regulations could be devised to produce the individual incentives necessary for continuous renewal. As an example, I recently saw a suggestion that each building have a mandatory trust fund into which the owner must pay a levy each year. At any time, whoever owns the building can draw out the money in the trust fund if he demolishes the building and clears the land. This, you see, would create an earlier incentive for replacement. Property tax levies and income tax accounting could both be changed to produce pressures in the same direction.

Our studies of managerial, urban, and other social systems have uncovered many general characteristics of complex systems to which we must be alert if we are to avoid continuing to create detrimental modes of behavior.

First, complex systems are counterintuitive. They behave in ways that are opposite to what most people expect. They are counterintuitive because our experience and intuition have been developed almost entirely from contact with simple systems. But in many ways, simple systems behave exactly in the opposite way from complex systems. Therefore, our experience misleads us into drawing the wrong conclusions about complex social systems.

Second, complex systems are strongly resistant to most policy changes. A new policy tends to warp the system so that slightly changed levels present new information to the policy points in the system. The new information, as processed through the new policies, tends to give the old results. There are inherent reasons within complex systems why so many of our attempts at correcting a city, a company, or an economy are destined to fail.

But third, the converse is also true. There are points in systems from which favorable influence will radiate. Often these points are difficult to perceive. Often the action required is the opposite to that which might be expected. But when these points are found, they tend to radiate new information streams in such a way that the new circumstances, when processed through the old attitudes and policies, produce a new result.

Fourth, complex systems tend to counteract most active programs aimed at alleviating symptoms. For example, [1, ch. 4] shows how a job training program can increase the number of underemployed in a city. When outside action tries to alter the condition of a system, the system relaxes its own internal processes aimed at the same result and throws the burden even more onto the outside force which is attempting to produce a correction. The internal need for action is reduced and the external supplier of action must work even harder.

Fifth, in complex systems the short-term response to a policy change is apt to be in the opposite direction from the long-term effect. This is especially treacherous. A policy change which improves matters in the short run lays a foundation for degradation in the long run. The short
tenure of men in political office favors decisions which produce results quickly. These are often the very actions that eventually drive the system to ever-worsening performance. Short- versus long-run reversal processes are all around us. If an agricultural country is to industrialize, it must accumulate railroads, factories, and steel mills. This capital accumulation can only be done by forgoing consumption and reducing the standard of living first in order that the standard of living may rise at a later time. If a company faces declining earnings because its products are obsolete, it must invest more heavily in product research and incur even deeper short-term losses if it is to recover in the more distant future to a profitable product stream. A student forgoes short-term earning opportunities by attending college in order to increase his longer term earning capability. This reversal between the short run and the long run occurs repeatedly.

Sixth, a system contains internal dynamic mechanisms that produce the observed undesirable behavior. If we ignore the fundamental causes and simply try to overwhelm the symptoms, we pit two great sets of forces against one another. In general, our social systems have evolved to a very stable configuration. If the system is troublesome, we should expect that the causes of the trouble are deeply embedded. The causes will outlast our persistence in overwhelming the symptoms. Furthermore, the internal pressures usually rise to counteract a corrective force from the outside. We can expend all our energy to no avail in trying to compensate for the troubles unless we discover the basic causes and redesign the system so that it spontaneously moves to a new mode of behavior.

And, as the last of these characteristics of complex systems, we must recognize that a certain ensemble of conditions goes with each possible mode of a system. More specifically, each mode of a system is accompanied by a set of pressures characteristic of that mode. We can not sustain a particular mode unless we are willing to accept the corresponding pressures. For example, contrast the depressed mode of a city in Figs. 5 and 6 with the revived mode in Figs. 7 and 8. The depressed mode is one characterized by the pressures that come from decaying buildings, low incomes, and social disorientation. But the revived mode also contains pressures. The revived mode is sustained by the housing shortage and the legal and tax pressures that generate a steady demolition and replacement of old buildings. But everyone in the system will want to alleviate the pressures. Active industry will want more employees; residents will want more floor space; and outsiders will want housing so they can move to the attractive job opportunities. Rents will be high. These pressures are easy to relieve by increasing the fraction of the land area permissible for housing, by keeping old buildings in place longer, and by allowing taller apartment buildings. But such moves will start the area back toward the depressed mode. We must decide the kind of system we want with knowledge of and acceptance of the accompanying pressures. Instead, much of our social legislation of the last several decades has consisted of trying to relieve one set of pressures after another. The result is a system mode characterized by inflexibility, conformity, crowding, frustration, supremacy of the organization over the individual, and a choking of the environment. And the resulting pressures, acting through the counterintuitive and short- versus long-term reversal characteristics of complex systems, may well move us further in the same direction.

We are suggesting that the time is approaching when we can design social systems to obtain far better behavior. Different policies could change our urban areas from ones which are designed to deteriorate into ones which are designed for self renewal. One can foresee a time when we will understand far better the relationships between monetary policy, interest rates, unemployment, and foreign exchange. Already such studies have thrown new light on the processes of corporate growth, on the reasons for product stagnation and loss of market share, and on the growth and decline of cities.

But to design new policies for social systems requires a level of skill which is rare. The kind of system modeling and policy design which we have been describing requires a professional training at least as extensive as that in any of the established professions. The proper training requires theory, laboratory, case studies, apprenticeship, and practicing experience.

But in the area of designing the dynamic behavior of social systems, there are as yet no adequate professional schools. The educational materials are still in the development stage. The few who show skill in this area have learned by apprenticeship and by trial and error.

Those interested in the long-run improvement of society can make the greatest contribution by encouraging research and educational programs aimed at developing a high level of talent. Again the long run competes with the short run. Creating educational materials and teachers will at first absorb money and talent which in the short run might instead be devoted to solving particular present social problems. Unless a proper balance is maintained, with substantial energy devoted to establishing an educational capability for enlarging the future pool of skills in social system design, the time when we can master our own systems will be further delayed.

NOMENCLATURE

Definitions For City Growth, Stagnation, and Revival Model

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<tr>
<th>Symbol</th>
<th>Description</th>
<th>Units</th>
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<tr>
<td>AMM</td>
<td>attractiveness-for-migration factor (dimensionless)</td>
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<tr>
<td>AMMP</td>
<td>attractiveness-for-migration multiplier perceived (dimensionless)</td>
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<tr>
<td>DID</td>
<td>declining-industry demolition (productive units per year)</td>
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<tr>
<td>LA</td>
<td>labor arrivals (men per year)</td>
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<td>LB</td>
<td>labor births (men per year)</td>
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<td>LD</td>
<td>labor deaths (men per year)</td>
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<tr>
<td>LTM</td>
<td>labor to manager (men per year)</td>
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<td>LTU</td>
<td>labor to underemployed (men per year)</td>
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<td>MA</td>
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A Case Study of Citizen Complaints as Social Indicators

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Abstract—The purpose is to illustrate the applicability of the approach and the techniques of systems engineering to certain urban problems. Systems engineering can be an effective tool in the design and operation of organizations to accomplish such urban activities as police scheduling, waste disposal, river purification, fire house location, etc. The relatively unploughed ground of applying systems engineering to the quality of urban life is addressed here. The quality of urban life, an elusive but intuitively satisfying concept, is operationally useful to the extent that a city can identify and move toward achieving the goals of its citizenry. Social indicators measure the extent to which these goals have been achieved.

For such indicators to be usable on line inputs for determining changes in urban subsystems, they must respond rapidly and sensitively to the citizenry's changing perception of the gap between goals and actual achievements. Indicators aggregated over long intervals of time, large physical areas, or population groups tend to be sluggish and historical. It is shown how unsolicited complaints and comments from the citizenry may help to define such operationally useful social indicators. A conceptual framework emphasizing adaptive urban subsystems is presented, and data are used to illustrate the feasibility of the approach.

I. Systems Engineering Context

A CITY IS an assembly of diverse physical, economic, administrative, and social subsystems. Some exist on a parallel level with one another; others are parts of a hierarchy. These subsystems, acting in concert, generate the characteristics of the city which are sensed by the residents as the quality of life in the city. This concept is fuzzy and difficult to quantify, and it is generally inferred from a series of plausible indices about such aspects of urban life as health, social mobility, income, physical environment, etc. [1]. Such indices as infant mortality, narcotics addiction, unemployment rate, air pollution measures, etc. have been used [2] to compare the quality of life in Washington, D.C., with 16 other major American cities. These comparisons provide valuable statistical benchmarks for assessing planned or unplanned social change. The drawbacks in using selected quality of life indicators, however plausible they may appear, are that 1) their choice is influenced by the values of the selector and 2) these indicators are generally broadly based aggregations over people, space, or time; Consequently, they are highly

MBD mature-business decline (productive units per year)
MPB managerial-professional births (men per year)
NEC new-enterprise construction (productive units per year)
NED new-enterprise decline (productive units per year)
PEM public-expenditure multiplier (dimensionless)
PHC premium-housing construction (housing units per year)
PHO premium-housing obsolescence (housing units per year)
SHD slum-housing demolition (housing units per year)
TC tax collections (dollars per year)
TPCR tax per capita ratio (dimensionless)
UA underemployed arrivals (men per year)
UAMM underemployed-arrivals-mobility multiplier (dimensionless)
UB underemployed births (men per year)
UD underemployed departures (men per year)
UHM underemployed/housing multiplier (dimensionless)

UHPM underemployed-housing-program multiplier (dimensionless)
UHPR underemployed-housing-program rate (dimensionless)
UHR underemployed/housing ratio (dimensionless)
UJ underemployed jobs (men)
UM underemployed mobility (fraction per year)
UR underemployed/job ratio (dimensionless)
WHO worker-housing construction (housing units per year)

REFERENCES