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## *From simulation model to public policy:*

### An examination of Forrester's "Urban Dynamics"



by

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LEO P. KADANOFF was educated as a physicist, but since 1965, his interests have been turning more and more toward problems of city growth. He was educated at Harvard, where he got his Bachelor's, Master's, and PhD degrees in theoretical physics. He then studied for a year and a half at the Bohr Institute for Theoretical Physics in Copenhagen. During his subsequent tenure at the University of Illinois (1962-1969), his research interests included the theory of solids, particularly behavior near phase transitions, and the use of urban growth models. He was also involved with computer display of urban growth patterns at the Coordinated Sciences Laboratories at the University of Illinois. Since 1969 he has been a professor at Brown University and has maintained in approximately equal measure an interest in solids and cities.

#### ABSTRACT

*Forrester's model is described and critically analyzed with a view to understanding the relationship between his conclusions and his normative scheme. He claims that his model produces "counterintuitive" results; it is argued here that the main results follow directly from his goals. An alternative method of evaluating the results of the model is proposed, based upon the model's calculation of the city's attractiveness for various groups. This alternative normative scheme leads to quite different conclusions from those reached by Forrester.*

#### INTRODUCTION

In the book *Urban Dynamics*<sup>1</sup> Jay W. Forrester constructs a simulation model of urban growth and then utilizes this model to assess and evaluate a variety of possible strategies for public policy. This work is provocative in several respects. First, computations based upon the model are used to reject as harmful or of mixed value a variety of the traditional "liberal" schemes for city improvement, including provision of jobs for unskilled workers, job training to increase the skills of the unskilled,

financial aid for the city, construction of low-cost housing, and income maintenance schemes. Concurrently, Forrester presses for some policies which have considerably less appeal for the liberal thinker, including discouragement of the construction of housing for workers, destruction of low-cost housing, and encouragement of industrial growth to the further detriment of housing.

Even more provocative than these specific conclusions, however, is his explanation of why he reached the "result that past programs designed to solve urban problems may well be making matters worse...while policy changes in exactly the opposite direction from present trends are needed if the decaying inner city is to be revived."<sup>2</sup> According to Forrester, he has gotten better results than his predecessor because planners and public policy makers have applied intuitive reasoning to the complex system that is a city. For this reason, their proposed policies turn out to be palliatives rather than cures. "With a high degree of confidence we can say that the intuitive solutions to the problems of complex social systems will be wrong most of the time. Here lies much of the explanation for...troubles of urban area."<sup>3</sup>

To reach a more effective treatment of city problems, Forrester proposes that we analyze them with the aid of the diagnostic techniques provided by simulation models. Public policies can be mathematically tested by working out the models and seeing all of the policies' effects, intended and unintended. In this way, one can reach conclusions, unhampered by the defects and perils of intuitive thought.

But, as Moynihan has pointed out,\* this point of view raises perplexing difficulties for planners, public policy makers, and ordinary citizens. Must we all be experts in systems analyses before we can make intelligent conclusions about public programs and policies? Must we train all planners\*\* and policy makers in computer programming so that they can avoid the necessary errors of "intuitive thinking?" Clearly these questions bear very seriously upon the educational experiences we propose for our future experts and our ordinary citizens.

To study this point, we shall examine Forrester's work in some detail and draw upon some earlier criticism.<sup>5,6,7</sup> The main conclusions of this paper are that:

- (a) The main policy recommendations of *Urban Dynamics* are in no sense counterintuitive; they follow directly from Forrester's implied normative scheme and intuitive thought.
- (b) Some of the apparently counterintuitive features of this book result from questionable representations of urban dynamics and incorrect representations of proposed public policies.

Despite these criticisms of Forrester's conclusions, I would argue that his model-making is so brilliant and beautiful that his ideas are certainly worthy of examination and further development. I would reject the conclusions, but accept the model as an appropriate basis for further work.

#### THE MODEL: FROM BASIC VARIABLES TO POLICY CONCLUSIONS

Forrester reaches his conclusions via a five-step process. First, he isolates a few basic variables which describe the social and economic composition of the city. Second, he writes down equations which describe the "natural" city development. These equations tell how the values of the variables at a given point in time determine their values at a later time. Third, public policies are introduced as modifications in these equations. Therefore, Forrester can as the fourth step find the composition of the city which results from each of the proposed policies or no policy at all. In the fifth and final step, he compares the resulting composition with his conception of a desirable city and thereby chooses the policies he would like to recommend.

The basic variables are chosen with an eye to city problems: the existence of large slum areas, the unemployment caused by industrial flight from the city, and insufficient tax revenue for city needs. The variables chosen are:

- (1) The numbers of people in various socioeconomic groups, namely:
  - (a) Management and professional workers
  - (b) Skilled workers (called Labor in the model)
  - (c) Unskilled workers (called Underemployed in the model)
- (2) The number of acres of housing devoted to each of the above groups.
- (3) The number of acres devoted to business and industrial uses. Maximum economic activity occurs in the newer areas, called "New Enterprise." As the enterprises age to "Mature Business" and then to "Declining Industry," the economic activity per acre declines.
- (4) Taxes. Here there are two important variables, the taxes needed and the actual taxes collected. The taxes the city needs to collect are assumed to be proportional to the number of people in the various social and economic groups, with

\* From speech at Hendrix College, April 6, 1970.

\*\* On this point see Ernest Erher, Editor<sup>4</sup>, especially the articles by Britton Harris, George M. Raymond, and Lawrence Mann.

the management and professional people requiring the least tax expenditure and the underemployed, the most. The actual tax collected usually lies below the taxes needed because the city can only respond imperfectly to an increase in its tax needs.

- (5) Land. The city is assumed to have a fixed area of 100,000 acres. Each unit of enterprise and housing subtracts from the pool of land available for further development.

Forrester's city is then a fixed land area, like an island, containing people, housing, and enterprises. It has a uniform tax rate. All the potential jobs and workers lie within this fixed area. Of course, this island-city is a poor representation<sup>9</sup> of either our central cities (which do have a fixed area but include many jobs filled by suburban workers) or of our metropolitan areas (which are continually growing). For this reason, this model does not include the effects of city-suburb interactions and in particular leaves out the influence of suburban growth upon the central city.<sup>10</sup>

In the model, the only interaction between the city and the outside world arises through the migration of people into and out of the city. Of course, the model includes the fact that a city which is more attractive for a given type of worker will have more immigration and less emigration of that group. Thus, the model includes the idea that--all other things being equal--a city which is more attractive for unskilled workers will tend to have more unskilled workers.

This point is important in understanding Forrester's conclusions, because his normative scheme seems to be one in which a "healthy" city contains relatively few unskilled workers. Forrester does not devote much attention to his goals, apparently because he does not consider them to be very controversial. Instead, he focuses attention upon the model's predictive methods. "The approach presented in this book is suggested as a method for evaluating urban policies *once the proposed dynamic model or a modification of it has been accepted as adequate.*"<sup>11</sup>

However, a careful reading does indicate the goals implicit in Forrester's work. These include the "minimization of the average per capita tax rate"<sup>12</sup> and "to diminish the population share of the underemployed."<sup>13</sup>

Given this point of view, the trend of Forrester's policy conclusions becomes obvious. Any policies which will make the city more attractive to unskilled workers will be classified under *Failures in urban programs*, because of this normative framework. Under this category we find the provision of jobs for the unskilled, the provision of housing for them, a tax subsidy, and also job training to increase their skills. All these programs draw the unskilled to the city and hence "fail" in Forrester's terms. On the other hand, he applauds policies designed to force out the unskilled. His most preferred scheme is to destroy their housing and to limit the construction of new housing for skilled workers, thus preventing filtering down. The resulting reduction in unskilled worker population and in tax rates is described as "Urban Revival."

In short, Forrester's conclusions follow from his goals without any counterintuitive steps.

## DYNAMIC PROCESSES

Nonetheless, it is instructive to study the detailed logic which leads to these conclusions. The model focuses upon rates of change. Each of the important variables change because of the flows which occur within the city and between the city and its external environment. For example, one of the key equations of the model calculates the number of "Underemployed"--that is, unskilled workers--as

$$\begin{aligned} & \text{(Number of unskilled workers this year)} \\ & = \text{(Number last year)} \\ & + \text{(Net flow into this group during year)}. \end{aligned} \quad (1)$$

Then, each of the rates is further broken down into its component parts.

For example:

$$\begin{aligned} & \text{(Net flow into unskilled group during year)} \\ & = \text{(Migration of Underemployed into the city per year)} \\ & + \text{(People added to this category via births)} \\ & + \text{(People added via downward mobility from the skilled workers category during year)} \\ & - \text{(People who have moved upward into skilled workers category during year)} \end{aligned} \quad (2)$$

The determination of the various levels then depends upon an accurate evaluation of the various component flow processes like those listed in Equation 2. All of the flows in the model have the same basic form:

$$\text{Flow per year} = \text{(Rate constant)} + \text{(Some level)} \quad (3)$$

Equation 4 looks technical, but several examples should serve to illustrate its meaning. For example:

(People added to Underemployed category per year via births)

$$= \text{(Birth rate)} \times \text{(Number of unskilled workers)} \quad (4a)$$

The flow is the expression on the left, which is a rate constant (the birth rate) times a level (in this case the number of Underemployed). As another example:

$$\begin{aligned} & \text{(Workers added to the unskilled group via downward mobility from the skilled worker category during year)} \\ & = \text{(Rate of downward mobility)} \times \text{(Number of skilled workers)}. \end{aligned} \quad (4b)$$

So far, we have seen how the job of determining levels--like the number of unskilled workers--can be reduced to a problem of determining rates of flow. Then, the rates of flow are written in terms of the known levels and rate constants, as in Equation 4. To finish the story, we need to know the rate constants. Once the rate constants are known, the model is completely determined.

Some of the rate constants are rather easy to know. For example, the "birth rate" of Equation 4--which is actually a birth rate minus a death rate--can be determined from tables of vital statistics once the age of distribution of the unskilled workers is estimated. Others are harder. The "rate of downward mobility" of Equation 4 is not known. But

Forrester makes a plausible guess by saying that this rate depends upon the ratio of workers to available jobs. He writes this guess as a graph (see Figure 1) which is incorporated into the model. This graph says that for small values of worker unemployment, the downward mobility rate is very small; while for larger values of unemployment, the ratio grows roughly in proportion to the amount of unemployment.



Figure 1

If the aim of *Urban dynamics* were an accurate prediction of the transition rate from labor to underemployed, the use of guesswork like that in Figure 1 would be unacceptable. However, the purpose is rather the comparison of different public policy alternatives. The model need only predict the kinds of changes caused by the different programs. In this case, it may be sufficient to obtain a qualitatively right form for the transition rate,<sup>14</sup> for the relative effects of different public policies may well be quite insensitive to variations of curves like the one in Figure 1.

The most important flow rates are those due to the in-migration and out-migration of underemployed people. In this case, the flow rates are determined by rate constants which can be respectively interpreted as:

- The attractiveness of the city as perceived by unskilled potential immigrants
- The unattractiveness of the city for the unskilled. The relevant rate equations are:

$$\begin{aligned} & \text{(Rate of in-migration)} = \text{(Perceived attractiveness for unskilled)} \times \\ & \text{(Number of skilled and unskilled workers)} \end{aligned} \quad (4c)$$

and

$$\begin{aligned} & \text{(Rate of out-migration)} = \text{(Unattractiveness for unskilled)} \times \text{(Number of unskilled workers)} \end{aligned} \quad (4d)$$

"Unattractiveness for the unskilled" appears in Equation 4d as a rate constant which determines the rate of out-migration from the city. Double the unattractiveness, while holding the number of unemployed fixed, and the rate of out-migration will double. Similarly, from Equation 4c, if you halve the perceived attractiveness, the rate of

in-migration of the underemployed will go down by a factor of two.

Forrester gives a precise numerical meaning to "attractiveness" by guessing the strength of the various forces which draw the unskilled to the city. Attractiveness for unskilled workers grows as their economic opportunity grows, as the density in their housing diminishes, as their unemployment rate diminishes, as the public expenditure per capita increases, and also as the underemployed housing program produces superior housing units. Mathematically, the attractiveness is a product of separate factors describing each of these separate components of attractiveness. For example, Figure 2 gives the dependence of the attractiveness upon residential density in the housing for the underemployed. This figure indicates that as the density rises from 120 people per acre to 180 people per acre, the attractiveness of the city diminishes by a factor of five.

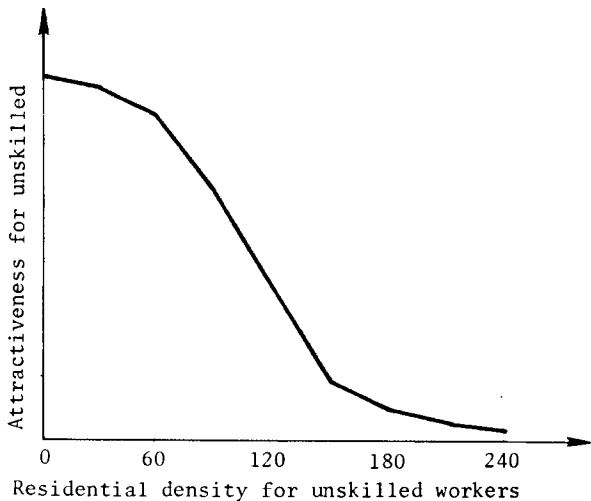


Figure 2

By using guesses like that in Figure 2, Forrester can give a numerical value to attractiveness. The unattractiveness which governs emigration is then given as the inverse of attractiveness

$$(\text{Unattractiveness}) = (\text{Attractiveness})^{-1} \quad (5)$$

The perceived attractiveness which governs immigration of unskilled workers is assumed to differ from the actual attractiveness because people outside the city do not immediately find out about changed conditions within the city. The model assumes a twenty year time lag so that this perceived attractiveness at a given moment is approximately equal to the actual attractiveness twenty years before.

In this way, Forrester gives concrete mathematical expression to his ideas about the flow of people into and out of the city, and achieves a model in which an increased attractiveness for the unskilled will draw more unskilled into the city.

Another key part of the model is the mechanism for producing new jobs via the creation of new enterprise. The rate constant for this kind of new job production is very sensitive to the amount of land still unutilized in the city. For the conditions most characteristic of the mature cities studied in

the model, a 1% drop in the land occupied by housing will cause a 5% increase in this kind of new job formation.

Once the rate constants are specified, Forrester's model is complete. He can then set the city at some initial point, year zero, and let his rate equations calculate the changes in all the variables between year zero and year one. Successive applications of this procedure give the year-by-year growth of the city. At each point, the model calculates the values of all the level-variables. Eventually, the city begins to fill most of its available land area with housing and industry. Thereafter, the city begins to settle down to an equilibrium in which all the levels remain roughly constant. We then have a description of the mature city.

#### THE MATURE CITY: STAGNATION AND REMEDIES

As Forrester looks at the mature city of his model, he finds that it contains many of the defects of our real cities. The story is summarized in Table 1. Notice the high unemployment rate among the unskilled, the lack of skilled labor, and the high land fraction (31%) occupied by the unskilled and their families. Their area is identified as slums even though the residential density is rather low. As Forrester points out, these slums are harmful to the city because they occupy land which could be utilized by industry which could provide more jobs. This condition is then termed "urban stagnation."

	Population group			Total
	Unskilled workers ="Underemployed"	Skilled workers ="Workers"	Management + Professionals	
Number of potential workers	377,300	392,600	71,100	841,000
Jobs for this category	208,300	403,500	51,800	663,600
Unemployed	169,000	- 10,900	19,300	177,400
Potential workers plus families	3,000,000	2,370,000	350,600	5,720,600
Land area occupied (acres)	31,000 "slums"	33,500	11,100	75,600
Density (people/acre)	98	71	32	76

Table 1 - Forrester's "stagnant" city. The unemployment is calculated as the first row in the table minus the second.

Next, Forrester examines a possible set of alternative strategies for city improvement; these strategies are inserted as changes in the model. For example, the underemployed job program simply provides jobs for 10% of the unskilled workers over and above those jobs naturally provided by the business sector. A job training program moves 5% of the underemployed into the skilled worker group without changing any of the other flow processes. The tax subsidy program makes \$100.00 per capita per year available to the city from outside sources. In the model, this permits extra tax expenditure which then has the effect of increasing the upward mobility of the underemployed.

All of these "liberal programs" are directly designed to reduce unemployment among the poor. To evaluate how well they work, the model is run for 50 years. After this time, a new equilibrium is reached as shown in Table 2. From the data in the first three rows, all three programs seem to have failed. The training program seems to have had no

Program	Some "liberal" programs						Some programs for city revival Demolition of slum housing			
	"Natural" development	Job program	Tax subsidy	Low-cost housing	Training program	New enterprise construction	Alone	+Discouragement of worker construction	+Encouragement of new enterprise construction	
Number of unskilled workers = underemployed (in thousands)	377	417 (+ 10%)	407 (+ 8%)	372 (- 1%)	382 (+ 1%)	452 (+ 20%)	317 (- 16%)	290 (- 23%)	356 (- 11%)	
Unemployment in this group (in thousands)	169	173 (+ 3%)	201 (+ 19%)	214 (+ 27%)	168 (+ 0%)	153 (- 9%)	57 (- 66%)	4 (- 97%)	22 (- 87%)	
Land area occupied by this group = slums (thousands of acres)	31.0	32.6 (+ 8%)	31.9 (+ 3%)	45.1 (+ 46%)	30.7 (- 1%)	32.0 (+ 3%)	17.4 (- 44%)	14.2 (- 54%)	17.5 (- 43%)	
Net upward social mobility (net flow underemployed to labor - thousands of workers per year)	5.5	6.8 (+ 24%)	7.6 (+ 38%)	3.8 (- 31%)	16.8 (+ 206%)	13.0 (+ 136%)	5.6 (+ 2%)	7.1 (+ 29%)	9.2 (+ 68%)	
A T T R A C T I V E N E S S	Underemployed	1	1.03	1.05	1.01	1.25	1.16	.89	.91	.95
	Labor	1	.90	.90	.91	.68	.78	1.08	1.03	.98
	Management and Professionals	1	.98	.91	.94	.94	.95	.98	.98	.97

Table 2 - Effects of programs in the Forrester model. The programs are each run for fifty years. The numbers in parentheses are the changes produced by the programs in comparison to the results of no programs at all. The effects of the programs can be assessed by looking at the net upward social mobility (fourth from the last row) and at the resulting attractiveness of the city for various social groups (last three rows).

effect. The job program and tax subsidy have increased the number of unskilled, the amount of unemployment in this group, and the amount of land devoted to slums.

If Forrester is right, the job program and the tax subsidy are harmful to the city. Those who have proposed them are the victims of "intuitive thinking" applied to a situation too complex for any simple method of thought.

The final liberal program in Table 2, low-cost housing, is inserted into the model as a simple addition to the stock of housing for the underemployed. Land available for industry decreases, jobs decline, and disastrous unemployment results.

To replace these "unsuccessful" liberal programs, Forrester proposes a set of programs aimed at city revival. The most obvious, the direct encouragement of additional new enterprise formation, is inserted into the model as an increase in the rate constant for new enterprise construction. However, this program is rejected both because its effects are too small and also because Forrester sees no way of directly effecting this encouragement of new enterprise.

An indirect method is proposed: a program of slum housing demolition which removes 5% of the slum housing each year. This is most effective when it is coupled with diminished worker housing construction or with increased new enterprise construction. From Table 2, these programs seem quite successful in alleviating unemployment among the unskilled and reducing the size of slums.

Of course, the results of these calculations are, in no sense, counterintuitive. Each of the liberal programs increases the city's attractiveness for the unskilled (see row 5 of Table 2) and draws them to

it. The programs for "city revival" are, as expected, unattractive for the unskilled. The model merely reproduces our intuitive expectations.

#### ANALYSIS OF BENEFITS: LOCAL VIEW

Each of the programs under consideration produces both gains and losses. For example, the demolition of slum housing combined with the discouragement of worker housing construction does decrease unemployment and diminish the area devoted to "slums." (The slum area goes down both because houses are pulled down and also because the "filtering down" of housing from the labor group to the underemployed group is inhibited). However, the density in the "slums" increases from 98 people per acre to 160 people per acre, while the density in the "labor" sections increases by 9%. How are we to balance the benefits of increased job opportunity against the disadvantage of more crowded housing?

Forrester does not exactly perform this balancing process. Rather, he has in mind an improved version of the city with fewer low-skilled workers, fewer slums, fewer people out of jobs, and more industrial growth. If a program produces results which approach these ends, he judges it to be successful. In essence, Forrester is working toward a goal which is to improve a given area of land--a city.

To see this reasoning at work, consider Forrester's evaluation of the training program. This program has the advantage that it increases the net flow of people from the "Underemployed" category to skilled "Labor." (This flow is recorded as the fourth row in Table 2). However, Forrester focuses upon the losses to the "city."

The training program has created a flow through the area with a much increased

underemployed-arrival rate and a much increased labor-departure rate. People come to the area because of the training program and leave when they find there is no use for the skills they have acquired. *As a service to society*, the program might be considered successful. But as a service to the city, its value is far less clear. The area is more crowded, the land fraction occupied has risen slightly, housing conditions are more crowded, the total of underemployed has risen very slightly, and the ratio of labor to jobs is higher, indicating a higher degree of unemployment.<sup>15</sup>

Forrester's assumption that there is an object called "the city" to which we can assign benefits or debits is, I think, incorrect. We should only assign benefits and hurts to people, since the goals of our policies should be to enable people to live more satisfactory lives.

Is there anything in the model which would permit the estimation of benefits to the people involved? There is. The attractiveness functions give numerical estimates of the worth of the city as perceived by various groups. The model computes the changes in attractiveness resulting from each of the proposed programs. These attractiveness numbers are listed in the last three rows of Table 2. The numbers in each row are divided by a constant factor so that the attractiveness is unity in the absence of any public program. These attractiveness numbers provide a numerical way of estimating the worth of any public program for the various groups involved.

The benefits and losses to the unskilled have already been discussed. Each program which is attractive to the unskilled reduces the city's attractiveness for the skilled group. This effect occurs because the attractiveness for the skilled includes a "social attractiveness" which decreases as the city draws in a larger proportion of unskilled workers. Conversely, the reduction in the proportion of unskilled workers produced by the destruction of their housing increases the city's attraction for the skilled group. However, when this program is coupled with new enterprise construction, the increased attractiveness for the skilled group is cancelled because not enough land is available for housing.

From the point of view of the attractiveness concept, Forrester's favored program of slum-housing demolition plus discouragement of labor-housing construction does not look very good. The attractiveness for Labor only increases 3%, while Underemployed and Management are respectively 9% and 2% worse off than before. On this basis, we should probably reject this program. Furthermore, the last program in Table 2 is favored by Forrester even though it seems bad for everyone!

However, one might argue that this result is not really fair to Forrester. After all, there is more industry in the city. Is this not a gain? It is true that, in general, industry is good for a city by providing jobs and paying taxes. But the attractiveness measures already include these benefits. We cannot count them again. All the other beneficial effects of increased industry are harder to evaluate because they are largely benefits which accrue to the entire nation rather than to the city in question. However, it is possible that the appearance

of this industry in this special city prevented the construction of competitive industry elsewhere. Perhaps the other location would have been better for the nation. We cannot know.

But there is one benefit which is possibly undervalued in the attractiveness measures. It is possible that the underemployed do not have a sufficiently long view to perceive the real value to themselves and their children of upward economic mobility. In the construction of city programs, we might consider the upward mobility from the low-skilled underemployed group to the higher-skilled labor group to be valuable in itself. In fact, one might argue that the main role of cities in American history has been to foster this upward mobility. Then, in evaluating the different proposed public policies in the context of this model, we should also consider--as Forrester does--the total number of potential workers who have been raised from the low-skilled group to the high. In the model, the traffic goes both ways: from "Underemployed" to "Labor" as well as vice versa. The key number is the net flow from "Underemployed" to "Labor". Table 2 shows this number for the models under consideration. From this point of view, the "favorable" program has a much less favorable impact than the direct training program. Both seem preferable to the "stagnation" result.

It is true, nonetheless, that the programs favored by Forrester do increase the net upward mobility. Or at least the model says that they do so. This mobility increase is supposed to occur because the programs result in increasing industry, and the increased jobs help the upward mobility. Furthermore, the improved "social atmosphere" caused by an increased ratio of skilled labor to unskilled is also supposed to increase upward mobility.

It is, however, extremely dangerous to base any public policy decisions upon the upward mobility predictions of this model. As Banfield has emphasized,<sup>16</sup> we know very little about the conditions which help upward mobility. Moynihan<sup>17</sup> has suggested that this mobility might be tightly interwoven with family structure considerations which are certainly not in the model. The mobility predictions of this model cannot be used to justify any public policy because they are completely unreliable.

#### A NATIONAL VIEW

The most striking fact about the changes in attractiveness listed in Table 2 is that they are very small. If you momentarily increase the attractiveness for any group, more of that group will enter the city, consume jobs and housing, and thereby reduce the attractiveness. To see this result in operation, consider the attractiveness effects of the job training program as indicated in Table 3.

		Before	After 10 years	After 50 years
Relative Attractiveness for	Underemployed	1	1.68	1.2
	Labor	1	.74	.68
	Management & Professionals	1	1.09	.9

Table 3 - Attractiveness Changes Produced by Training Program

According to the following table, after the first ten years, the training program produces a very large favorable effect for the unskilled in that the attractiveness for this group increases 68%. On the other hand, there is an immediate harmful effect to the skilled laboring population produced by the increased job and housing competition felt by this group. This effect is initially smaller than the benefit to the unskilled, being only a 26% decrease in attractiveness.

Notice that after 50 years a large fraction of the benefits of this job training program for the unskilled group disappears, while the losses for the fully-skilled labor group increase. This kind of dissipation of benefits occurs because the increased attractiveness of the city draws more unskilled into the city so that a larger group of people must compete for a roughly fixed number of jobs. Hence, everyone is worse off at year 50 compared to their state at year 10.

Forrester points out that this dissipation of benefits produced by increased in-migration is a general effect of all programs designed to give direct aid to any group of people. However, it is important to notice that this analysis only applies to a program which is applied only to the single city in question. If the program were applied nationwide, the attractiveness of all areas for the unskilled would increase equally. As a result, there would be no increase in the migration into any city. The long-term deterioration shown in the last two columns of Table 2 would then be replaced by a long-term improvement.

This discussion then leads us to the following conclusion: *Programs for improving the lot of the unskilled should be applied nationally rather than locally in order to prevent the partial neutralization of these policies as a result of the concentration of the unskilled in the program areas.* Forrester's model automatically assumes that all his programs are locally employed; hence, his work is simply inapplicable to the analysis of the long-range effects of any policy applied nationwide.

To see the striking effects of policies applied nationwide, imagine that nothing at all were changed within the city under study, but the rest of the nation improved its conditions suddenly to make its attractiveness for the unskilled group a factor of two better than before. Then immediately this group's in-migration decreases by a factor of two. Even though nothing has changed within the city itself, the results of this nationwide change would be quite substantial, at least for the unskilled group. These changes are summarized in Table 4. The conditions of this group have bettered very substantially, without anyone else in the city being the worse off.

Naturally, the course we have just described is not a realistic policy alternative. Forrester's published analysis does not permit us to study and evaluate the results of realistic policies applied nationwide.

	Before nation-wide change	After 10 years	After 50 years
Number of unskilled potential workers = "Underemployed" (in thousands)	377	296 (- 20%)	322 (- 14%)
Unemployed in this category	166	86 (- 41%)	102 (- 39%)
Land occupied by "Underemployed" = "slums" (in thousands of acres)	31.0	29.5 (- 5%)	28.7 (- 8%)
A T T R A C T I O N S S E S			
Unskilled workers ("Underemployed")	1	2.58	1.88
Skilled workers ("Labor")	1	1.08	1.02
Management	1	1.02	1.00
Underemployed to Labor net in thousands	5.5	5.9 (+ 8%)	5.6 (+ 2%)

Table 4 - Effects of an increase in the national level of the attraction for unskilled workers upon a city which itself is not changed in any structural sense. Numbers in parentheses refer to the percentage changes in this city caused by the change in the environment.

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