From Simulation Model to Public Policy

A case study of the relationship between simulation models of urban social systems and evaluations of proposed public policies

In Urban Dynamics Jay W. Forrester constructs a simulation model of the housing, industry, and population of a single urban area (U). From this model he draws conclusions about the relative effectiveness of various public policies. This paper discusses both the original Forrester model and an adaptation of it which can be used to simulate any number of urban areas. The latter model is used to show that the effectiveness of the policies can be strongly dependent on whether they are applied nationally or only to individual urban areas. This result calls into question the usefulness of a model of a single area in the evaluation of national urban policy.

The Forrester model

The most of Forrester's effort was the construction of a coupled simulation model which would catch the essential features of an urban area of fixed size. The resulting model uses as its basic variables the amounts of population, housing, and industry, together with the level of taxation. Population is divided into three groups: management and professional workers, skilled workers (called labor, or U), and unskilled workers (called underemployed, or U').

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Forrester gives a purely numerical treatment to "attractiveness", by guessing the strength of the various forces which drive the unskilled to the city. Attractiveness for unskilled workers grows as their economic opportunity grows, as the density in their housing diminishes, and their unemployment rate declines, as the public expenditure per capita increases, and also as the underemployed housing problems develop superior housing units. Mathematically, the attractiveness is a product of several factors describing each of the separate components of attractiveness. For example, Figure 1 shows Forrester's estimate of the departure rate of unattractive unskilled workers from residential density in the housing for the underemployed.

Using these like that in Figure 1, Forrester gives a numerical value to attractiveness and thereby specifies the right-hand side of the departure equation, Eq. (2). The perceived attractiveness which governs immigration of unskilled workers is assumed to be the same as 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 geometric decrease of perceived attractiveness at a
Before discussing these changes, we should mention an alteration that has been made to Forester's work (1, 2). This model is completely unaltered.

The number put into it have not been checked against reality. Forester argues that his aim is not the accurate prediction of the state of the city, but rather an estimate of the direction of change that will be produced by changes in public policy. He also states that his results are rather insensitive to many changes in inputs.

For this reason, in the next section, I will allow myself to make one change in Forester's model: I have given different values to the multiplicative constants in the integration equations. Eq. (2) and (3), and in the corresponding equations for the other two population groups. These changes, which do not cause any important qualitative modifications in the results obtained, are inserted to make the model more compatible with the national model described below.

Goals and Evaluation

Forester reduces the clearance program as his favored method for urban renewal and reports the training program, by including it as an example of "failures in urban renewal" and for characterizing it as being of "mixed value." Although Forester never directly states his goals for the criteria (4) he has concluded that his model aims are to make the city better by (1) reducing the proportion of unskilled workers in the population, (2) reducing taxes, and (3) increasing net upward mobility from unskilled workers.

The clearance program is quite effective in achieving these goals. Housing for the unskilled is demolished, and at the same time the discouragement of unskilled-worker housing inhibits the natural "bleeding down" of housing to the U-group, thereby increasing the amount of housing for the unskilled. According to Figure 1, they will then tend to leave the city. As a result, the goal of reducing the U-group population is attained, as shown in Figure 2, and, with fewer poor people present, the city's taxes can be lowered. The load lifted by the destruction of U-group housing can then be utilized for the construction of new industry. As industry increases, job opportunities in-
Figure 3. Changes in attractiveness produced by police programs support in one metropolitan area. The attractiveness for each group is multiplied by a constant so that each attractiveness number is equal to one in the steady state situation.

Figure 3 shows plots of the attractiveness of the city for the two main population groups as they are changed by the effects of the training and clearance programs. The training program produces increased upward mobility for the L-group and, hence, a more attractive city for its members. However, more skilled workers are produced via this enhanced upward mobility, a larger number of them must compete for a roughly fixed set of housing and jobs. This group consequently suffers, as shown in the decreased attractiveness for L.

On the other hand, the clearance program frees land which is then used to provide more industry. The T-group gains from the extra jobs that are added and attractiveness increases for them. But because the clearance program eliminates housing for the T-group, they suffer, especially in the early years of the program. Later on, after about fifteen years, the situation for the T-group improves. These numbers are fewer, since many have been forced out of the city in the early years of the program and because extra jobs in the city have provided increased upward mobility. Consequently, the lack of housing has less.

In summary, I would suggest that changes in the attractiveness numbers be used as a measure of the benefits produced by changes in public policy as perceived by each of the social classes. This measure permits the benefits to be referred to people rather than to a geographical or political entity. In addition, I would follow Forrester in including the net rate of upward social mobility. It is possible that the population does not have a sufficiently long view to perceive the real value of upward social mobility to themselves and to their children. For this reason, the change in upward mobility might be indicated as another index of the policy's worth.

When this point of view is adopted, another policy appears to be clearly valuable. The training program produces a substantial upward in upward mobility and in the quality of the city for the T-group, at some cost to the L-group. On the other hand, the clearance program produces increased upward mobility together with a small gain to the T-group at the cost of a substantial short-term loss for the unskilled.

One might argue, however, that this result is not really fair to the clearance program. After all, it puts more industry in the city. Is this not a gain? In truth, it is, in general, industry is good for a city because it provides jobs and pays taxes. Yet, the attractiveness measure already includes these benefits, we cannot count them again. All the other salutary effects of increased industry are harder to evaluate because they are largely benefits that accrue to the entire city, or to the city in question. It is possible that the appearance of an industry in a particular city, prevents the concentration of competitive industry elsewhere. Perhaps the other location would have been better for the nation. We cannot know.

A broader view

So far, it has been assumed that the proposed policies are to be applied to only one city and that only the people of that city are important. In actuality, the programs have important effects upon the rest of the nation because they change migration patterns and, therefore, the number of people in other cities. We might expect that the training program would tend to draw unskilled workers from other cities and that the clearance program would...
Figure 4. A matrix version of the Forrester model. The shaded areas are fully urbanized and are each described by a Forrester model. The unshaded, less urbanized regions are based on a fixed proportion of the population and a fixed attractiveness. The arrows tend to force these workers into the rest of the region. Hence, the clearance program might be detrimental to the remainder of the nation—Kuhn (2) has described this as a "going-by-next-door" policy.

To examine this point and also to study the effects of applying these programs more broadly, I have extended the Forrester model to include many different metropolitan areas as well as a rural sector (see Fig. 4). Each metropolitan area is divided into urban and suburban sections. The urban part can be further subdivided into districts, in which the programs can be applied or left out at will. With the point of this analysis is the examination of the Forrester model, the urban areas are each described in a manner identical to that in Urban Dynamics, except for a change in migration equations, described below. The crudest possible model is used for the suburban and rural areas. The rural areas are assumed to have a fixed attractiveness and a fixed proportion of the national population in each of the social groups. The suburban areas are assumed to have a fixed proportion of the metropolitan areas population in each of the social groups, and they are also described by a fixed attractiveness. The only real change in the model from that proposed by Forrester is the extension of his migration equations to permit movement from one urban area to another, from urban area to suburb, and back and forth from urban area to the rural sector. The intrametropolitan migrations take the form

\[
\text{Yearly migration from area } A \text{ to area } B = 0.081 \times \left(\left(\sum U_i \times L_j \times AT_{ij} \right) \times \left(\sum U_i \times AT_{ij}\right) \times \left(U_i \times AT_{ij}\right) \times \left(U_i \times AT_{ij}\right) \right)
\]

Total (U+L) in metropolitan area. (4)

A similar equation describes inter-
metropolitan, rural-urban, and urban-rural migration, except that the constant in the numerator is reduced by a factor of three while the denominator is the total national population in the U- and L-groups. The other population categories are handled in similar fashion.

This many-city model is the simplest possible generalization of the original Urban Dynamics equations to include migration between cities. Each city in the many-city model comes to the same steady state as its original one-city model. If we apply public programs to just one city within this many-city model, the results may be entirely identical to those obtained from the Urban Dynamics model, except that the multiplicative constant in the migration equations are different. This is because the social groups in the many-city model are based on fixed proportions of the national population. The various social groups in the many-city model are based on fixed proportions of the national population. The various social groups in the many-city model are based on fixed proportions of the national population. The various social groups in the many-city model are based on fixed proportions of the national population.

At our first application of this extended Forrester model, consider a national training program. As we saw, the main objection raised by Forrester to the training program is that, as unskilled workers are trained for skilled jobs, they are replaced by a wave of unskilled immigrants. But if the training programs were applied nationally, this change in migration patterns would not occur. This point is illustrated in Fig. 5a, which shows that, according to the model, only a small change takes place in the number of unskilled workers within the city and in their unemployment rate when the training program is applied to one city. The main decrease in the number of unskilled workers is spread out over the entire nation. But when this program is applied to all cities, each city experiences a large decrease in the number of unskilled workers, and since the number of jobs open to them remains roughly constant, unemployment in this group drops considerably.

Figure 5b shows that the Forrester indices of the tax rate and the fraction of the tax rate increased more favorably by the nationwide program than by the local one. The pattern of upward mobility produced is about equally favorable in both cases. Finally, Forrester's 6 shows that attractiveness both for the skilled and the unskilled increases when the program is widened to include the entire country. The large increase for the U-group reflects the fact that there are many fewer unskilled workers competing for the portions of the U-group openings to them. Despite the great improvement caused by widening the program.
skilled-labor group still seek a loss in urban attractiveness compared to the result of no program at all. After all, people have been added to this group within the city but there has been no explicit increase in the resources available to the city. In summary, it appears that the training program is better if applied nationally than locally.

To study Kahn’s suggestion that the clearance program would be burdensome to cities which do not take part in the program, the national model was used for a case in which half the metropolitan areas of the country contained cities that employed the program. Each city which had the program was assumed to contain one-third of the urban area within its metropolitan region. For technical reasons, Kahn felt that it was necessary to make one additional change in the equations, a change that had been suggested by previous critics (4, 9) of Urban Dynamics.

This change was the replacement of the factor (U^1 + U) in the numerator and denominator of Eq. (4) by U^1 alone. The result is to make the number of Ys who arrive in a given urban area proportional to the number of Ys already present rather than to the total number of skilled and unskilled workers. When all the cities are identical to one another, or in the steady-state situation, this change in migration equation produces no change whenever in migration patterns. The steady-state solution does not change. When, however, different types of cities exchange population, as a result of clearance programs in some of these, it would seem reasonable for reciprocal migration to balance when the attractiveness of two cities is identical. Eq. (4) does not have this property, but the modified equation does here does.

Consider the result of applying the clearance program to half the nation’s metropolitan areas. Figure 6a describes what happens in the programs cities. Just as in the case in which the programs is applied locally, net upward mobility, the tax rate, and the fraction of workers in the L-group all show what Forrester would describe as an improvement. The attractiveness for L-groupers, while the attractiveness for Y's shows a substantial drop and then a rise above its initial value. From these results, we might guess that, in the long run, the clearance program is beneficial in all respects.

Figure 6b, however, suggests a different answer for the urban sections of metropolitan areas that do not have the clearance program. All indices show a loss, or, at best, no gain. The attractiveness for L remain essentially fixed, the attractiveness for the unskilled group drops by 18 percent at year 1. Upside mobility goes down, tax goes up, and the fraction of workers in the Y-group increases. Over this 20-year span, the application of the clearance program to some cities in the nation has pushed poor people out of the programs areas and into the non-program areas and thereby hurt them. This analysis supports Kahn’s criticism.

Notice, that the model demonstrates that if some cities adopt Forrester’s clearance program, then all cities would be well advised to do so to ensure the city that decides not to eliminate housing for the poor will end up being flooded by them. Such cities will see all the disadvantages of clearance in respect of dislocation of poorer citizens without seeing the advantages of industrial growth that occur in the program areas. If this analysis is right, and if cities are allowed to choose whether or not they will have this program, it might be considered in the “New Federalism” – the freedom thereby given is quite illusory. Any city that does not choose the program is bound to be hurt by the application of the program elsewhere.

Conclusions

Table 1 summarizes the effects of national applications of the two programs under consideration. Each program may be applied in two ways: either to the central city or to the ex-
Figure 6. Results of applying the modified national model to the case in which the training program is applied to half the metropolitan areas of the nation. Left, results for cities with the program; right, results for cities in which the program is not applied.

The training program is clearly better when applied nationwide than locally.
3. In choosing between the two programs, on a nationwide basis, the nation should choose the training program and reject the clearance program.
4. When applied to only one city, there are more gains and some losses from both programs.

I do not suggest that these conclusions be considered as a reliable result of a careful analysis which has been based upon a fully evaluated model. On the contrary, the results are different in point of view and in substance from the stated conclusions of Forrester's examination of the very same model. He and I have each used the model to explain our different points of view and to put our reasoning in numerical form.

Models like this one provide an illuminating way of documenting public policy issues. However, the discussion should give more light if the models were more realistic. Accordingly, a group of us at Brown University and at the Rhode Island state government is at the process of trying to build upon Forrester's groundbreaking model. Our aim is to include more features of the real world (for example, the tax laws in the city) to calibrate the model against existing census and other data, and to make the analysis for program evaluation more useful and meaningful. Others are also trying to develop better urban models. I hope that, as we continue to study and to critique each other's work, we will develop tools that will be useful in examining the effects and values of various urban policies.

References

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