SPATIAL PLANNING IN YUGOSLAVIA: AN APPLICATION OF MARKOV CHAIN ANALYSIS TO CHANGING SETTLEMENT PATTERNS

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INTRODUCTION: YUGOSLAV DECENTRALIZATION

The adoption of a new Constitution in April, 1963 marked the official beginning of a new policy of decentralization in Yugoslavia, a decentralization which, in effect, gave each republic and commune the initiative and responsibility to develop its economy on the basis of its own resources with a minimum of political influence from higher governmental levels. This decentralization, a marked departure from the Soviet style structure adopted by the Yugoslavs directly after World War II, has resulted in greater discretion being given to both workers' enterprises and local governmental units in the management of a greater proportion of their own funds. Predictably, this discretion has led to investments in areas of greatest economic return, and away from so-called political investments which played a predominant role in the immediate post-War period.

The greater emphasis on market forces and local government to determine investment strategies has led to an increased need for coordination of such strategies, including that which represents the planning function, both physical and socio-economic. The potential for addressing this need is embodied in the principle of "self-management." At the enterprise level the principle is designed to increase worker motivation through a collective structure of responsibility. At the government level, it has resulted in a shift toward mass-participation in the decision-making structure of local socio-political groups. In contrast to the decade immediately preceding the 1963 Constitution, communes can no longer expect that federal intervention in the form of political investments will guarantee equity in social wealth among communes. The communes must now largely fend for themselves, a fact which obviously favors those in the wealthier and more developed republics. It has been the previous experience that standards of equality set down from the federal level were difficult to attain.

SPATIAL PLANNING FUNCTION

Regional spatial planning in Yugoslavia is an outgrowth of traditional urban physical planning developed in the late 1950's. Two major obstacles to effective planning were apparent from the beginning: (1) a general lack of planning experience which resulted in a dependence on a relatively few agencies to perform most of the needed work, and (2) the inadequate professional training of physical (primarily architect-type) planners for conducting regional analysis and for coordinating physical and socio-economic planning efforts.

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To alleviate these problems an attempt was made during the sixties to bring economic and physical planners together to address spatial issues. Other problems began to surface, however. First, enterprises responsible for fulfilling the planning function in Yugoslavia are expected to be self-financing, i. e., be able to sell their services to local government or other enterprises. Second, the pressure to conduct studies which lead directly to physical projects at the urban scale is substantial, and places research and analysis necessary for regional planning endeavors at a relative disadvantage and at a lower priority. Third, as could be expected, the communal structure of government proved to be too small to deal effectively with major intercommunal problems and projects. The difficulties of organizing and coordinating local programs are well known to Yugoslavs as well as to Americans.

On the other hand, during the 1960's several developments positively and significantly influenced the urban and regional planning profession and discipline in Yugoslavia. Among these were the Southern Adriatic Project of the United Nations, which concentrated on the economic development potential of the southern Adriatic coast. A comparable study of the northern Adriatic is presently underway. The planning for the redevelopment of Skopje after the devastating earthquake of 1963, and local planning efforts in Belgrade, Zagreb and Ljubljana (plus several other cities) have provided increased opportunities for expanding the profession and increasing the experience of planners in urban and regional spatial planning.

One complementary effort is represented by the so-called American-Yugoslav Project in Ljubljana which, since its inception in 1966, has stimulated a broader approach to Yugoslav planning through educational and training programs, including research projects conducted on a joint basis with Yugoslavs and Americans, as well as a demonstration of a prototype metropolitan planning study for the Ljubljana Region itself.¹ Although divorced from local on-going planning activities, several components of the Ljubljana study proved to be of direct relevance and interest to the local planners. The utilization of computer-assisted programs for projecting transportation demand and regional land use, the elucidation of a planning process into which such programs might fit, as well as a number of functional area studies (housing, industrial location, agricultural location, agricultural development, etc.) stimulated local interest. The Project, although operating in Ljubljana, has undertaken activities which have included participants from all corners of Yugoslavia as well as planners and institutes in other countries in both Eastern and Western Europe.

PLANNING IN SLOVENIA

Slovenia, whose capital is Ljubljana, is the most developed of the Yugoslav republics and by several criteria could qualify as a regional planning entity in itself. Although regional spatial planning has been undertaken in other republics, especially Croatia, Slovenia was the first republic to recognize the importance of regional physical planning coordination and programming of infrastructure investments at the republican level. A mechanism for this coordination, the rationalization of regional location decisions, and social equity through the provision of a minimum consumption level of social goods became the goals of the Slovene experiment. In 1967, the Slovene Assembly passed the Regional Spatial Planning Act and the Urban Planning Act thus defining and authorizing at the republican level, for the first time in Yugoslavia, a systematic program in the field of spatial planning². Under the decentralized decision-making milieu of today's Yugoslavia, the coordinative role in spatial planning at the regional level has been given to governmental agencies. Economic planning on the other hand rests largely with enterprises through whom the integration of economies of the several

Yugoslav republics and regions mostly depends. Enabling legislation in Slovenia, therefore, defines the tasks of regional planning to include only the spatial aspects of regional planning although such plans are expected to consider the social and economic realities and constraints of each area. With the passage of the Regional Spatial Planning Act, Slovenia has taken a step in the direction of integrating these elements of spatial and socio-economic planning.

The structure for government policy-making now lies in three bodies: (1) a legislative Committee for Urban Planning, Communal Affairs and Housing in the Assembly of Slovenia, (2) a Commission For Regional Spatial Planning headed by a member of the executive Council (and whose membership includes representatives of republican bodies whose functional responsibilities would be integrated by the republican planning function), and (3) the Bureau of Regional Planning in the Republican Secretariat of Urban Planning.³ This bureau is the operational agency responsible for coordinating research work and the preparation of a regional spatial plan. Although still having a very small staff, the Bureau has enlisted the cooperation of a number of agencies in the government, as well as in enterprises and research foundations which have interest and competence in a number of relevant fields.

In 1971, the Bureau is expected to present a proposed plan to a parliamentary commission for review. According to the provisions of the Regional Planning Act, this plan should include:

- socio-economic goals, objectives and guidelines for the economy and the suggested spatial organization of the republic and landscape preservation;
- general concepts for the basic transportation, water economy and power network;
- land use distribution for the basic categories of agriculture, forestry, tourism, housing, transportation, and infrastructure, and the designation of various preserved zones.⁴

This plan and subsequent activities will be oriented primarily to the increasing coordination of infrastructure investments and land use controls to effectuate a more rational development of communal and regional space, including the preservation of the Republic's scenic beauty and cultural heritage. They are also directed to prevent increased environmental pollution, and the development of a comprehensive republican (and metropolitan) transportation system. In an era when decision-making has become increasingly decentralized and cooperation quite difficult at best, this coordinative role of the republican planning bureau takes on increased significance.

URBANIZATION, TRANSFORMATION AND METROPOLITAN MODELING

Not unrelated to the decentralization policies which have characterized the Yugoslav scene for the past decade, and longer, is the increasing urbanization throughout the federation. For the less developed regions, this new self dependence and present inability of local economies to provide the facilities and services of the more developed regions, has led to a large-scale migration to the wealthier northern regions and cities, principally Zagreb and Belgrade.

The services and employment opportunities available in these larger and more developed cities works like a magnet pulling people off Serbian, Bos-

nian and Macedonian farms. The increased wealth of the northern cities has increased per capita incomes and social and private services to the point where significant shifts in life styles are apparent. In Slovenia, for example, per capita incomes are twice that of the federation's average,⁵ car ownership doubles every three or four years, and a general dispersion of the population into the hinterlands of Ljubljana is beginning to take place. The traditional agricultural sector, which in Slovenia is largely represented by individual farming households, clustered in rural settlements, is being transformed into a mixed economy, and gradually is leading to the rapid disappearance of the traditional employment. It is this transformation process, which is represented by a shift in employment from agricultural to non-agricultural pursuits, and by gradual changes in the population mix of the Slovene settlement in this era of cultural change that is the focus of the present analysis.

Despite the ongoing transformation, the traditional primary sector has been and still remains quite significant to the local economy. Concern for the natural environment and the changing relationship of man to it, have become an important policy issue in Slovene regional strategy. The significance of the concern for continued agricultural and environmental management is apparent in republican planning legislation and, even more so, in the metropolitan Demonstration Study undertaken by the American-Yugoslav Project.

A modified Lowry Model was utilized in the Demonstration Study in an attempt to adapt the model to cultural conditions prevalent in the Ljubljana metropolitan area.⁶ One modification deemed necessary involved an explicit consideration of an agricultural population whose change over time was dealt with quite independently from that of the non-agricultural population. Because a significant proportion of the 1961 base population in the so-called region of study was agricultural, its relationship to other sectors and the techniques for forecasting changes in the distribution of this sector varied from that usually employed in the Lowry Model. During the Demonstration Study, several questions were raised concerning the appropriateness of the modified model for analyzing changes in the spatial distribution of this segment of the population, questions which lead to a deeper consideration of the underlying factors related to the transformation underway, e.g., the influence of resource factors, accessibility, etc.

Only one hundred years ago, the villages immediately surrounding the old city of Ljubljana were purely peasant communities, depending on agriculture for their livelihood and physically separated from the city by tracts of agricultural land. Even today, the villages in the 15-commune so-called Ljubljana Region are primarily small with, at most, a few hundred inhabitants. Their size is directly related to both the quantity and quality of land surrounding them, neither of which are adequate (with few exceptions) to support large scale modern agriculture as it exists today in other parts of Yugoslavia. Furthermore, these villages are not sufficiently large to encourage or support a general decentralization of commercial or social services.

In these respects the villages of Slovenia, the predominant type of urban settlement in the republic, are not unlike typical European settlements. One should keep in mind, furthermore, that when we speak of a Ljubljana Region, until now this has been much less integrated in a functional sense than its counterpart in, say, the United States. This relative lack of integration is a reflection, of course, of the historical dependence on the primary sector in the hinterland and the undeveloped transportation system linking small towns to the focal point of the region, Ljubljana.

That a rapid transformation of the hinterland economy is taking place is evident from the fact that the percentage of the total population of the 15-com-

mune region which was considered agricultural, decreased from 50% in 1931 to less than 20% in the early 1960's (during the same period comparable percentages for the republic declined from 58% to 30%). Two significant characteristics affecting the transformation process in the Region have been: (1) the large proportion of small privately owned farms and the subsequent small cash earnings of households (the relatively few social farm enterprises are limited to the few large areas of flat plain and excellent soil); and (2) the fairly dense network of improved roads suitable for motor transport throughout the region. This factor coupled with recently improved and expanded bus service has resulted in good accessibility for most settlements, even small previously isolated ones off main railroad routes.

In line with transformation processes throughout the world, the shift to a mixed employment type has been largely dependent on the opening up of new commercial and industrial jobs in the Region. Although the transformation from agricultural to industrial probably has not kept pace with that first planned after the War, two objectives of present policies influencing this transformation in Slovenia are to reduce agricultural population continually while, at the same time, to provide a decent living for those still on the farm, even those on private holdings. It is interesting to note that although communal plans of land development have foreseen the gradual expansion of the social sector of agriculture to include most if not all of the best agricultural land in the Region, recent events have shown that social farms, run by enterprises whose investments are becoming more and more diversified, are becoming less interested in expanding their land holdings and more interested in investments in other sectors of the economy. It is not unusual for such enterprises to lease land back to private farmers. Whether this is simply a phenomenon reflecting a short-term maladjustment in the system or a harbinger of a major shift in the socialist objective of a gradual socialization of the Yugoslav countryside remains unclear at this time.

If one were to summarize the immediate effects on the transformation and urbanization processes on the rural hinterland of the Region, the following facts would stand out: (1) although not all settlements have experienced continued growth in the post War period, villages of all sizes have shown increases or at least stability; (2) although there has been a continual reduction in the agricultural population per se, the amount of land that has gone out of production since World War II has remained quite negligible; (3) the relatively high value of all land, particularly that with excellent soil, is reflected in the observation that very little good land has been taken for residential and other urban uses; and, (4) that partially due to the facts that policies have been undertaken to improve both the financial and social position of the so-called peasant farmer in the recent years and that accessibility has increased substantially, many of those who have made the transition from farm to mixed or non-farm household, have continued to live in the village, at least until accumulating sufficient capital for the purchase of a housing unit closer to their place of work. Many have remained on the family homestead, reflecting a fervent desire for continued land ownership.

It became clear during the above mentioned Demonstration Study that there was a general lack of understanding about the net effect of the policies affecting the rural hinterland's spatial character and that a further investigation of these processes beyond that modeled in the Lowry Model was warranted. In addition to the lack of analytical tools and experience in dealing with the spatial dimensions of the processes identified, a very real problem in the utilization, much less modification, of an existing known model was the fact that population and employment levels in this hinterland, although clustered in easily identified villages, were low.

Following the lead of spatial theorists such as Olsson and Curry, an optimizing model was put aside and attention was given to behavioral approaches to the transformation process. Olsson has called for a modification in modelling assumptions which would generally admit to imperfect knowledge about the phenomena, explicit consideration of the complexity of (both personal and institutional) behavior with such relaxed assumptions, and the need to develop a model which treats spatial and temporal sequences concomitantly.⁷ Curry has suggested the use of probabilistic models of social behavior in cases in which considerable ignorance can be admitted (e.g., of the values and explicit and implicit reasons behind locational decisions in the Ljubljana hinterland).

... that the format of the language of probabilities is equally germane to discussing both physical and human events, both spatial and temporal ordering, both retrospective and anticipatory explanations of actions, both individual and collective activities, the physical world both as exclusive of man and as the environment of man, bespeaks its versatility.⁸

Morrill in a study of the extension of the urban pattern on the urban fringe of Seattle utilized a probabilistic model to test hypotheses about property owner behavior with respect to development and the "randomizing or diffusional effect" arising from uncertainty and individual and property variability.⁹ The urbanization considered by Morrill dealt largely with the conversion of land from non-urban to urban use. The transformation process, on the other hand, as utilized in this context is more concerned with the change in the basic economic structure of the local population from subsistence to modern farming and from agriculture to non-agriculture in general. There is reason to believe, however, that probabilistic models which generally apply to one of these processes may find some applicability in describing, if not explaining the other. After some attempts to isolate a number of factors casually related to changes in population (both agricultural and non-agricultural) in the Ljubljana Region through regression analysis, it was found that factors such as accessibility, land resource characteristics and quality were indeed statistically significant in explaining a small proportion of the observed changes in the spatial distribution of total population. Although these exercises were useful in identifying such factors, it was obvious that other important factors had not been identified or quantified. For example, it could be assumed that with respect to both urbanization and transformation processes, a number of policies could be identified as having an effect on the dynamics observed. If a model describing the change in population levels in the hinterland was desired, (one which might make a contribution to a prediction of expected future distributions) a different tool was required. Attention was then focused on an application of the Markov Chain.

APPLICATION OF MARKOV CHAIN ANALYSIS TO CHANGES IN SETTLEMENT PATTERNS

The Markovian model, of course, has been used in a wide variety of analyses. Among those having relevance for this study are those of Fuguitt¹⁰ who found such a model useful in comparing the structure of shifts between size groups of Wisconsin towns in different ten-year periods; Fano¹¹ who utilized the model as one way to describe city-sized distribution over time; Bourne,¹² who studied changes in urban land use in Toronto; and Stoyke,¹³ for analyzing dynamic changes in agricultural land use. In addition, Harris¹⁴ developed a semi-Markov Chain to analyze land use changes in a rural-urban fringe in California. Brown,¹⁵ in a critical and comprehensive review of the use of the Markov Chain model in spatial analyses, concluded that the model

is easily implemented, being constructed around a process mechanism (the transition matrix), and provides a possibly useful starting point in the design of suitable geographic models, despite the rather stringent assumptions behind its use.

Kemeny and Snell have defined a Markov Chain process as follows:

A Markov Chain process is determined by specifying a given set of states ($S_1, S_2, \dots, S_r$). This process can be in one and only one of these states at a given time and it moves successively from one state to another. Each move is called a step. The probability that the process moves from S_i to S_j depends only on the state S_i that it occupied before the step. The transitional probability P_{ij} , which gives the probability that the process will move from S_i to S_j is given for every ordered pair of states. The matrix of probabilities is called the transitional probability matrix. The matrix must be square (the same number of rows as columns), and the sum of the rows of probabilities must, in each case, equal 1.0.¹⁶

The principal requirements for the setting up of the Chain are transitional data for at least two different time periods, the selection of an appropriate number and size of states, and the conversion of the data into a probability matrix. Given that urbanization of agricultural land has not proceeded very far in the Ljubljana Region, and that excellent settlement data for both non-agricultural and agricultural population exists in Slovenia, a decision was made to concentrate primarily on such data for two Census years, 1953 and 1961. Quite fortunately unpublished 1969 data was available as well. Two geographic areas in the Region were selected for analysis. Initially, the entire 15-commune Region was studied as an entity. Raw data for each of the 1567 settlements was collected for the three time periods and changes in each settlement's size were first traced for the 1953-1969 period. This basic transitional matrix is shown in Table I, according to the actual states chosen for the analysis.

One of the reasons for using this technique, of course, was to develop a model for possible predictive purposes. Prediction of population size distribution through the use of the Markov model involves converting the basic matrix into a transitional probability matrix. The general assumptions must be made that probabilities for growth and decline remain the same over time, and that the only explicit factor influencing a settlements growth is the size it was in the initial time period. Some factors have been uncovered and others suspected of having a casual relationship to population change so that one is naturally somewhat skeptical of making such simple assumptions. Modifications using added information about these factors will be treated later.

Before actually utilizing the model for predictive purposes, the availability of population data for three time periods provided an opportunity to test the stationarity assumption over time or, in effect, to see how well a model based on population changes between 1953-61 would be for predicting a 1969 distribution. The conversion of the eight-year matrix into a probability matrix and multiplication by the distribution of settlements by size in 1961 provided this expected distribution for 1969. Comparing this expected distribution for 1969. Comparing this expected distribution with the observed distribution, provided a test of these hypotheses and associated assumptions (see table 2). Utilizing a Chi-square test, it was shown that by carefully selecting an appropriate number and sizes of states (S_1 through S_r), it

was possible to accept the hypothesis that the probability matrix did not significantly change during the latter eight-year period.

Despite the fact that a certain degree of statistical significance was achieved,¹⁷ such information can serve only as an indication that the sixteen-year matrix with the similar states may satisfactorily predict the distribution of states in 1985. One may feel more comfortable having demonstrated some degree of stationarity of probabilities over time. A prediction was made for 1985 (table 4) for the Region using the 1953-1969 probability matrix (table 3) as a basis for multiplication by the observed 1969 distribution. A comparable prediction utilizing the square of the 1953-1961 matrix could, of course, also be conducted.

A smaller study area of the Ljubljana Region (Kamnik-Domzale Study Area) was also chosen for more detailed analysis of the influence of other factors such as accessibility and resource characteristics on changing patterns of settlement. Agricultural and non-agricultural population data was also utilized and analyzed for the same time periods but for slightly different states. The data base, however, was converted from settlements to 431 square kilometer cells. Although chains were developed for both agricultural and non-agricultural population in the Kamnik-Domzale area, a single model was chosen with states which, for smaller size cells, differentiated between those with greater or less than 50% of the population classified as agricultural. The probability matrix of this model for the 1953-1969 period is shown below (table 5). The size and number of states chosen and analyzed had previously led to the acceptance of the hypothesis of stationarity of probabilities from the 1953-1961 through 1961-1969 periods. The multiplication of the 1953-1969 matrix, as before, would provide a prediction of states in 1985. Furthermore, multiplication could also be easily done for predictions of 2001, which, incidentally, coincides with the horizon date chosen for the Ljubljana Demonstration Study.

LONG-RUN IMPLICATION OF THE MARKOV CHAIN MODEL

Perhaps useful in the sense that it provides some indication of changes in settlement size distribution in the study areas in the past period as well as expected future distributions, there are also other inherent features of the Markov model from which one can derive additional insight into its long-run implications. For example, by utilizing the so-called "absorbing chain," the analyst may be in a superior position to examine the long-run implications of the continuation of past trends in changes of spatial patterns, Kemeny defined an absorbing chain as follows:

A state in a Markov chain is an absorbing state if it is impossible to leave it. A Markov chain is absorbing if (1) it has at least one absorbing state, and (2) from every state it is possible to go to an absorbing state (not necessarily in one step).¹⁸

The matrices utilized in the previous section were absorbing at one end, the largest state, from which there was a zero probability of leaving once a cell had reached that state. There are a number of features of such an absorbing chain that can be extracted relatively easily through matrix manipulation. These features include: (1) the mean number of steps, or time period each cell spends in each non-absorbing state before absorption; (2) starting at any state, the mean number of steps before absorption; and, (3) starting at any non-absorbing state, the probability of ending in any absorbing state.

Although each of the indicated operations can be performed on a matrix with only one absorbing state, their utility for present purposes increases substantially with the introduction of a second absorbing state, at the other extreme being considered. If it is found, or at best assumable, that not only did cells which reached the highest state in the matrix have zero probability of leaving it, but that cells which reached the lowest size also had zero probability of growing, the conditions for a potentially most rewarding analysis would be met.

To provide an analytical foundation, consider the following transitional probability matrix which features two absorbing states S_0 and S_3 .

	S_0	S_1	S_2	S_3
S_0	1	0	0	0
S_1	.1	.5	.4	0
S_2	0	.3	.6	.1
S_3	0	0	0	1

The matrix may be written in a more standard form in which

	S_0	S_3	S_1	S_2
S_0	1	0	0	0
S_3	0	1	0	0
S_1	.1	0	.5	.4
S_2	0	.1	.3	.6

$$= \begin{pmatrix} I & R \\ 0 & Q \end{pmatrix}$$

where I is an identity matrix, 0 is a zero matrix, R is the probability matrix of going from any non-absorbing state to an absorbing state, and Q is the transitional matrix among non-absorbing states. All further operations are concerned with these four sub-matrices. The fundamental matrix under the present analysis is transformed into a similar form on the following page.

It should be noted that in order to utilize the absorbing chain technique to the greatest applicability, the probabilities were changed slightly for cells starting the study period in state S_{16} . Instead of having a probability of .10 of growing to S_{15} , it is assumed that all such cells must remain in the same S_{16} state. This slight modification will result in greater significance of the remaining matrix operations without substantially changing the assumptions within the past trends. Such an assumption, it must be realized, cannot always be justifiably made.

Through a new matrix $N = (I - Q)^{-1}$, the analyst derives directly the first of the characteristics identified earlier, i. e., the mean number of steps that study area cells will spend in each non-absorbing state before reaching either absorbing state. By summing horizontally the mean number of total periods

that a cell will spend in all non-absorbing states before absorption is obtained. Further examination will obviously highlight those states in which long-run stagnation or rapid change are likely to occur. The results of these operations are given in Tables 6 and 7.

One more operation can produce the third and perhaps most interesting of our objectives--the long-range probability of cells starting at any state and absorbing in either of the two states (i.e., the long-run prospects from growth or decline). This is accomplished simply by multiplying the previously determined N matrix by the R matrix. The resulting probabilities for the 16-yr. matrix are given below.

The results of these operations show that cells of all sizes have a greater probability for growth than for decline in the long-run. It might be noted that the cells with greater than 50% agricultural population generally have smaller chances for growth, a continuation of recent trends. A breakdown of cells into those most and least accessible to urban centers has shown that these probabilities are quite sensitive to accessibility levels.¹⁹

The efforts to this point, therefore, have been toward devising and understanding the fundamental properties of a Markov model based on past trends, and differentiating between those smaller sized cells which could be generally differentiated by percentage of population classified as agricultural. It is noteworthy that an explicit natural resource (e.g., land) has not yet been included. The following section describes two methods by which this important factor could be brought into the Markov Chain analysis.²⁰

MODEL EXPANSION

To this point, the Markov operations have dealt only with square kilometer cells with population, or only 226 of a study area total of 431 cells. The character of the settlement pattern itself and allocation of population to cells was such that no cells contained population in 1969 and not in any of the previous time periods. In addition, no cells were found to lose all their population during the 16-year period. One would not expect that this peculiarity would continue into the future, even if it had been a characteristic of recent development within the study area. One could logically expect new urbanized areas to be established under both private initiative and social policy. Furthermore, it is not beyond the realm of possibility that some zones will either lose what population they have at present, or at least develop what might be referred to as a scattered pattern, reflecting either an isolated farmstead or vacation house. It would be useful to expand the model to include all cells in the region and to take into consideration the above possibilities, especially as they might be related to other factors.

Adelman,²¹ Stanton,²² and others have addressed themselves to the problem of so-called "exist and entry" into a Markov system. Although their specific analyses concern completely different phenomena than this analysis, their thoughts are applicable.

To the initial transitional matrix, Adelman suggests the addition of another state which would act as a reservoir of potential "entrants" into the Matrix system as well as a state to which "leavers" of the system would be allocated. In Adelman's application to industrial structure it is suggested that the probability of moving from the reservoir group to the original group would equal the actual observed probability of new firms started annually in the appropriate size category. In an open-ended system such as the industrial example, a very real and important problem is the determination of the size of the reservoir group, i.e., the actual number of potential entrants in

any cycle or year. As Stanton pointed out, the number of potential entrants assumed in the system will affect both the rate at which changes in size take place and the project rate of exit. He states, "As the number of potential entrants is increased, the net effect on the resulting projections decreases at a decreasing rate."²³

The problem of the number of entrants is also faced when making short-term projections, and Stanton recommends that, in the industrial example, if conditions in any industry resemble those of perfect competition in which a large number of new firms could be established, then the number of potential entrants should be estimated to be large relative to the number of active firms. He has emphasized the desirability of utilizing more than one set of projections based on different alternative numbers of potential entrants as a sensitivity test.

Applying those remarks to the present analysis, it would seem relevant to include additional states for those cells which have no (or scattered) population from which new entrants into the system could be drawn each period. A number of alternatives suggest themselves. For example, one could assume that only a relatively small number of cells in the study area having any probability of "becoming populated" during any one round, perhaps those which have superior accessibility and/or resource characteristics. Still another and perhaps more suitable alternative is to add two or three reservoir states, based on accessibility and resource characteristics and which could include all cells in the study area. Movement among the reservoir states could indicate shifts in relative attractiveness of cells for development and could reflect changes in the economic use of the cell (for forest, large-scale intensive and extensive agriculture).

A problem in the present analysis, as implied before, is the lack of data with which to calibrate a prototype model such as suggested above. Nevertheless a hypothetical addition to the present model could be made but is beyond the scope of this paper. Longer-range application of such a model must be tempered by limiting assumptions about future probabilities for change as was the case with the more fundamental model. The prototype, however, can serve as an illustration of a more complete model of the process of urbanization, as well as a neater description of the probability for urbanization of cells presently unpopulated.

The relevance of such analysis for spatial planning in Slovenia would appear to be (1) to suggest a framework for studying past trends in growth of rural settlements, and (2) to provide the regional analyst with a tool for analyzing future possibilities for growth in the hinterland. An understanding of such possibilities based implicitly on the net effect of a number of forces, including social policy, may aid in the making of regional locational decisions.

Technically, it is possible to say without reservation that the Markov Chain model provides a useful framework for analyzing and describing changes in patterns of growth in rural settlements.

The extensions of the model suggested in this paper represent an attempt to break through some of the barriers inherent in the model. Although calibration with real data has been impossible at this juncture, perhaps future work in this direction will prove meaningful. The use of the Markov Chain appears to have definite limits for the study of human spatial dynamics, however, and future use of the such analysis will probably most fruitfully concentrate on basic analysis such as that presented by this paper.

TABLE 1. SHIFTS IN SETTLEMENT SIZE IN THE LJUBLJANA REGION,
1953-1969

1969

Settlement Size	S	—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Over 4000	1		2														2
3001 - 4000	2		4														4
2001 - 3000	3			2													2
1001 - 2000	4				4	5	1										10
751 - 1000	5				1	10	1	1									13
501 - 750	6				1	4	14	28	1	2							50
401 - 500	7						2	11	12		1						26
301 - 400	8						3	8	20	28	8	2					69
251 - 300	9								2	20	9	9		1			50
201 - 250	10					1				10	19	32	19	1			82
151 - 200	11							1		5	5	21	57	33			122
101 - 150	12									1		2	30	99	59		191
51 - 100	13													38	298	88	424
1 - 50	14														33	489	522
Total			6	2	6	20	21	49	35	66	51	66	106	172	390	577	1567

TABLE 2. COMPARISON OF "PREDICTED" AND ACTUAL
DISTRIBUTION OF SIZES OF SETTLEMENTS IN LJUBLJANA REGION IN
1969

<u>State</u>	<u>Size</u>	<u>Predicted</u>	<u>Actual</u>	<u>Difference</u>
S ₁	over 4000	5.5	6	+ .5
S ₂	3001-4000	3.0	2	-1.0
S ₃	2001-3000	5.0	6	+1.0
S ₄	1001-2000	22.5	20	-2.5
S ₅	751-1000	19.8	21	+1.2
S ₆	501- 750	51.8	49	-2.8
S ₇	401- 500	44.4	35	-9.4
S ₈	301- 400	67.9	66	-1.9
S ₉	251- 300	49.7	51	+1.3
S ₁₀	201- 250	71.2	66	-5.2
S ₁₁	151- 200	95.6	106	+10.4
S ₁₂	101- 150	162.7	172	+9.3
S ₁₃	51- 100	395.4	390	-5.4
S ₁₄	1- 50	572.4	577	+4.6
Total		1566.9	1567	

$\chi^2 = 5.31$ (d.f. = 13). Hypothesis of stationarity accepted at a 5 per cent level of significance.

TABLE 3. TRANSITIONAL PROBABILITY MATRIX OF CHANGES IN SETTLEMENT
SIZE IN THE LJUBLJANA REGION, 1953-1969

1969

Settlement Size	S	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Over 4000	1	1.000													
3001-4000	2	1.000													
2001-3000	3		1.000												
1001-2000	4			.400	.500	.100									
751-1000	5			.077	.769	.077	.077								
501- 750	6			.020	.080	.280	.560	.020	.040						
401- 500	7					.077	.423	.461	.039						
301- 400	8					.043	.116	.290	.406	.116	.029				
251- 300	9							.040	.400	.360	.180	.020			
201- 250	10				.012				.122	.232	.390	.232	.012		
151- 200	11						.008		.041	.041	.172	.468	.270		
101- 150	12								.005		.010	.157	.519	.309	
51- 100	13												.090	.702	.208
1- 50	14													.063	.937

TABLE 4. SIZE DISTRIBUTION OF SETTLEMENTS IN LJUBLJANA
REGION, 1953, 1961, 1969 AND PREDICTED FOR 1985

<u>Size</u>	<u>1953</u>	<u>1961</u>	<u>1969</u>	<u>1985*</u>
over 4000	2	4	6	8.0
3001 - 4000	4	3	2	6.0
2001 - 3000	2	3	6	13.9
1001 - 1500	10	16	20	27.3
751 - 1000	13	18	21	22.3
501 - 750	50	48	49	52.4
401 - 500	26	38	35	38.3
301 - 400	69	68	66	63.7
251 - 300	50	51	51	45.7
201 - 250	82	77	66	56.8
151 - 200	122	107	106	91.9
101 - 150	191	176	172	154.9
51 - 100	424	409	390	363.3
1 - 50	522	549	577	621.8

*Predicted on the basis of 1953 - 1969 trends.

TABLE 5. TRANSITIONAL PROBABILITY MATRIX OF CHANGES IN CELL
POPULATION IN KAMNIK-DOMZALE STUDY AREA, 1953-1969

Cell Population	s	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
over1000	1	1.000															
501-1000	2	.632	.362														
401- 500	3		.667	.333													
301- 400	4		.222	.445	.333												
251- 300	5			.200	.500	.200	.100										
201- 250	6				.267	.200	.333	.200									
151- 200	7				.071	.143	.107	.536	.143								
126- 150	8							.300	.100	.500	.100						
101- 125	9							.158	.211	.263	.211	.158					
76- 100	10							.077		.231	.077		.385		.077	.154	
76- 100	11*								.143	.286	.286	.143	.143				
51- 75	12								.143	.286		.571					
51- 75	13*									.080		.200	.440	.040	.240		
26- 50	14											.200		.800			
26- 50	15*											.111		.222		.556	.111
1- 25	16														.100		.900

*Cell population includes at least 50% classified as agricultural.

TABLE 6. MEAN NUMBER OF STEPS CELLS WILL SPEND IN EACH
NON-ABSORBING STATE BEFORE ABSORPTION, KAMNIK-DOMZALE, AREA

	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	S ₉	S ₁₀	S ₁₁	S ₁₂	S ₁₃	S ₁₄	S ₁₅	Total
S ₂	1.58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.58
S ₃	1.58	1.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.08
S ₄	1.58	1.00	1.50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.08
S ₅	1.58	1.13	1.10	1.33	0.22	0.13	0.03	0.04	0.03	0.01	0.05	0.00	0.03	0.01	5.69
S ₆	1.57	1.05	1.30	0.63	1.77	1.07	0.25	0.33	0.24	0.07	0.36	0.02	0.20	0.09	8.93
S ₇	1.53	1.05	1.22	0.78	0.67	3.44	0.79	1.04	0.76	0.23	1.16	0.06	0.63	0.30	13.65
S ₈	1.44	0.98	1.14	0.73	0.63	3.22	2.35	3.10	2.26	0.69	3.44	0.18	1.88	0.88	22.91
S ₉	1.40	0.96	1.12	0.72	0.61	3.14	1.50	4.26	2.78	0.94	4.29	0.24	2.33	1.09	25.38
S ₁₀	1.32	0.90	1.05	0.67	0.58	2.97	1.29	3.50	4.15	0.78	6.04	0.20	3.36	1.55	28.37
S ₁₁	1.32	0.90	1.05	0.67	0.58	2.97	1.33	3.67	3.63	2.21	6.18	0.57	3.25	1.57	29.90
S ₁₂	1.35	0.92	1.07	0.69	0.59	3.03	1.36	3.75	3.70	0.83	7.79	0.21	3.02	1.40	29.70
S ₁₃	1.20	0.82	0.96	0.61	0.52	2.70	1.20	3.32	3.37	0.73	6.71	1.97	4.17	2.23	30.51
S ₁₄	1.35	0.92	1.07	0.69	0.59	3.03	1.36	3.75	3.70	0.83	7.79	0.21	8.02	1.40	34.70
S ₁₅	1.01	0.69	0.81	0.52	0.44	2.27	1.02	2.82	2.77	0.62	5.84	0.16	4.76	3.30	27.03

TABLE 7. LONG-RUN PROBABILITY FOR GROWTH AND DECLINE
OF CELLS BY STATE IN KAMNIK-DOMZALE AREA

<u>Starting in State</u>	<u>Probability for Growth</u>	<u>Probability for Decline</u>
s_2	1.00	0.00
s_3	1.00	0.00
s_4	1.00	0.00
s_5	1.00	0.00
s_6	.99	.01
s_7	.97	.03
s_8	.91	.09
s_9	.89	.11
s_{10}	.84	.16
s_{11}	.84	.16
s_{12}	.85	.15
s_{13}	.76	.24
s_{14}	.85	.15
s_{15}	.64	.36

FOOTNOTES

¹The reader is referred to a number of articles and reports generated by the Project. In particular, attention is called to the Draft Report of Spatial Policies for Regional Development, published in 1970 by the American/Yugoslav Project in a final report accompanied by twelve technical reports. This paper claims heavily upon the work of the Project and that of several Yugoslavs and Americans. Also see Jack C. Fisher, Yugoslavia: A Multinational State (San Francisco, Chandler Publishing Co., 1966); Jack Fisher, "The Emergence of Regional Spatial Planning in Yugoslavia: The Slovenian Experience," in George W. Hoffman (ed.) Eastern Europe: Essays in Geographical Problems (Methuen and Co., Ltd. London, 1970) pp. 301-363; and Barry R. Lawson, "An Application of Markov Chains to the Analysis of Growth and Decline of Settlements in the Ljubljana Metropolitan Area" (American/Yugoslav Project, Ljubljana, 1970).

²Fisher (in Hoffman), p. 321.

³Ibid. p. 321.

⁴Ibid. p. 322.

⁵Ibid. p. 313.

⁶See Technical Report No. 10, "The Lowry Model--A Mathematical Model for Forecasting the Distribution of Population and Jobs in an Urban Region," (American/Yugoslav Project, Ljubljana, 1970).

⁷Gunnar Olsson and Stephen Gale, "Spatial Theory and Human Behavior," Regional Science Papers, Vol. 21, 1968, p. 234.

⁸L. Curry, "Chance and Landscape," Northern Geographical Essays, (Oriel Press, Ltd., Newcastle upon Tyne, 1966), p. 52.

⁹Richard L. Morrill, "Expansion of the Urban Fringe: A Simulation Experiment," Regional Science Papers, Vol. 15, 1965, p. 185.

¹⁰Glenn V. Fuguitt, "The Growth and Decline of Small Towns as A Probability Process," American Sociological Review, Vol. 30, No. 3 (June, 1965) pp. 403-411.

¹¹Pietro L. Fano, "L'Evoluzione dei Sistemi Urbani; un Apprezzo Probabilistico," Archive di Studi Urbani e Regionali, Anno (May, 1968) pp. 1-7.

¹²Larry S. Bourne, "Physical Adjustment Processes and Land Use Succession: A Conceptual Review and Central City Example," Economic Geography, Vol. 47, No. 1 (January, 1971) pp. 1-15.

¹³Judith Stoyale, "Land Utilization as a Stochastic Process," Canadian Journal of Agricultural Economics, Vol. 11, No. 2 (1963), pp. 52-64.

¹⁴Curtis C. Harris, "Suburban Development a Stochastic Process," The Center for Real Estate and Urban Economics Institute of Urban and Regional Development, University of California, Berkeley, 1966 (Technical Report No. 1) 87 pp.

¹⁵Lawrence A. Brown, "On the Use of Markov Chains in Movement Re-

search," Economic Geography, Vol. 46, No. 2 (Supplement), (June, 1970), pp. 393-403.

¹⁶ John G. Kemeny, et. al. Finite Mathematical Structures (Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1958) p. 148.

¹⁷ The reader should realize that the purpose of conducting a statistical test in this context is simply to provide some sensitivity of the model generated. There are, of course, several parameters within the model which can be manipulated so as to reduce the error involved and hence increase statistical significance. A high degree of significance for the eight-year matrix model does not in itself justify the use of a sixteen-year model for predictive purposes.

¹⁸ John G. Kemeny and Laurie J. Snell, Finite Markov Chains, (D. Van Nostrand Co., Inc., Princeton, 1960), p. 210.

¹⁹ See forthcoming thesis by Barry R. Lawson, "The Role of Resource Use in the Development of a Generalized Model of Settlement Transformation of the Periphery of the Metropolitan Area," Department of Agricultural Economics, Cornell University, Ithaca, New York, 1971.

²⁰ It is beyond the scope of this paper to do a detailed analysis of the techniques utilized other than to state the general approach.

²¹ Irma Adelman, "A Stochastic Analysis of the Size Distribution of Firms," Journal of the American Statistical Association, Vol. 53. (Dec., 1968), pp. 893-904.

²² Bernard F. Stanton and Lauri Kettunen, "Potential Entrants and Projections in Markov Chain Analysis," Journal of Farm Economics, Vol. 49, No. 3 (August, 1967), pp. 633-642.

²³ Stanton, p. 635.