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INFORMATION SYSTEMS IN AN UNCERTAIN
PLANNING ENVIRONMENT - SOME METHODS

E. Hinloopen*
P. Nijkamp*

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*Department of Economics,
Free University,
Amsterdam, The Netherlands

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

This paper is written as part of a joint research project between the Integrated Regional and Urban Development Project (IIASA) and the Department of Regional Economics, Free University, Amsterdam. This research project concerns the design and use of information systems for a coherent and effective regional planning.

The present paper reviews some recent issues in this field, viz. scenario analysis, qualitative evaluation, monitoring and early warning systems, and spatially disaggregated locational information systems (particularly geocoding).

Börje Johansson
Acting Leader
Regional Development Group
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INFORMATION SYSTEMS IN AN UNCERTAIN
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Edwin Hinloopen
Peter Nijkamp

1. INTRODUCTION

Information systems are related to sets of structured data (including modeling activities, statistical tests, (dis)aggregation procedures, transformations, computer packages, etc.) that serve to reduce the uncertainty or lack of insight into an object (e.g. future states) in planning and decision-making.

In general, *uncertainty* refers to lack of insight into the occurrence of a phenomenon; it means that the probability density function regarding a certain event is unknown. Thus, uncertainty implies that probabilistic statements regarding events can hardly be made.

Clearly, uncertainty is a basic aspect of planning and decision-making. Information systems may aim at eliminating part of the uncertainty implied by a certain planning or decision problem, but the uncertainty will never be entirely removed.

Uncertainty may not only lead to biased decisions, but also to delayed decisions. Very often decisions are postponed due to lack of insight into the consequences of a certain action. Such a delay is indeed reasonable, if the time saved by the delay serves to gather extra information. If this were not the case, the costs involved in delaying a certain decision would make it necessary

to take immediate decisions. Consequently, if no such costs were involved, it would be better to leave open all relevant options until perfect insight has been achieved.

In regard to a justification for a delay in taking decisions, a special situation may emerge if a certain planned action is *irreversible*. In that case the information gathered is decisive for the long-run outcome of a planning or decision problem. Irreversible actions require a careful consideration based on reliable information. Clearly, if no transaction costs were involved in reverting a certain action, there would normally be no need to postpone a decision.

Thus, altogether uncertainty is a basic ingredient of planning and policy making, so that indeed information systems may act as important decision support systems.

Various kinds of uncertainties may play a role in different stages of a planning or policy problem (see for a review Voogd, 1982). A sample of methods dealing with uncertainty will briefly be discussed here.

A first kind of uncertainty may emerge if decisions are to be taken regarding medium- or long-term actions, characterized by lack of insight into the *structure* of the decision problem concerned. This means that the "decision environment", the available options, the political priorities and the expected consequences of actions are to a high degree unknown. This is a usual phenomenon in strategic choice problems (Friend and Jessop, 1969; Friend et al. 1974). A meaningful and increasingly powerful instrument for structuring the uncertainty in such cases is *scenario analysis*. This will be briefly discussed in section 2.

A second category of uncertainty arises if decisions are to be taken regarding a well-defined choice problem (i.e. all alternative actions or options are known, while also all judgement criteria are specified), for which, however, *no metric outcomes or priorities* (weights, for example) are known. This implies that only categorical information (e.g. "yes" or "no", binary information, or ordinal information) regarding the impacts of decisions and the priorities of decision-makers is available. In this case, *qualitative evaluation methods* have turned out to be a powerful tool. These will be discussed in section 3.

Another source of uncertainty may be lack of insight into the *moment* a certain policy should come into action. Even in the case of a well-defined decision problem characterized by quantitative information regarding the outcomes of alternative actions, it may still be uncertain *when* certain decisions are to be taken. Very often a "management by exception" strategy is adopted, meaning that a certain policy will only be put into effect if a certain critical threshold level is surpassed. Clearly, such cases would require a permanent monitoring system. With regard to this, a so-called *early warning system* is increasingly being regarded as an appropriate tool (see section 4).

Apart from the structure, the level of measurement or the time horizon of choice problems, lack of insight may also be due to the *level of aggregation* of information. If information is provided in a very aggregate form, it does not yield sufficiently relevant insight, so that its usefulness is very small. On the other hand, if information is provided in a very disaggregate way, it may involve a great deal of redundant or confusing elements, so that its usefulness is again very small (see Figure 1). The problem of various spatial scales may be effectively handled by means of new monitoring systems such as *geocoding*. This will be discussed in section 5.

It should be noted that the above mentioned methods are by no means mutually exclusive. They may quite well be complementary. For instance, the design of scenarios in a long lasting planning process may be supported by qualitative evaluation methods, monitoring systems or geocoding systems.

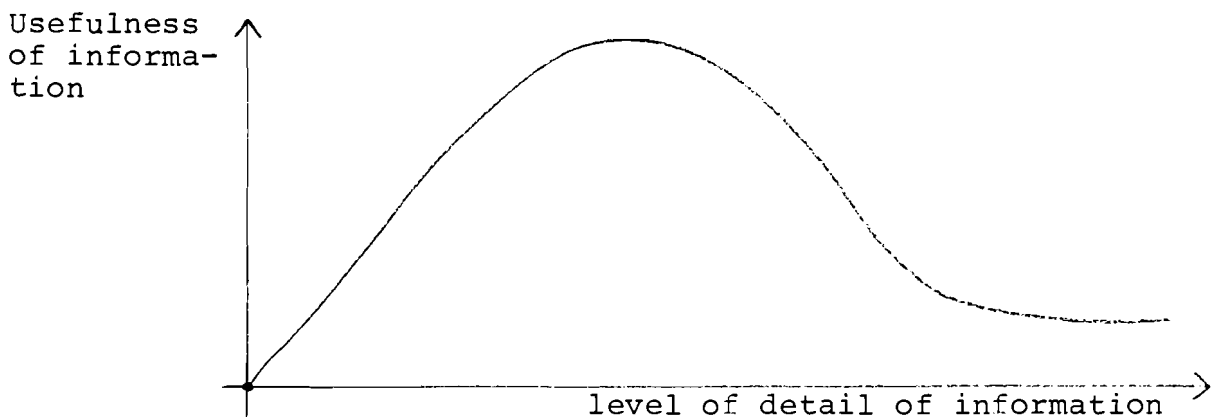


Figure 1. Relationship between aggregation and usefulness of information.

2. SCENARIO ANALYSIS

2.1 General Introduction

Scenario analysis is one of the methods and techniques of prospective policy research that have become very popular since the late sixties. Especially in the case of unstructured decision problems with uncertain outcomes, scenario analysis may be an appropriate instrument. The main difference between scenario analysis and conventional methods of policy analysis is that scenarios do not only contain a description of one or more future situations, but also a description of a consistent series of events that may connect the present situation with the described future situation(s).

Instead of giving a formal definition of scenario analysis, it may be more helpful to explain this approach by means of an illustrative figure.

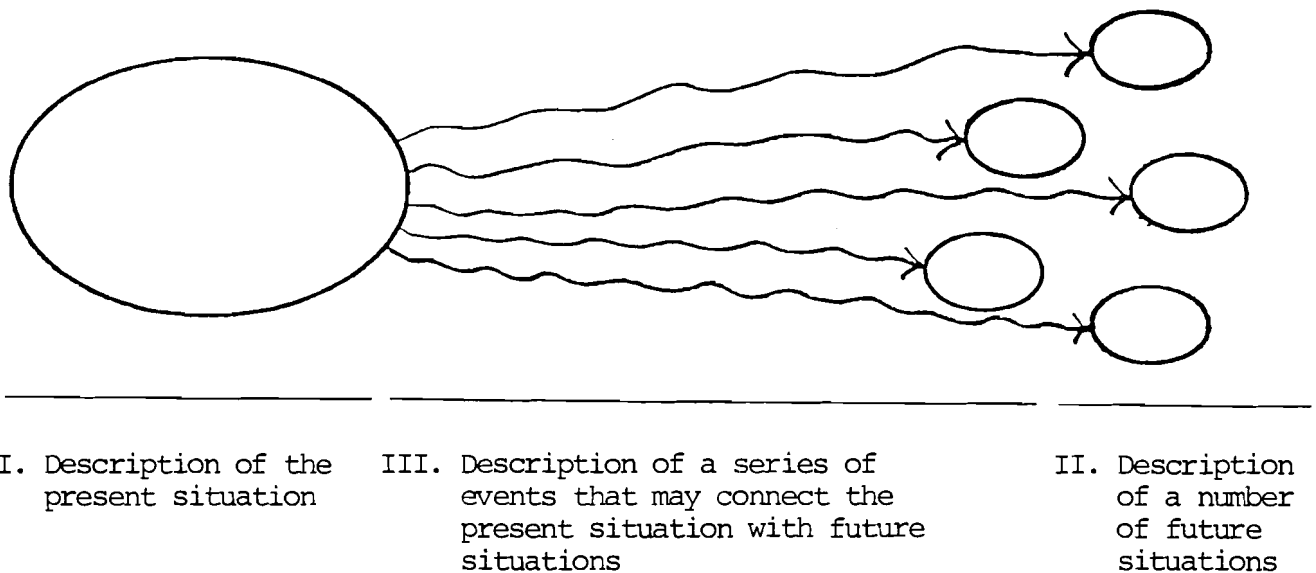


Figure 2. Series of events between present and future situations.

Figure 2 shows that a scenario analysis contains three components:

- I. Present situation.
- II. Future situations.
- III. Paths from the present to the future situations.

Each of these components *must* be a part of the scenario analysis, otherwise the scenario will not provide useful information for a better structuring of a choice problem. For instance, if there is no description of the present situation, then it is very likely that the construction of the future situations and the paths that may lead to it, are based upon incorrect assumptions about the present situation. Also, the description of the future situations may not be absent, because scenarios try to provide a description of the future on the medium- and long-term. If only the characteristics and developments of the present situation are extrapolated to get a picture of the future, then this picture will be full of many uncertainties, so that an essential part of a scenario analysis--the provision of (clear) pictures of some plausible and desirable future situations--will fail. Also, the construction of paths leading from the present situation to the described future situations is an essential part of a scenario analysis; without these paths, the links between the present situation and the future situations under study will be missing.

Depending on the specific circumstances under which a scenario is constructed, some of these three components may not require as much attention as the other ones. If, for instance, a scenario is constructed for a problem that has already been examined in greater detail, then it is probably quite easy to find information required for the description of the present situation. Then evidently most emphasis can be placed upon the two other components of the scenario analysis. On the other hand, if the paths from the present to the future are well known, then only a brief description will be sufficient to perform a meaningful scenario analysis.

Finally, sometimes the future may be surrounded with so many uncertainties, that it is hardly possible to describe a plausible future situation. In such cases, especially the feasible paths to the future may be a topic of discussion.

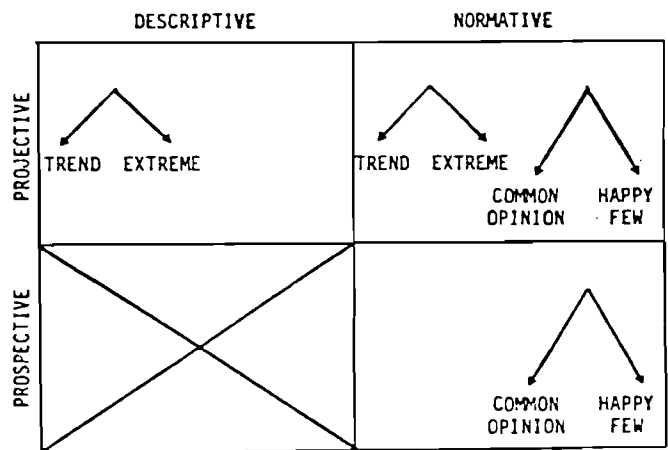
2.2 Specific Characteristics

Scenarios can be identified by four characteristics (cf Van Doorn and Van Vught, 1981):

- A scenario is either *descriptive* or *normative*. The prospective paths and pictures of a descriptive scenario are based on the know-how developed in the past and present. The question whether these paths and pictures are desirable or not, is not raised. The first scenarios designed by Herman Kahn (1967), are in agreement with this description. The construction of normative scenarios is based upon the ideas of the scenario-writers or scenario-users. The future paths and pictures are selected by these writers and users. The so-called Ozbekkan-scenarios, as a reaction on Kahn, may be regarded as members of this category (cf van Doorn and van Vught, 1981).
- Another distinction that can be made is the difference in direction of the scenario analysis. If future pictures are based upon the present situation and the future paths, then the scenario is said to be *projective*. On the other hand, if at first the future situations are determined and next the paths leading to this situation, then in fact these paths lead from the future backwards to the present. As they are composed afterwards, the scenario belongs to the class of *prospective* scenarios. Prospective scenarios are always normative, while projective scenarios are either descriptive or normative.
- A scenario can be characterized as a *trend* scenario or as an *extreme* (or contrast) scenario. Trend scenarios are in fact an extrapolation of the present situation. Extreme scenarios on the other hand, try to construct future paths and future situations that are considered to be in principle feasible, though very unlikely. They are both always projective scenarios.

-- The last distinction to be made is whether a normative scenario is based upon the preferences of the majority of people, or whether it is based on the preferences of a small minority. The first group may be characterized as "common opinion" scenarios, and the second as "happy few" scenarios.

The relations between these characteristics are shown in the following figure.



Source: Van Doorn and Van Vught (1981)

Figure 3. Characteristics of scenarios.

On the basis of Figure 3, various compound scenarios can be constructed, each made up by features of the successive individual scenarios. This is illustrated in Figure 4, where the entries $S_{I,1}, \dots$ indicate a blend of characteristics of various scenarios.

It is assumed in Figure 4 that state 1 at the top of the table is a trend, while the remaining states 2, ..., N are alternative, feasible (maybe sometimes extreme) states of the system concerned. The (linear or nonlinear) combination of these states makes up the external boundaries of all possibilities of the system. The policy priorities are reflected in the common

opinion view I, the normative (maybe sometimes extreme) priority schemes II, ... (the happy few, e.g.), and the endogenized priority responses upon the external conditions (1, ..., N) indicated by XI, The latter category is by its very nature essentially a set of descriptive scenarios.

Alternative external conditions various societal values	States of exogenous conditions				
	1	2	3	N
I	$S_{I,1}$	$S_{I,2}$		
II	$S_{II,1}$				
.	.				
.	.				
.	.				
.	.				
XI					
.					

Figure 4. Various compound scenarios.

2.3 Illustration of a Scenario Analysis for Regional Development

This section will discuss an example of scenario analysis in regional development (cf Verbaan et al. 1982). This example concerns spatial development and spatial development policy in the Netherlands, starting in 1966 when the Second Memorandum on Physical Planning in the Netherlands was published. In this document an analysis has been made of spatial and social developments and changes that took place in the Netherlands during the post-war period. This analysis was the basis on which the expected future situation in the year 2000 had been constructed. Two tendencies formed the main part on which these future pictures have been based--the expected population growth and the expected growth in welfare.

The results of these two assumptions indicated that an increase in leisure time, an increase in mobility, and a desire for more choice possibilities would take place. The spatial consequences were a large sprawl of urban areas, a great quantity of recreation areas and an increase in transportation infrastructure. The government policy was to anticipate as much as possible these expected developments.

Although the Memorandum was not presented as a scenario, it complies with the description of a descriptive (no desirable future images had been selected), projective (the future path started in the present and terminated in the future) and trend scenario (simply the two major developments on which the forecasts have been based, were extrapolated). Hence, this document is in agreement with the scenarios of Herman Kahn.

However, a few years later the assumptions on which the above mentioned forecasting had been based turned out to be incorrect. Especially the expected population growth had been over-estimated. Therefore the Memorandum had to be revised. In 1973, the first part of the Third Memorandum was published. In this note, special attention was paid to three issues that had been neglected in the previous document: the environment, the unlimited economic growth, and the inequity and imbalance in the development of certain parts of the country. The results of this new analysis were published in the second and third parts of the Third Memorandum: the Urbanization Memorandum and the Rural Areas Memorandum.

These documents were quite different from the Second Memorandum. In the first place, the relevant planning period ends around 1990. In the second place, the document does not contain only one expected future situation, and in the third place, it does not select one of those future pictures as the one that should be pursued.

Several quantitative and qualitative future investigations have taken place in order to design meaningful scenarios for this Memorandum. Forecasts have been made of the expected national and regional demographic developments, the expected demand for

dwellings, the developments of the national and regional labor markets and the expected transportation developments.

The qualitative forecasts required the development of four scenarios. A trend scenario has been described, very similar to the Second Memorandum; a second scenario has been developed in which the main issues are intensive urban growth and a strong development of the international relations; a third scenario described an environmental and energy-saving future situation, while the last scenario focused on optimizing housing supply, while improving the housing standards of the lower social classes.

The Urbanization Memorandum does not make a choice between those scenarios. It uses the scenarios solely to guide short-term policy; the short-term policy should leave a certain flexibility, so that it does not exclude one of these four scenarios.

The differences in the scenario parts between the Second and Third Memoranda are that in the latest one several scenarios were created instead of just one. The previous descriptive, projective, and trend scenario has been repeated, but also some normative, projective, and extreme scenarios have been developed. No choice between the scenarios has been made, though in a sense each of these extreme scenarios may be a "common opinion" scenario.

3. QUALITATIVE EVALUATION METHODS

Conflict analysis is a basic ingredient of regional and urban planning, as there are usually multiple actors, multiple objectives and multiple levels involved in any choice problem. With regard to this, multicriteria analysis has demonstrated its problem-solving capacity in regional and urban planning problems marked by conflicts emerging from the above mentioned sources (see among others Nijkamp, 1980; Nijkamp and Spronk, 1981; Rietveld, 1980; Spronk, 1981, and Voogd, 1982).

Multicriteria analysis is a mode of thinking by which choice problems with conflicting options can be structured and rationalized. Normally two elements are involved in multicriteria analysis, viz. the assessment of impacts of policy measures for all relevant alternative choice options and the determination of sets of (political or societal) priorities.

Very often the impacts and priorities are hard to assess in a cardinal metric. Therefore, qualitative (soft) multicriteria models (based on ordinal or binary information) may offer a meaningful perspective.

In the case of qualitative or soft multi-criteria analysis, various methods may be employed in order to draw consistent inferences regarding the rankings of alternatives (plans, projects, policies, etc.). In the present section, only a brief survey will be given. For more details the reader is referred to Hinloopen et al. (1983).

(a) Expected Value Method

The expected value method assumes ordinal information for both the impact matrix and the priorities (weights). The ordinal effects of all alternatives for a certain criterion j are ranked in descending rank order, while the preference scores or weights are conceived of as semi-probabilities which are also ranked in descending order of importance. Then, for each alternative i the ordinal impacts are multiplied with the corresponding ordinal preference scores or weights. The alternative with the highest total score will be selected as the best one, while also all other alternatives may be ranked according to their "expected values".

It should be noticed that this method is essentially a rather crude aggregation procedure based on non-permissible numerical operations on ordinal numbers.

(b) Lexicographic Method

The lexicographic method takes for granted a classification of the evaluation criteria according to a priori defined importance classes. In addition, for each criterion j the impact values of all alternatives are also classified according to their degree of performance into a priori defined performance classes. Next, the alternatives may be ranked via a lexicographic ordering by means of a combination of the importance and performance classes.

This method is a fairly simple and practical tool, although it should be added that the identification of ordinal (or qualitative) equivalence categories is sometimes arbitrary.

(c) Frequency Method

The frequency method is related to the lexicographic method and is also based on qualitative importance and performance classes. This method assigns the successive preference scores and criterion effects to a priori defined importance and performance classes, respectively. Next, one may construct compound importance-performance classes by means of a combinatorial analysis. Finally, one may count for each alternative the number of times that it falls into a compound class. Clearly, especially an alternative falling often into a compound class characterized by a high performance and a high preference, may be regarded as a promising candidate in the final rank order of alternatives.

This method is also fairly simple and does not use unpermissible numerical operations, although it may be sometimes somewhat difficult to infer unambiguous solutions.

(d) Ordinal Concordance Method

The ordinal concordance method is an ordinal variant of the quantitative concordance (or Electre) method. This method is based on a pairwise comparison of alternatives. Two kinds of indicators are calculated, viz. the concordance index (an aggregate preference score for those criteria in regard to which a certain alternative performs better than all other alternatives) and the discordance index (an aggregate discrepancy index for those judgement criteria in regard to which a certain alternative has worse outcomes than all other alternatives).

This method is a fairly popular tool, especially in the French evaluation literature, although it should be noticed that numerical problems may arise in the aggregation phase of ordinal scores during the pairwise comparisons.

(e) Permutation Method

The permutation method is also based on ordinal rankings of the information on the impacts and weights. The main emphasis of this method is on the extent to which each alternative i supports the hypothesis that this alternative dominates all others. The method is based on a permutation of rankings for all plans; it attempts to identify by means of a simultaneous analysis of weights and performances a certain ranking that is most probably in agreement with the above mentioned hypothesis.

This method uses a fairly complicated procedure, in which problems may emerge due to the large number of permutations, the less comprehensible statements about probable rank orders of alternatives, and the less clear interpretations of weights during the permutations.

(f) Metagame Method

The metagame analysis can be interpreted as a specific game-theoretic method designed for non-quantitative (usually, binary) information. This method is particularly relevant in the case of conflicting views among policy-makers or judges regarding the evaluation of alternatives. It is based on assigning zero-one values to particular options in order to indicate whether or not an option will be accepted by the policy-makers or judges. Next, a combination and comparison of various options of the policy-makers or judges may lead to the ultimate identification of a compromise solution that is acceptable for all parties involved and that is marked by stability conditions via a qualitative min-max criterion.

A limitation of metagame analysis is that it is usually only based on binary information, so that no complete rankings are taken into account. In addition, the various steps in the compromise procedure are not always unambiguous.

(g) Eigenvalue Method

The eigenvalue (or prioritization) method is based on a matrix of pairwise comparisons of alternatives, that is constructed such that the entries of this matrix reflect the dominance of

one alternative over another with respect to a specific comparison criterion. Next, this prioritization problem may be transformed into an eigenvalue problem by means of ratios or weights, so that a vector of relative cardinal weights of the alternatives being compared can be determined. This eigenvalue priority model is particularly suitable for deriving a cardinal judgement scale that may next be used in a qualitative multicriteria analysis.

The eigenvalue method is evidently not an evaluation method per se; usually a complementary analysis is necessary. A drawback of this method is its uncritical interpretation and transformation of qualitative weights.

(h) Multidimensional Scaling Method

Multidimensional scaling methods are particularly appropriate for coping with ordinal data problems. This method transforms ordinal data into metric (cardinal) data, such that the new cardinal configuration has a maximum agreement with regard to the initial ordinal rankings. This method can be used to transform both the ordinal impact matrix and the ordinal weight vector into cardinal units, so that finally a set of weighted outcomes of alternatives (in a cardinal sense) is obtained. These results may allow a ranking of alternatives according to their aggregate performance.

The multidimensional scaling method is a fully operational method that uses no unpermitted mathematical operations on ordinal numbers. A drawback, however, is its fairly complicated computational algorithm. In addition, under certain circumstances no unambiguous final conclusion can be drawn, as sometimes multiple rankings of alternatives are in agreement with the original ordinal data input.

(i) Regime Method

The regime method is a recently developed soft multicriteria technique. The method has originally been developed in the area of soft econometrics and categorical data analysis in order to take account of ordinal data in econometric models.

The essence of this approach is again a pairwise comparison of all alternatives for each criterion j . By assigning binary numbers to the results of this pairwise comparison (depending on whether a certain outcome is higher or lower than any other outcome), a long-stretched binary matrix of so-called regimes is obtained. The same may also be done for the elements of the weight vector. By combining the information from both the regimes and the ordinal weights via a successive permutation procedure, the dominance of plans (i.e., the most likely ranking of alternatives) may be inferred.

This method is very recent, and has only been tested in a few case studies, but it is a simple and comprehensible technique with many perspectives.

The provisional conclusion from this section is that information systems yielding only qualitative (ordinal or binary) data are still meaningful, as many methods do exist that are able to take account of qualitative information.

4. PLANNING CONTROL AND EARLY WARNING SYSTEMS

It is increasingly being recognized that information systems are a part of the planning process. One of the main difficulties is the fact that the planning process and the technology (computer hardware, etc.) that supports it are evolving in a rapid and interdependent way. Therefore, it is unwise to design an information system exclusively for a given existing planning process; the planning process should also be oriented toward the new technology on which the information system is based.

Clearly, a major problem is how to design an information system. Rosove (1967) distinguishes between major design alternatives:

- design the system in one step;
- design the system step-by-step, with each next step more sophisticated than the previous one.

He also distinguishes between two different approaches:

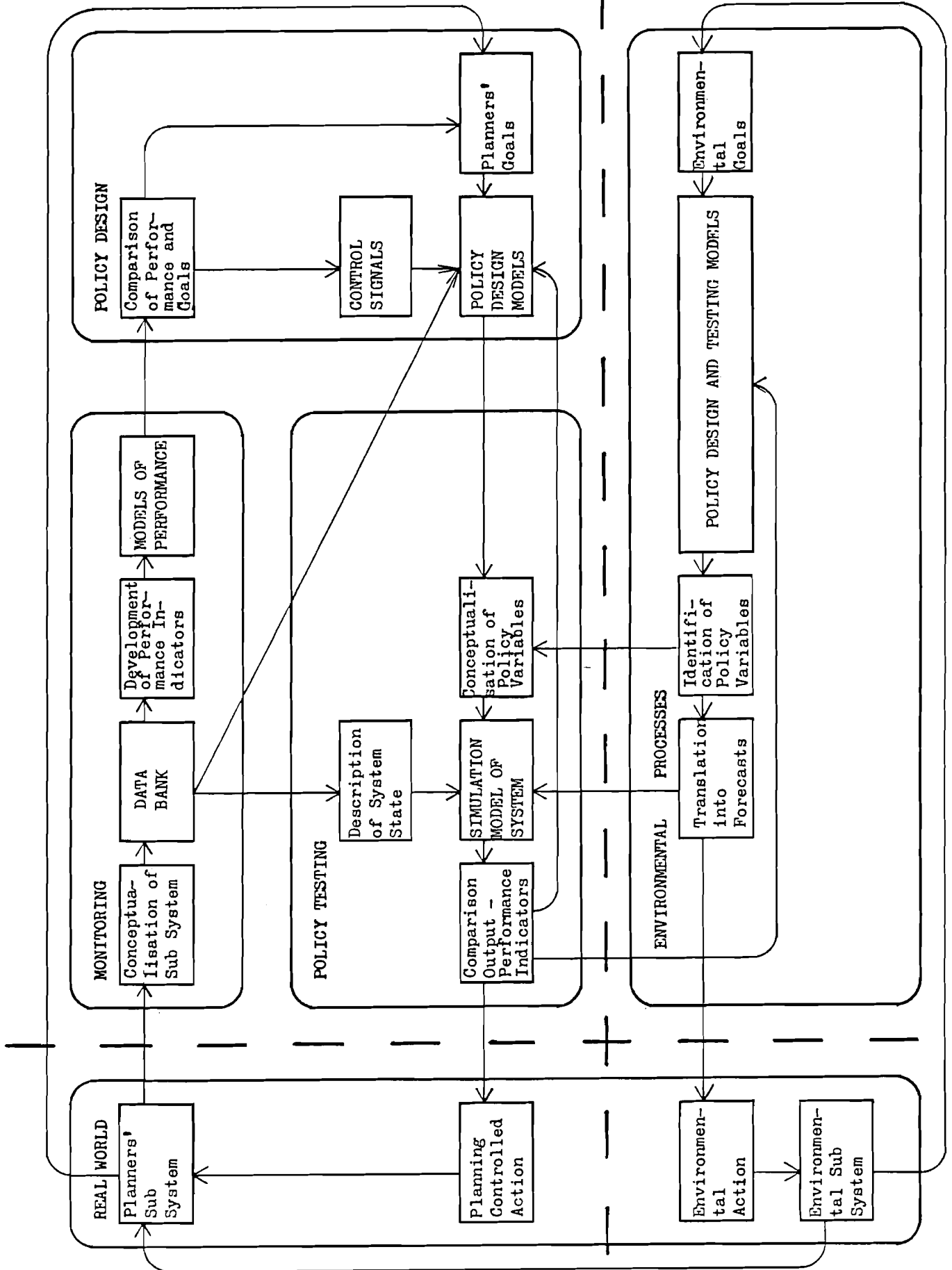
- the inductive approach. This means that the technology of the existing information system is updated without changing the information system;
- the deductive approach. This means a complete redesign of the planning process, based on its goals and opportunities for their achievements. In the latter context the new information system should be developed.

If the information system is to be designed for a stable, simple and closed system, then the one step inductive approach would be sufficient. Since "urban systems are notoriously dynamic, complex and open, their aims and objectives are difficult to identify, they are difficult to analyse and their performance is difficult to evaluate and they are managed by many people whose attitudes sometimes seem regressive in a time when change is inevitable" (Wiley, 1972, pp 15), the iterative deductive approach is more appropriate.

Rosove (1967) also suggests an iterative approach; the planning process should go through several stages, each stage more sophisticated than the previous one. The first stage should be an experimental model or prototype of the planning process to be designed. This approach needs a description of the planning process served by the information system. The planning process operates in a structure that can be considered to be a network of arrows and nodes; the arrows represent the information channels and the nodes represent the decision points. Figure 5 gives an example of such a planning process. The monitoring function, the policy design function and the policy testing function form the *planning control process*.

This planning control process has, among several other difficulties, to deal with a great amount and variety of uncertainties (cf. also section 1): uncertainties about society's values, uncertainties about the effect of related decisions or uncertainties about the environment and its future (Friend et al 1970). To reduce these uncertainties one can use a so-called Early Warning System (see Dickey and Watts, 1978).

Figure 5. A model of a planning system (Willis, 1972, pp 17).



Four (or five) phases of an Early Warning System can be distinguished (cf Dickey and Watts, 1970):

1. Development of conceptual relationships
2. Collection of data
3. Screening and evaluation of the data
4. Establishing of thresholds
- (5. Checks on the fulfillment of short-term projections or trends that are evolving.)

1. Conceptual relationships

The first step is to make a rough selection of the data to eliminate redundant information--Ackoff (1967) indicates the risks involved in an inefficient management caused by redundant information. The selection of data can be achieved by creating a conceptual model of the factors and interrelationships under study (cf. Dickey and Watts, 1978). If the major variables and their connections can be identified, the input data can be accepted or screened according to their relevance to one or more of these factors or interrelationships. This can be achieved by the following procedure:

- consider the main inputs for the relationships that have already been developed
- create a graph which visualizes the (qualitative) relationships between these variables,
- make a more detailed description of these relationships, for instance, by measuring them (if possible).

These conceptual relationships can help to reduce the uncertainties about the effect of related decisions and about the future effects of the decisions that are taken.

2. Collection of data

Dickey and Watts (1978) distinguish between three data sources that are relevant to an Early Warning System:

- discussion with experts in particular fields
- direct search of the literature
- use of information systems

-- Discussion with experts

At first a selection of experts is made, based on the field under study. They are consulted every two months and have to answer questions about the following subjects (Dickey, 1976):

- recent changes in the area of concern
- short-term trends
- long-term trends

They are also asked to give their opinion about the implications of possible future decisions. These views offer the possibility of reducing the uncertainty about the environment and about society's values (recent changes) and about the future effects of the decisions that are to be taken. The fact that every two months such consultations take place, gives the possibility of adapting the planning control process rapidly and effectively to the new situation.

-- Direct search of literature

This can be regarded as a method of discovering developments and trends in parts of the field under study which do not belong to the hot items of discussion.

-- Use of information systems

Dickey (1976) suggests reading relevant journals, trade magazines, newspapers, etc. He advises placing emphasis on:

- statistical information on past events
- short- and long-term forecasts and implications.

3. Screening and evaluation of data

The collected data should be listed at regular intervals under each functional classification. This listing is the basis on which redundant information is screened out. At this stage the data can be evaluated. The results of this evaluation can be used by determining the implications of the apparent trends and patterns. The result of this evaluation can be used to create short- and long-term projections in order to reduce the uncertainties about the effects of related decisions.

4. Establishing of thresholds

The aim of this phase is to find to which extent a change in a particular situation does not affect the attitude of people who are concerned with this situation, especially those people who are elected and appointed officials.

The threshold setting can be achieved in two ways:

- discussions with persons involved, like elected officials and experts in political science and government,
- confront the persons involved with an actual decision situation and ask these persons whether actions are required in the near future or not (this may also be based on a retrospective investigation of time series).

These steps represent altogether the Early Warning System. It is evident that several kinds of uncertainties can be treated by an Early Warning System, especially those uncertainties that contain dynamic aspects (Voogd and Hamerslag, 1981).

Early Warning Systems were originally developed for small-scale or business problems but evidently they do have a perspective for regional and urban planning as well, especially in the case of process decisions.

5. GEOCODING

5.1 Introduction

In regional and urban planning, an important attribute of any phenomenon is its location. The spatial configuration of phenomena and their attributes have implications for the way data can be retrieved geographically, and the way geographical relationships between phenomena can be explored and displayed. Such spatial aspects contribute to both the initial costs and the running costs of data management.

In general, the management of information systems is carried out by various agencies. These agencies operate on various institutional levels and in various sectors. Differences in orientation of different information systems (for instance, differences in classification and in spatial and temporal disaggregation of the information required by various data

management agencies) and lack of coordination between these agencies cause many costs and difficulties in comparing and combining the information. If a versatility (multiple use of data by others than its primary users) is pursued and if the system at hand is spatially oriented (dealing with any desired combination of data in relation to its spatial location), consideration must be given to the design of a system for geographically identifying relevant data that will satisfy most users.

5.2 Aspects of a Spatially Oriented Information System

In this subsection some specific attention will be given to geographical aspects of information systems, especially because the level of detail (or aggregation) is sometimes a major source of uncertainty.

Hermansen (1971) has formulated some criteria for a system of geographical data identification. Some of these criteria are:

- The system should be neutral with respect to particular real world situations
- The system should be flexible enough to permit both general and specialized subsystems of spatial units. It should allow transformations from one subsystem to another and the formation of new subsystems within the general system
- The system should contain possibilities for the hierarchical ordering of units, i.e. the formation of vertical subsystems.

The above mentioned criteria do not give precise guidelines for systems of geographical coding. Barraclough (1964) has distinguished two different systems of geographical data identification:

- "The name method". The name method attempts to classify elements localised in space and hence divides space into regions or areas that depend on the characteristics of the elements, for example: the response upon a questionnaire marked by the location of the respondent,
- "The location method". The location method establishes principles of spatial subdivision and next the spatial system is, according to those principles, provided

with geographical coordinates referring to any location within its boundary (see also geocoding).

An illustration may make the difference between the two methods more clear:

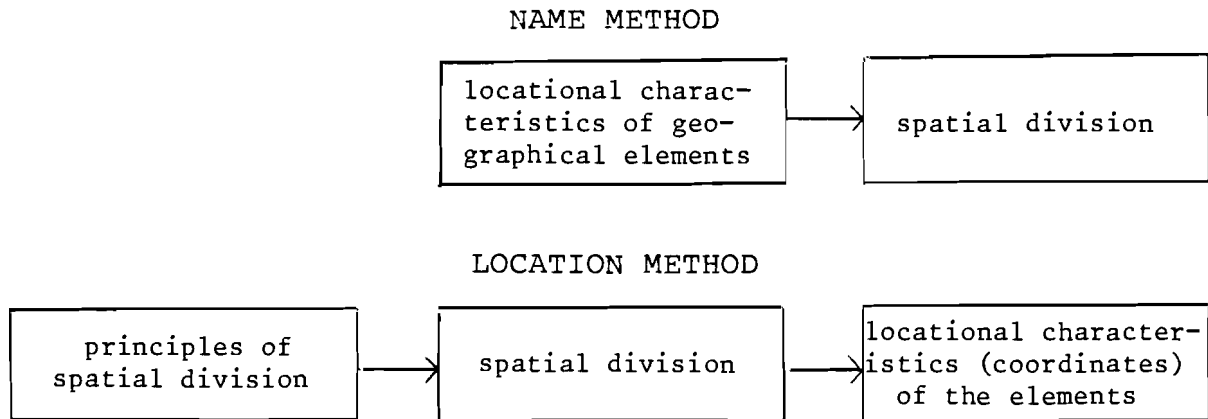


Figure 6. Two systems of geographical data identification.

If the name method is confronted with Hermanson's criteria, the following conclusions can be drawn (Willis, 1972):

- Name methods are unlikely to be spatially neutral, because by their nature the space is devised by particular users, who spatially organize the data for their own special function
- Name methods have very limited flexibility because their boundaries are determined in advance of any analysis. Transformation between one spatial subsystem and another can only be achieved with considerable effort and with a certain loss of information
- With the name method each alternative aggregation of spatial units--though possible on the basis of individual spatial units--would require a lot of strain. Spatial aggregations are possible but only with considerable effort.

In general, the location method is regarded as more appropriate. In this connection attention will be paid to a recently developed method, called geocoding. Geocoding means geographical data identification by means of the location method. The main goal of a spatially oriented information system like geocoding is to improve the organization of data and the display of information.

5.3 The Construction of a Spatially Oriented Information System According to the Location Method (Geocoding)

Various cartographic mapping techniques have been developed in recent years (see for instance, Tobler, 1979, and Steiner, 1980). Clearly, such mapping techniques have to deal with such questions as: the level of aggregation of objects in relation to planning and policy issues, the selection or elimination of data for a specific problem orientation, the required degree of homogeneity or heterogeneity of attributes of objects, the design of similarity measures and significance tests (a chi-square statistic, for example), etc. (cf. also Grimmeau, 1981, and Thelander, 1981).

In general objects can be characterized by means of three different main categories of spatial configuration:

- An object can be regarded as a *point location*, such as an individual building
- An object may have a spatial linkage structure, particularly a *network*, such as a road network. This network is made up by *segments* and *ties*.
- An object may have a two-dimensional representation, particularly a *polygon* (for instance, a park).

The geocoding system is fairly flexible, as it provides information on objects and attributes at any desired geographical scale within an area. Geocoding has been developed especially for detailed urban planning purposes, but it has no doubt a potential in a regional planning context.

The following example may illustrate the construction of a spatially oriented information system at a very detailed spatial scale (cf. van Est, 1981).

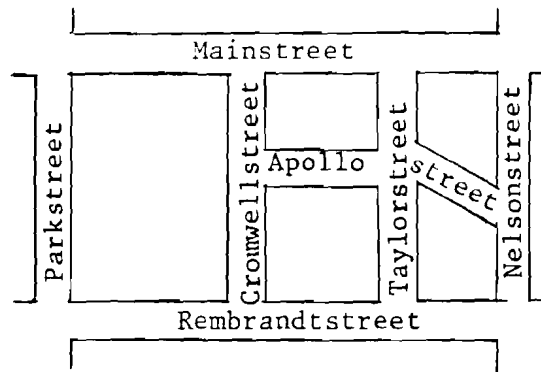


Figure 7. A spatial structure on a micro level of a part of a town. (cf Van Est et al, 1981, pp 7)

Suppose that only shops and dwellings are located in this part. Then this information can be displayed as follows:

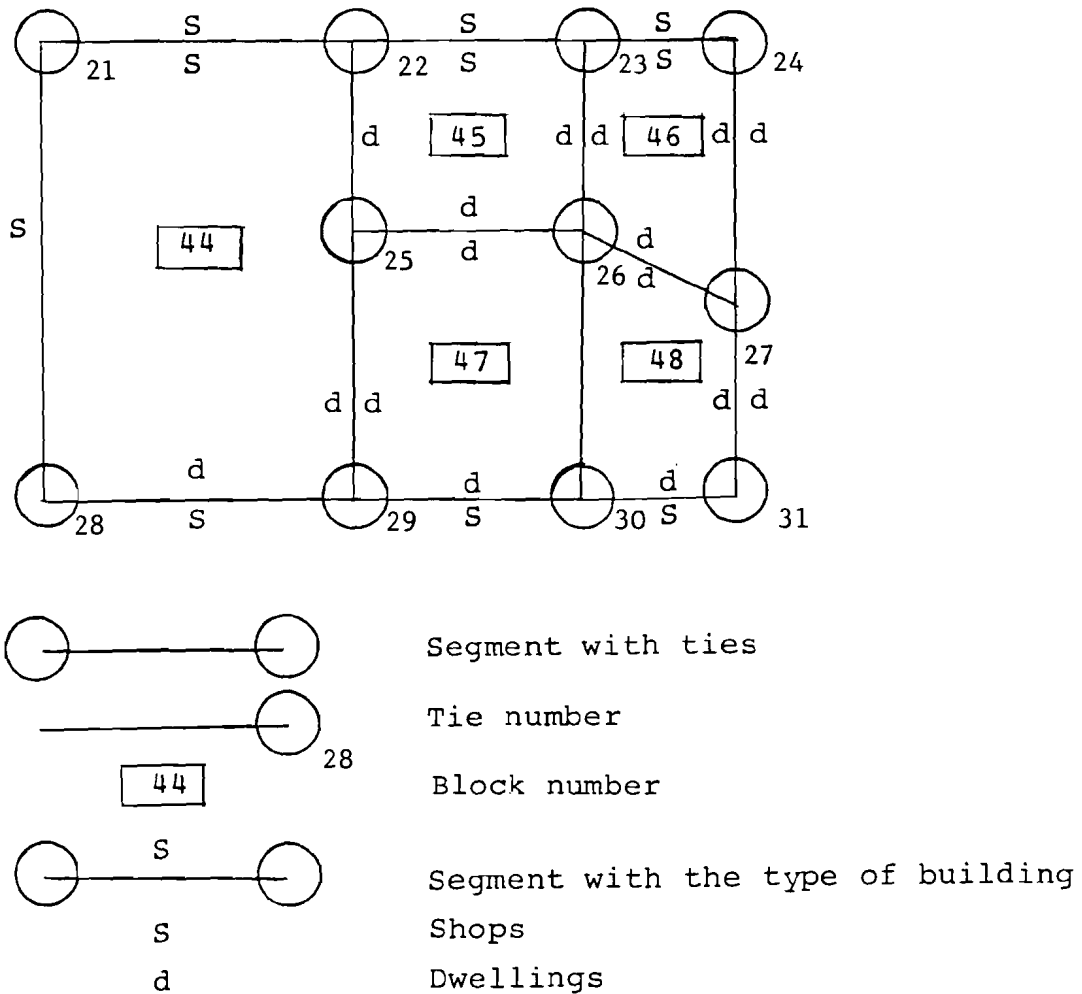


Figure 8. Display of a spatially oriented information system. (cf Van Est et al, 1981, pp 8)

Also other information can be attached to the segments. The segments are determined by their ties: This segment begins in A and ends in B. This also determines the left side and the right side of the segment. An example is given in Figure 8.

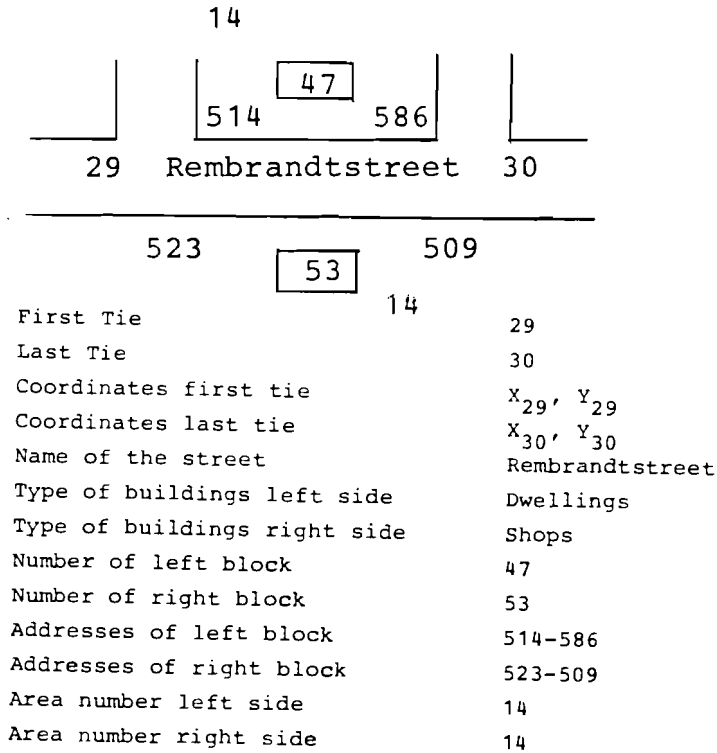


Figure 9. Display of a segment with its geographical attributes according to the "two-sided line-method".
(cf Van Est et al. 1981, pp 9)

The street is also an essential part of this method, because this constitutes the link between the indices and the spatial structure.

The construction of the network and the application of the geocoding principles gives us a detailed picture of a real geographical pattern. Such a picture contains four elements (van Est et al. 1981):

- *A cartographic structure.* The network with its coordinates form a cartographic structure. This is necessary to achieve a cartographic reproduction of the data and to process the data

- *A street structure.* The segments are provided with their corresponding street names
- *A relation structure* of the spatial units, like housing blocks or school districts linking objects to space
- *An infrastructure* which contains the relational and technical characteristics of the network.

The above-mentioned four structures and the network structure can be the basis for storing and processing data. It is essential that the data have a spatial dimension and that they can be located by a location indicator, a "geographic key" (cf. Van Est et al. 1981).

The network, the data and the geographic keys are the basis of a spatially oriented information system (see Figure 10).

The result of the geocoding process is that the boundaries of aggregate areas can be drawn *after* the data are collected and processed. The data can be retrieved by not just one set of boundaries, but by several.

Geocoding appears to be a fairly flexible way of dealing with detailed geographical data. It may be an accessible tool for an expert-user dialogue, while it may also be linked with computer cartographic approaches. Its major strength is its strong spatial orientation, though a weakness is its static nature: a structural change in the spatial configuration will have a drastic impact on the information content of geocoding.

Another specific example of the location method is given in the next two figures (Willis, 1972). Suppose that one of the segment characteristics is the number of inhabitants. Then an aggregation of the total number of inhabitants per square kilometre can be reproduced (each grid square is identified by the coordinates of one corner).

The distribution of inhabitants in the small rectangle in Figure 11 is given in the next figure (Figure 12), in which the reference points are located on a 100 x 100 metres grid.

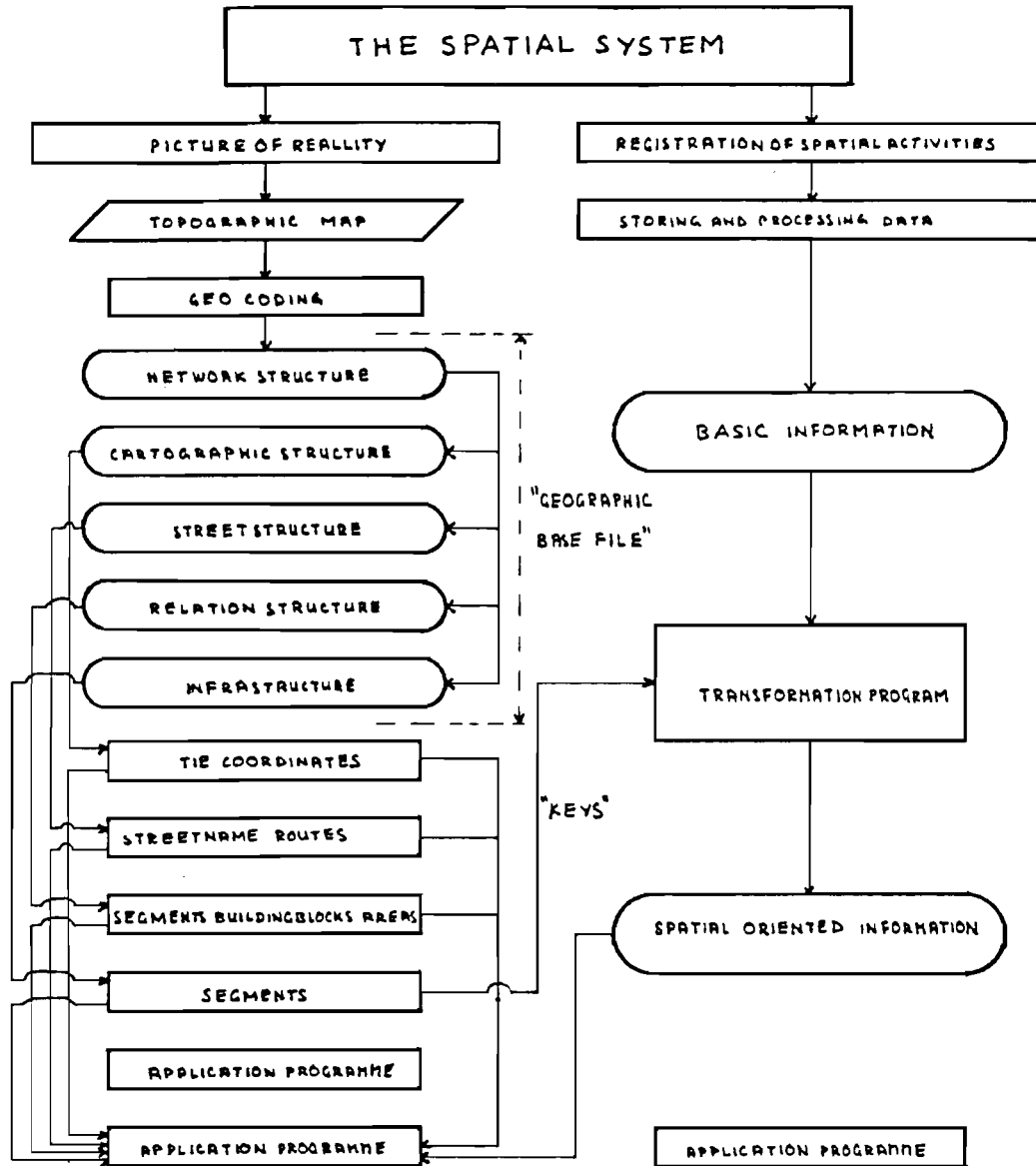
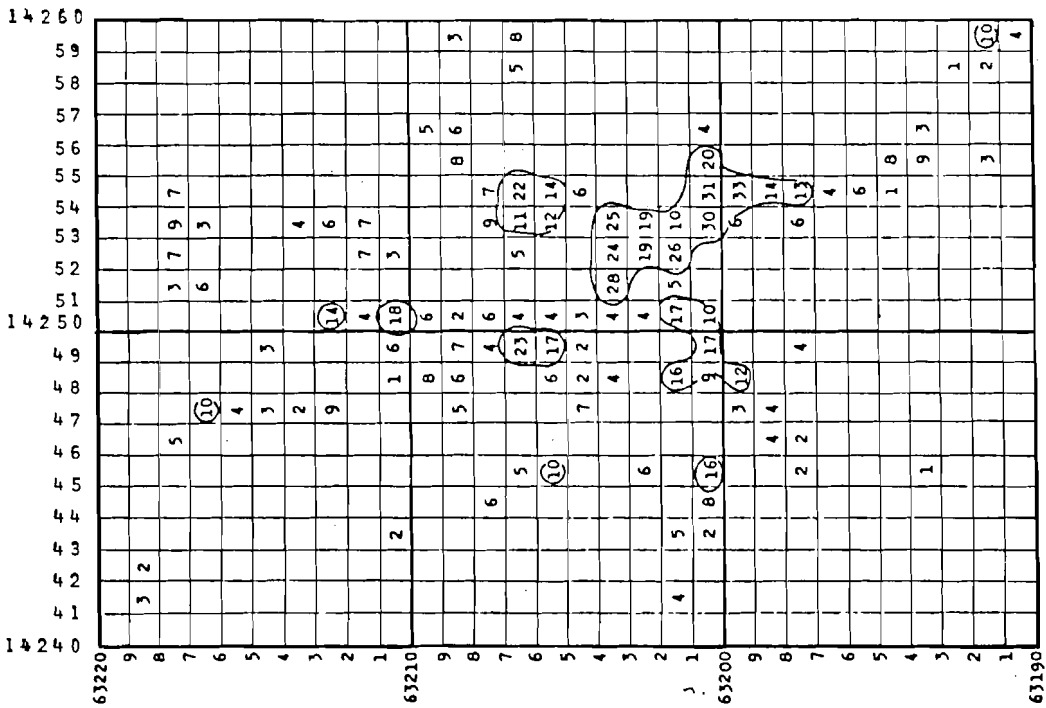
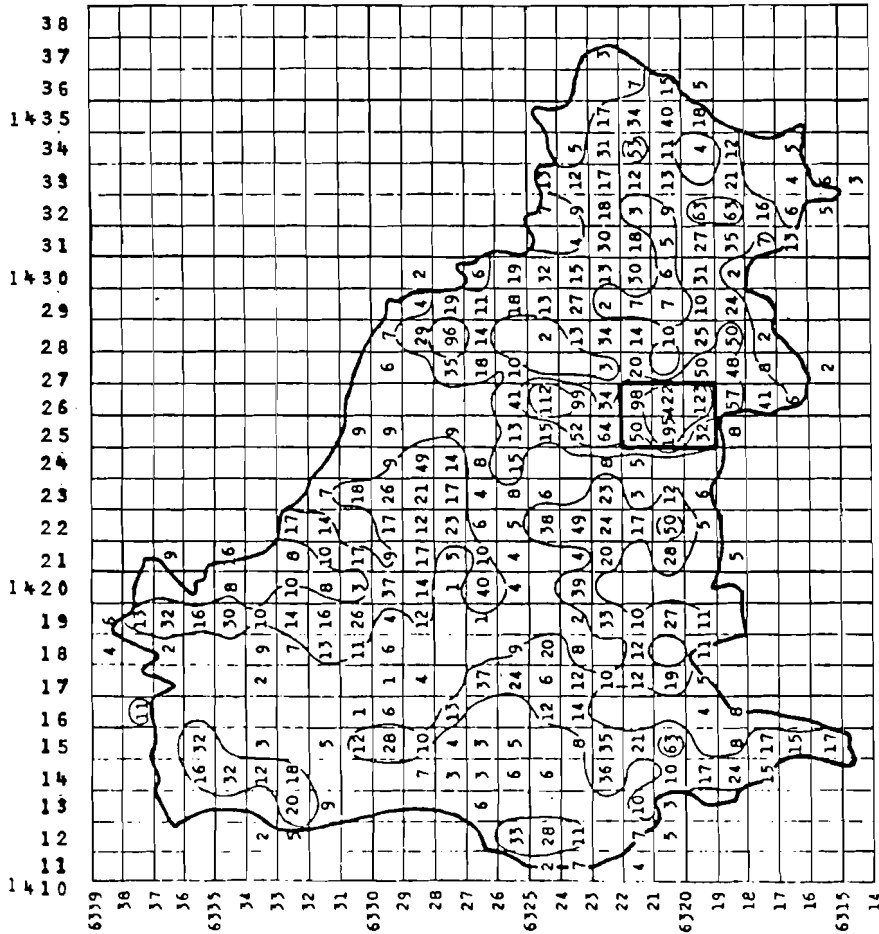


Figure 10. Spatially oriented information system.
(cf Van Est et al, 1981, pp 11)



Grid System for Urban Population
 Figure 12. Inhabitants per hecter in the village of Moheda 1940
 Source: Willis (1972), p.56.



Grid System for Urban Population
 Figure 11. Inhabitants per km² in Moheda according to the 1940 census. Isarithms as to 10, 50 and 100 inh./km².
 Source: Willis (1972), p.56.

6. CONCLUSIONS

Information systems aim at providing more and adequate insight into the complex nature of planning and policy problems. Structural uncertainty regarding future states of a complex system can never be removed, but a systematic analysis of (single and compound) images of an uncertain future may lead to a rationalization of choices regarding the future. Analogously, a systematic use of soft data and evaluation methods, of disaggregate monitoring and early warning systems, and of locationally-tied information systems may enhance the effectiveness and successfulness of regional planning efforts.

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