

THRESHOLD ANALYSIS:

Theoretical Background, Evaluation and Development

by

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ABSTRACT

ACKNOWLEDGMENTS

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## ABSTRACT

The main subject of this research thesis concerns in general the interrelations between rationalisation and quantification in the urban planning approach, exposed mainly by critical evaluation and development of one particular quantitative method known as threshold analysis.

Part 1 of the thesis explains the theoretical background of this analysis developed on the basis of threshold theory. Threshold theory, developed in Poland by B. Malisz in 1963, states from observation that towns encounter physical limitations to their expansion which have been called DEVELOPMENT THRESHOLDS. They are not irremediable but can be overcome only at 'additional' cost, i.e. at THRESHOLD COSTS which must either be spent before the land is opened up for development, or which have to be spread over the period of time. Threshold analysis in turn allows (i) the identification of thresholds as lines on maps and/or as points on development curves, and (ii) the calculation of costs necessary for their overstepping. It therefore creates a framework for comparison of the 'effectiveness' of development variants and points out where and how thresholds could be met so that saving of inputs for expansion can be maximised. The scope of application of threshold analysis ranges from analysing and comparing urban development possibilities of a single town to its indirect use in regional planning by providing important parameters deriving from threshold analysis of all towns within the region concerned. The recently discovered possibility of direct application of the threshold concept to regional analyses by analysing 'thresholds' in exploitation or expansion of regional resources upon which any development of economic activities depends is also discussed and presented in more detail.

Part 2 of the thesis concentrates on evaluation of threshold analysis in urban planning by presenting and assessing results achieved in its application in Poland and by testing the method in the two Scottish sub-regional plans, for Grangemouth/Falkirk and the Central Borders. Similar investigations follow in the field of direct application of threshold analysis to regional analyses. This approach was tested first by B. Malisz in Yugoslavia and then within the Planning Research Unit, Edinburgh University, in the study dealing with angling potential in Ireland. Part 2 results in a comprehensive and critical assessment of the validity of threshold analysis with all its advantages and disadvantages clearly exposed. This finally leads to outlining the implications for further research necessary if the latent potential of threshold analysis is to be fully exploited in planning practice.

Part 3 of the thesis, following the criticism of existing forms of threshold analysis, attempts to take the previously indicated guidelines in order to improve and refine the whole threshold approach. Firstly, steps are taken to remove a great deal of confusion about the nature of thresholds, by developing definitions which in a 'neutral' mathematical way describe

basic notions of threshold analysis, and by offering a framework for classifying thresholds in an unequivocal way. Secondly, the simple form of threshold analysis is developed into a comprehensive 'model' process allowing for the introduction into the course of the analysis of all factors (such as the impact of frozen assets, exploitation costs, etc.) so far missing, while maintaining its basic simplicity to warrant its applicability in everyday planning practice. Thirdly, the contribution of threshold analysis is considered within the context of the overall planning process, the model of which is proposed both in a simplified and an expanded version. The role of threshold analysis in its framework is then discussed with particular emphasis attached to the concept of integrating it with other complementary techniques (Optimisation Method, Planning Balance Sheet, and Goals-Achievement Matrix) which may greatly help in general rationalisation of the urban planning approach.

The conclusions from the research are thus greatly inherent in Part 3, but the major points deriving are summarised at the end, culminating in the final statement that threshold analysis is not a complete theory of planning. It embodies only some parameters for the development of urban strategy and it does not measure the benefits of alternative urban forms. It does indicate, however, the cost of these forms and helps to identify the factors causing variations in these costs. In general it does not replace other judgments but puts them on a more objective foundation.

## ACKNOWLEDGMENTS

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The initiation and development of this work could not, however, have taken place without the presence and wholehearted support of Richard T. Bigwood, Director of the Planning Research Unit, where he has succeeded in creating a unique atmosphere for research. His understanding and patient forbearance in all the ups and downs occurring during the period of work, and readiness to offer his advice and wisdom whenever necessary, were of enormous help.

It is also difficult to imagine that there would have been any significant progress in this research without continuous and exceptionally friendly stimulus from Professor Boleslaw Malisz of the Academy of Science, Warsaw, who, although so far away, was always ready to assist with his unique professional knowledge and experience in overcoming the numerous 'thresholds' encountered during the whole period of work.

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It must also be acknowledged that the work connected with the practical application of threshold analysis in Scotland benefitted greatly from the willing efforts of the whole Planning Research Unit team; particular contributions were made by Serge Domicelj, James Hope, Gillian Penrose, Jean Marshall and Ivor Samuels. More recently, the interest, sympathy and fresh ideas of Nikolaos Famelis, Rosalind Brown and Salamah Subiotto were of great help during the final stages of the research.

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# INTRODUCTION

## Background

The first paragraph discusses the general context of the study, mentioning the importance of understanding the underlying mechanisms of the process being investigated. It highlights the need for a comprehensive approach that considers both theoretical and practical aspects.

The second paragraph provides a brief overview of the research objectives and the scope of the study. It outlines the key questions that the research aims to address and the methods that will be employed to achieve these goals.

## INTRODUCTION

The third paragraph delves into the specific details of the research methodology. It describes the experimental design, the data collection procedures, and the statistical analysis techniques used to interpret the results. It also discusses the limitations of the study and the potential for future research.

The final paragraph summarizes the main findings of the study and discusses their implications. It highlights the key contributions of the research and provides a conclusion that ties back to the initial objectives and the broader context of the field.

## INTRODUCTION

### Research Objectives

Before discussing some of the basic ideas providing a general platform for this research it seems necessary to present its primary objectives. Thus its main aim in the most general terms is to find out to what degree a selfcontained and particular quantitative planning method can influence an urban planning approach.

It is maintained that in fact any quantitative method, apart from refining specific aspects of the designing process within the field of its direct applicability can and should make a wider, often significant, contribution towards the rationalisation of the overall planning process and decision making. Certainly this statement may only hold true for methods based generally on scientifically sound and logical assumptions but do not necessarily require that the methods be free from various shortcomings and discrepancies; these latter can always be removed from such methods through critical discussions, research and practical testing. It is intended to prove it in this research by an example of a specific method selected for this purpose.

The basic principle to be kept in mind is that any method should always be analysed and developed in the wider context of a full cycle of the planning process and planning machinery structure. Only then both potential and limitations of a particular method can be clearly seen, its misuse prevented and misunderstandings avoided.

These objectives will be looked upon through the analysis of the role and potential contribution of the quantitative method originated in Poland by B. Malisz in 1963 and known as threshold theory and analysis. It is hoped that in addition to providing supporting evidence for the main hypotheses just formulated, comprehensive analyses will also allow for modifications and development of the method itself, providing a refined framework for its practical application, thus extending knowledge in the field of applied planning methodology.

Threshold theory and analysis has been selected as the subject because it is a relatively new method introduced to this country in 1965 by the author and because it can be seen to be correct in principle and founded on logical assumptions. Its theoretical 'spine' remained unaffected by numerous discussions and criticisms (often quite violent) concerning the whole threshold approach, which took place mostly in Poland where the method has been widely introduced into practice, and also in Britain immediately after its first application in the Grangemouth/Falkirk study.

In spite of its shortcomings threshold analysis was later seen, in the words of Professor J.N. Wolfe in his Introduction to the Central Borders study, as "rapidly gaining favour in physical planning circles". The analysis, although often highly appreciated, was also found to have various deficiencies, but this only seems to support its selection as a suitable 'guinea pig' for the purpose of this research, which is subdivided into three main parts dealing with the theoretical background, evaluation, and development of threshold analysis respectively.

Theoretical Background aims to build a research platform by discussing basic aspects of rationalisation and quantification in planning, introducing original formulations of threshold theory and finally by indicating the scope of threshold analysis as a working method of applying threshold concepts to the planning practice. This part thus endeavours primarily to provide supporting evidence for the statement that the method "can be seen as correct in principles and founded on logical assumptions".

Evaluation deals primarily with selected practical cases in which threshold analysis was applied - some of these were initiated and tested by the author in the Planning Research Unit, others represent its application in Poland and in Yugoslavia. From a careful scrutiny of all these cases a comprehensive critical assessment of the validity of threshold analysis is then formulated and followed up by conclusions indicating the directions of further research necessary to remove the main shortcomings of the method and pointing to the ways through which its potential contribution to the overall planning approach can best be exploited.

Development takes up these implications and attempts to increase the viability of threshold analysis by refining its theoretical formulations, expanding its analytical proceedings, and finally indicating how the wider influence of the analysis upon the overall planning process can be more fully effected. Conclusions emerging from successive chapters and sections of this part clearly indicate not only that most of the major deficiencies of threshold analysis can be removed, but also that its expanded and refined form can make a significant contribution towards rationalisation of the urban planning approach and decision making, thus confirming the basic hypotheses of this research.

General conclusions then follow, which summarise the overall results and explicitly set out the main characteristics of threshold analysis as seen in the light of all research findings and evaluations.

**Part One**

**THEORETICAL BACKGROUND**

## 1. RATIONALISATION IN URBAN PLANNING

Basic notions - rationalisation of planning structure -  
rationalisation of planning process - conclusions - research  
objectives

The main object of this research concerns the interrelations between rationalisation and quantification in the urban planning approach exposed by detailed analysis, critical evaluation and development of a quantitative method known as THRESHOLD ANALYSIS. As a starting point to the research itself, basic notions are discussed and the meanings of Plan, Planning Process and Rationalisation clarified. It is also argued that rationalisation of Urban Planning calls primarily for rationalisation of the structure in which the whole planning machinery should be organised and of the process in which planning decisions are taken. Discussing planning structure, interrelations between a development programme and the location of its components in physical space on all main planning levels are pointed out and the concept of an Integrated Planning System is presented. Analysis of the planning process indicates the need to minimise means while maximising effects and accordingly to reveal the applicability of quantification.

## RATIONALISATION IN URBAN PLANNING

### Basic Notions

The main object of this research study concerns the interrelations between RATIONALISATION and QUANTIFICATION in the urban planning process, exposed by detailed analysis, critical evaluation and development of the quantitative method commonly known as THRESHOLD ANALYSIS.

Following synthesis of the theme it seems necessary to clarify what will here be understood by a PLAN and consequently a PLANNING PROCESS; which general CONDITIONS ought to be fulfilled by any planning solution; and what is the meaning of RATIONALISATION in the context of planning methodology. Further, general links between rationalisation and QUANTITATIVE METHODS will be examined and conclusions sought so that a general platform with recommendations for follow-up research may be established.

A PLAN may be said to represent a data bank for a 'client'. It should define the course of action to be taken in order to achieve some future image of the settlement or settlement system under study. This image should, in an optimised way, guarantee the fulfilment of presupposed goals concerning the future of an urban community within its environment - compatibility being essential between these two since only by achieving this can the best possible conditions for the life of men be created and further developed. It can also be seen that any Plan must have two major facets:

(a) "Image"-Plan, revealing how an analysed system should look by the target date, and indicating further possibilities for its expansion.

(b) "Action"-Plan, pointing out how the implementation process and development strategies should be steered to approach as closely as possible to the recommended image.<sup>(1)</sup>

Urban physical planning can be defined as an art dealing with the organisation of space for living in the built environment and as a science evolving the most rational methods to achieve this.

Consequently, the urban physical planning process (or simply the planning process ) would determine the course of action in urban planning, leading towards the construction of a plan.

Any plan should comply with two basic conditions, irrelevant to its specific goals. These conditions would be met if the answers to the following essential questions were in the affirmative:

(1) Does the Plan ascertain that the proposed urban system would function properly and does it provide optimum opportunities for the cultural, social and economic evolution of the whole community?

(2) Are the recommendations of the Plan realistic, i.e. are they in full accordance with the natural and economic potential of the analysed community within its administrative, social and political structure?<sup>(2)</sup>

Rationalisation lies at the foundations of modern planning thinking, although as a broad term it can be explained in various ways. Most generally, to rationalise means "to bring into conformity with reason" or "to reform by eliminating waste in labour, time, materials ..."<sup>(3)</sup> In the field of planning, as Reiner and Davidoff<sup>(4)</sup> put it, "rationality is sometimes conceived of as (a) referring to increasing reasonableness of decision and sometimes as (b) involving full knowledge of the system in question ... the latter concept of rationality (b) is far more demanding of planning, for it requires identification of the best of all alternatives evaluated with reference to all ends at stake. The alternative thus selected as optimal implies, and is implied by, an efficient course of action". Hill<sup>(5)</sup> follows the same lines, but is more specific when he states that "rational planning is defined as a process for determining appropriate future action by utilising scarce resources in such a way as to maximise the expected attainment of a set of given ends".

J. Kozlowski and J. T. Hughes<sup>(6)</sup> maintain that "to an economist 'rational' means 'consistent with the end of planning' and in economics the end or ultimate aim of all planning is the best allocation of resources, while to a planner a 'rational' decision means one reached in an objective and calculated, non-intuitive way, by using the most efficient methods. To both the essence of 'rationality' lies in the objective comparison of various development hypotheses for a single town, for a region or for various directions of broader urban policy on a national level".

It seems important to note that rationalisation calls for the division of the whole planning process into sequential parts so that each conclusion logically leads to the next and this latter, of course, can always be checked for validity on the basis of previous premises. Urban

physical planning is already becoming significantly influenced by the evolution of new methods of approach for achieving in a more rational way those objectives which in the 'fifties and early 'sixties were often achieved by intuition or subjective analysis. It would be unreasonable, however, to assume that an 'absolute' objective methodology like the Philosophers' Stone will be developed to solve all physical planning problems in their entire complexity. It would therefore be wiser to approach the rationalisation of the urban planning process by trying constantly to reduce, rather than to eliminate, intuitive and subjective decisions.

It should be pointed out that purely intuitive planning may bring outstanding results in specific cases, particularly when a great 'creator' is involved - such men, however, are uncommon, and any form of planning organised on a national scale and involving numerous planning teams is bound to result in a heavy waste of capital and resources if its approach is based solely on intuitive and subjective evaluations.

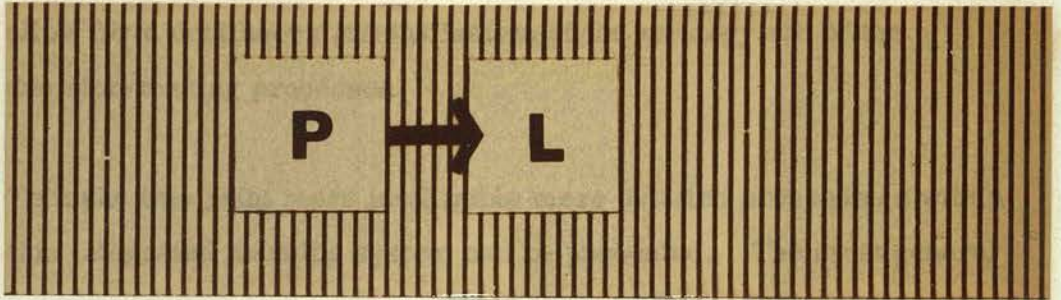
In considering how far urban planning can be rationalised two separate but interrelated forms in which planning can be seen must be analysed, namely the STRUCTURE in which the whole planning machinery should be organised and the PROCESS in which planning decisions are taken.

#### Rationalisation of Planning Structure

The very essence of planning is generally in the formulation of the Development Programme<sup>(7)</sup> (later called simply 'Programme') and in the location of its components in some area - a country, region, town or village. Planners and authorities would certainly like to find the

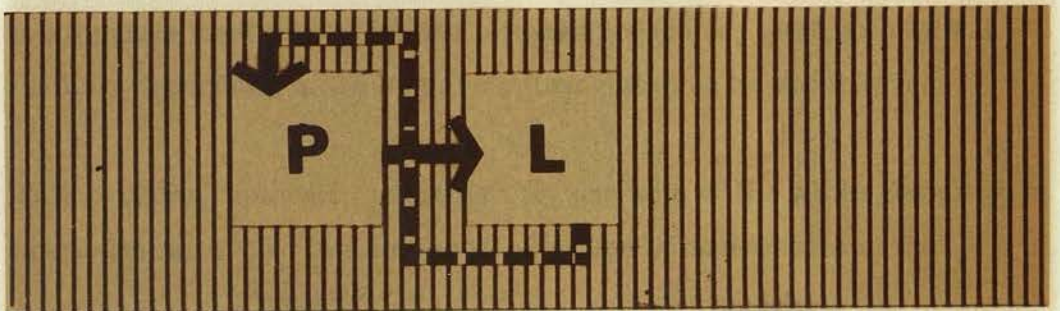
relatively best or optimum solution of this problem; it is, however, only possible to do this in cases where mutual interrelationships between programme setting and locational analyses are taken into account.

Diagram 1



In terms of the more traditional approach, there was only a one-way relationship between the Programme and the location (see Diagram 1). Planners were given the task of allocating environmental components specified in the Programme, but were not expected to comment or to call for any alterations; nothing could be more false than this approach, since any rational planning must be based on two-way processes with feedback from locational analyses to Programme setting (see Diagram 2).

Diagram 2



The feedback must, however, operate also between various planning levels as one can never achieve any optimum solution for, say, a region by producing optimum solutions for all the towns involved and simply adding them together. Sound planning structure must be based on a comprehensive approach on all levels, i.e. on a national, regional and local level, which can be called an 'integrated system', and if properly organised should lead to continually improving solutions and allow for a continuous rationalisation of the strategy and of the decision-making processes.

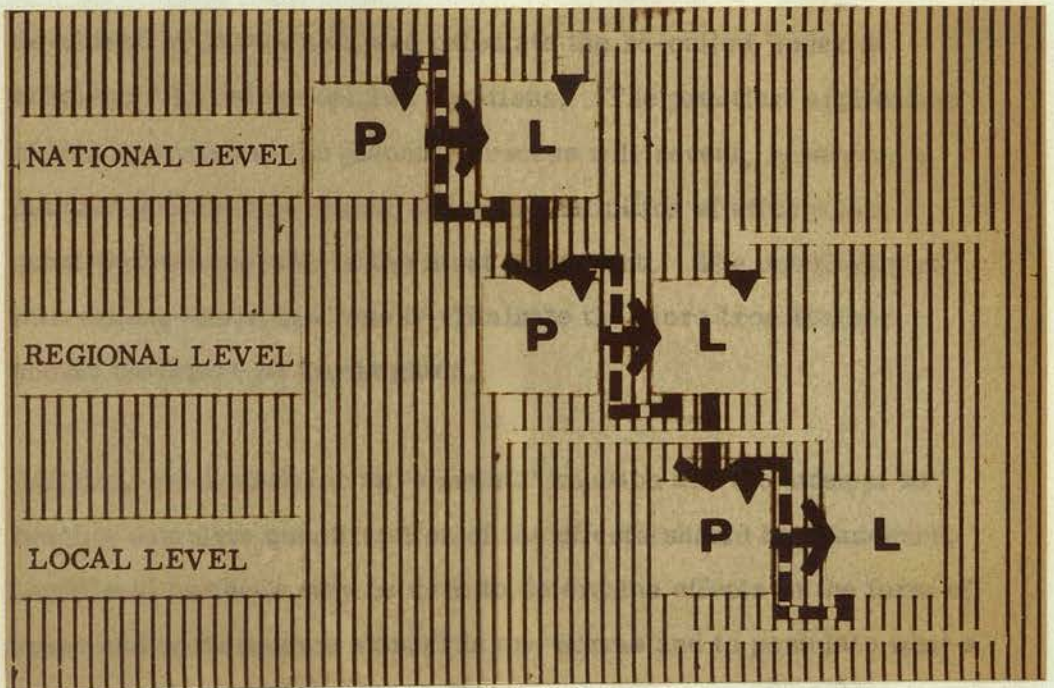
To make this point more intelligible more detailed proceedings within this integrated planning system can be presented. The most general guidelines are bound to emerge on a national level. The Programme should be formulated for a given time period and will consist, again in the most general terms, of forecasts concerning the expected population growth and the estimated increase in the national income as a whole. The location of the components of this Programme, i.e. of the population increase and of the main productive forces, must then be determined. It may clearly be seen that this location on the national level would provide a starting point for the formulation of Programmes for all regions, where the location of their components would follow as a result of physical planning analyses, to provide a basis for setting Programmes for all the towns and the location of their components on an appropriate local level. In the process presented, each step is thus directly dependent on the decisions formulated on an upper level.

This process, however, presents only one side of the whole complicated operation involved: in practice the location of components of the Programme in a concrete situation is bound to necessitate its verification if the relatively best and most efficient solution is to be rationally achieved. This feedback between the Programme and its

location is of critical importance in any attempts towards the rationalisation of ways in which planning machinery operates, as it points to the obvious necessity of setting in motion a feedback process between various planning levels so that any change of the Programme on a lower level implies the need for changing location on an upper level. The parameters necessary for the proper functioning of the feedback machinery within the whole integrated planning system can be obtained only through quantitative methods, so their potential contribution in this field seems self-evident.

This continuous communication between both Programmes and locations and between various planning levels is thus the inmost nature of the integrated planning system and the main warrant of its appropriate and fully rationalised functioning. A graphic representation of the concept is shown in Diagram 3.<sup>(8)</sup>

Diagram 3



Rationalisation of the Planning Process

Physical planners, by allocating environmental components in space, can influence the means (basically costs). There is therefore an important task to evolve a planning methodology which guides the allocation of these components in such a way that all functional and social requirements will be safeguarded, whilst at the same time minimising all the means involved, and ensuring that 'boundary conditions' determined by various constraints (and indicating development possibilities) have been respected. Two major variants may then arise:

- (a) when there are defined effects to be achieved, and the problem is to minimise the means;
- (b) when the means are given, and the problem is to maximise effects.

It may be tempting to deal with these variants by using methods developed by economists and calculate the so-called 'index of efficiency' by using complex equations. The practical application of this approach to the planning process will reveal, however, a number of problems among which the definition of effects in a quantitative form will be the most prominent. The possibility of introducing simplifications to eliminate the more troublesome should therefore be investigated.

Initially, the search for an 'absolute' solution and the attempt to reach a complete quantification of the effects should be abandoned; traditional methods may be used to determine effects in the form of space and performance standards and norms and to postulate what a planning solution must provide in order to create an acceptable

environment for all human needs, so that 'boundary limitations' for the planning exercise can be created. Having established the goals the problem remains of how to safeguard them satisfactorily whilst minimising the means, which can more easily be quantified. The solution, in general terms, is to define for each urban function those areas of land which have a combination of the lowest costs with the highest aggregate of positive characteristics for the particular function, including all mutual interactions among them, and to select (through the design process) from the numerous combinations involved, the one which fulfils the goals in the relatively best or optimised way.

It may be argued that this is what the physical planners have always done, but studying the usual methods applied, several doubts arise: surveys and analyses are usually carried out separately for each planning aspect and although there is a tendency to synthesise the results, a mechanical integration of widely differing aspects always leaves a substantial margin for interpretation, and comprehensive planning implications are bound to be formulated with varying degrees of subjectivity.

The only way to prepare these results for objective comparison and synthesis would be by quantifying as many aspects as possible during the whole course of analytical proceedings, instead of a number of hypotheses or models produced in the final stages of the planning process, disregarding the way in which these hypotheses have been formulated, because if this occurs there may be possibilities which fulfilled the aims at least as well as the others and offered additional benefits such as, for example, lower development costs, which have been overlooked.

It is therefore of prime importance continually to increase the degree of objectivity, to introduce quantification at the very beginning of the planning exercise, and to proceed with it consequentially throughout the successive stages of the planning process. Only then can the principle of rationalisation be realised, which rules that during the planning process not only a few intuitive (or semi-intuitive) solutions, but all those logically possible, together with their consequences, should be considered.<sup>(9)</sup> The significance of quantification for necessary comparison and rational selection for the final choice can never be overestimated.

### Conclusion

By summarising all these brief remarks it is possible to suggest a general conclusion that at the very foundations of the rationalisation of urban planning lies the need to:

- (a) develop logical frameworks or models for both the structure of planning machinery with all its hierarchical and mutual interrelations and of the planning process, allowing its logical and scientifically sound organisation.
- (b) introduce into these models a quantification, or quantitative methods, as the main safeguard and control device leading towards the consequent reduction of the degree of subjectivity and allowing for the verification of any parts of the planning process involved.

In practical terms properly established multi-disciplinary co-operation in urban planning seems to be of prime importance in the latter case.

In the follow-up research threshold analysis will always be considered in the light of its possible contribution both towards the structure of planning machinery and towards the planning process itself.

Primarily, however, provision must be made to remove all major deficiencies and shortcomings of the method so that it can be accepted as a reliable tool and safely recommended for practical use by planners in the field.

## 2. THRESHOLD THEORY AND ITS ROLE IN URBAN PLANNING

### (a) Original Formulations

Generators - urban growth and topographical limitations - urban growth and technological limitations - urban growth and structural limitations - concept of threshold and threshold cost

B. Malisz's Threshold Theory was generated by the need to develop effective co-operation between physical planners and economists; to help in the 'dialogue' between various planning levels and to refine long-term planning methodology. It was derived from the observation that towns encounter physical limitations to their development due to topography, land uses and technology of infrastructure. These limitations, called development THRESHOLDS, are not irremediable and can be overcome but only at 'additional' development costs, or THRESHOLD COSTS. Thresholds therefore impose a marked effect on the continuity and strategy of urban development.

### (b) Implications for Planning Practice

The Method of threshold analysis - implications from threshold analysis

Threshold analysis indicates a step by step process aiming towards the definition of thresholds and evaluation of cost necessary for their overstepping. This allows the identification of urban growth possibilities at an early stage in the planning process and by indicating the varying costs of those possibilities provides a basis for further design.

### (c) Scope for Application

Long term planning - growth possibilities of a single town - analysis of decentralised patterns - 'indirect' application to regional planning

Threshold analysis helps decision making by indicating how and when thresholds can be overcome most efficiently. It can contribute particularly in long term planning methodology, in analysing growth possibilities of a single town, in detecting when the urban development should be changing from compact to decentralised patterns and indirectly in regional analyses leading towards the optimisation of population distribution.

(a) ORIGINAL FORMULATIONS

Generators

Physical planning represents a particular type of activity, which has strong economic implications, which means that if it is realistically to influence and steer urbanisation processes, physical planning must aim at establishing proper links and a common platform for discussion with economists.

The need for these relations between physical and economic planners became particularly essential in Poland in the early 'fifties when economic planning was fully dominating the planning field and physical planners were lagging behind in their traditional approach to the complex problems of the erupting urbanisation and economic development of the country. Their opinions and proposals thus used to be treated by the authorities almost as artists' impressions; interesting and beautifully presented, but unrealistic pictures on paper. Since the possibility that economists would help in the recognition of the place of physical planning in overall development policies seemed rather remote, physical planners had to change their traditional way of thinking to prove the relevance of the physical planning approach for the country's development and economy.

After a few interesting but too theoretical attempts the main breakthrough can be dated from the period when B. Malisz began to concentrate his research activities on the important field of town planning economics. His writings<sup>(1)</sup> representing the pioneering contribution were followed up by other authors<sup>(2)</sup> and opened new horizons for planning research which in the course of the subsequent years changed the conservative

image of Polish physical planning and evolved a number of new techniques and methods. <sup>(3)</sup>

It cannot be denied that the cornerstone of a number of these scientific and practical activities has been provided by the formulation of the so-called threshold theory in 1963. <sup>(4)</sup>

An attempt to find a common language and platform for interdisciplinary understanding and co-operation with economists was certainly at the root of the development of this theory. Two other well known problems are however usually considered as its basic generators, namely (1) the problem of what may be called the 'dialogue' between various planning levels, particularly concerning the feedback of information from local to regional planners, and (2) the problem of approaching long-term physical planning in general, and in particular of identifying the most natural period of time for long-term studies such that they will be consistent with the natural rhythm of physical growth of the town concerned.

It was at this point that a few basic questions emerged: How do towns grow? Do they grow in a continuous way, or in distinct stages? Are there any identifiable factors which will allow the formulation of a set of rules highlighting the character of physical growth of towns and settlements?

As often happens in research work, most of the answers were found through observations and analyses of various examples of growing towns. It seems that by following this approach the background of the resulting threshold theory will evolve logically thus making the presentation of its basic principles more obvious and therefore more convincing. <sup>(5)</sup>

### Urban Growth and Topographical Limitations

To start from the most extreme and simple case of a town situated on an island, it is possible to consider or to simulate its most probable development trends. Assuming that the island is mainly characterised by easily developable land and that its only major topographical feature is a mountain in one corner, it can be predicted that in any normal circumstances the growing town will take all the immediately available flat land (if necessary). This growth will proceed in a continuous way but eventually there will come a time when all land on the island suitable for urban development will have been used and thus the further physical growth of the town will face its discontinuity point, or in other words its limitation in the form of the mountain or the sea shores. Does this mean that the growth of the town has reached its end and that the limitations are of an absolute character?

To find the answer the ways of overcoming these limitations must be investigated: either the mountain may be removed or new land be reclaimed from the sea. Once this has been done, further continuous urban growth can follow until the successive limitation is faced. Having predicted or simulated the way in which the urban growth of the analysed town will most probably proceed and how the limitation encountered has disrupted its continuity, it is interesting to look at the resulting implications for urban growth in an attempt to discover whether there are any common features connected with the process of overstepping these limitations.

It is clear that both removing the mountain and reclaiming the land will involve some investment costs on top of those which have to be spent in any case for urban development (for housing, roads, infrastructure, etc), which can be called 'additional' investment costs and appear in the process of overstepping either of the two limitations.

Since this case is of an extreme character it is necessary to find out whether these initial findings would be valid in a more common situation. The observation of growth processes in a number of towns will provide an affirmative answer - the majority of them will have to encounter, from time to time, limitations due to the topography and natural features of the surrounding areas: the most common in the course of urban development being represented by steep slopes, marshy land and wide rivers. These limitations, while not so distinct as in the previous case, will often impose quite severe constraints on the further physical expansion of the town. Again, it is noticeable that limitations may be overcome but always at the additional investment costs, as in the case of the town on an island. It can therefore be said that this type of topographical limitation is a common phenomenon in the process of the physical growth of towns and settlements.

The value of this very simple but important statement will be substantially reduced when it is pointed out that many towns are built on flat land without topographical constraints to urban development possibilities. Other types of limitation may then be identified, since it is not only topography which influences development.

#### Urban Growth and Technological Limitations

A town as an urban organism can function and develop only on the basis of appropriate infrastructure systems. It can be seen, therefore, that any constraints to the expansion of those systems impose limitations to the physical growth of the town itself. There may be a number of varying constraints involved but usually more important would be those deriving from physical laws on the basis of which respective systems operate: for instance in a sewerage system it can be said that the law of

gravitation will play an essential role in its functioning and extension. Therefore a watershed will always limit the further development of any sewerage network and theoretically if a town is to grow it will be necessary to construct a whole new system for the first dwelling unit beyond this watershed. Technological means allow some extension of the system beyond its natural catchment area (e. g. pumping), but this will be insufficient for large developments, and the fact remains that a limitation exists at this point which will require additional investment costs to open up a new area for the further physical expansion of the town involved.

There are a number of other factors which can impose similar constraints (e. g. diameter of pipes, capacity of treatment plant, etc.) but since the main aim of this chapter is to formulate more general conclusions, it seems irrelevant to go deeper into technical details of sewerage treatment at this stage.

Taking water supply as the next of the basic infrastructure systems, similarities can be discovered: the yield, or capacity, of the existing water source will be such a limitation. Any expansion of the town concerned will require either the construction of a new water source (such as an artificial lake) or the transport of water from some other, often distant, river or lake. In any case additional investment costs will be involved to overcome the limitation and to proceed with the development, as in all previous examples.

Theoretically, a point in an urban development process can be defined after which even one new dwelling unit more would require the provision of water from a new source.<sup>(6)</sup> This point will clearly be a point of

discontinuity in the physical growth of the town involved. Among many other factors which may impose constraints to the extension of water supply and in consequence limit urban development possibilities, worth mentioning are: contour lines indicating under- or over-pressurised areas (thus unsuitable for building purposes), and diameter of pipes in the existing water supply systems (limiting its overall capacity). It should be remembered that all these limitations, however difficult to overcome, are never absolute in their character, but always require additional spending in financial terms.

Another system vital for the proper functioning growth of any urban organism, is a transportation one. Suppose that a small town of say 20,000 or 30,000 inhabitants is considered. Normally a town of such size would be pedestrian-orientated and not therefore requiring any specially organised public transport system. The situation will be changing as the town grows and a moment must come when a public transport system will be a necessity. However difficult it may be to define this moment precisely, although modern transport study techniques make it possible, its existence cannot be denied. It can thus be said that the transportation system imposed a limitation to the further physical growth of this town. Therefore, if the town is to grow and the population be properly serviced a public transport system has to be created. Authorities will then have to buy buses, appoint staff, build garages and so on.

Thus again the overstepping of this particular limitation will require additional costs in order to open up new possibilities for the urban expansion of the town in question. Similar situations will also occur in large towns already having well-established public transport systems which would be appropriate only up to a certain scale of

urbanisation and once this critical level is approached the introduction of a new system (e.g. an underground network) is necessary if the growth possibilities for this town are to be kept open. Such successive limitations imposed by transport needs will be connected with lump sum investment costs required for the implementation of new systems. These costs will again represent additional spendings in the development budget of the town concerned.

The point can be made that there are countries such as the U.S. where, as a result of a high rate of car ownership, the value of public systems has been greatly reduced and, therefore, no limitations imposed by transportation systems are encountered. However, as traffic experts well know, there are great difficulties inflicted by the situation where an existing road system reaches saturation point and only a complete reconstruction of the system, at a very high cost (of an additional character) would allow for further urban development.

The above arguments seem to support the conclusion that in addition to 'topographical' limitations there exists another group embodying constraints imposed by the technology of various public utility networks and transportation systems. Although these technological limitations are of an entirely different character they have essential similarities to those from the first group - they are not absolute limitations, but they do prevent further continuous urban growth unless some additional investment costs are allocated for their overcoming.

#### Urban Growth and Structural Limitations

Limitations to the physical growth of towns may exist which would not fit either of the categories already discussed. These will occur when internal urban structure imposes constraints for further urban

development of the town concerned. Each town, for instance, must have its main centre providing necessary services and shops for the inhabitants. This centre has to develop its activities according to the growth of the town but it may happen that while an increased population necessitates its further continuous expansion it can be so restricted by existing built-up areas that further physical growth is impossible and thus a limitation to the development of the whole town would be imposed. As in all previous cases this limitation can be overcome in a number of ways. Surrounding buildings restricting the centre's expansion may, for instance, be knocked down and population shifted elsewhere, thus opening up the possibility of expanding the centre and, accordingly, the town.

Another solution would be to create a ring of new sub-centres on undeveloped land around the town core. In both cases, again, additional lump sum investment costs would be required to overstep this third kind of 'structural' limitation.

#### Concept of threshold and Threshold Cost

Summarising briefly the impact of limitations on the physical growth of towns in the light of the above, it can be said that there exist discontinuity points in urban development processes and that in most cases these are the result of limitations restricting further physical expansion of the towns concerned. These limitations are not irremediable but can only be overcome at additional - usually disproportionately high - investment costs, since they involve major improvements of land, implementation of new infrastructure systems or radical reconstruction of existing ones. They will fall into three main categories: those due to topography, to the technology of the various public utility networks and transportation

systems, and to the existing urban structure and uses. (7)

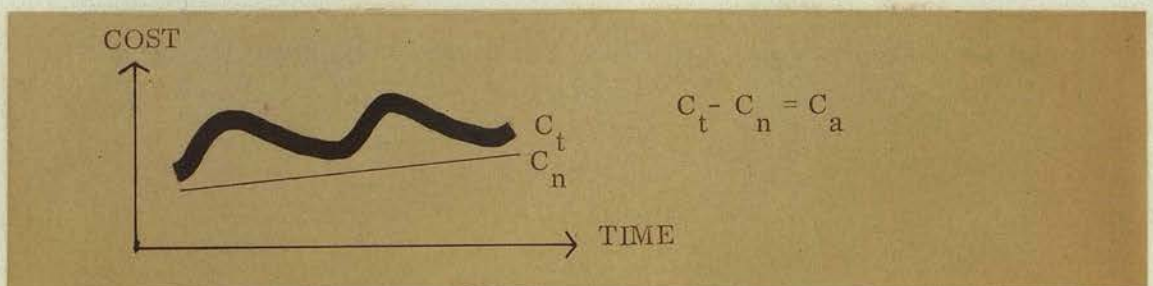
An important inference from these observations is that the physical growth of towns is not smoothly continuous but proceeds by 'jumps' marked by the successive limitations which have been called the THRESHOLDS of urban development. Thus capital investment costs needed for the expansion of the town will change over time disproportionately to the increasing numbers of inhabitants, reflecting periods when additional lump sums must be spent to open successive areas for further urban development. Thus in general the costs necessary to locate one new inhabitant in a town ( $C_t$  = total costs) are at least twofold:

- a) costs not connected with given locations of constructions necessary to accommodate new inhabitants which would constitute the 'normal' costs and have to be spent in any case ( $C_n$  = normal costs)
- b) costs tied to existing conditions and characteristics of given land which constitute 'additional' costs substantially varying from one location to another ( $C_a$  = additional costs)

Thus  $C_t = C_n + C_a$

This type of subdivision is relevant to the previous discussion and particularly striking for the analysis of per capita costs during the whole period of town growth. The curve on Diagram 1 illustrates this.

Diagram 1.



It is clear that the need to overcome a given threshold results in a violent rise in investment costs  $C_a$ . The overstepping of the threshold limitation, ie. completion of all investments necessary to open new land for town expansion, results in a decline in these costs. The peak points on the cost curve are in fact one of the ways in which thresholds can be presented.

The above formulations are intended to help in understanding the definition of THRESHOLD COSTS as variable costs necessary to overcome threshold limitations in the process of urban development. It is important to note that threshold costs can be categorised by the stages in which they are incurred: one type is those which must be spent before the land is made suitable for development (e. g. a bridge, a treatment plant or an access road) and which will have a special bearing on urban development as causing the freezing of assets due to the indivisibility of some investments. A second type is those which have to be spread over the whole period of development (such as costs connected with building on land with low load-bearing capacity of soil<sup>(8)</sup>). The relationship of these divisions to overhead and direct costs is obvious; the timing of these costs and the work associated with them will have repercussions for the programming of investment.

(b) IMPLICATIONS FOR PLANNING PRACTICE

The Method of Threshold Analysis

It can be said that physical planning was always involved in analysis of the various constraints enumerated in the previous section. The conventional procedures (sieve techniques or other feasibility studies) did not make, however, sufficient use of these limitations in their methodology. Therefore the formulation of the threshold theory has been followed up by development of its practical application in the planning process, known as the Analysis of Town Development Possibilities<sup>(1)</sup> or more simply as Threshold Analysis. This method applies the threshold concept to the analysis and comparison of various possible alternatives of urban expansion early in the planning process and thus helps to determine the choice of the most desirable directions for growth. To make this possible, threshold limitations must first be defined in cartographic form and examined from the viewpoint of the cost involved in their overstepping.

In principle for each town first and successive thresholds can be defined after first examining:

- (i) physiographic suitability of land for urban development;
- (ii) possibilities of extending the public utility networks and transportation systems;
- (iii) possibilities of changing the existing land use patterns.

The results must be formulated quantitatively (which constitutes the most important difference in comparison with conventional methods), then the cost indices can be deduced and subsequently the amount of additional

outlays required to open up new areas for town growth assessed.

For the majority of towns (excluding only large conurbations) simple graphical methods can be used to show these results on a map since all areas analysed from the viewpoint of each of the three survey groups can be subdivided into: land immediately suitable for urban development; land needing essential improvements and/or capital investments before becoming suitable for urban development; and land unsuitable for urban development. First and boundary thresholds can then be identified in each of the groups.

The information can then be correlated to form a synthesis in which all the fundamental premises influencing the physical urban growth have been taken into account. This gives the method great consistency, and, as the total process of synthesis is verifiable, it greatly adds to the rationalisation of the planning work.

On the basis of this summary, the lines of urban development thresholds can now be defined: they are formed by several superimposed threshold lines resulting from partial analyses done within all the groups of studies. Those which are spatially defined used to be called "physical" thresholds but not all the limitations can be shown as a line on a base map; thus "quantitative thresholds" (indicating the limited capacity or yield of various public utility works, sources or networks) will represent those which can only be expressed in population figures. "Structural thresholds" form a separate group since they may fall simultaneously into either of these two categories. (2)

### Implications from Threshold Analysis

A threshold as seen through the theoretical principles of threshold analysis is not any limitation faced during the expansion of a town; by definition it is a major one which poses a serious problem and which has a marked effect on the costs per head of new population to be accommodated. Its wider significance derives from this feature. When a town meets a threshold or there is a prospect of one occurring in the near future, the time has come for a reappraisal of the pattern of development to ensure that a more efficient one does not exist. It should also be noted that thresholds cannot be considered in abstract but always in relation to a particular settlement. A village, for instance, will face different thresholds from those faced by a large town - in the case of the former almost any obstacle will raise costs disproportionately high while for the latter only particular types of obstacles will have a similar financial impact (e.g. the need to construct a new underground line).

- ✓ The nature of thresholds gives wide opportunities to analyse and to evaluate all reasonable planning alternatives, since the notion of threshold has become a key element in the integration of all partial results for the three groups of analyses (natural features, public utility networks and communication systems, land-use patterns) from which the most suitable physical growth directions for a town can be deduced. By estimating the threshold costs, indispensable for opening up new land for urban development, and by calculating the capacity of threshold areas (in numbers of new inhabitants) important data for determining the most viable solutions to the various possibilities for further expansion taking into account existing physical conditions can be obtained. From this the sequence in which adjacent areas should

be developed can also be indicated, and the moment detected after which further compact growth of a town would no longer be economically justified and a change towards a decentralised system may be implied.

Threshold analysis aims at evaluating these various possibilities, or in other words depicting all reasonable directions for the urban development of a town. In the course of the analysis alternatives thought less satisfactory are not eliminated a priori; the whole procedure makes it possible to return to any alternative whenever new facts or new approaches reveal such a necessity. The analysis thus provides a basis for the design and investigation of various urban structure models deriving from different presumptions and for consideration of alternative development programmes which can be subsequently superimposed and tested against the threshold implications. There is no need, however, to formulate such a programme in advance in the case of threshold analysis, since its main aim is to determine the implications of the existing situation and to give them economic emphasis.

In this context it is necessary always "to bear in mind that the measurement of the costs of a certain development constitutes only one part of the economic calculation; it must be complemented by an assessment of the results of development. One can discern two kinds of result: (i) the economic output of the development (e.g. the population of a new industrial unit) and (ii) the increase in population connected with the development. We are concerned here with the second of these categories. In other words, we assume for the time being that the programmed output is to be reached in any case. What interests us is how to reach it by minimising the costs of necessary urban expansion."<sup>(3)</sup>

### (c) SCOPE FOR APPLICATION

The basic aim of the threshold theory is not to discover how to limit an urban development process. On the contrary, threshold limitations, once identified, will allow the assessment of the additional costs involved in overcoming them and will help to deduce how and when this can be done in the most efficient and rational way from the viewpoint of urban development strategy for the town concerned. Thus threshold analysis represents a quantitative tool to help decision-making. The notion of threshold costs also provides an important common denominator making it possible to analyse and compare implications for urban growth potential imposed by entirely different physical factors influencing development processes. <sup>(1)</sup>

Bearing this in mind it might now be appropriate to look more closely at the main fields in which the application of the threshold theory seems to offer particular benefits to the physical planning process.

#### Long-term Planning

In the first place immediate and direct use of threshold theory can be made in selecting and evaluating the most efficient growth possibilities within the scope of a single town. By comparing the consequences of all logically feasible development variants on the basis of threshold cost indices, an objective quantitative basis is created upon which choice can be made and long-term hypotheses analysed and assessed. It must be pointed out that interrelations between threshold theory and long-term planning are particularly strong. It seems therefore necessary to develop this problem more fully.

It is a well known fact that human settlements are in a continuous process of change, and at certain stages in their development most of them show a tendency towards longer or shorter periods of stabilisation. Methods can be introduced to control, accelerate or retard these processes; of these the commonest is the statutory Urban Development Plan known by different terms in various countries.

For various reasons this sort of plan must be prepared for a definite time period and this only by sheer accident might coincide with the natural rhythm at which a town develops. A long-term plan, for the more remote future, is needed as an additional tool for comprehensive town design and, to make a real contribution, it should be based on a different approach. Thus a number of given premises for statutory plans (e. g. time period, demographic hypothesis, study area) would have to be subject to research in the longterm planning process. Long-term analyses can, therefore, help to overcome the dissonance between conventionally-imposed time scales in town planning and the natural rhythm of urban growth. Here threshold theory comes into close contact with long-term planning problems, since the long-term plan should consider the image of an urban settlement at that moment when the stabilisation of its growth and expansion may be expected. It seems that this would occur when such a settlement is confronted with its development threshold.

At this point such a settlement would tend to keep within its limit, which is within the range of 'normal' costs for accommodating new inhabitants. Thus a threshold even when finally overcome would mark a distinct phase in any urban growth processes. It is relatively simple to calculate the long-term growth potential as determined by threshold limitations, and the period needed for its realisation. From this it is possible to deduce the date by which this tendency to 'stabilisation'

would start, the date which would be the most appropriate for undertaking long-term development studies.

There are, however, a number of factors which make this prediction more difficult. First, as is usually the case, there may be several possibilities for development and the tendency to stabilisation will appear at different dates according to the location of the various thresholds. On consideration of all these possibilities, a series of long-term growth potential figures will be obtained, indicating the dates by which they will be met. In addition, when different urban standards (i.e. gross densities) are assumed, another series of alternatives will arise.

This means a series of feasible long-term development hypotheses for the given settlement should be prepared, which would be of assistance in deciding the optimum solution for a statutory plan by providing the opportunity for a rational choice of development areas.

In any case it is much more natural to evolve a comprehensive scheme for an urban settlement for the time period and within the area defined by threshold limitations than to do this for an arbitrary date which only by the 'magic of figures' seems to indicate some important stage in the growth of an urban settlement (such as 20 years ahead, or 2000 A.D.). Once a long-term study is completed there is nothing against successive designs of statutory type plans for a given time period which can then be considered as one of the stages leading towards the general urban structure indicated by long-term considerations.

From a broad range of theoretical aspects connected with long-term studies, only those related to the threshold concept have been briefly discussed. There is much more expanded background theory relating to the long-term planning problem on the lines presented above, much of it developed by B. Malisz<sup>(2)</sup> in Poland and followed up in some writings in Britain<sup>(3)</sup>, but further discussion of this aspect will certainly go beyond the framework of this work.

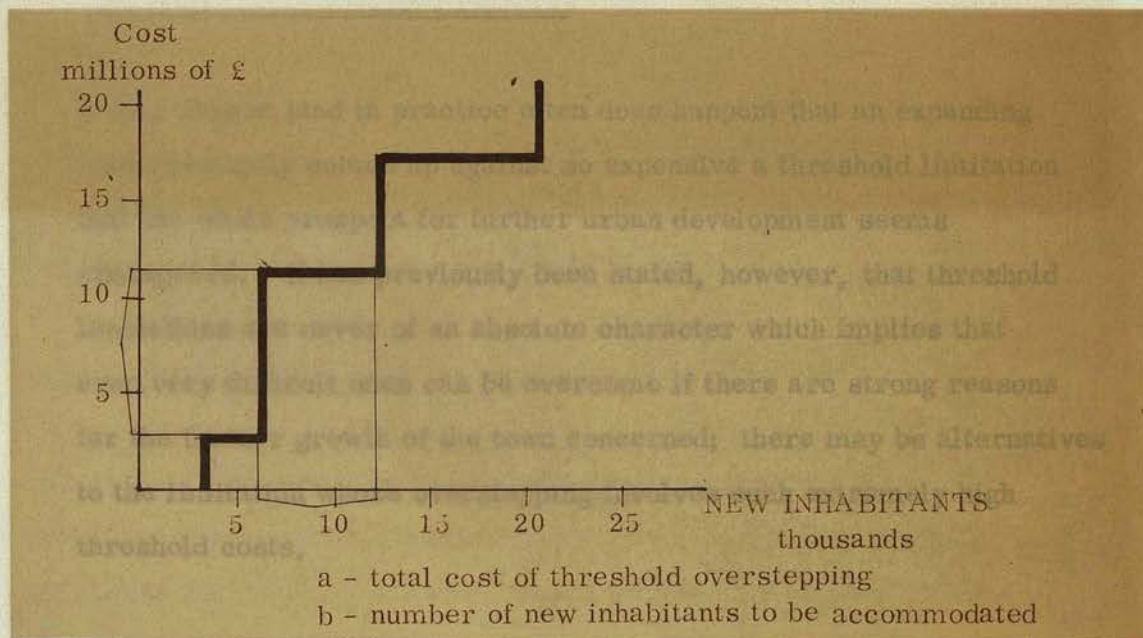
### Growth Possibilities of a Single Town

It may be useful to show, by a simple example, the type of implication for urban development which derives from threshold analysis. The meaning of successive thresholds being encountered by a growing town and their economic impact can be presented in a form of diagram (Diagram 1) where the x-axis shows the population increase in number of inhabitants and the y-axis the total additional costs involved in overcoming successive threshold limitations (i. e. threshold costs). The number of new inhabitants is calculated for each area opened up by overcoming respective thresholds and limited by the next one. Thus the immediate relation between an input in terms of total threshold costs and an output in terms of new inhabitants that can be accommodated is clearly indicated.

This information has wider significance; the population increase, for instance, follows a certain rate and it may take a long time for the area to fulfil its capacity. In terms of economics, it means that crossing thresholds is always connected with freezing some capital assets. It would imply, therefore, the necessity to concentrate increase in population on this area alone and clearly indicate the dangerous consequences of crossing more than one threshold simultaneously.

Other means may be used in order to reduce the time period for which the outlays would be frozen, such as financial incentives to speed up in-migration processes. If the population increase, on the other hand, is fairly well defined and difficult to alter, the crossing of a much more expensive threshold may be economically justified where the area opened up would be very close to this population target. Implications for long-term plans have already been discussed, but from the diagram it can also be seen that it is possible not only to consider and to evaluate the future consequences of overcoming the first but also the successive threshold limitations, so that the efficiency of various development possibilities can be shown not only in their initial stages but in the long-term period.

Diagram 1



So far, problems connected with a single town, growing as one compact urban organism, have been discussed and some of the ways indicated in which, by means of threshold analysis, it may be practicable to

discover alternative patterns of development and to compare them. Threshold analysis helps to provide a sound and reasonably objective basis for this comparison which is essential if decision-making in the planning process is to be more than an intelligent guess based on intuition and experience. At this stage it may be necessary to indicate that threshold analysis, although simple, must not be oversimplified and no 'automatic' conclusions should be drawn from it. This means, for instance, that a development alternative more expensive from the viewpoint of threshold indices need not necessarily be less acceptable than those which are cheaper, since it may offer much more in other fields (social benefits, for instance) which are beyond the scope of threshold analysis and will normally be subject to investigation in later stages of the planning process.

#### Analysis of Decentralised Patterns

It may happen (and in practice often does happen) that an expanding town eventually comes up against so expensive a threshold limitation that the whole prospect for further urban development seems endangered. It has previously been stated, however, that threshold limitations are never of an absolute character which implies that even very difficult ones can be overcome if there are strong reasons for the further growth of the town concerned; there may be alternatives to the limitation whose overstepping involves such extremely high threshold costs.

The most obvious alternative is to cease further development of this town as a compact organism and to move into a decentralised pattern based on new satellite urban systems linked with the 'mother' town by main transport lines. This is the well-known, almost classical alternative; but it may be very difficult to decide when it would be

more efficient to select such an alternative instead of overcoming a particular threshold limitation, because an important argument will immediately be brought into consideration, namely that the new satellite settlements are bound to face a number of initial thresholds, since everything (such as infrastructure systems and roads) must be built from scratch.

However, it has been shown that the size and character of thresholds is entirely different in a small village and in a large town. In consequence, costs needed to overcome these thresholds will also differ substantially, and it may happen that the summation of all additional investments connected with meeting initial thresholds in a new satellite settlement would still involve much lower costs than those necessary to overstep a major threshold faced by the 'mother' town.

In this way threshold analysis can provide useful parameters to detect the moment when further expansion of a town as a compact organism can no longer be economically justified. In this case further physical growth through decentralisation would be implied with the increase of population accommodated in satellite urban units. <sup>(4)</sup>

#### Indirect Application to Regional Planning

Indirect use of quantified results from threshold analysis can constitute an important element in the regional planners' decision-making and makes it possible to transfer important information from local analyses up to the regional planning level. This is one aspect of feedback in the overall planning process which threshold analysis facilitates and it would most commonly occur:

- (a) when alternative locations of some significant investment are to be decided within a region, and, most important,
- (b) when a regional policy concerning the distribution of the expected population increase is in the making.

In the first case, threshold cost indices would provide additional parameters throwing light on the consequences of selecting alternatives as seen from the viewpoint of urban development possibilities of those settlements which will be connected with respective locational proposals.

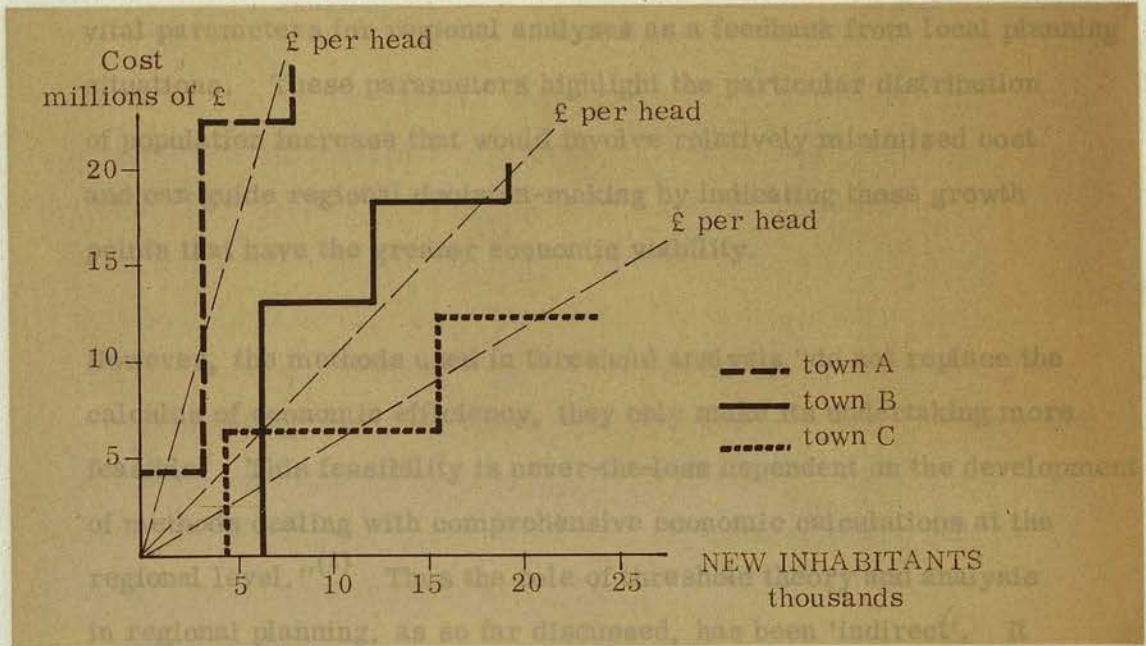
In the second case, requiring threshold analysis to be carried out for all towns within the region, the possibilities of verifying or influencing important aspects of regional and sub-regional planning in the light of local analysis will be disclosed, by indicating the most economically viable town units where the main urban generating functions (the prime one being industry) should be located and towards which a population increase should be directed.

Diagram 2 explains one case in which it is feasible to compare some aspects of the economic effectiveness of growth among a series of towns within a region. It shows what the threshold costs are per new inhabitant and how many new inhabitants can be accommodated for this additional cost, not counting of course the expenditure which, according to the standards employed, is constant in all the towns concerned.

The parameters provided by this kind of diagram indicate the effects of certain locations (of main economic activities within a region) on population distribution, by reflecting to some degree what are termed

the 'social costs' of entrepreneurial activities. For comprehensive planning it will be essential to quantify these costs so as to enable the possible amendment of decisions by respective firms or investors reached through economic calculations.

Diagram 2



Thus if properly exploited, threshold analysis is particularly promising as a tool to indicate that regional distribution of growth which would give relatively minimal costs and to select regional growth points on a rational and economically sound basis. It seems necessary to add, however, that "threshold cost indices are not in themselves measures of economic efficiency. But they are useful assets for the regional planner, enabling him to choose the optimal location for the programmed development of economic activities. This is not to say that difficult thresholds must always be avoided; but in terms of economics it seems reasonable to cross thresholds at the point where maximum efficiency is derived."<sup>(5)</sup>

(a) FIELDS OF POSSIBLE CONTRIBUTION

In discussing the benefits of threshold theory in relation to regional planning it must be emphasised that threshold indices may represent vital parameters for regional analyses as a feedback from local planning situations. These parameters highlight the particular distribution of population increase that would involve relatively minimised cost and can guide regional decision-making by indicating those growth points that have the greater economic viability.

However, the methods used in threshold analysis "do not replace the calculus of economic efficiency, they only make its undertaking more feasible. This feasibility is never-the-less dependent on the development of methods dealing with comprehensive economic calculations at the regional level."<sup>(1)</sup> Thus the role of threshold theory and analysis in regional planning, as so far discussed, has been 'indirect'. It might be thought to be more worthwhile to look for a 'direct' application of the threshold approach to regional analyses in their entire complexity. It is important to realise that of numerous problems facing the regional planner "the one which for many regions is the most critical, is the problem of how to put to best use a limited, if not niggardly, endowment of resources. For example, a region may have limited water available for industrial development. How best to employ that water in terms of a predetermined goal? Or a region may be short on both capital and skilled labour, as is true of many underdeveloped regions. How to exploit these resources most efficiently to attain certain income, employment, or other objectives?"<sup>(2)</sup>

It should be noted that threshold theory is concerned with aspects of scarcity since it aims at defining the amount of land immediately suitable for development from the physiographical standpoint, the amount of land being served by existing public utility networks, and so on. These analyses, however, whether used by regional planners or others, are undertaken at the level of a single town or settlement and are therefore limited to the local conditions.

The most recent development of the theory has revealed new 'open-ended' possibilities for its direct application to regional analyses. In 1967 - 68 B. Malisz was responsible for the establishment of a planning methodology for the United Nations sponsored operation for the South Adriatic region in Yugoslavia: he took this opportunity to expand the threshold theory into the regional planning field and to test it in practice for one of the sub-regions involved. Later he formulated the basic theoretical principles that could lead to the introduction of the threshold concept into regional planning methodology in general, and to resource analyses in particular.<sup>(3)</sup>

#### Rationalisation of Resource Analyses

One of the essential problems faced in regional analyses is to pin down the most efficient use of existing regional resources.<sup>(4)</sup> Therefore, the question of analysis and evaluation of these resources is of prime importance. Looking into the majority of methods currently applied, a number of weaknesses may be pointed out, but two of them are of particular significance.

First the types of resources (natural and man-made) are analysed separately, often by the use of different techniques, or scoring systems, according to their widely different character, and second, a general lack

of any common denominator precludes objective assessment, so that their integration or comparison and subsequently the whole evaluation is threatened by subjective interpretation. "There is a lack of any quantitative platform that would allow the bringing together of direct interconnections between all kinds of resources and to relate them to the intended levels of different economic activities within the analysed region."<sup>(5)</sup>

It is clear that where evaluation of existing resources is inadequate and even partly subjective there is nothing that can prevent the final results of the whole planning exercise representing at least the same, and usually a much higher, degree of subjectivity. Therefore, any rationalisation of the way in which existing resources are analysed would be a significant contribution to regional planning methodology. Direct application of threshold theory to such analysis represents an important step in this direction since it aims "to find relatively optimum levels of development for different economic activities by evaluating the potential of existing resources, both natural and man-made; and investigating the possibilities for its extension."<sup>(6)</sup>

It should be emphasised that, as in the case of local analyses, threshold analysis on a regional level must not be considered as the 'only and final' tool for decision-making - its role would be to provide (a) important parameters for subsequent comprehensive regional analyses embracing other significant social or economic aspects, (b) a sounder foundation on which to base final decisions, and (c) a feedback to the national planning level, to allow comparative assessment of resource potential for the country as a whole.

### 3. THRESHOLD THEORY WITHIN THE SCOPE OF REGIONAL PLANNING

#### (a) Fields of Possible Contribution

Indirect and direct applications - rationalisation of resource analyses

One of the main regional planning problems is how best to allocate limited resources which are needed for the development of different economic activities. A quantitative platform for measuring resource capacities and for relating them to development options of respective economic activities is necessary and a direct application of threshold concepts to regional analyses can contribute in this field.

#### (b) Outline of the Methodology

Simplified concept of threshold approach - complex and multi-complex situations

Certain resources can only develop in 'jumps' indicated by the threshold concept, thus implicitly determining stages of saturation of particular economic activities. Freezing of capital assets resulting from crossing resource thresholds must be analysed if the most efficient options are to be selected. In cases where more than one activity is involved, either more sophisticated techniques must be applied, or the problem may be simplified by disintegrating the regions into less complex sub-regions.

(b) OUTLINE OF THE METHODOLOGY

From these initial formulations a new approach has begun to emerge based on direct application of the threshold concept to analysis of major economic activities on the regional scale, which claims to be capable of showing the proportions in which these should be developed or exploited, and at the same time another field of research related to the threshold theory with particularly promising prospects has been opened up.

Simplified concept of 'Threshold' Approach

To make this approach most intelligible, one should start from a relatively high degree of abstraction and consider first a very simplified model of a region, the development of which is based on one economic activity only. The question now arises: is it possible to analyse such a region by directly applying the methods evolved from the threshold theory? An affirmative answer should show the way in which this analysis could be carried out and form an integral part of the planning process.

Observation and experience reveal that all economic activities and their development depend on resources which, according to Malisz<sup>(1)</sup>, can be subdivided into three main groups:

- (i) natural resources such as land available, raw materials, amount of water, etc.
- (ii) man-made resources such as infrastructure networks, buildings or factories, service facilities, etc.
- (iii) labour resources (employment potential).

Or, as he suggests elsewhere, it might be more convenient to sub-divide the resources into two other groups: "those whose capacity can be increased (more or less) in proportion to the growing needs, and those whose capacity can only be increased in 'jumps', that is, in major portions, which creates the phenomenon of freezing capital assets. This is because the created capacity can be used in full only after longer periods of concentrating activities within the range of the newly created resource capacity. Considering the second group of resources we shall find that to increase their capacity will only be possible by overpassing some subsequent threshold limitations".<sup>(2)</sup>

It might thus be noticed that the more absolute the character of a limitation (of a particular resource) the greater the reason for keeping an activity within some threshold limitations. This may introduce the notion of saturation of some economic activity. The state of saturation would be the level to which some activity can be developed.

Resources are always characterised by their capacity and by possibilities of its extension, but this capacity can also be related quantitatively to any economic activity concerned.<sup>(3)</sup> In the case of tourism, for instance, it can be translated into the number of tourists that it is possible to serve, or accommodate, and in the case of industry into its gross product in money terms or production units.

Thus in trying to define the relatively optimum level to which a given activity can be developed, one can find the answer by looking into the possibilities of extending the capacity in those groups of resources on which the development of this activity is based.

Several development options may be set up and analysed. The investment cost needed to bring up capacities in each group of resources to the level required by the option considered would be compared with the

expected return expressed in money terms. The relationship between these investment outlays and revenues would clearly indicate the most favourable option from the efficiency viewpoint; the more options that are analysed, the more closely the optimum one could be approached.

It is in the course of this analysis that the significance of determining threshold limitations within all resource groups would be particularly important. Obviously, there may be a number of options dependent only on the development of those resources that are characterised by an ability to expand by gradual increments. More often, however, options would be based on those groups of resources which can only be expanded discontinuously or in jumps. To overcome a threshold in these groups of resources will always involve initial lump sum investment before any increase of capacity can be achieved. This investment sum will be fixed and would not depend on the capacity required for the option involved.

Therefore, the whole threshold cost would have to be taken into account. If the option analysed did not fully use the spare capacity opened up by the crossing of a threshold this would result in the freezing of valuable capital assets and this, in turn, would considerably reduce the economic efficiency of the option developed. Thus it can clearly be seen that only those options which take account of the phenomenon of threshold constraints are economically viable.

Threshold analysis applied directly at the regional planning level is thus significant both as a tool to provide new parameters for overall regional analysis and as a feedback to the national planning level.

The foregoing is of course only a very rough outline of a starting point for further research and practical testing; Malisz concluded that: "this inevitable roughness may throw into relief the many practical difficulties and, perhaps, theoretical discrepancies that accompany its concepts. But I am convinced that we must run the risk of making mistakes and be ready to discuss our errors constructively if we are to make progress to understand the world for which we plan."<sup>(4)</sup>

### Complex and Multicomplex Situations

This simple exercise with only one economic activity would, however, hardly be the case in reality since the properly balanced economic growth of any region cannot be based exclusively on one basic economic activity. If three of them were to be analysed in the way previously discussed, the whole problem would immediately emerge as a multi-complex one. It would not be known which part of any potential capacity at a given time could be allocated to which of the three activities since this would be one of the questions to be answered. One of the activities could be of a dominant character which would allow priority to be given to it and thus simplify the problem; but this would not be typical where a large region is the subject of planning analysis.

It might, therefore, be worth trying a successive approximation approach by subdividing the region into such sub-regions defined by one clearly dominating activity, and only then to carry out further analysis on a sub-regional level. Even on this level it may be difficult clearly to distinguish only one dominant activity, but in most cases they can be reduced to two. Thus a question will arise: in what mutual proportion should these two activities be developed to achieve a relatively optimum solution?

According to Isard<sup>(5)</sup> the regional problem involving two activities and a limited number of resources can be solved quite easily in linear programming by the use of a graph. In applying this method Isard finds the optimal solution by defining a segmented line, designated the 'efficiency frontier' or Combined Effective Limitation Line, which is convex to the origin. Points beyond (i. e. to the right of) the frontier are unattainable given the constraints of resource limitation. Points within (i. e. to the left of) the frontier are 'inefficient' in that either or both activities can be increased without involving a reduction in the other.

Thus a theoretical background already exists to solve a problem involving two main economic activities but at the cost of using techniques which are beyond the capacity of all but a few specialist teams. It also requires knowledge of the resource requirements of the activities and the degree to which their capacity can be efficiently developed. It may, however, be possible to make some progress towards this latter question on the basis of threshold theory formulations.

This solution deals with a situation where there are more than two resources constraining development but limited to only two activities existing within the region. According to Isard "the graphic solution becomes complex when a third activity is introduced into the problem. Three dimensions must be used, the level of the third activity being measured along the third dimension. And when we introduce a fourth activity, a fifth or sixth ... and finally a n-th activity into the problem, a direct graphic solution is not possible. It is at this point that other types of solutions must be sought to the linear programming problem."<sup>(6)</sup>

It is possible to postulate a scheme which is capable of analysing cases where there are three activities, say agriculture, industry and tourism; exceptionally there might be four. The problem is to maximise regional income subject to the condition that the sum of the requirements of any one resource by all activities does not exceed the supply of that resource. Objections may be twofold: highspeed computation is necessary for systems optimising several activities subject to a number of constraints, and a more serious objection is that any formal method will underestimate the degree of complexity of alternative economic strategies.

As a matter of judgment about the likely future of regional development planning, it would appear that the typical situation would be to put forward a finite number of alternatives reached by analysis of the potential for economic growth. These might be tested for cost and feasibility by a threshold-related technique. In the absence of a perfect tool for prediction, an alternative process of testing the sensitivity of regional development to growth factors and resource constraints may prove an effective tool of planning.

This last remark indicates the full scope of possible research into the role of threshold theory in regional analyses, the scope of which while briefly outlined, seems to reveal a wide range of possibilities, from the simple to the multi-complex, although of course there is much to be done before practical field tests could be undertaken.

APPENDIX: FOOTNOTES

## 1. RATIONALISATION IN URBAN PLANNING

1. In fact J. Regulski suggests the distinguishing of a FUNCTION-PLAN showing how the proposed system operates (J. Regulski 51), but this could be an inherent part of the "image" plan.
2. Similar, though more expanded criteria for the assessment of final planning solutions have already been proposed by B. Malisz (B. Malisz 41).
3. "The Concise Oxford Dictionary", Oxford University Press, 1964.
4. P. Davidoff and T. Reiner (8).
5. M. Hill (16).
6. J. Kozłowski and J. T. Hughes (29).
7. As 'programme' has a specific meaning in U.K. planning, implying elaboration of time phases for some planning action, it must be made clear that a Development Programme is here understood to mean "that part of the planning process dealing with the quantitative aspect of a proposal treated in successive periods of time" (the first draft of the International Vocabulary Concerning the Realm of Physical Planning, United Nations Development Programme, 1968) - thus all basic demographic projections and corresponding space requirements would become an integral part of it.
8. The 'Integrated Planning System' was first outlined by B. Malisz in 1966 (B. Malisz 41).
9. This, of course, constitutes one of the basic principles on which the Optimisation Method has been evolved. (J. Kozłowski 27).

## 2. THRESHOLD THEORY AND ITS ROLE IN URBAN PLANNING

### (a) Original Formulations

1. Numerous papers and articles eventually culminated in the book on town planning economics (B. Malisz 39).
2. Particularly by J. Regulski and S. Wyganowski (52), J. Adamus (2).
3. Such as the Optimisation Method first described by J. Olszewski (49), and recently by J. Kozłowski (27).
4. This theory dealing with the problem of discontinuity in urban growth was fully formulated by B. Malisz (39) (published in a shorter version (37 and (38)). More recent expositions of threshold theory and analysis are by B. Malisz (41) and in numerous articles published in several languages. The first presentation of the theory in Britain was by J. Kozłowski and J. T. Hughes (29).

(a) Original Formulations (continued)

5. The following outline of the theoretical background of threshold theory and analysis is based solely on original formulations as presented by B. Malisz in his writings and lectures of the early 'sixties and not including subsequent modifications resulting from critical discussions and practical experience, which are presented and developed in Part 3.
6. It is understood here that in all discussed cases the possibilities of lowering accepted living standards are not taken into account - only on the basis of such an assumption is it possible clearly to identify a point when a given limitation must be overstepped if the urban growth is to continue.
7. In fact, in his most recent summary (43), B. Malisz introduced the following subdivision of limitations to the process of spatial growth of towns:
  - Physical limitations: being the consequence of the differentiation of the physiographical environment,
  - Functional limitations: resulting from the existing pattern of land use,
  - Technological limitations: due to the technological infrastructure systems,
  - Structural limitations: connected with large-scale urban renewal.
8. This was first noted in the analysis of town development possibilities undertaken in 1964 by the Warsaw Province Town Planning Office led by Mrs B. Maliszowa and J. Regulski - this analysis is described in detail in Part 2.

(b) Implications for Planning Practice

1. This has been tested in Poland in 1964 in all 17 Province Town Planning Offices in their relevant territories. A total of about 600 towns were analysed. Synthetical results and conclusions were presented and discussed at the Third National Review of Town Plans which took place in Warsaw in 1964 (these reviews are organised in Poland every four years) and are presented in detail in Part 2.
2. This synthetical step by step procedure of threshold analysis has been presented by J. Kozłowski (29).
3. B. Malisz (44).

(c) Scope for Application

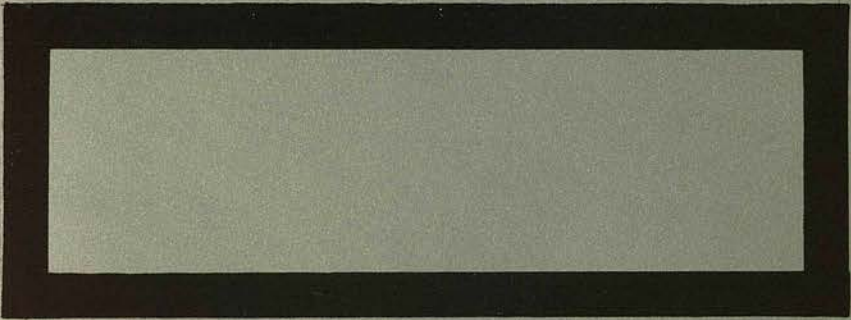
1. This is not a case in 'classical' methodology for defining land suitability where "surveys are usually carried out separately for each planning aspect and though there is a tendency to synthesise results, a mechanical integration of widely differing aspects always leaves a substantial margin for interpretation. Thus the comprehensive planning implications are simply bound to be formulated with varying degrees of subjectivity and one can never be sure that land assigned in the category of best suitability would really be the best when other characteristics were measured and compared" J. Kozłowski (27).
2. B. Malisz (35) and (36).
3. J. Kozłowski and J. T. Hughes (29), and (60).
4. Malisz argues that "this will normally happen when the population of a city is nearing the 400,000 mark, since that level of population tends to impose strains on transportation systems which can be relieved only by incurring the very high threshold costs of a new system" (44). It hardly seems possible, however, to define this sort of figure in abstract: the population figures arrived at would vary from country to country since they greatly depend on majority means of transport (private cars as opposed to public transport media, for example), on densities being applied, and above all on what are considered appropriate and acceptable traffic standards in a given country.
5. B. Malisz (44).

3. THRESHOLD THEORY WITHIN THE SCOPE OF REGIONAL PLANNING(a) Fields of Possible Contribution

1. B. Malisz (42)
2. W. Isard (18).
3. B. Malisz (45).
4. K. Dziewonski, like Isard and other regional scientists, points out that one of the three main goals of a national plan should be "better and more balanced use, in national and regional economy, of natural resources and accumulated work of man", K. Dziewonski (10).
5. B. Malisz (45)
6. B. Malisz (45).

(b) Outline of the Methodology

1. B. Malisz (45).
2. B. Malisz (44).
3. In a number of cases, special research would be required to define these relations precisely, but a certain amount of 'norms' are already available from various scientific bodies (much data in this respect has been accumulated by the Institute of Town Planning and Architecture, Warsaw).
4. B. Malisz (44).
5. W. Isard (18).
6. W. Isard (18).



**Part Two**

**EVALUATION**



## 1. APPLICATION OF THE THRESHOLD THEORY IN POLAND

### (a) Nationwide Test

Applied process of threshold analysis - shortcomings and achievements - general outcome - implications for urban growth strategies

Threshold analysis was applied to about 600 towns following a simplified step by step process based on official government instructions. As a result threshold limitations and the costs of their overstepping were defined providing, in spite of numerous shortcomings in the technical proceedings, a basis for rationalisation of urban growth strategies on the regional level. Thus the towns could be classified according to their potential 'development efficiency' ranging from those where possibilities of cheap growth were not exploited, to those where any more significant population increase would involve substantial waste of investment expenditures.

### (b) Analysis of Urban Development Possibilities for the Warsaw Voivodship

Economic interpretation of threshold theory - optimisation of population distribution on a regional level - subdivision of threshold cost

This application was preceded by research attempting an economic interpretation of threshold theory. Concepts of marginal costs, fixed capital per inhabitant, and standards of town equipment were introduced and related to the problem of threshold overstepping. From these considerations a mathematical model was formulated for 'optimising', in the light of threshold indices, the distribution of population increase on the regional level. Though simplifications were necessary the model has proved its validity in practice. In addition to the methodological progress a new way of subdividing costs was presented in the study as another refinement of threshold approach.

### (c) Evaluation Outline

Basic benefits from the application of threshold analysis were gained by confirming the possibility of calculating economic efficiency parameters providing a basis for interdisciplinary 'dialogue' and for the feedback between planning levels; by making planners more aware of threshold phenomena and their significance; and by indicating new research avenues. Shortcomings such as ill-founded conclusions or unreliable cost indices, were caused by lack of a 'maturing period' for the method and shortage of experts to supervise its nationwide testing. The most sophisticated application, while not lacking in discrepancies, was that of the Warsaw Voivodship. Generally, threshold analysis initiated a breakthrough in the planning approach and stimulated further research both in Poland and abroad.

(a) NATIONWIDE TEST

Applied Process of Threshold Analysis

The development of the threshold theory followed a similar, though rather accelerated, path to most other theoretical concepts which have potential for practical application. The general outline of its theoretical formulations was presented by B. Malisz in 1961 and during 1962 multi-disciplinary discussions took place.<sup>(1)</sup> Simultaneously pilot studies were carried out in the Institute of Town Planning and Architecture and in some selected Town Planning Offices. As a result the theory was polished and refined. Soon afterwards it was decided that it might provide an excellent methodological basis for analysing the possibilities of town development - an operation to be undertaken on a broad national scale. The results were presented later at the previously mentioned Third National Review and Exhibition of Local Development Plans, sponsored by the Ministry of Construction.

The analyses were undertaken by Town Planning Offices<sup>(2)</sup> and were based on the method of threshold analysis, unified for the whole country. Simplification was one of the major characteristics of the method and although it reflected the basic formulations of threshold theory it naturally lost much of its subtlety and sophistication. This fact was often overlooked by later critics who, by pointing out the shortcomings of the results obtained, tried to draw conclusions to disqualify the theory itself.<sup>(3)</sup>

It therefore seems advisable to outline how this analysis (known as "Analysis of Town Development Possibilities" but for brevity now called threshold analysis) was carried out, following official instructions, in the six hundred selected towns throughout the country.

It became apparent that the analysis could not be undertaken for all the towns for lack of time. Town Planning Offices therefore as the first step had to eliminate a number of towns from the exercise. This general elimination included all towns with an apparently unfavourable location within the settlement system, towns lacking distinct functions, and those with poor natural conditions and/or lack of proper infrastructure since these kinds of conditions usually resulted in development stagnation without any serious prospects for radical changes in the future. The Regional Planning Offices in each province involved were also consulted as regards the elimination of towns for analysis and after agreement was reached the following sequence of work was commonly applied to the finally selected "growth towns":

1. Definition of the area to be analysed, based in most cases on the maximum time-distance from the city centre thought to be acceptable for daily commuting.
2. Physical analysis leading towards the definition of areas most suitable for urban development carried out with the aim of finding out:
  - a) the availability of land for urban development from the viewpoint of its natural characteristics, by defining areas directly suitable and those which would require substantial improvement before becoming suitable for building purposes
  - b) the possibilities of changing existing land uses by analysing built-up areas in order to detect free pockets of buildable land and to define areas for adaptation, renovation or complete renewal.
  - c) possibilities of using and developing existing public utilities and roads by determining areas served by these networks together with areas into which they may be extended, and those areas which would require the construction of new main networks or works before becoming suitable for urban development.

3. Definition of threshold limitations within each of the three groups and their subdivision into:

- a) "physical" thresholds imposed by natural features, conditions for development of infrastructure and existing or determined land uses (such as committed development)
- b) "quantitative" thresholds imposed by the capacity of works, yield of sources and capabilities of transport networks
- c) "structural" thresholds imposed by the needs for changing existing uses.

4. Definition of threshold limitations to further urban development of any town involved, from the synthesis of previous results. It was generally accepted that the first threshold delimited areas served by existing infrastructure networks and that no more than two successive thresholds should be determined. Analysis of "quantitative" and "structural" thresholds was considered more complex and requiring specific studies; it was therefore indicated that these thresholds would be presented only in round figures (population, hectares) and later in costs.

5. Definition of urban growth potential (in numbers of population) within successive threshold limitations. To undertake this task it was necessary to eliminate all areas unsuitable for urban development and then to define those which according to the locational principles should be qualified for industrial purposes. The remaining areas represented land suitable for residential and ancillary uses. Its urban growth potential was then calculated by using average density standards based on the official figures.

6. Calculation of costs necessary to open successive areas for urban development, or in other words of costs necessary for overstepping successive threshold limitations. All other costs were eliminated from these calculations (e.g. those needed to improve existing standards or those not related to particular locations). The cost indices used for the exercise were based on a unified "catalogue of costs for local physical plans and towns and settlements" and in addition a specification of major items to be considered within particular groups of investments was provided.

7. Calculations of indices W1, W2 and W3 which were supposed to reflect various aspects of urban development cost for each particular town involved. The indices represented:

a) cost per one new inhabitant. 
$$W1 = \frac{A}{M_p}$$

b) cost per one hectare of land now suitable  
for development 
$$= W2 \frac{A}{p}$$

c) aggregated index of cost per one inhabitant 
$$= W3 = \frac{B}{M_m} + \frac{C}{M_p}$$

Where:

$M_p$  = number of new inhabitants

$M_m$  = number of all inhabitants in a town

B = the cost calculated for all inhabitants in a town

C = the cost calculated for new inhabitants

A = total cost equalling B + C

8. Joint comparative analysis of town development possibilities within each province involved.

### Shortcomings and Achievements

It would go well beyond the scope of this research to analyse here in detail all the problems faced by the planners during this comprehensive exercise. Some benefits certainly accrued from the first attempt at practical application of the quantitative planning method on such a broad scale, but shortcomings were bound to occur because of the simplification inherent in the official instructions. There is a wide bibliography on this subject and all that is relevant to the critical assessment of threshold theory and analysis will be included in the chapter dealing with this particular problem.

It is enough, here, to present a summary of the conclusions from this first general test of threshold analysis (based on the original one presented by B. Malisz in 1964<sup>(4)</sup>). The analyses revealed that the new method encountered a number of practical difficulties - notably the way in which successive threshold lines had been determined and the way in which threshold costs had been calculated, leading to the formulation of cost indices per one new inhabitant (W1) and for one average inhabitant (W3). It was also noted that the more precise the cost calculation, the higher the investment expenditures resulting from them. Some costs not of a threshold character were often brought into the calculations, thus raising the final per capita indices. It had therefore to be admitted that the results obtained did not allow for quantitative comparisons on the national, but on the regional level the information was thought sufficiently homogenous and comparable to be useful for regional planning purposes.

In spite of differences in the calculation of the costs involved in threshold overstepping, the whole material, as prepared by Town Planning Offices, was sufficiently unified by the method of approach for several general conclusions concerning development strategies to be formulated.

On the basis of the results of this analysis towns were compared for 'development efficiency', that is from the view-point of cost indices necessary for threshold overstepping (W1 and W2). Towns were then ranked according to their diminishing development efficiency. In some offices (e.g. the Warsaw Voivodship) the analysis of costs developed in a very interesting way since threshold costs were subdivided into (a) those which must be spent at once (so-called 'conditioning costs') and (b) those which must be spent successively while expanding urban development in a particular area. Threshold costs can be subdivided according to their character (that is, their cause) and the following have been distinguished: costs resulting from the adaptation of unfavourable natural conditions; costs resulting from the elimination or shifting of existing land users together with acquisition costs; and costs of various public utility networks necessary to open up particular areas.

Threshold costs calculated for various towns have differed substantially. On 'per one average inhabitant' as a basis they (W3) varied from below 2,000 zlotys<sup>(5)</sup> up to 20,000 zlotys or more. Thus it was relatively easy to assess whether the development of a particular town would be cheap or expensive. Accommodating new inhabitants in a town always involves expenditures connected with the preparation of building sites, and thus the factors making towns different from each other would be the costs of overcoming development thresholds - a necessity for the further growth of a town.

#### General Outcome

From the analysis of threshold costs the Town Planning Offices were able to divide the towns into the following categories:

- i) Towns where development has already been predetermined by economic decisions and in which thresholds, should they occur, would in any case have to be crossed.
- ii) Towns with low threshold costs, which for this reason should be recommended for further intensive development.
- iii) Towns with restricted development due to the nature of their difficulties, revealed by the analyses.
- iv) Towns with high per capita indices, at the same time showing no favourable indications for further development.

At the final stage the Voivodship Town Planning Offices were supposed to 'optimise' the distribution of population increase in their regions, taking into account the results of the threshold analysis. From the increase of urban population recommended for each Voivodship by the relevant regional Planning Offices it was first calculated which part of this increase would have to go into the 'not-developing' towns. The rate of growth for these towns was determined by calculating their natural increase which was then subtracted from the expected urban population increase, the distribution of which would then be the subject of further optimisation. Here again the most interesting results were seen in the Town Planning Office for the Warsaw Voivodship, and the method applied there will be described in more detail.

The Town Planning Offices were, however, fully aware that the analysis of development possibilities, although an important one, was only one of the parameters for decision-making. Other parameters established on a regional planning level might often determine the necessity to develop particular towns, even if this was not in accord with recommendations

from local (threshold) analyses. The essence of this method was then first that it produced measurable parameters which should never be overlooked in the process of decision-making.

This type of analysis done simultaneously with settlements in the whole Voivodship provided a valuable basis for critical assessment and review both of approved general plans for towns, and of directives deriving from economic planning. In particular, the economic planning authorities, being informed of the threshold limitations and threshold cost indices for the respective towns, were given an important indication for locating industry, particularly since the Town Planning Offices also devoted great attention to the conditions for industrial location. By means of especially elaborated tables the Regional Planning Offices were fully informed as to the size of areas suitable for industrial purposes in the respective towns and about the particular characteristics of those areas in the light of investment technology and production profit of various industries.

#### Implications for Urban Growth Strategies

More pragmatic conclusions evolved by Town Planning Offices as a result of analysing the towns' development possibilities can now be presented. In all the Polish provinces a substantial increase in the urban population was expected up to 1980, amounting to approximately eight million people. Thus the urban population would constitute about 40% of the total population in the less urbanised parts of the country, whereas in the more urbanised areas these figures might reach 80%.

Such intensive urbanisation processes and substantial increases in urban population makes the problem of the rational distribution of this increase critically important. Rational distribution means a distribution which creates the best possible environmental conditions for the population,

while at the same time remaining economically efficient.

In this context by "the best possible environmental conditions" it should be understood:

- a) the shortest possible commuting distance for the majority of the working population,
- b) the provision of flats with all modern conveniences,
- c) adequate shopping and cultural centres easily accessible to the total population;

and by "economically efficient possibilities of implementation"

- i) relatively low expenditure for accommodating each new inhabitant in a town,
- ii) intense use of urbanised land,
- iii) concentration of investments in order that they may be implemented in a cheaper and more efficient way.

The general plans for towns were, in consequence, supposed to consider the possibilities of minimising investment expenditures by 'optimising' distribution of the urban population as a result of local analyses. Completed analyses of development potential indicated all the Voivodship towns in which the possibilities of 'cheap' accommodation of new inhabitants were not exploited, and also showed that in a number of towns the increase of population to the level predetermined by economic directives would involve wasting substantial amounts of investment expenditure.

Taking into account other planning analyses and looking into the characteristics of threshold costs in the respective towns, the following general conclusions were developed:

1. In towns where development possibilities were pre-determined by economic decisions, the tendency should be to achieve population increase by the maximum use of job potential, regardless of the cost of accommodating

new inhabitants. The results of threshold analysis in these towns should thus be used for defining a more economically viable rate of development, that is for relating the development stages, with the periods indicated by the potential of respective areas within threshold lines.

2. In towns characterised by the lowest threshold cost per new inhabitant the tendency should be to locate new places of work and to expand the existing ones up to the population limits determined by threshold potential.

3. Some of the towns having potential to become service centres for the existing settlement network, should be developed in spite of their current lack of town generating factors and in spite of their high costs of expansion. This seems to be justified as leading to an appropriate structure of community facility centres.

4. The smallest towns, with undefined functions and with agriculture as the major employment, should be restricted in development because the high additional expenditure and the spread of investment would give a very poor return of capital. Towns in this category should become local service centres for an agricultural hinterland. Up to 1980 they may not be fully serviced by new public utility networks, assuming that their expansion would be strongly limited in scale.

5. Growth towns, i. e. towns where economic decisions have already been made and towns where per capita costs are minimal as a result of concentration on investment processes, should enable the best development of productive forces and the provision of the most adequate servicing centres. From calculations it appeared possible to allocate to these towns over 90% of the expected urban population increase up to 1980.

It was clear that it would be necessary to incur threshold cost in the selected towns as shown above. Without overcoming these thresholds, development would be limited by the scope of the existing infrastructure, which would be inadequate for the expected urbanisation processes. However, to overcome thresholds in towns selected through the proper analysis would be more economically efficient since it would allow more land within successive threshold lines to be obtained at relatively lower per capita expenditure. In addition, such a policy would allow for purposeful concentration of the urban investment processes, which of course would also increase the overall economic efficiency.

(b) ANALYSIS OF URBAN DEVELOPMENT POSSIBILITIES FOR  
THE WARSAW VOIVODSHIP <sup>(1)</sup>

As previously mentioned, the application of the threshold theory to the Warsaw Voivodship was particularly interesting and produced a number of new formulations both in theoretical and practical fields. It seems, therefore, the best to present all these findings as they were originally described by J. Regulski and S. Wyganowski in their paper on 'Economic Interpretations of the Threshold Theory' published in 1965. The paper starts with an introductory section where an outline of the theory is presented and then the authors proceed further into the theoretical and practical development of the theory as follows.

Economic Interpretation of Threshold Theory <sup>(2)</sup>

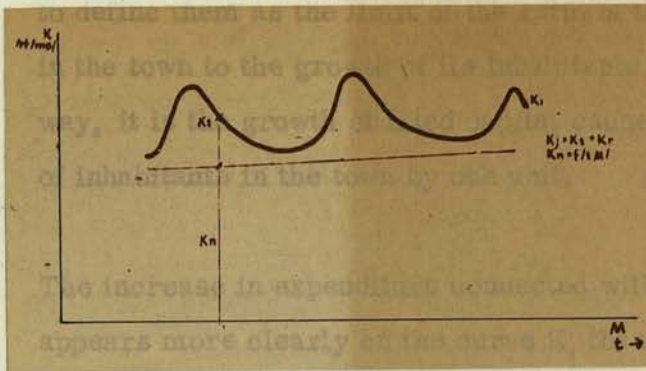
Analysing costs involved with the allocation of one inhabitant in a town ( $K_j$ ), one can subdivide them into two parts:

- (a) costs independent of the specific location of constructions needed for the allocation of inhabitants ( $K_n$ )
- (b) costs strictly dependent upon the existing conditions of the specific location ( $K_A$ ).

$$\text{Total Costs } K_j = K_n + K_A$$

This subdivision is fundamental to the analysis of the shape of the curve  $K$  which illustrates (Diagram 1) the behaviour of unit costs per inhabitant as the town grows in size. This has an undulating shape to which B. Malisz directed attention in his work "The Economics of Town Planning". If both constituent parts of  $K$  are analysed, it will occur that  $K_n = f(tM)$ ;  $K_n$  is thus a function of the time and of the number of inhabitants in the town. This is a linear function and increases in proportion to the growth of the standard of equipment of the town. On the other hand costs,  $K_t$ , influence the undulating shape of the curve  $K_j$ ;

Diagram 1



$K_t$  is a function both of the numbers of population ( $M$ ) and land conditions in a particular town:

$$K_t = f(M, T)$$

The necessity of overcoming the definite threshold in the development of this town causes rapid growth of the costs  $K_t$ . When this threshold is crossed, costs  $K_t$  decline rapidly over the next period. These phenomena are illustrated in Diagram 1.

The outlays for municipal investments increase the value of the fixed capital of the town. If, for simplification, the problem of amortisation is omitted it can be seen that the value of fixed capital (according to the replacement value) will be as follows:

$$Z_p + \int_0^M K_j dM$$

where  $Z_p$  = value of the fixed capital, measured according to the initial value

$K_j$  = unit costs

$M$  = number of inhabitants

The curve  $Z_p$  has been evolved by integration of the function  $K_j$  (Diagram 2).

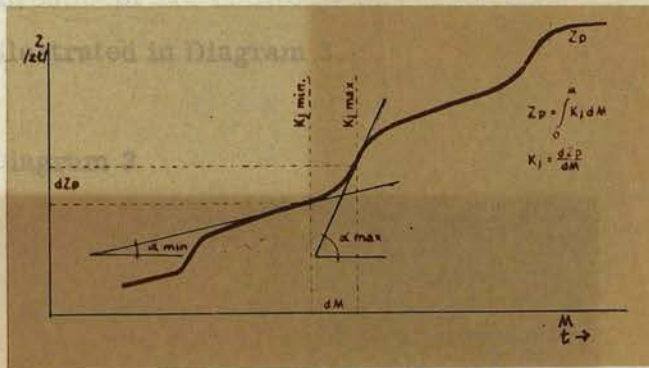
Thus it is possible to say that the costs  $K_j$  are the first derivative of the function  $Z_p$ , that is:

$$K_j = \frac{dZ_p}{dM}$$

Unit costs are, therefore, a marginal cost of investment; it is possible to define them as the limit of the ratio of the growth of fixed capital in the town to the growth of its inhabitants. Formulating this another way, it is the growth of fixed capital caused by the growth of the number of inhabitants in the town by one unit.

The increase in expenditure connected with overcoming thresholds appears more clearly on the curve  $K_j$  than on the curve  $Z_p$  because the curve of marginal costs shows every deviation from expenditure which is proportional to the growth of population.

Diagram 2



Unit cost  $K_j = \frac{dZ_p}{dM}$  is measurable by tangents of an angle  $\alpha$  which is made by the tangent to the curve in a given point with the axis of  $x$ . A characteristic point is when tangent  $\alpha$  reaches the extreme values. As can be seen from Diagram 2, those values appear at the points of the bends of the curve  $Z_p$ . These points determine the magnitude of a town at which minimal or maximal values of unit costs for a new inhabitant exist.

It seems appropriate to introduce the notion of the average value of investment ( $Z_s$ ) for one inhabitant, that is:

$$Z_s = \frac{Z_p}{M}$$

which may be treated as a synthetic index revealing the standard of the

town equipment. The greater the value of fixed capital per inhabitant, the better the living standards in the town, which depend, among other factors, on a widely understood standard of equipment. To study the interdependence between  $K_j$  and  $Z_s$ , (meaning capital equipment) is therefore particularly interesting:

$$Z_s = Sw = \frac{Z_p}{M}$$

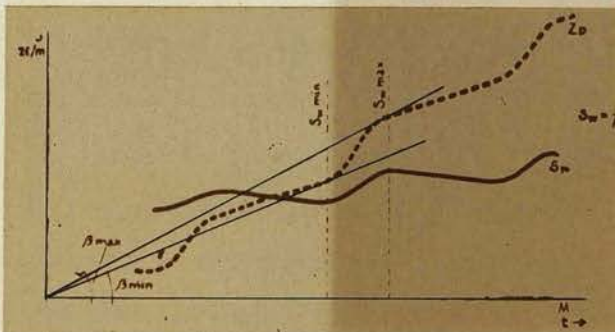
where  $Sw$  = standard of town equipment

$Z_p$  = value of investment

$M$  = number of inhabitants

since for simplification the problems of amortisation and liquidation of investment are omitted, the curve of the standard ( $Sw$ ) will take shape as illustrated in Diagram 3.

Diagram 3

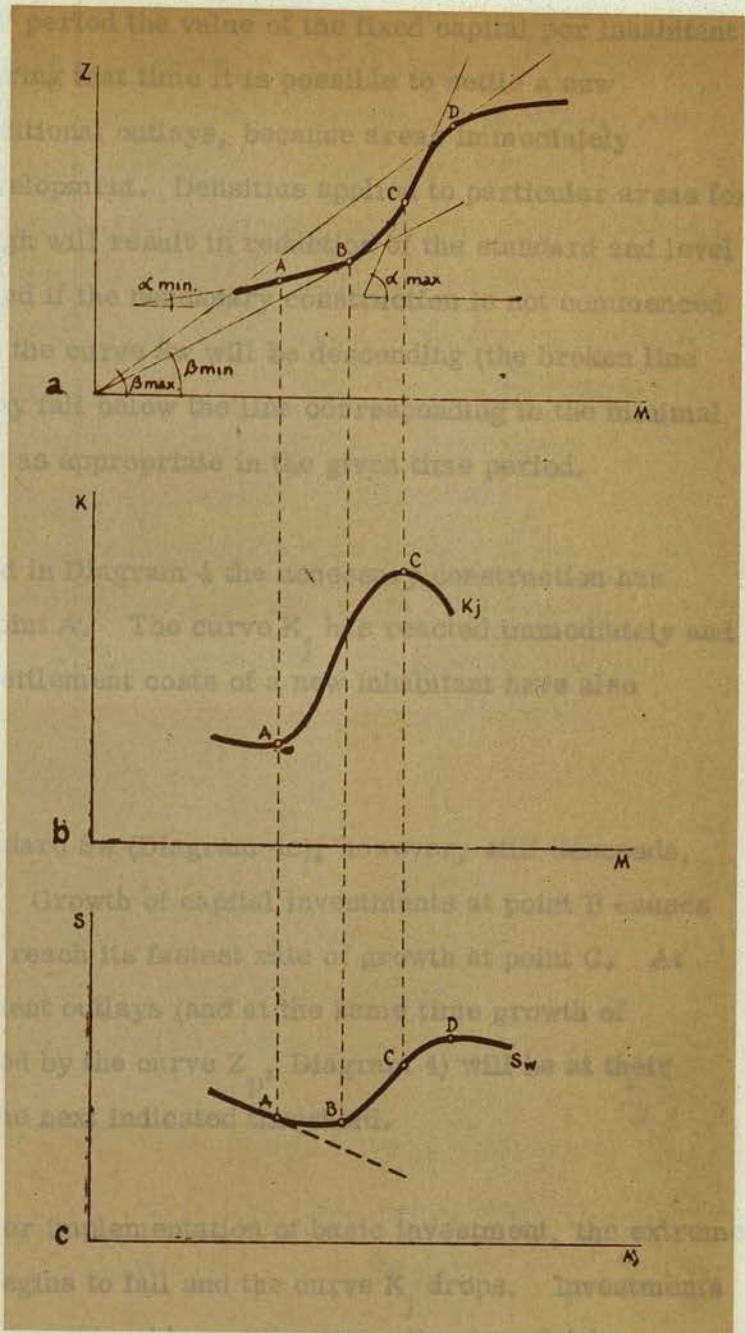


The value  $Sw$  is measured by the tangent  $\beta$  which is made by the line linking a given point of the curve  $Z_p$  with the beginning of the system of co-ordinates, with the axis of  $X$ , since,

$$Tg = \frac{Z_p}{M} = Sw$$

The extreme values of the tangents of angle  $\beta$  appear at the points at which those straight lines are tangential to the curve  $Z_p$ . At those points, the standard of town equipment will also be reaching its minimum and maximum. The problems which will occur with the development of the town in the period of threshold overcoming (Diagram 4) can now be analysed.

Diagram 4



It is when the town is approaching the threshold line that investments have to be made to make available the land beyond that line, and as the period of construction lasts some time the implementation should start before the area is required for settlement of incoming inhabitants.

In the 'pre-threshold' period the value of the fixed capital per inhabitant ( $Sw$ ) decreases. During that time it is possible to settle a new inhabitant without additional outlays, because areas immediately suitable exist for development. Densities applied to particular areas for which they are too high will result in reduction of the standard and level of living conditions and if the necessary construction is not commenced at a suitable moment the curve  $Sw$  will be descending (the broken line in Diagram 4) and may fall below the line corresponding to the minimal standards recognised as appropriate in the given time period.

In the case illustrated in Diagram 4 the necessary construction has been undertaken at point A. The curve  $K_j$  has reacted immediately and rises (Diagram 4b) since settlement costs of a new inhabitant have also increased.

The curve of the standard  $Sw$  (Diagram 4c), however, still descends, but at a slower rate. Growth of capital investments at point B causes the value increase to reach its fastest rate of growth at point C. At this point the investment outlays (and at the same time growth of constructions indicated by the curve  $Z_p$ , Diagram 4) will be at their greatest and this is the next indicated threshold.

At the next stage, after implementation of basic investment, the extreme costs of investment begins to fall and the curve  $K_j$  drops. Investments are at this stage still considerable and the curve  $Z_p$  rises fairly steeply to point D, where the curve  $Sw$  reaches its maximum. This means that sizeable reserves have been created and that they may be used for relatively cheap settlement of further inhabitants. The curve  $Sw$  will vary according to the growth of these reserves.

The curve Sw illustrates the standard of equipment, so at the same time it indicates the level of living conditions. The question of whether the living conditions will be bettered after overcoming the threshold, when Sw reaches its maximum now arises; it is clear that outlays for construction in the town will advantageously influence these conditions, but this growth will be disproportionally smaller than the outlays involved. Certain alterations in the structure of the fixed capital invested in the town may now take place, caused by the fact that the purpose of investments connected with crossing a threshold is to overcome definite limitations indicated by this threshold. On the other hand, the line Sw may reflect the living conditions only in the case of preservation, a particular inward structure of the fixed capital of the town. Thus whilst analysing the standards of the town equipment it is necessary to study not only the general value of investment but the structure of that investment as well.

The phenomenon of substitution, meaning the replacement of investments designated for particular needs by other investments, appears in the economy of the town in a limited way. This problem would however require separate research studies and is not dealt with here.

The problem of losses of fixed capital must next be considered. Decreases of fixed capital, apart from devaluation, arise either from amortisation, i.e. a slow consuming of original value, or from liquidation of unamortised objects due to town planning indications, and can be symbolised thus:

$W'$  = decrease in the value of the fixed capital

$W_a$  = decrease by amortisation

$W_u$  = decrease due to town planning indications.

The decrease  $W_a$  arises from a slow consuming of particular objects in the form of annual deductions, amounting to the constant part of the original value for a given type of objects. Thus  $W_a$  is a function of the time and of the initial value, i.e.:

$$W_a = f(Z_{pt})$$

On the other hand the decrease  $W_u$  is not a function of the time, but emerges from the growth of a town and is connected with necessary changes in the way of using the land. Thus  $W_u$  is dependent on the development of the town, which may be expressed by growth of the number of inhabitants. The size of this decrease depends on existing investment, its physical location, method of use, technical and economic value, etc.; and it must be emphasised that physical elements play their part as well as the kind and value of the investment in the economic sense.

The considerations so far developed aim at economic interpretation of the threshold theory. The task which the authors set themselves also requires the preparation of information systems which would help decision-makers in the field of regional population increase. Added to the parameters deriving from regional investigations are additional criteria resulting from threshold analysis: it seems that transmittal of information by description or cartography does not solve the problem and these additional criteria mentioned above could be costs of the settlement of inhabitants in a particular town. The concept of dislocation of the population apparently should not and cannot be formulated by this criterion only. There are many other factors influencing decision-making in this field, which create the 'boundary' conditions, limiting the area of admissible solutions.

The practical solution of this task necessitated the introduction of many additional simplifications. Definition of the curves of the investment and the curves of final costs for particular towns meet a number of difficulties which result from the following causes:

1. The lack of information to enable definition of the value of existing investment in these towns. The material of the Common Inventory of the fixed capital was useless, because these were made in branch sections.
2. The methodological principles of how to formulate the amortisation deductions have not so far been worked out.
3. The lack of research into the mutual dependence between the period of investment of outlays and the period of receiving the effects in the form of making a particular piece of land available for development.

Two types of investment may be distinguished here: the first must be executed before starting to use a particular piece of land, the second may be realised successively according to the preceding development. Quantification of the outlays on either of these groups would require further research.

Considering these difficulties, the values of existing investment as well as that part of the unit costs ( $K_j$ ) which might be recognised as proportional to the growth of inhabitants ( $K_n$ ) have been ignored and only costs connected with local conditions studied.

The advantage of this method is that elements which at this stage are insoluble can be left aside. Moreover this method is connected with the analysis of development possibilities being made on the scale of the whole country, which makes it easier to obtain numerical data. The disadvantage of this method is, however, the elimination of possibilities of applying standard indices and the possibility of operating with only part of the investment outlays which may lead to mistakes at decision-making.

The costs connected with local conditions (Kt) can be subdivided into four groups and consist of:

- a) costs of making the land suitable for building purposes (meliorations, increased costs of foundations, etc).
- b) costs of communication investments connected with crossing the threshold (town communications, main roads, bridges, etc).
- c) costs of public utility networks: water supply, purification stations (trunk collectors).
- d) values of liquidated fixed capital (demolition, reimbursing, etc).

Independent of restrictions to the scope of the analysis are two further simplifications which were introduced to facilitate not only the mathematical formulation of the model, but also its practical solution.

#### The optimisation of population distribution on a regional level

The general considerations introduced in the preceding chapters illustrated the essence of the problem and mathematical formulation of the model must now be set out together with proposals to use the analysis of town development possibilities for optimal location of population increase on the regional level. The latter was particularly emphasised and the Warsaw Voivodship was used as a test case. In the concept of population distribution among the towns of the voivodship the following limitations were considered for the size of the towns recognised as growth points:

The number of future inhabitants cannot be lower than (a) the number of inhabitants resulting from the present development trends of a town and (b) the number of inhabitants connected with economic decisions regarding the development of industry which have already been taken; and cannot be higher than (c) the number of inhabitants for whom, in relation to the organisation and productive potential of construction industries, it would be

possible to ensure a certain standard of living conditions, and (d) the growth capacity of land within the development threshold (which cannot be crossed in the time involved for economic and technical reasons).

The limitations mentioned provide the basis for definition, in every concrete case of measurable magnitude which it is possible to consider as boundary conditions to the set of admissible decisions.

The task has been formulated as follows:

TO FIND FOR RESPECTIVE TOWNS AND SUCCESSIVE TIME-PERIODS THE GROWTH OF INHABITANTS X WHICH WOULD ALLOW THE SUM OF COSTS K TO REACH MINIMUM.

1)

$$K = k_1^1 x_1^1 + k_1^2 x_1^2 + \dots + k_1^m x_1^m + k_2^1 k_2^1 +$$

$$+ k_2^2 x_2^2 + \dots + k_2^m x_2^m + \dots + k_n^1 x_n^1 +$$

$$k_n^2 x_n^2 + \dots + k_n^m x_n^m$$

maintaining the following conditions:

(2)

$$x_1^1 + x_2^1 + \dots + x_n^1 = A^1$$

$$x_1^2 + x_2^2 + \dots + x_n^2 = A^2$$

$$x_1^3 + x_2^3 + \dots + x_n^3 = A^3$$

.....

$$x_1^m + x_2^m + \dots + x_n^m = A^m$$

(3)

$x_1^1$	$\geq B_1^1$
$x_1^1$	$\leq C_1^1$
$x_1^2$	$\geq B_1^2$
$x_1^2$	$\leq C_1^2$
$x_1^3$	$\geq B_1^3$
$x_1^3$	$\leq C_1^3$
$x_2^1$	$\geq B_2^1$
$x_2^1$	$\leq C_2^1$
$x_2^2$	$\geq B_2^2$
$x_2^2$	$\leq C_2^2$
$x_2^3$	$\geq B_2^3$
$x_2^3$	$\leq C_2^3$
.....	.....
.....	.....
$x_n^1$	$\geq B_n^1$
$x_n^1$	$\leq C_n^1$
$x_n^2$	$\geq B_n^2$
$x_n^2$	$\leq C_n^2$
$x_n^3$	$\geq B_n^3$
$x_n^3$	$\leq C_n^3$
.....	.....



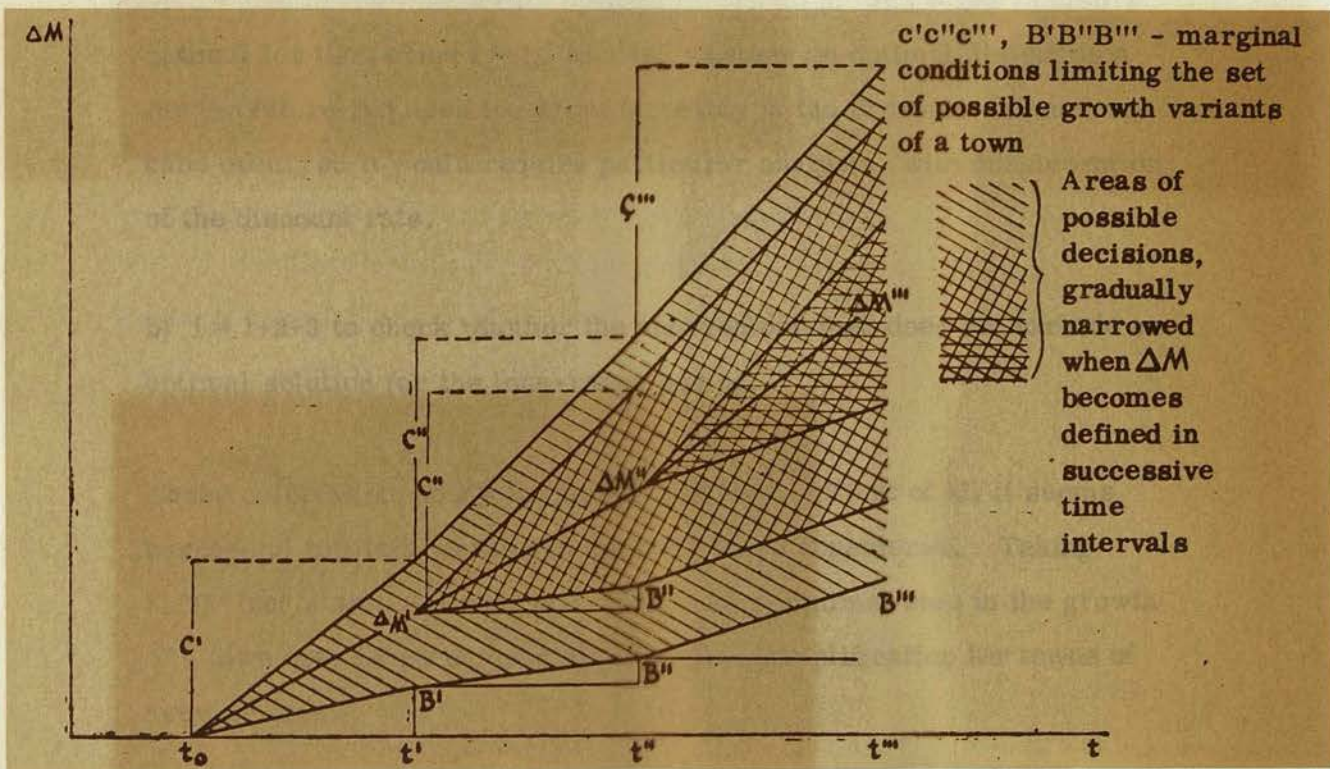
to be distributed.

Relations (3) protect against crossing of admissible magnitudes of the growth in individual towns.

Condition (4) rejects the possibility of decrease in an individual town.

The essential element here is the dynamic character of the towns' development. It is not enough to optimise a dislocation of the population in only one section of time; every decision is a starting point to the next period, and narrows the field of possible solutions (see Diagram 5).

Diagram 5



It may happen that in this way the possibility of effective solutions for long-range periods will be eliminated, and it is necessary to look into the next period to find whether intended decisions would not eliminate an optimal

solution for this period. Thus besides the analysis concerning the perspective, i.e. 20-year period, the population distribution in the several successive periods of the time must be defined.

At present it is possible to take the three following periods  $i$  :

First period 1965-1970

Second period 1971-1980

Third period 1981-1990

As the basic criterion it would be necessary to take the minimisation of the costs for the period  $i = 1+2$ , that is 1965-1980, and to check it through calculations for the purpose of:

- a)  $i = 1$  to check whether an optimal distribution for  $i = 1+2$  is also optimal for the period  $i = 1$ ; that is, whether an optimal distribution for the future requires too great an outlay in the present. If such a case occurred it would require particular analysis, with consideration of the discount rate.
- b)  $i = 1+2+3$  to check whether the solution obtained does not exclude an optimal solution for the long-range period.

These calculations allow for simplifications. First of all it seems purposeful to limit quantity in the town sizes considered. Taking 5,000 inhabitants (the unit of a 'jump') as a minimal step in the growth of a town may be recognised as a justified simplification for towns of average size.

It also seems to be justified to introduce simplification of the curve of the investment outlays ( $Z$ ) to a broken curve consisting of several straight segments. The diagram shown in Chapter 1 in a general form will then take the form shown in Diagram 6 because only growths of the population which are in multiples of 5,000 are considered.



An example of presenting the task after implementing these simplifications would be as follows:

The boundary condition of the value  $x$ :

$$B_j^i \leq x_j^i \leq C_j^i$$

$$\sum_{j=1}^n x_j^i = A^i$$

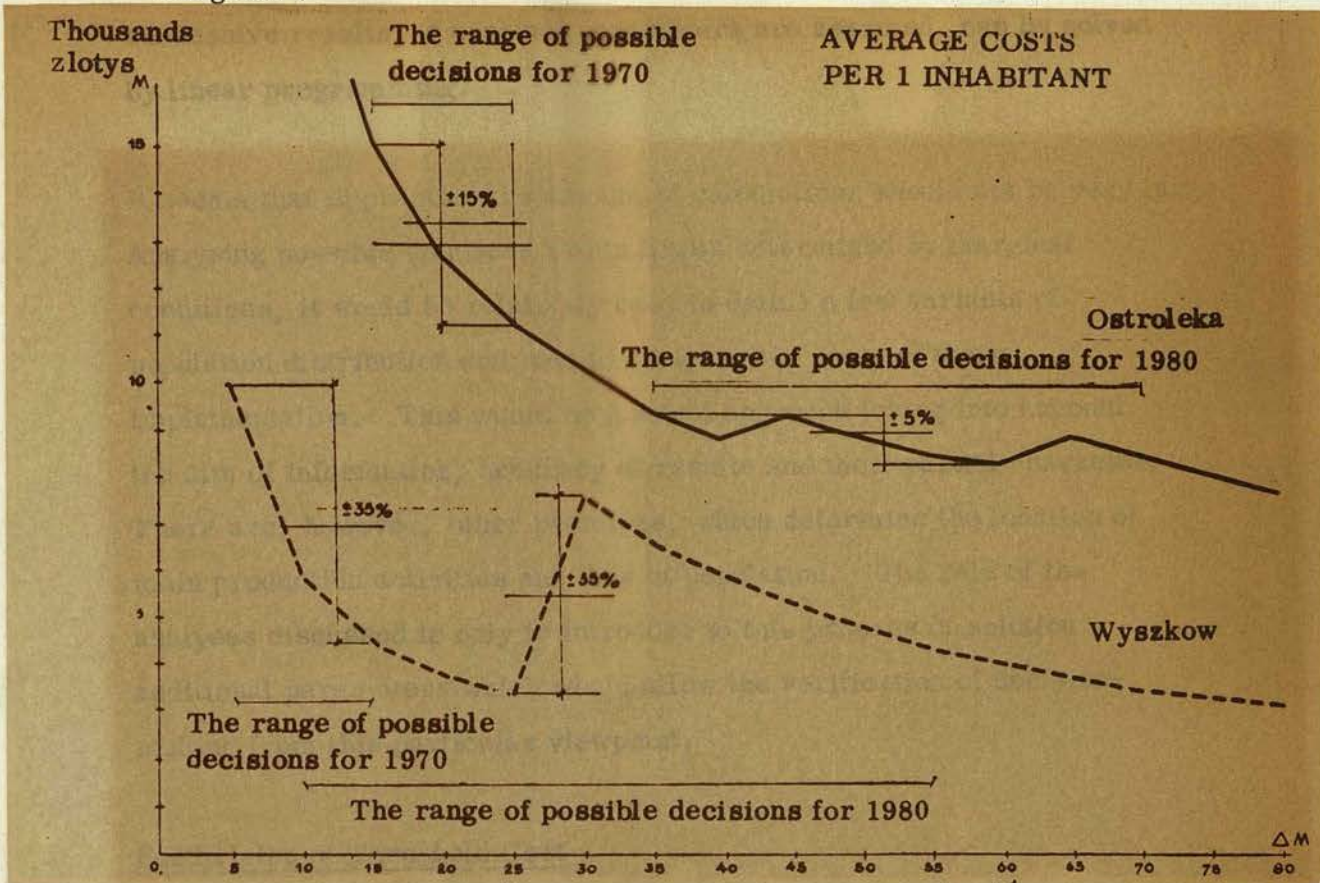
The fact that mutability of coefficients depends on the magnitudes of decision variables makes the solution difficult. The unit cost  $K_j$  is the function of the number of inhabitants in the town; it is thus a case of a feed-back phenomenon. The optimal magnitude of decision variables depends on coefficients, whose magnitudes are a function of decision variables.

The application of linear programming requires invariable parameters. It is therefore necessary to define the magnitude  $K$  for particular intervals.

Taking the towns Ostroleka and Wyskow as examples, the mutability of average costs per 1 inhabitant is shown in Diagram 7 as a function of the growth of population, and the range of possible decisions for respective periods is also shown.

From the diagram it is clear that taking the average cost for the whole interval in the case of Ostroleka may result in a mistake of +15% for 1970, and a mistake of +5% for 1980, which are quite admissible mistakes in a first approximation. In the case of Wyszow, however, these mistakes would be about 40%. Thus it is necessary to consider two variants from each of these periods; for example for 1980 it would be necessary to take:

Diagram 7



the first variant:  $B^2 = 10,000 \text{ M}$   
 $C^2 = 25,000 \text{ M}$   
 $B^2 \times C^2$   
 $K^2 = \text{nearly } 4,000 - 5,000 \text{ zlotys per inhabitant}$

Possible mistake up to 22%

the second variant:  $B^2 = 30,000 \text{ M}$   
 $C^2 = 55,000 \text{ M}$   
 $B^2 \times C^2$   
 $K^2 = \text{nearly } 8,000 \text{ zlotys per inhabitant}$

Possible mistake up to 20%

Application of the iteration methods can be considered, or each of the successive results, if constant parameters are assumed, can be solved by linear programming.

It seems that in practice the amount of calculations should not be very large. Analysing possible solutions within limits determined by marginal conditions, it would be relatively easy to define a few variants of population distribution and then to compare the costs of their implementation. This would be a sound approach taking into account the aim of information, accuracy of results and their partial character. There are, however, other premises, which determine the location of main production activities and thus of population. The role of the analyses discussed is only to introduce to this process of solution additional parameters which would allow the verification of decision-making from this particular viewpoint.

#### Subdivision of Threshold Cost

In addition to the interesting refinements and developments of the threshold analysis as presented above by S. Wyganowski and J. Regulski, an important step was taken in the same study concerning the subdivision of threshold costs into two categories:<sup>(3)</sup>

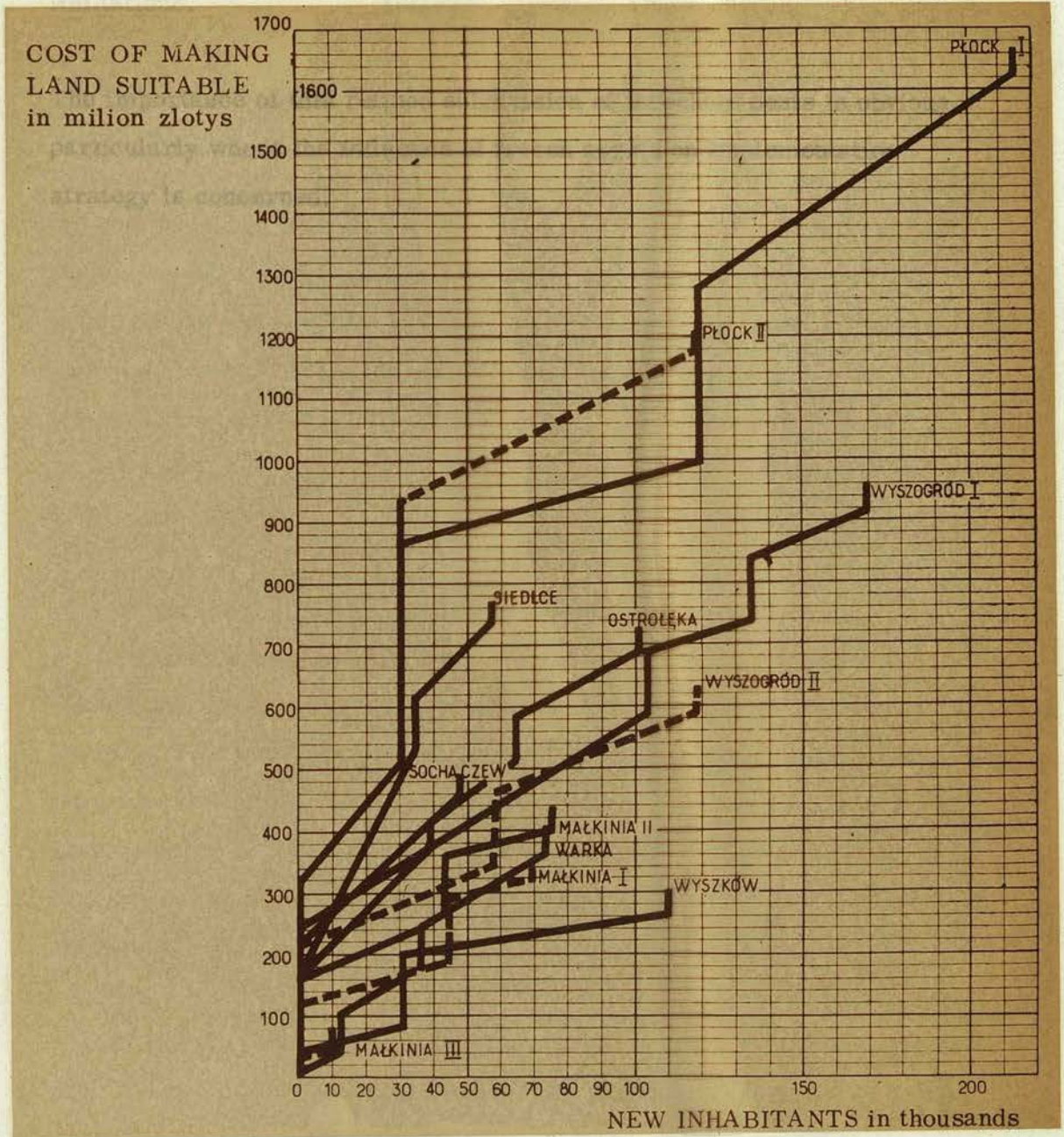
(i) investment costs W which must be spent in the first phase of implementation since they condition the possibilities of allocating new inhabitants (e.g. costs involved in constructing roads, public utility networks, etc.).

(ii) investment costs S which can be spent successively during the implementation process (e.g. increased costs of foundations, etc.).

This subdivision allowed the verification and diagrammatic comparison of development efficiency among various towns and its presentation in a new

and more sophisticated form, which is shown in Diagram 8.

Diagram 8



In this diagram new inhabitants have been put on the x axis and costs (additional costs) needed to open new areas for urban development on the y axis. Point O represents the existing situation. Investment costs W have been indicated vertically at points where new land must be opened up in order

to accommodate new inhabitants in a given town, and investment costs S have been spread over the number of inhabitants which could be allocated within the respective areas delimited by successive threshold limitations.

The importance of this refined subdivision of threshold costs is obvious, particularly where the influence of frozen assets on implementation strategy is concerned.

(c) EVALUATION OUTLINE

Even a tentative evaluation of the nationwide practical application of a new method, which had insufficient time to mature, must bring up the basic question as to how far hopes and expectations connected with its development were fulfilled in this broad life test.

In answering this one should start from positive achievements, discounting the shortcomings bound to emerge from such an ambitious exercise. No doubts were left, however, that a tool offering a new approach to urban design and decision-making processes had been invented, and that this tool, if properly developed, would bring a breakthrough in the traditional methods used in urban planning. It seems that from various benefits gained in this first application of the Threshold Theory the three basic ones were:

(i) Confirmation of the possibility of providing and of calculating for practical use some of the economic efficiency parameters (so far almost entirely ignored) concerning urban development processes and deriving from local physical analyses of towns and settlements. Thus the common platform for interdisciplinary dialogue between economists and town planners was formed. In addition threshold analysis made it possible to set in motion a feedback process between the local and regional planning levels.

(ii) Creation of the awareness among a great number of professional staff involved in statutory planning of threshold phenomena, and, in consequence, of the meaning which ought to be attached to certain investment cost indices as essential elements in the designing process.

(iii) Indication of the starting point for further research towards the evolution of new ways of thinking in physical planning methodology and practice.

Shortcomings were numerous and were later discussed and analysed both by B. Malisz and by other authors. The main criticism focussed on the viability of cost calculations and on some general conclusions which were drawn from aggregated results of the analysis.

It is important to raise at this moment one basic objection which seems to be one of the general causes of the main practical failures. The point is that this broad national test for a relatively new method followed the formulation of its background theory too closely in time. There was virtually no maturing period involving a series of pilot studies leading step by step towards verifications and refinements of the basic and detailed aspects of the analytical process proposed for practical application.<sup>(1)</sup>

A few seminars organised at the beginning of the project did not fully overcome the other essential problem, one which is always associated with new tools: the lack of experts able properly to supervise the analyses of more than 500 towns. It was therefore found necessary to prepare a standard instruction manual, which established the main framework of the proceedings. The manual had to be as short and simple as possible and at the same time was supposed to cope with all possible difficulties likely to be faced in a practical test. Some of these difficulties were expected but the author could not possibly foresee all; hence the manual was in parts not only simplified but oversimplified, and some of the results obtained were much less reliable than they should have been from the viewpoint of convincing and well-constructed theoretical formulations. Different elements were considered in various towns as generating threshold costs and the way the main indices were calculated was far from unified in spite of a considerable effort made to meet this danger in the manual's instructions.<sup>(2)</sup>

Inexperienced planners in remote towns having only a vague idea of the whole threshold concept had to answer complicated questions of what to include as threshold costs; as a result large towns with much better prepared background data and more experts available to carry out all the specialist studies necessary produced a comprehensive type of analysis and revealed relatively high cost indices while in small towns the approach was made in a more superficial way and indices in consequence lower.<sup>(3)</sup> Comparisons might thus have led to false conclusions, for instance the attempt to formulate a "law of towns' efficiency" according to which large towns were supposed, as a rule, to be more expensive for development than medium sized towns.

This statement, hastily and categorically imposed, generated violent discussion and criticism, particularly from economists. J. Kolipinski argued<sup>(4)</sup> that development cost indices of large and medium sized towns would have more facilities serving their hinterlands and resulting in entirely different and much higher living standards. S. Wyganowski criticised<sup>(5)</sup> the way in which indices were calculated, pointing out that "the faster the rate of growth the lower the indices would be: hence the lowest indices were derived in medium sized towns because for these towns the fastest rate of growth was anticipated" and not because they are implicitly cheaper per se.

While agreeing with most of these arguments it must be noted that conclusions concerning threshold theory were incorrectly formulated because they assumed that the very concept of the theory led to unreliable results, whereas only the simplified and somewhat immature method of threshold analysis interpreted without necessary caution was the cause of most of these deficiencies. It has also been forgotten that threshold analysis was never supposed to become a tool for the development of theoretical rules relating cost indices with the size of towns.

The main lesson deriving from this application for any future attempts on a similar scale leads to a simple conclusion; either such an analysis must be preceded by a series of test studies allowing for the preparation of a very reliable foolproof manual, or its results must be very severely verified before any implications are fed back to the planning process and above all to the decision-makers.<sup>(6)</sup>

All this seems obvious today, but of course it is easy to see mistakes years after they have been made. Another potential danger inherent in the clarity and attractiveness of the threshold concept is worth mentioning: some planners were so fascinated by this new approach, its logic and obvious merits, that they wanted to see in it a kind of panaceum for all planning problems which would replace all other methods and techniques. Needless to say, the threshold theory never claimed to be a complete theory of planning, which was strongly emphasised later by B. Malisz<sup>(7)</sup> and by other authors<sup>(8)</sup>.

The most sophisticated of all threshold studies in Poland was beyond doubt that carried out in the Warsaw Voivodship. It clearly revealed the latent potential inherent in the threshold theory both in the field of theoretical development and in its practical application, and particularly promising seems to be the attempts to widen the scope of the background theory. Consideration of the curve  $K_a$  (representing additional investment costs) moves to the curve  $Z_p$  (indicating the value of fixed capital in a given town) and successively to the notion of the average value of investment for one inhabitant  $Z_s$  which, as the authors claim, may possibly be treated as a synthetic index revealing the standard of the town equipment. This would be a very stimulating concept although doubts arise when the way in which  $Z_p$  and  $Z_s$  are obtained is considered. To integrate the function  $K_j$  will lead to serious double counting since the curve does not in fact represent unit cost, as some authors imply. At each point  $t$  on the  $x$  axis

the corresponding value can be found on the y axis from the curve Kj. This is, however, only the average unit cost up to that point t. If the reading is done successively for t, the pure unit cost at t will not be the same and for this simple reason the curve Kj cannot be integrated. This is not the place to go into more detailed mathematical criticism which does not affect the importance of relations between investment costs and standards of the town equipment which have been pointed out by these authors, although the indices presented seem logically to be more valid in the case of new towns than in the case of already developed towns having a complicated existing urban structure. It cannot be denied, however, that the problem is a crucial one and requires further serious consideration.

Even more revealing and stimulating was the attempted optimisation of population distribution on a regional level, based on parameters provided by the threshold analysis and carried out through the set of mathematical equations. Thus it has been shown that the further development of threshold analysis allows the introduction of computers and, in consequence, the substantial increase of data and variants to be handled.<sup>(9)</sup> This first attempt to minimise the investment cost through optimising the population distribution on a regional level was a very successful exercise indicating the latent development potential of the threshold theory, and led to the tackling in a similar sophisticated way of the problem of optimising the sequence in which various thresholds should be overcome in the light of implications deriving from different categories of threshold costs and in relation to alternative urban development strategies.

To summarise briefly, it can be said that this exercise, unprecedented in scale, aimed towards a widespread introduction of a new progressive method into the overall planning machinery, and did succeed in initiating a breakthrough of the traditional approach. In addition it generated follow-up and new research carried out later both in Poland and abroad.

This world wide interest in threshold theory and analysis is worth emphasising. It has now been applied to the Moscow region and in Yugoslavia for a United Nations sponsored project for the South Adriatic region.<sup>(10)</sup> Its introduction and development in Scotland will to a great extent be discussed in this work. From other cases one could select the application of threshold analysis to the Montreal region,<sup>(11)</sup> attempts at its mathematical interpretation in India,<sup>(12)</sup> its practical testing in Uganda,<sup>(13)</sup> research study undertaken at Chicago University,<sup>(14)</sup> and, finally, interest in its further development expressed by numerous institutions and scientific bodies in Europe and America.<sup>(15)</sup>

Shortcomings and deficiencies of threshold analysis were also revealed though their relatively large number was much more due to the haste in which the whole exercise was undertaken than to the theoretical discrepancies of the basic concept. In any case they did not affect or invalidate the theory itself since most of them appeared to be overcome or at least lessened through further research and practical testing.

## 2. TESTING AND DEVELOPMENT OF THE THRESHOLD THEORY IN SCOTLAND

### (a) Grangemouth/Falkirk Sub-Regional Plan

The Sub-Regional Plan and threshold analysis - natural growth potential - main aims of threshold analysis - simplified economic assessment - general implications

Strong arguments point to the need for recognition of sub-regional planning as an additional rung in the planning ladder. Rationalisation of the methodology is essential. The search for optimised techniques in the Grangemouth/Falkirk study indicated the potential of threshold analysis and it was applied here for the first time in the context of the sub-region in the conditions of a free market economy. The simplified form of the analysis, based initially on direct survey and natural growth potential studies, concentrated on examining natural features, infrastructures and built-up areas to define thresholds and to calculate urban growth potential. Crude economic assessment followed in which the cost of overstepping each threshold was estimated. The analysis thus provided an objective basis for choice, for programming and for definition of long-term growth possibilities.

### (b) Central Borders - A Plan for Expansion

Threshold analysis and the Central Borders study - physical aspects - financial aspects - general implications

Growth in the Central Borders, a sub-region facing economic stagnancy, was to be generated by the introduction of 25,000 new inhabitants by 1980. The planners' task was to advise on their optimised distribution and threshold analysis was used in this exercise. Its physical approach resulted in the definition of various thresholds and their categorisation according to their significance. Intangible values were also considered and an amenity threshold identified. Financial assessment led to a crude evaluation of development efficiency for the towns of the sub-region. Results from the analysis and from studies of other important planning factors helped in the formulation of recommendations concerning urban strategies, population distribution, the sequence of implementation and long-term policies.

### (c) Evaluation Outline

Conclusions from the Polish experience enabled the application of threshold analysis in Scotland to be prudently undertaken. The physical side of the analysis was expanded and better adapted to local conditions, while economic aspects were approached more tentatively. The process was fully elaborated in the Grangemouth/Falkirk study, although the Central Borders study seemed to contribute more to the threshold theory. Both studies generated further theoretical development of the method and facilitated the listing of its 'pros' and 'cons' which revealed that the latter, in most cases, could be overcome by research.

(a) GRANGEMOUTH/FALKIRK SUB-REGIONAL PLAN

The first practical application of threshold analysis in Britain was introduced by the author in the Grangemouth/Falkirk area study commissioned by the Secretary of State for Scotland in 1965 and undertaken by the Planning Research Unit of Edinburgh University.<sup>(1)</sup> The analysis was thought to be particularly useful in this study<sup>(2)</sup> since it was mainly concerned with the determination of urban areas suitable for expansion. After definition of the main principles, aims and character of the Grangemouth/Falkirk Plan itself the practical application of threshold theory can be discussed and its contribution to research towards refinements of planning methods and rationalisation of decision making assessed. The essence of 'rationality' lies in the objective comparison of various development hypotheses for a single town, for a region or for various directions of broader urban policy on a national level. This comparison can be considered as one of the main tools for controlling and steering all development processes and the application of threshold theory seems to be particularly useful here.

The Sub-Regional Plan and Threshold Analysis

It is well known that regional planning means highly complex planning. It involves intricate economic analyses which often make it very difficult to devise concise and unequivocal recommendations for development strategies. In addition, the area of a 'region' is usually so widely extended that it is hardly possible to tackle its compound problems in such a comprehensive way as to counteract in time its spontaneous urban growth processes. The lack of legislative power and formally organised regional planning machinery covering the whole country considerably worsens the situation. Thus the recognition of 'sub-regional planning' as an additional rung in the planning ladder is indicated and can be supported by a number of arguments.

A sub-regional plan would be of particular relevance for areas not covered by any form of regional planning; it would deal with relatively small areas in which economic aspects become far more manageable, can be produced in a short time period and in spite of its simplicity (in relation to regional plans) it would provide an efficient tool for overall urbanisation policies and decision making - these and other advantages of sub-regional planning are beginning to gain ground and to be recognised in planning circles.<sup>(3)</sup>

The notion of a sub-region is known and applied in the field of economic geography so it seems unnecessary to discuss its definition although the term is not without certain ambiguities, but it is important to explain here what is understood by a sub-regional plan particularly since the Grangemouth/Falkirk area clearly exhibits a settlement system for which the term 'urbanised sub-region' is most applicable.

A sub-regional plan by its very nature is a plan mainly devised for areas which are homogeneous as regards their natural environmental features, which at the same time are delimited by the outer limits of commuting journeys. The plan should act as an effective medium for communication among the separate levels of urban and regional planning, as a guide to planning in areas under development where there is no comprehensive regional planning, and as an agent for the formulation of principles and the general framework of development as a whole. As such the sub-regional plan steers and controls urbanisation policies in order to provide the best environment based on a functionally interdependent settlement structure. Although human values are given priority, the background of the planning proposals must be economically sound and directly relevant to the implications evolved from the existing conditions of the surveyed area.

The construction of the sub-regional plan can be based mainly on the techniques applied in urban planning and the final results should include provisions for a 20-year development period (the master plan type), long-range directions of growth, and programming of implementation. The emphasis in a sub-regional planning approach would, however, be on different aspects from those in urban planning carried out on the local level. In designing a town an important contribution may arise from the development and analysis of ideal theoretical models of urban forms, even in cases where these have been created without reference to any concrete locality or physical background. This situation changes when a whole sub-region (or a region) in its entire complexity becomes the planning target, as it then becomes necessary to take its very particular natural features together with its urban structure into consideration before any solution can be ventured. Therefore, although the formulation of a sub-regional plan can be, to some extent, influenced by a study of purely theoretical patterns, any attempts towards constructing the ideal model of a sub-region can be nothing more than pure abstraction.<sup>(4)</sup> Hence the logic and consistency of the planning process itself and the search for an 'optimised' methodology become particularly vital in the sub-regional planning process.

In the case of Grangemouth/Falkirk, to cope satisfactorily with this specific type of plan, to help in the creation of a standard method for its construction and to achieve the relatively optimum results, additional methodological studies were undertaken which besides advancing this type of research, produced evidence to support the concept of introducing threshold analysis into the framework of the model method which was devised.<sup>(5)</sup>

The need for a planning methodology which would integrate the science of economics with that of physical planning more effectively was clearly indicated and further investigations indicated that this could be achieved by looking for 'optimised', scientifically sound, techniques which would lead to the minimisation of investment costs but which would at the same time safeguard the basic human needs within a well-functioning urban community.

Unfortunately it must be admitted that "planning for 40 to 50 years ahead, even limited to an assumed growth of gross national product ... cannot claim to be based on any scientific arguments"<sup>(6)</sup>. However, "there are situations in the life of persons or communities where decisions are needed, the consequences of which extend many years ahead and are often practically irreversible. These decisions, however, are bound to be taken when there are alternatives of choice - it is important to limit numbers of such final decisions to the really indispensable ... and to consistently minimise the degree of subjectivity"<sup>(6)</sup>.

In this light threshold analysis looked an excellent tool to enhance the traditional (although refined and sophisticated) planning methods usually employed in Scotland for sub-regional development studies. The main difficulties to be encountered in its introduction were connected with the fact that it was the first time this analysis was applied in the conditions of a so-called free market economy and that so far it had never been tested on a sub-regional scale.

The best way of showing how these initial difficulties were overcome is by describing the analytical proceedings adopted and the role of threshold analysis in the course of this planning exercise.

### Natural Growth Potential

Apart from purely technical information received from various working parties and other technical bodies in the later stages, the analysis was based mainly on information obtained by the Planning Research Unit from two groups of studies which can be called the direct survey and the natural growth potential.

The first study (direct survey) was to obtain full information on existing conditions, by visits to the area, site investigations, map analyses, etc. The three main parts of this survey (that is, natural features, land uses, and infrastructure) pointed to certain conclusions forming the first planning implications, but without involving critical analyses in more depth at this point. This set up the 'preliminary diagnosis' for the sub-region, and was the starting point for more comprehensive analytical investigations, grouped under the heading 'growth potential', the first part of which (natural growth potential) was the other cornerstone of the threshold analysis. This study dealt with the requirements of the main sub-regional functions involved based mainly on natural characteristics. The comprehensive analyses evolved under this heading were to reveal the 'natural' possibilities for the further development and thus to help in the selection of the best directions of growth for the area as a whole. The study then investigated, by a thorough examination of the natural features, the suitability of undeveloped land for main sub-regional functions: industry, residential and ancillary uses, recreation, agriculture and forestry.

It was assumed that suitability of the land for each function could be affected by positive, negative, or 'modifiable' factors, and these were presented separately for each function. In the course of the analysis, all the factors excluding possible location (that is, negative factors) were first noted graphically on the base map. Areas of optimum conditions were then determined separately and the remaining portions of land

grouped together as being affected by modifiable limitations - those with varying possibilities for improvement. The system of overlapping areas decided the issue: for each principal function degrees of suitability were graded and areas outlined, and thus hypotheses of relative optimum development conditions at this stage were obtained.

The results of this study formed the general background for threshold analysis, particularly those which later enabled the sub-division of threshold areas into two main functions: industrial and residential with ancillaries.

### Main Aims of Threshold Analysis

Threshold analysis applied in the Grangemouth/Falkirk study was a simplified form <sup>(7)</sup> similar to that developed in Poland. Its main aims were to provide additional parameters for:

1. the calculation of growth potential for the sub-region
2. the definition of long range directions of growth
3. the optimum distribution of the elements of the development programme
4. the best allocation of theoretical patterns resulting from the model structure research.

The results achieved within this part of the work were the definition of urban development thresholds and consequently of areas suitable for urban growth over the whole region, and the basis for the specification of the sequence in which adjacent areas should be developed. This helped in guiding urban structure for the final development model, and in the programming of its implementation. The aim of the analysis was to arrive at the objective definition of areas suitable for town expansion and the calculation of the overall growth potential for the region by using average urban density standards. This definition prepared the basis for an economic assessment by cost indices, and showed the rational sequence of development and the most desirable direction for growth both for the

area as a whole and for each specific town involved. The particular role of the analysis in investigations of long-term directions of growth in the light of present constraints should be stressed, because future development may be directed either to land having serious threshold limitations or beyond the sub-regional boundaries.

#### Definition of Threshold Lines

To define threshold lines for the sub-region, the factors affecting development were examined within three main groups to find:

1. the suitability of land for urban development from the physiographic standpoint
2. the possibilities of extending the public utility networks and roads
3. the possibilities of altering the existing urban land use patterns.

In the simplified graphic technique applied in this exercise a further breakdown in the three groups mentioned above was made, to define:

1. land immediately suitable for building purposes, that is, areas where the cost of location of new inhabitants is relatively normal
2. land which requires essential improvements and/or new investments before becoming suitable for building
3. land unsuitable for building purposes being areas where reclamation, new networks, etc., would involve highly excessive and thus unreasonable investment costs.

This type of subdivision allows the quantitative formulation of results as opposed to conventional methods which do not use common denominators embracing all factors analysed.

Before the final definition of threshold lines, two partial integrations of the separate results were produced. First, all land unsuitable for

development was eliminated from further analysis, and the main existing linear limitations for spatial urban expansion were indicated. Secondly, partial integration was attempted by the delimitation of the best areas, such as those immediately suitable for urban development from the viewpoint of all partial analysis within all groups involved. Then the successive threshold lines were drawn on the base map from the integration of overall analytical results, taking into consideration their various interrelations. The lines mostly delimited homogeneous areas within which the additional per capita costs of the location of the new inhabitants were for the most part similar. The main types of threshold included:

First Threshold Line (I): contained urban areas and suitable areas for immediate development, having infrastructure systems and pertinent natural features.

Second Threshold Line (II): contained land requiring essential improvements with substantial capital investment before becoming suitable for urban development.

Third Threshold Line (III): contained land as in the second threshold above, but which was in an isolated location.

Ultimate Threshold Line: contained land unsuitable for urban development and therefore eliminated from further investigation.

The next step towards the calculation of urban potential was the subdivision of land within these threshold areas for two main functions only, that is, areas suitable for industry and those more suitable for other urban functions. This was based mainly on industrial analysis in the Grangemouth/Falkirk study, where the importance and inflexibility of the location of industry demanded priority because the whole development of the sub-region is due to the dynamic growth of the big industries there. Information from the first urban models constructed before hand was taken into consideration too.

The final result obtained from this physical application of threshold analysis was the calculation of the capacity of residential areas within the threshold lines I, II and III. This was based on urban density standards, defined by parallel environmental research for future urban structure in the area. The average gross densities of 30 pps (75 pp hectare) for Threshold I and 20 ppa (50 pp hectare) for Threshold II and III were used; growth potential was calculated, the findings indicated graphically and a number of tables compiled.

### Simplified Economic Assessment

The general aims of the economic assessment of urban growth potential undertaken in the course of threshold analysis were:

1. to show the rational and economically sound sequence in which adjacent areas suitable for urban expansion should be developed and thus to give the basis for development phasing and programming
2. to enable construction and comparison of the various possible hypotheses and long-term directions of growth, and thus to help in the choice during the formulation of the final physical development model
3. to act as a test case for this new type of analysis, as a contribution to research for rationalisation of planning methods.

It was assumed that the results might be achieved partly by calculating cost indices showing additional capital expenditure for opening up any of the threshold areas involved, or in other words, expenditure necessary to cross thresholds.

To enable the exercise to be done in a relatively short time, a number of basic simplifying assumptions were determined as follows:

First Assumption: As the main interest of analysis is the cost of location of new inhabitants and as the location of industry was mainly settled before hand, it was decided to analyse threshold areas designated

for residential functions only.

Second Assumption: Following the decisions of the physical approach, it was decided to eliminate from the calculations all areas beyond the ultimate threshold line.

Third Assumption: As in Scotland social demands evolved from long-term traditions and living habits have established fairly strictly-defined environmental standards, average gross densities in certain areas are relatively stable. Therefore, it was decided that only two types of previously established average standard densities would be taken into account in the course of this analysis and that no alternatives should be considered.

Fourth Assumption: Because this study was prepared within the 'physical planning' team, it was necessarily only the forerunner of a more comprehensive economic assessment. It was therefore decided to exclude analyses of exploitation costs and 'frozen assets'.

The three main groups of costs were then distinguished further calculation; these included the following items:

First Group: Costs connected with adaptation of land for building purposes (based on physiographical factors). Various factors within this group may create a substantial increase in the costs of construction, for example a rise in the direct building costs of housing, public utility networks, or roads; or the imposition of limitations on residential densities.

From the results of investigations the following additional per capita costs were calculated:

1. those incurred by construction on slopes (more than 1:6, 1:12 to 1:6 and 1:20 to 1:12) in comparison with construction on flat land
2. those required to prepare wooded areas for building purposes
3. those for foundations on land with limited bearing capacity such as shallow peat bogs (piling or rafting). This was, however, ignored since most of the future residential development was to be two- and three-storey houses without serious foundation problems.

Second Group: Costs of acquisition of land and/or its reclamation.

Various costs can be involved within this group, such as direct costs to be paid to the owner; indirect costs (important at the regional and national level) connected with changing the existing use of the land, thus decreasing agricultural or other productivity; costs involved in necessary relocation of existing land uses; rehabilitation costs for land detrimentally affected by different activities such as quarrying, mining, etc.; compensation for various rights affecting some areas, etc.

The following per capita costs were calculated in this group:

1. market price for all analysed areas (excluding land owned by local authorities, the acquisition cost of which was taken as zero)
2. compensation to the Coal Board (where applicable)
3. the cost of rehabilitating derelict areas

Third Group: Costs connected with the construction of main lines of public utilities (mostly dependent on the distance from sources of supply or from treatment plants) and of major new roads to provide direct access to respective areas, etc. The following items were calculated to obtain per capita cost indices:

1. the costs of laying new trunk collectors according to their length and diameter in relation to the population to be served and the slope of the land;

2. the costs of extending the existing sewage treatment plant(s), based on recent estimates.
3. the costs of constructing new treatment plant(s) in relation to the assumed capacity;
4. the costs of constructing new roads (primary and district distributors)
5. the costs of constructing new bridges, tunnels, etc.

On this basis, all the indices were presented in the form of one matrix, including all items considered for all analysed threshold areas. In addition, a map and a diagram indicated the comparative additional costs of development of the main settlement groups in the growth area based on threshold cost analysis.

### General Implications

The results from this simplified type of threshold analysis appeared to indicate two linked but separate conclusions:

the first revealed an objective, quantitative basis upon which choice could be made between alternative areas of development, making it possible to eliminate high cost areas. Implications were thus obtained to help in the direction of long-term urban growth in the sub-region and in the construction of the final development model<sup>(8)</sup>. One of the most obvious conclusions was that the data for the growth area ought to be fed back into an assessment of the comparative costs of development in various parts of Scotland, since such a rational integration of local and region-wide policy formulation is one of the main properties of the threshold technique.

the second general conclusion concerned the programming of public investment. A great deal of threshold expenditure must precede exploitation of the areas, and in the development of an area there is an

initial 'lump' investment before even one house is completed, which may lead to periods of exceptionally high investment expenditure when one or more threshold areas are being opened up.

To maintain the desired population growth, even at a constant annual rate, may entail considerable disruption of the budgeting by public authorities and it is therefore more realistic to programme investment to a constant capital expenditure per year, or an amount which increases at a reasonable rate. This implies the recognition of thresholds far enough in advance to arrange them in sequence; if two or more major thresholds coincided a period during which population increase would be seriously curtailed would result and this might well bring serious consequences for industrial growth owing to restrictions on the availability of labour. Population growth, however, cannot be disregarded here.

The analysis clearly distinguishes two types of areas suitable for development: small intra-threshold pockets, and larger extra-threshold areas. The former are much more flexible and can be developed quickly and cheaply - they should be used in circumstances which will exploit this flexibility, for example to allow a more rapid start to the build-up of the area than would be possible in the case of a major development, or to provide flexibility in the programme at later stages.

As the threshold theory was initially generated by research in the method of construction of long-range plans, it is natural that in this field it would normally play an important role. This, however, was not the case in the Grangemouth/Falkirk area because its characteristics did not require comprehensive long-range plan construction. The total growth potential only slightly exceeded the target population figures for the period of the Master Plan and the possibilities for developing various long-range models

were therefore rather limited and irrelevant for the construction of the final plan. Long-range problems were however considered in the formulation of directions of growth. These were defined as:

1. the allocation of the ultimate threshold line, by which the tendency to relative stabilisation of further growth can be determined physically and in time
2. the possibilities for urban expansion after 1986 (within the boundaries of the sub-region and its ultimate threshold line) giving urban growth potential figures
3. directions in which studies would be carried out if ultimate urban potential were to be expanded within the boundaries of the growth area
4. directions in which urban expansion towards adjacent areas might be considered and further planning studies which could be undertaken.



(b) CENTRAL BORDERS - A PLAN FOR EXPANSION<sup>(1)</sup>

Threshold Analysis and the Central Borders study

This study, commissioned by the Secretary of State for Scotland and undertaken by the Planning Research Unit of Edinburgh University in 1966, was the third application of threshold analysis in Scotland.<sup>(2)</sup> The White Paper<sup>(3)</sup> which generated the study also set out the reasons for the undertaking. It stated that the area was one of the most attractive parts of Britain but that it was in a situation of unbalance and decline; the principal concern has been regarding depopulation. Many rural areas in the western world exhibit depopulation, which is a product of the increasing efficiency and falling manpower requirements of agriculture and increasing industrialisation and urbanisation, and the physical characteristic of the Borders is that this depopulation is affecting the towns.

Manufacturing and service industries are under-represented and the industrial scene is dominated by the textile firms. Unemployment is low as there is an acute shortage of labour, but continuous depopulation will seriously affect the existing industries which could force closure or removal, further accelerating the decline.

The serious economic situation of the area was first considered at governmental level in a wide context and urgent action was proposed to enable the region to contribute more effectively to the Scottish economy and to offer better opportunities to Borderers. To achieve these aims the introduction of about 25,000 people by 1980 was proposed by the Scottish Development Department and the planners' task was to advise on the programming and distribution of this expansion in order to meet all basic current demands within the region and to make the Central Borders a self-regenerating area after 1980.

The problems facing the area were directly opposite in character to those of the Grangemouth/Falkirk area where dynamic growth was envisaged, and in

consequence threshold analysis developed in a somewhat different way during this planning exercise. The Central Borders study attempted to solve the problem mainly at the sub-regional level and the main purpose of the analysis was to provide a substitute for feedback from the local level (since the necessary parameters were lacking in the approved development plans) by revealing the urban growth potential of all towns in the sub-region and pointing out sites most suitable for the location of a new community should this become necessary. The results of threshold analysis were then used as a general basis for developing models of population distribution both for the period of growth up to 1980 and for longer term possibilities.

A detailed appraisal of these models was carried out by services and road working parties together with complementary studies of industrial location and linkages, shopping and social needs, traffic movements and amenity factors. Integrated results provided a basis upon which final development proposals were formulated, outlining recommended urbanisation strategies and implementation programmes.

Threshold analysis was also of assistance during this last phase of the planning exercise particularly in determining the stages into which the urban development process was to be subdivided. The analysis emphasised two aspects, physical and financial, which were fully investigated and are discussed here in detail.

#### (1) Physical Aspects

The physical approach of the analysis was guided by the simplified method previously applied to the Grangemouth/Falkirk study although in the Central Borders it was carried out in a less collective way. The general aim of the analysis was achieved by determining threshold limitations to be faced by the towns in the sub-region in cases where their urban expansion would be generated. Two main types of thresholds have been analysed and defined:

- (i) physical thresholds imposed by the existing physical features of the sub-region;
- (ii) quantitative thresholds imposed by the capacity of the public utility networks and particularly by the capacity of their central works (treatment plants and water sources).

Threshold limitations were defined from the integration of partial analyses in which the following groups of factors were examined:

Natural Features including exposure levels, gradient and orientation of slopes, land liable to flooding, sand and gravel deposits, woodlands and fertile soils;

Services including extent of areas served by existing public utility networks, capacity of existing treatment plants and water supply, together with possibilities for their future expansion without the implementation of new works;

Roads including capacity of existing roads in relation to traffic flows and degree of accessibility afforded by existing road networks;

Built-up areas including technical conditions of the existing urban to reveal the needs and possibilities for urban renewal schemes;

Amenity assets including quality of the landscape and scenic values which might impose severe restrictions for future urban development.

The result of this part of the analysis helped to identify two main development thresholds:

1. A Regional Threshold encompassing areas affected by negative physical factors and therefore highly undesirable for urban development. These areas were excluded from further analysis. An important factor was introduced at this stage to threshold analysis: unique natural attractions of the sub-region, calling for particular care and protection, were taken into account and as a result of specialised study an 'amenity threshold' was identified enclosing areas

where urban development would considerably affect and spoil the natural beauty of the landscape. This new type of threshold<sup>(4)</sup> was considered as part of a regional one and its definition indicated an additional set of areas to be excluded from further analysis as unsuitable for any form of urban development.

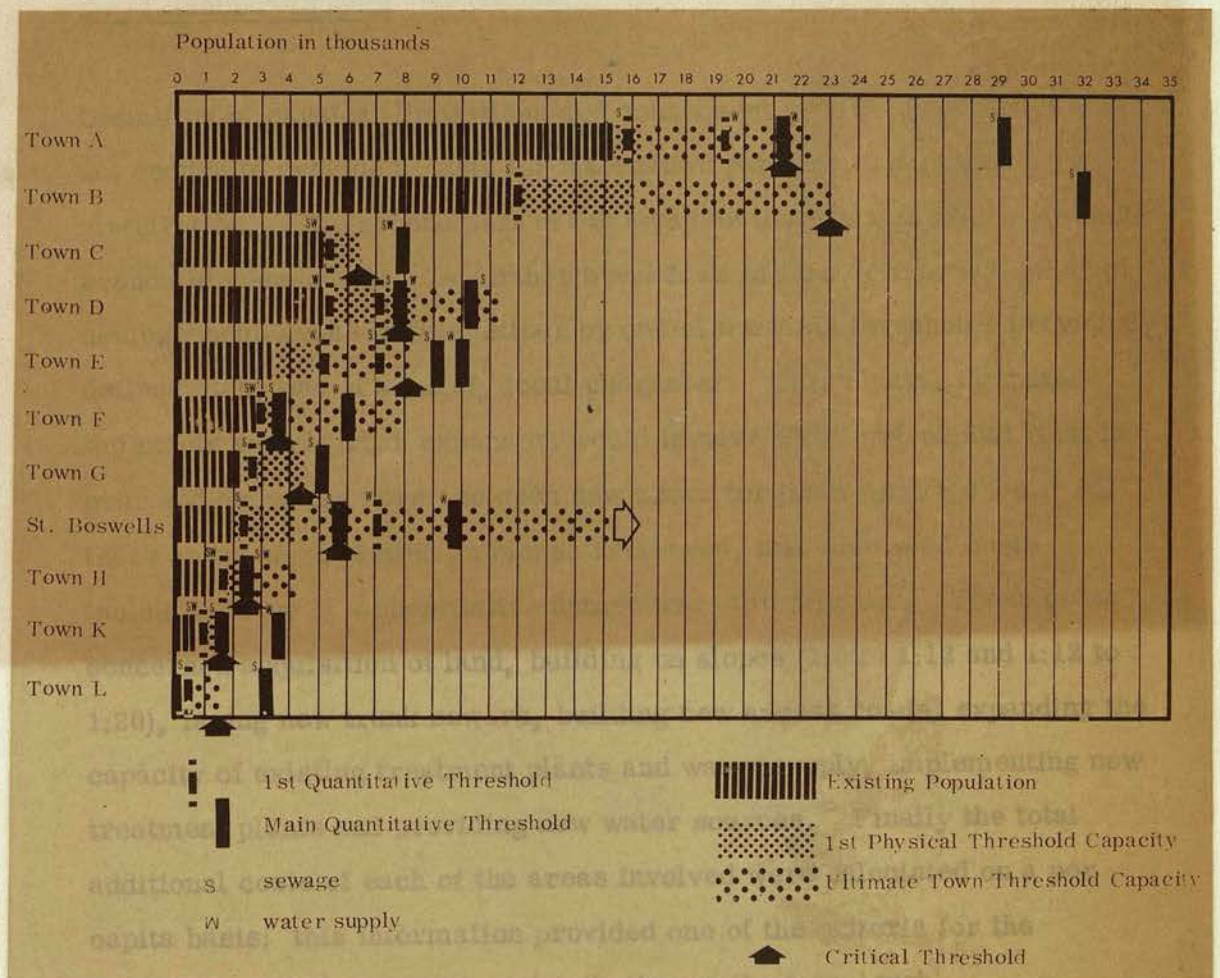
2. Ultimate Town Thresholds, indicating how far existing towns may be expanded without facing major barriers whose overstepping would be highly undesirable owing to costs and/or other difficulties involved. It should be noted that, due to the natural characteristics of the area, the main towns in the Borders had fairly well-defined ultimate threshold lines and therefore limited urban growth potential.

While both the regional threshold and the ultimate town thresholds provided the main guide lines for possible population distribution, it was necessary to go into more detailed analysis for individual towns. Limitations relevant to their expansion were defined and necessary parameters for feedback from the local to the sub-regional planning level obtained; two further categories of threshold occurred at this local level: 'network thresholds', which delimited all areas served by existing sewerage systems, and 'quantitative thresholds' which showed the successive limitations of the existing capacity of treatment plants and water resources, and of the possibilities for their expansion. A 'main quantitative threshold' thus indicated the maximum number of newcomers to be accommodated within any of the analysed towns without the necessity of high capital investment costs entailed by new public utility works. Results showing these thresholds are given in Diagram 1, in which critical threshold limitations which would be of particular significance in the process of urban development are indicated.

Having defined the development thresholds, the total urban growth potential was calculated on the basis of an average gross density of 25 persons per

acre (62 pp hectare). The figures obtained exceeded 30,000 new inhabitants, thus revealing the theoretical possibility of accommodating the expected increase up to 1980 and beyond by expanding the existing towns. In many cases, however, such expansion would require the overstepping of critical thresholds by implementation of, for instance, a new treatment plant or a new water supply source in towns where the main quantitative threshold must be crossed before the ultimate one. Building new works involves high

Diagram 1



Urban Development Thresholds Identified in the Central Borders Area

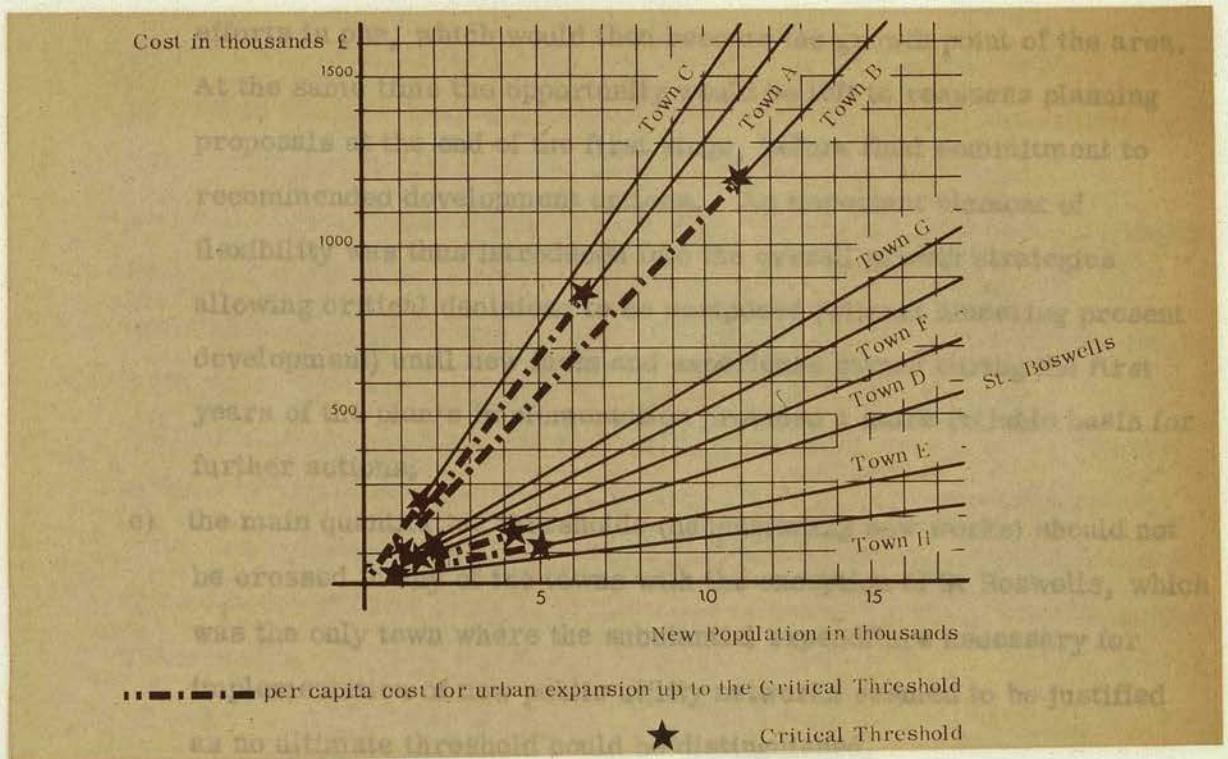
investment costs which necessitate careful economic investigation to balance such decisions in the light of possible benefits and likely freezing of capital assets. Information deriving from the analysis seemed to provide insufficient backing for this undertaking mainly because in many cases the urban growth potential of the town concerned would not allow for substantial growth after new works had been built. There was one important exception - that of St Boswells (a small town of about 2,000 inhabitants) - where no ultimate thresholds were identified and where implementation of new public utility works would be justified in the light of its almost unlimited possibilities for further urban expansion.

## (2) Financial Aspects

Definition of physical limitations and consequent growth possibilities was not enough to provide a basis for alternative patterns of population distribution. The second part of the analysis therefore provided a simple economic assessment. A further breakdown of land defined a number of homogeneous areas limited either by one of the main thresholds previously defined or by one of a purely local character. This clearly indicated the points where urban expansion would involve additional capital (that is over and above the norm) to open new areas for building purposes. All these areas were plotted on maps, numbered, and additional costs including those of a quantitative nature were investigated. These costs concerned acquisition of land, building on slopes (1:6 to 1:12 and 1:12 to 1:20), laying new trunk sewers, building new access roads, expanding the capacity of existing treatment plants and water supply, implementing new treatment plants and providing new water sources. Finally the total additional costs of each of the areas involved were calculated on a per capita basis; this information provided one of the criteria for the formulation of the population distribution on the town level.

Diagram 2 was prepared to show the relationship between the amount of additional capital expenditure required and the amount of new population that would fully use the growth potential in any town contained within its critical threshold. Aspects of financial effectiveness of urban expansion were thus revealed as another factor contributing to rational and objective decisions made in the course of the planning process.

Diagram 2



### Comparison of Threshold Costs

#### General Implications

Implications derived from the analysis outlined the optimum distribution of population which could then be further tested against other important criteria in the later phases of the planning exercise. The following were

the main objectives:

- a) urban development should preferably be phased in stages following the limitations imposed by the network, quantitative and ultimate thresholds;
- b) the first stage of development should concentrate on exploitation of easily usable areas located within network thresholds in all towns and within the spare capacity of treatment plants and water supply. This would allow the initial continuation of existing trends by developing all towns in the sub-region proportionally while simultaneously undertaking preparations to concentrate later efforts in one, which would then become the growth point of the area. At the same time the opportunity would be left to reassess planning proposals at the end of the first stage, before final commitment to recommended development options. An important element of flexibility was thus introduced into the overall growth strategies allowing critical decisions to be postponed (without hindering present development) until new facts and experience gained during the first years of the plan's implementation provided a more reliable basis for further actions;
- c) the main quantitative thresholds (necessitating new works) should not be crossed in any of the towns with the exception of St Boswells, which was the only town where the substantial expenditure necessary for implementation of new public utility networks seemed to be justified as no ultimate threshold could be distinguished.

Implications for long-term strategies were also significant; they indicated that if any substantial urban growth is to take place within the Central Borders area after 1980 (based on a considerable planned migration to the area) then St Boswells will be the only possible place for expansion, providing however that this has already begun and that the various future development options can be implemented. All in all, results of the analysis for the Central Borders seem to prove at least that it has justly earned the name of a 'quantified common sense' suggested at the time by the members of the Borders Consultative Group.

(c) EVALUATION OUTLINE

Practical application of threshold theory to the studies of the Grangemouth/Falkirk and the Central Borders areas seemed to support the initial assumption that there were no absolute and critical difficulties in introducing this method to a country with different socio-economic systems and in the scope of a sub-region. No drastic adaptations were needed in the course of analytical proceedings in the two Scottish cases.

Before evaluating direct effects and influence of the analysis it must be pointed out that conclusions from the Polish experience were taken into account, particularly after interpretation of the final results. Thus all implications or indices deriving from the analysis were cautiously verified before undergoing serious consideration in the design and decision making processes. Most of the cost indices, for instance, played a rather modest and informative role, and served basically as additional parameters for the phasing of proposed development. The method of obtaining these indices showed that, had the calculations been done on a reliable basis, they could have led towards important reductions of capital investment costs in the process of urban growth in the sub-regions concerned.

Since these applications of threshold analysis were initiated and led by an architect/planner it was natural that the physical part contributed more than the economic part. The course of the analysis was expanded, new elements were introduced (such as costs connected with acquisition of land), and the emphasis shifted from one group to another (the road systems had to be analysed more thoroughly than in Poland where in the majority of towns they played an insignificant role). In the case of Grangemouth/Falkirk the phase in which subdivision of land for the growth of the main functions was carried out as a small additional study and presented as an alternative

to the Polish approach, in a working programme called the 'simplified method of threshold analysis' where most of these adaptations and extensions were briefly summarised.<sup>(1)</sup>

Although the Grangemouth/Falkirk approach was a more elaborate study and provided a full description and explanation of the analytical proceedings, the Central Borders study was in many ways a more interesting example of the application of the threshold concept.<sup>(2)</sup> Being the second exercise, experience from the first and the follow-up professional discussions, comments and criticism could be taken into account; in addition, the problem itself was different - distribution of a given population increase among a group of small towns dispersed in the sub-region, allowing the consideration of a number of variants. This field was one in which threshold analysis was particularly useful whereas in the Grangemouth/Falkirk study the total growth potential was only slightly in excess of target population and the development of alternative solutions therefore impracticable. Threshold analysis was also used in the Borders study to substitute for unified implications from local statutory plans which clearly revealed its genuine validity in the feedback process. Finally, joint physical and quantitative thresholds were successfully presented in diagrammatic form (shown in the preceding section) giving a clear picture of direct practical implications of the analysis.

Further research carried out parallel to the practical work led to development of the background theory and indicated the fields in which studies in more depth would be desirable. Introduction of new terms such as 'regional threshold', 'ultimate town threshold' and 'main quantitative threshold' for instance, represented an attempt to define which of the numerous thresholds were critical ones and to develop a method for defining these critical thresholds. Basic definitions of threshold limitations seemed insufficient and if guesswork and confusion in the course of the practical application was to be avoided these should be more refined.

Consideration was also given in the studies to the fact that there was a tendency to operate with one aggregate threshold cost index embodying two different types of costs (those which must be spent before and those during the period of urban development); serious doubts arose as to whether it was correct to amalgamate costs having different implications for urban development strategies, which provided another indication of directions for further research.

Difficulties connected with the necessity of taking into account the costs involved in the acquisition of land (these were less important in Poland because of the possibility of compulsory acquisition at fixed non-speculative prices) were encountered, showing the need for serious analysis of how the problem of land tenure could be incorporated into the threshold approach.

Some alternatives were introduced into the process of mapping to improve data recording. The classical subdivision into land 'immediately suitable', 'suitable after improvements' and 'unsuitable', was abandoned in the Central Borders for joint physiographical features since this necessitated additional work when threshold cost indices were to be calculated. Thus features like slopes, bearing capacity of soil, woodland, fertility of soil, etc., were plotted separately on the base map and subdivided into various categories of development suitability.

Summarising inferences from the two studies and from this short evaluation of the first 'Scottish editions' of threshold analysis some of the advantages and disadvantages of this planning tool can be listed as follows:<sup>(3)</sup>

#### Advantages

Threshold analysis, even in its most simplified form, allows the quantification and the objective comparison of implications from the survey, covering all important factors fairly comprehensively. It is in fact the only quantitative method which due to its simplicity can be widely used in everyday planning.

The introduction of the threshold concept itself helps greatly in the rationalisation of the planning process and in the elimination of many subjective judgments. The simple threshold notion has long been used in other sciences and it is difficult to understand why it has not until now been applied in physical planning. However, clear definition of thresholds is complex. Threshold analysis as applied in practice can be extremely useful in the field of interdisciplinary collaboration since a common language is introduced by using 'per capita costs' terms in which its results are usually expressed.

Threshold analysis shows the wider effect of physical planning decisions on the economy, particularly on the level and distribution of investment resources. It allows the economist to apply general concepts of opportunity costs, the margin, and detailed criteria of investment planning to problems of local character.

Even in its purely physical form (that is, without the calculation of cost indices) threshold analysis is of great importance in decisions connected with long-range planning. It allows the most favourable directions of urban expansion to be determined and to be linked with the important problem of development discontinuity.

The analysis provides the basis for planning work over a considerable period of time which is particularly important in regard to reviews of plans. This holds true also in its economic aspect since although actual costs change, relative costs remain valid for longer periods. Thus the analysis, once done, avoids the necessity of constant basic research, allowing most efficient use of time and of planning staff.

On the regional level, it can indicate the regional distribution of growth to give relatively minimised costs and plays an essential part in the selection of growth points. Above all, the analysis represents a new way of thinking on physical planning and has substantial latent possibilities for further evolution leading to rationalised, progressive planning methods.

### Disadvantages

A major weakness of the analysis is that cost calculations have been concerned with initial investment expenditure only. More comprehensive analyses of 'frozen assets' and 'running costs' may, however, change the final conclusions.<sup>(4)</sup> The scope of the analysis should be widened to incorporate this type of calculation. Indeed, only then could the results prevent serious mistakes occurring in the field of economics.

The question of the relative value of cost indices calculated for long periods in the future may also be brought up. Forecasts in this sphere can never be very accurate but until now there has been no other, or better, practical way to tackle this problem; it should be pointed out that by using indices calculated in the same way for all areas involved, mistakes can be greatly reduced. It is also important to remember that the main aim of the analysis is not a direct study of investment costs, but their comparison in relation to various possible directions of urban growth.

Threshold costs represent only a fraction of total development costs, amounting to 30 per cent in some cases, but normally below 10 per cent. However, even 5 per cent of total development costs represents a substantial amount of money and savings which may be effected, if without detriment to the basic standards of 'man and environment' must be one of the most vital targets in modern planning; threshold costs are a particular type of

additional costs directly determined by planning decisions and can thus be reduced by proper design, which is hardly possible in the case of 'normal' development costs.

Another disadvantage is that in practice thresholds are rarely clear-cut. Several of them may nearly overlap and their precise definition is often impossible, unlike theoretical presentations. This reflects the fact that reality is far from simple, but does not invalidate the basic theoretical formulations.

In general, it can be said that the advantages of threshold analysis outweigh the disadvantages, particularly as the latter can normally be overcome by further research; the use of the analysis in planning practice may be endorsed, but caution is necessary when making decisions using the results. Above all, however, the whole threshold philosophy should be treated as an introduction to new, promising research into the development and rationalisation of planning methodology.

### 3. INTRODUCTION OF THE THRESHOLD CONCEPT INTO REGIONAL ANALYSES

#### (a) Tourism Development Possibilities in the South Adriatic Region in Yugoslavia

Principles of resource analysis - definition of capacities - towards an optimised choice

In 1968 B. Malisz attempted a direct application of the threshold concept to regional analyses of tourism in the South Adriatic Region. As with any other economic activity, tourism development depends on particular resources which could be categorised by their suitability for tourists and by possibilities of expansion; threshold analysis was applied in this latter category. Capacities of resources were analysed and compared with the existing level of tourism, and development options produced by analysing the relations between investment needed to extend resource capacities and revenues expected from the resulting increase in the numbers of tourists. Threshold limitations (as previously defined) were of significance in this stage, which eventually led to the selection of an optimised development option.

#### (b) Assessment of Angling Potential in the Republic of Ireland

Outline of the proposed methodology - existing capacity - spare capacity - potential capacity - development incentives - development impediments - synthesis

Another example of the introduction of the threshold concept to regional analyses was an assessment of angling potential in Ireland. From defining the objectives the study proceeded successively through quantitative and qualitative approaches to the final synthesis. The main contribution from threshold analysis applied both on regional and local levels was in identifying potential capacities, the major part of the quantitative approach. Results were indicated diagrammatically and were jointly analysed with intangible aspects mainly concerning incentives and impediments to angling development. Finally, critical resource thresholds were formulated as of significant influence on the process of synthesis.

#### (c) Evaluation Outline

An evaluation of threshold approach applied directly to regional analyses can only be made in a very tentative form. It seems, however, that this approach may contribute greatly towards the further rationalisation of planning methodology and although its present simplicity gives a wide potential for extensive practical use, it may be developed into a much more sophisticated form. In any case, research and above all testing in the field is vital before any significant progress can be achieved.

(a) TOURISM DEVELOPMENT POSSIBILITIES IN THE SOUTH ADRIATIC REGION OF YUGOSLAVIA

A few years ago a United Nations sponsored planning team undertook a study assessment of the existing geographical environment and development needs of tourism in Donegal, Ireland.<sup>(1)</sup> During this study an interesting method was evolved allowing analytical comparison between capital outlays and expected revenues connected with particular options of tourism development, from a simplified model of the region based on only one economic activity. This was further developed by B. Malisz,<sup>(2)</sup> who introduced the threshold concept, resulting in a new subdivision of resources on which the development of tourism depends.

The method was then tested in one of the sub-regions involved in the project for the South Adriatic Region. An outline of this approach is presented below.

Principles of Resource Analysis

The leading principle of this pilot study was that tourism as an economic activity can be developed only within such limits as would allow the balance to be maintained among natural features of the geographical environment. Its development, like that of any other economic activity, is bound to depend on a particular group of resources; in the case of tourism these would generally fall into one of three major categories:

- (i) Tourist Attractions: all assets which encourage tourists to visit the particular area (beautiful landscape, beaches, possibilities of mountaineering, yachting, swimming, etc.);
- (ii) Tourist Services: the whole range of facilities designed to serve tourists (adequate accommodation, restaurants, car servicing, water supply, sewerage, etc.);
- (iii) Employment in Tourism: the labour force which could be employed in the service of incoming tourists and in the tourist industry as a whole.

All these resources (which in the analysed case provide the basis for the development of tourism as the major economic activity of a region) are characterised by the capacity of their expansion, which, however, can normally be increased in various ways. All the resources involved were subdivided into the two following groups, as proposed by B. Malisz:<sup>(3)</sup>

- (a) Those whose capacity can be gradually expanded, according to increasing requirements;
- (b) Those which can expand capacity only 'discontinuously' or in major finite stages.

For example, night accommodation may be analysed. In broad terms, including hotels, motels, camp-sites and private houses providing bed and breakfast, it is quite feasible to cope with increasing tourist trade by enlarging the capacity of night accommodation in proportions directly corresponding with requirements. If, however, the water supply in the analysed region is considered, it may be found that gradual expansion can occur up to the limits of the water source; there may be plenty of water initially but no water source is unlimited, and when its capacity is reached a threshold limitation will be encountered. The need for water can then only be met from a new water source involving a substantial investment ( in building a new reservoir, etc.).

This second group of 'discontinuously' expanding resources may however be ignored as development of the analysed activity depends only on the increments of gradually increasing resources; but it is necessary to define the point at which various resources of this group are expected to encounter their thresholds, since they would impose critical constraints on further development. In the case of tourism, tourist attractions are resources which cannot easily be expanded once their capacities are reached. Taking an example, if beautiful sunny beaches are the only attraction generating tourist traffic to a region, it is possible to measure the areas of all the beach sections, to analyse their character (sand, rock, etc)

and to define standards of capacity (the number of people who can use the beaches without overcrowding). Thus the maximum number of people for all the beaches can be calculated and this will reveal the capacity of tourist attractions in the region. The accuracy of such calculations may be criticised since they are rather arbitrary; in some countries such as France these standards have however been carefully studied and formulated, and could be applied in similar circumstances subject to specialised research.

In Yugoslavia, an extensive survey revealed that there is a constant mutual relationship between the number of people on the beach and the total number of tourists staying in a particular resort at the same time; in most cases for every 100 tourists and other persons on the beach there were 140 tourists visiting the resort. This coefficient of 1.4 is variable, increasing near old towns (e.g. Dubrovnik) and decreasing in small villages where the beach is the only attraction. From such information, the capacity of tourist attractions in a region can be calculated fairly precisely and if it is exceeded "feedback" may significantly decrease the tourist inflow. It can be said that this capacity represents a natural threshold to the further development of tourist activities in the region, and that this threshold will certainly be of a critical, if not ultimate, character.

When the natural capacity is established two other important factors should be considered. First would be the suitability for urban development of land along the coastline; this should reveal whether the possible shortage of buildable land will affect the provision of necessary accommodation for the number of tourists defined by the capacity of the tourist attractions. Second would be scenic values: these may impose constraints on urban development since their natural, unspoilt beauty may be the major attraction and must therefore be preserved.

All these considerations should allow the ultimate natural capacity or ultimate natural threshold that limits development of tourism in the analysed region to be verified and defined.

Other resources whose capacity can only be increased by lump sum investment should now be examined, (e.g. water supply, communications networks, employment potential) as thresholds for their future expansion will be valuable in the development of tourist activity. For instance, it would be uneconomical to use natural tourist attractions to their ultimate capacity if before it was reached the major water supply threshold would have to be surmounted, requiring substantial investments; the decision would have to be carefully balanced particularly with regard to the freezing of capital assets. It may, therefore, be concluded that thresholds associated with indivisible resources will indicate particular levels to which the volume of tourist inflows can rise, and would predict the development of this activity in distinct phases, each dependent on specific threshold investments. It is possible to proceed within these intervals until the ultimate natural capacity is reached and perhaps beyond, as this need not be of an absolute character. It might theoretically be overcome by constructing, for instance, an artificial island to increase the natural capacity of beaches in the region. The relevance of thresholds in this context is clear and their identification should greatly influence the phasing of development of the analysed economic activity.

#### Definition of Capacities

Continuing with the simplified outline of the applied method, it would seem appropriate now to develop it in more detail for analysis on a less complex sub-regional level.

The whole concept may be presented in diagrammatic form (See Diagram 1), where  $D$  = the existing level of tourism (i.e. the average number per day of

seasonal tourists in a particular sub-region). To subdivide further,

$D = A + B + C$ , where:

A = tourists using night accommodation

B = tourists passing through, but stopping in the sub-region

C = the local population using tourist attractions and other resources

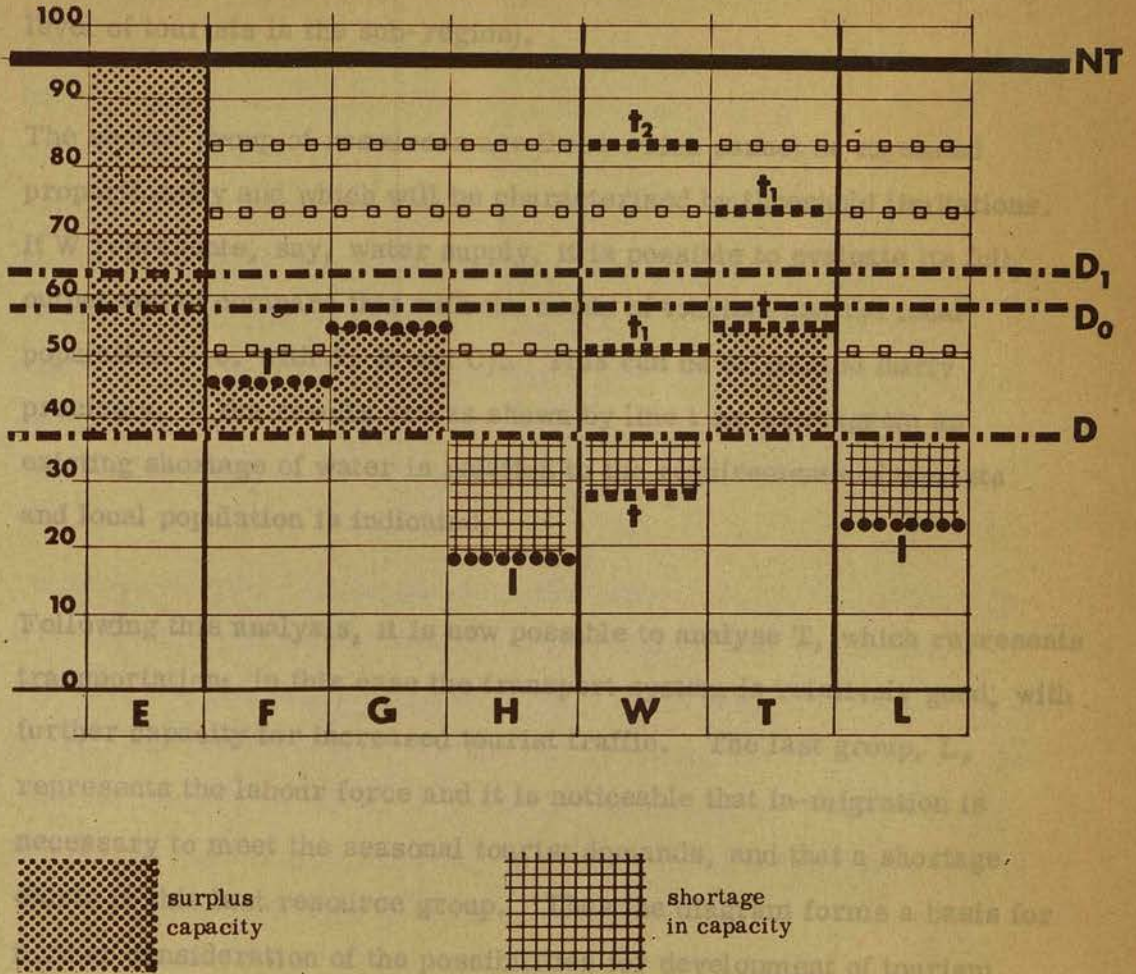
D can be statistically identified by means of a survey to allocate tourists to each of the groups A, B and C.

The vertical columns E, F, G, H, W, T and L in the diagram represent various resources: E represents the natural resources of tourist attraction which have a substantial spare capacity in relation to the present level of use by amount of tourists D. This capacity may be defined by identifying its natural threshold determining the ultimate limits to which tourist activity in the sub-region may be developed, indicated by the line Nt. F, G and H are the "gradually increasing" resources: F represents night accommodation, G places in restaurants and H parking spaces. The existing capacity of these three resources must be calculated and compared with the existing number of tourists in the sub-region indicated by line D.

Starting with night accommodation F, it is clear that from the number of tourists represented by A, B and C, only A will indicate the number of beds needed, since B represents those passing through and C have their own beds to sleep in. Therefore, F should at least equal A. Assuming that the survey has revealed that  $F > A$ , there is spare capacity in night accommodation in relation to the number of tourists D. If  $F = A$  there is sufficient accommodation for D since B and C are irrelevant here.

Taking resources G, which represent places in all types of restaurants, it is possible to analyse the existing capacity in relation to the three groups

Diagram 1



of potential users A, B and C. It is probably the case that A will need full board, B will require no more than one meal and C will use restaurants very little. Complications are bound to arise, but there is no doubt that it is possible to define the existing capacity of all restaurants and to compare it with the existing level and structure of seasonal tourists. Assuming that the results show an excess of restaurant places in relation to D, one can proceed to analyse the parking resource H and calculate full capacity for comparison with the requirements of incoming tourists. As in the previous

cases, this is a purely technical problem, and is shown on the diagram as indicating a shortage of parking spaces. All the results are shown by lines l and thus the relation between existing capacities of various resources from the first group is clear (line D represents the existing level of tourists in the sub-region).

The second group of resources are those which cannot be expanded proportionally and which will be characterised by threshold limitations. If W represents, say, water supply, it is possible to evaluate its full output and to compare this with the needs of tourism and the local population (i. e. with A, B and C). This can be calculated fairly precisely; if the results are as shown by line t on the diagram an existing shortage of water in relation to the requirements of tourists and local population is indicated.

Following this analysis, it is now possible to analyse T, which represents transportation: in this case the transport system is relatively good, with further capacity for increased tourist traffic. The last group, L, represents the labour force and it is noticeable that in-migration is necessary to meet the seasonal tourist demands, and that a shortage exists in this last resource group. Thus the diagram forms a basis for further consideration of the possibilities for development of tourism (according to the initial assumptions) as the main activity in the sub-region.

This analysis, however, indicates the need for immediate improvements of the existing situation. It can be seen that in order to meet the requirements of D tourists now visiting the region, additional investments are needed within groups of resources H, W and L. It can also be said that the line D reveals that tourists are not adequately serviced and that the resident population may be suffering even more. The provision of water, for instance, may be kept on an appropriate level in hotels, but because there is a general water shortage this will eventually affect the local supply.

Towards an 'Optimised' Development Option

Studying the future prospects for the development of tourism in the sub-region it is now possible to consider various options and to superimpose them on the diagram. Usually these options will reflect previously formulated development directions or targets for the analysed economic activity. Several variants can be investigated according to regional or national policies, or those of the authorities for the sub-region involved. It might, for instance, be necessary to examine the consequences of doubling groups A and B in the next ten years, or of greatly increasing group A with only marginal increases in group B, and so on. Thus a certain option  $D_1$  with predetermined proportions of A, B and C can be developed.

Following the same approach as for the analysis of existing conditions, the resources needed to meet this proposed level can be calculated, and shown on the diagram. The amount of investment necessary to fill the gap between the line  $D_1$  and the lines showing the existing capacities of resources (E, F, G, H, W, T and L) will be shown: this is the investment expenditure necessary to accommodate a desired number of tourists  $D_1$  or to develop tourism up to the level  $D_1$ .

Another important aspect of the exercise is the problem of income. Tourists spend money, the amount of which may be expressed as an average rate: group A of tourists will certainly spend more than B, while C should not be brought into these calculations since the main point is to look into the possibilities of bringing money into the sub-region from outside.

To go into this problem more deeply, further breakdowns within the analysed groups may be suggested. A, for instance, may be further subdivided into  $A_1$ ,  $A_2$  and  $A_3$  to reflect various categories of tourists:

those who live in the most expensive hotels, those who stay in medium priced ones and those who prefer guesthouses and hostels. This subdivision is needed to analyse the possible income to be expected from each of these categories, which would make it possible to calculate fairly accurately the total amount of money which may be spent in the sub-region by  $D_1$  tourists.

Having completed this analysis it is possible to compare (for option  $D_1$ ) all investment expenditures involved, with the expected revenue, or in other words with the amount of money which this particular mixture of tourists will inject into the economy of the sub-region. Assuming that a number of options were analysed ( $D_1$ ,  $D_2$ ,  $D_3$ , etc.) it is natural that for each option the relationship between investments and expected revenue will be characterised by different indices. The lowest index will indicate the most effective option and represents the level which should be maintained as being more economically sound than the others.

This is, however, an initial approximation of a complex problem since one should also analyse the influence of threshold limitations on the resources concerned. To simplify the explanation, it may be assumed that the only difficulties lie in the supply of water, shown by successive thresholds marked by lines  $t$ ,  $t_1$  and  $t_2$  on the diagram, and that the broken line  $D_0$  represents an optimum option selected from all those previously considered.

It may be seen that this option is not the optimum one if it requires a very costly overstepping of the water supply threshold; in the illustrated case, after the level  $D_0$  is reached the larger part of the new capacity created by implementation of new water reservoirs would remain unexploited for some time. The degree of this inefficiency may be presented quantitatively by calculation of the frozen investment expenditures.

The conclusions to be drawn in the case presented are obvious - option  $D_0$  should be lowered to the level defined by the 'water threshold' and with a relatively high degree of certainty it might be assumed that this level would represent a relatively optimised option, and in consequence be the best for the sub-regional economy. Thus the importance of threshold limitations associated with the capacities of main resources is demonstrated, and while the presentation of this case is extremely simplified, the implications for developing this approach and linking it with non-linear programming techniques are encouraging and call for further research in the field.

(b) ASSESSMENT OF ANGLING POTENTIAL IN THE REPUBLIC OF IRELAND

Outline of the Proposed Methodology

Theoretical evolution of the threshold theory in Yugoslavia revealed the practical possibilities of its direct application to the regional analyses which were followed up in the study of angling potential in Ireland, an exercise undertaken by the Planning Research Unit in Edinburgh and commissioned by the Irish Tourist Board in 1969.

Potential advantages from introducing the threshold concept into this task were revealed during the first scrutiny of the study brief, and it was also apparent that a comprehensive method would have to be devised in order to make the threshold approach a logically inherent part of it. This chapter attempts to outline the role of threshold theory in the formulation of that method.

To make the whole problem intelligible, it should be noted that the current trend in Irish tourism, and one which must be encouraged, is a rapid increase in the number of visitors each year. The report prepared by Colin Buchanan<sup>(1)</sup> estimated that the number of visitors staying more than twenty-four hours would increase from 1,700,000 in 1966 to between 3,000,000 and 3,750,000 by 1986. Obviously, if this economically desirable growth is to be achieved, a large amount of investment will be required in the form of air and sea ferries, accommodation, facilities and attractions for tourists, particularly those connected with a specific interest such as fishing. Much of the required investment will be produced by market forces and the general promotion of Irish tourism.

Thus the primary objective of the study undertaken by the Planning Research Unit was the formulation of possible development strategies for the extension of valuable existing resources for various types of angling, and more

broadly, to encourage the development of tourism in the country as a whole; the specific purpose of the study was to ensure that investment in fishing and related facilities would be directed to the areas or regions of greatest expected return both in money terms and in growth of tourism generally.

To indicate roughly the scale of the problem, it should be mentioned that between 1960 and 1966 the proportion of visitors to Ireland who were anglers increased from 2.8% to 6.2%.<sup>(2)</sup> Assuming that the proportion of anglers remains the same, there will be at least an extra 110,000 anglers visiting Ireland each year by 1986 as compared with the present (1966) total of 111,800.

If each of the 275 listed fishing centres<sup>(2)</sup> accommodated an equal share of these additional anglers, each would have to cater for an additional 400 anglers each year, which in practice means about 400 families. If a five-month season with an average length of stay of one week were assumed, this would mean that 20 extra people would have to be accommodated at one time, if it were possible to spread incoming tourists evenly throughout the season. The provision for 20 extra people (or families) over a period of 20 years at each of the 275 centres would indeed involve grossly inefficient use of resources. Many of the required facilities, such as accommodation or entertainment facilities, can only be provided economically in large indivisible units. It is plain, therefore, that development and investment must take place at selected centres in order to bring about the best return and the lowest risk in capital investment.

The method of approach outlined below was designed in the first instance for the analysis of eighteen selected centres, but had wider implications for the evolution of a model method to be used as a framework for continuous studies leading to the definition of the best options and directions

for the future development of angling on a regional level. Hence it appeared necessary in the initial stages of the study to formulate a process dealing with this complex subject, in which the qualitative and quantitative aspects are merged for the formulation of final conclusions.

The main aim of the method was to provide a relatively optimum solution by optimum use being made of the natural resources (meaning relatively high revenues while maintaining the natural balance of the environment);<sup>(3)</sup> this may be achieved by the following means:

- a) indicating how the quantitative capacity of the various resources may be measured and their development potential assessed
- b) showing how the qualitative analysis of the less tangible aspects may be carried out and eventually superimposed on the results obtained by the quantitative approach.

The quantitative approach may be reduced to three stages of work which should be successive analyses of:

- 1) existing capacity (from capacity-determining resources)
- 2) spare capacity
- 3) potential capacity

Simultaneously, the qualitative approach can be divided into two stages:

- 4) development incentives
- 5) development impediments

The results obtained from investigations of these subdivisions can then be analysed to obtain various feasible development options from which general conclusions and recommendations will emerge. This whole process is shown below:

Quantitative Approach

Qualitative Approach

Capacity<sup>(4)</sup>

Development

Incentives

Impediments

Existing

Spare

Potential

Synthesis

Options

Conclusions

Recommendations

Having formulated in general terms the main objectives, aims and means, it now seems necessary to outline the method in its successive stages.

Existing Capacity

The measurement of existing capacity may be quite straightforward if preceded by the discovery of not only how to measure but what is to be measured and why. Since the study's main objective was to recommend the best possible strategy for the future of angling, and since any new development is always dependent on corresponding resources, there was no doubt that the capacity of resources determining the possibilities for the development of angling should be the subject of careful scrutiny. The survey covered three groups of resources:

- a) accommodation: all hotels and guesthouses, bed and breakfasts, farmhouses, caravans, camping, cabin cruisers, chalets, etc.<sup>(5)</sup>
- b) fishing resources: total area of fishing water, length of river banks, numbers of fish in selected areas, number of boats and/or quays available for fishing, etc.
- c) utility services: water supply systems, sewage treatment and drainage networks etc.

It may be noted that only the second group is used exclusively by anglers (local or tourist) while the remaining serve other tourists and the local population. All tourist and local population activities must be analysed if the recommendations and conclusions are to prove valid.

How to measure requires more detailed analysis of each resource involved, and in some cases the answers can best be found during the course of the analysis itself. Results must, however, be expressed in figures representing the number of people who can simultaneously use any particular group of existing resources. This is sometimes quite straightforward such as the number of beds in hotels, which can be taken from the survey. In other cases there are difficulties requiring additional investigations; to give an example, the total area of fishing water does not directly indicate the number of anglers who can be accommodated. First the character of the water must be established (lake, river, bay, etc.), and then some margin ratio established to reveal the number of anglers that the water can comfortably tolerate without becoming overcrowded, as this inevitably leads to a decrease in the number of angling visitors. Although no such threat was found in any of the centres involved, this difficulty may be expected during the capacity measurement exercise.

Another major problem involved at this stage was the definition of study areas, since any quantitative approach must refer to a distinctly delimited area. It would have been ideal to investigate these problems over the whole country if general 'strategy guide lines' were to be evolved, but because of restrictions in time and manpower the scope of the study had to be limited and the field of analysis curtailed. The aims of the study were thus recommendations of strategy for angling development in the selected centres only, and the establishment of a 'model' method of approach, tested in the selected centres, which could later be verified and applied on a wider scale.

Other tourists fell into one of the two following categories:

$T_A$  - tourists associated with visiting anglers (families, party members, etc. who may not be fishing)

$T_I$  - independent tourists, i.e. any other tourists coming to the area for purposes other than fishing

The total number of other tourists  $T_T$  (exclusive of anglers) =  $T_A + T_I$

These categories may be further subdivided in the same way as for visiting anglers  $A_V$ :

$$T_A = T_{A1} + T_{A2} + T_{A3} \text{ and } T_I = T_{I1} + T_{I2} + T_{I3}$$

Local population  $L_C$  using tourist facilities represents a fraction of the overall population which differs in relation to different groups of resources. Thus  $L_C = kP$ , where  $P$  is the total population of the centre, and  $k$  a coefficient indicating that percentage of  $P$  which uses a particular group of resources.  $k$  will be varying and will have to be defined separately for each of these groups.

In most cases these subdivisions should not require extensive statistical surveys, and the information from a random questionnaire should enable characteristic patterns and proportions within the categories and sub-categories to be established for each centre. Thus, knowing only the total amount of anglers  $A$ , the total number of tourists  $T$ , and the size of the total population in the centre  $P$ , it should be possible to obtain other categories without too much difficulty.

Next, the extent to which anglers, tourists, and local residents use the existing resources should be analysed. In some cases this would be straightforward, and in others assessments based on experience and observation would be required.

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All groups of resources should then be related to the most likely numbers of users from each category (A, T and P). Since the existing capacity would already have been established, this should determine which resources are fully used, which have spare capacity and which are over-used according to previously determined acceptable standards.

Analysis of the resources used by anglers only would of course indicate 'absolute spare capacity', if any, whereas analysis of groups of resources in which other tourists and local population were involved would reveal 'relative spare capacity' as far as anglers are concerned, since the capacity would reflect the combination of anglers, tourists and local residents using particular resources.

#### Potential Capacity

Potential capacities can be precisely represented for most of the resources concerned only if the threshold concept is introduced at this stage of the analysis. Its application is important on two different planning levels: first and most essential, relative to the development potential within various groups of resources, and second, connected with the building possibilities.

To give an example: by analysing resources it may be found that the only thing preventing substantial development of fishing is shortage of bed accommodation, all other resources having adequate spare capacity. The immediate conclusion would seem to be to proceed with hotel development. However, suitable sites in the area (with satisfactory natural characteristics, adequate infrastructure and accessibility) must be found and in some cases - perhaps if a substantial number of beds is required - it may be more sensible to develop an alternative centre which may not have such large spare capacities but is not restricted as regards urban development possibilities. This need not be a

complicated study and can be based on simplified threshold analysis (6) which can be done for any of the centres as a one- or two-day field appraisal, providing the preliminary data is previously provided by the appropriate authorities.

From these analyses various threshold constraints would be revealed and from their comparison critical ones would have to be selected (mainly those requiring large-scale investment before development). These would be most important since indivisible investments always have the greatest impact on the efficiency of any development action or strategy.

In the course of this analysis the first priority, however, should be to establish the 'Immediate Development Potential' for each of the centres to indicate whether it would be possible immediately to increase the number of anglers without additional investment costs. If all the resources showed spare capacity the overall potential in each centre would be indicated either by the resource group with the lowest spare capacity (which may be determined by a threshold constraint<sup>(7)</sup>), or by some urban development threshold identified in the course of the centre's threshold analysis. This phase may be called the definition of first threshold for potential capacity, and it shows that there may or may not be enough 'immediate capacity' for the centre concerned to continue expansion for several years, thus greatly reducing the scope of successive stages of quantitative analysis.

In general the analysis for potential capacity can be broken up into four stages to define for each centre:

- a) Immediate Spare Capacity - derived from the quantitative analysis of the various resources and including a definition of the first threshold;

- b) Successive Constraints - encountered in all groups of resources, which will identify threshold constraints, indicating the saturation points in each area if angling is substantially developed;
- c) Building Development Possibilities - within the administrative boundaries of the areas (based on simplified threshold analysis);
- d) Critical Threshold Constraints - from the viewpoint of the overall angling development strategy.

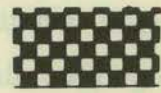
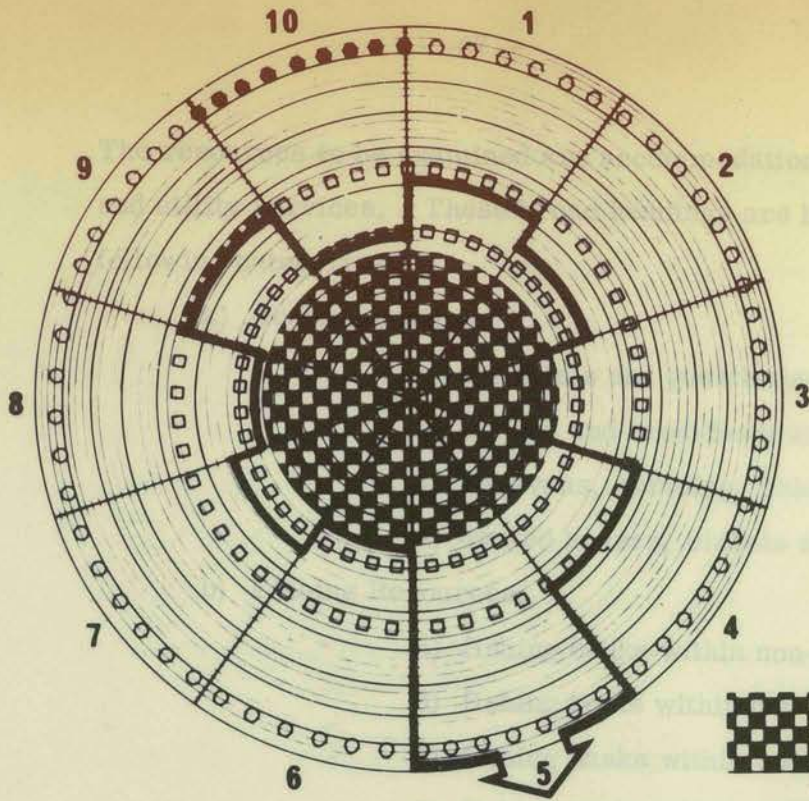
It was considered essential to indicate clearly the impact of threshold constraints on the overall development potential. The diagrams below were devised to show the relationship between existing resources and the use that is made and that could be made of them.

The radius of Diagram A relates to the number of anglers who fish in the centre to which the diagram refers. The scale is arranged logarithmically from the centre, the advantages of this system being:

1. To allow comparatively detailed analysis in the lower numerical ranges;
2. The distortions of areas arising from the use of segments instead of bars tends to be counteracted by the logarithmical scale.

On the diagram the number of anglers presently using the centre is shown. This may be the total for the peak night of the year, or an average of the peak season, or of the off season. The difficulty of using seasons rather than peaks is that the season will tend to vary from centre to centre according to the types of fishing undertaken, which would make comparison of the diagrams difficult, and an accompanying graph showing yearly use would have to be devised to overcome this difficulty.

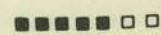
Diagram A



Number of anglers using the centre at present



Existing capacity

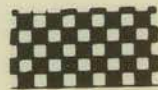
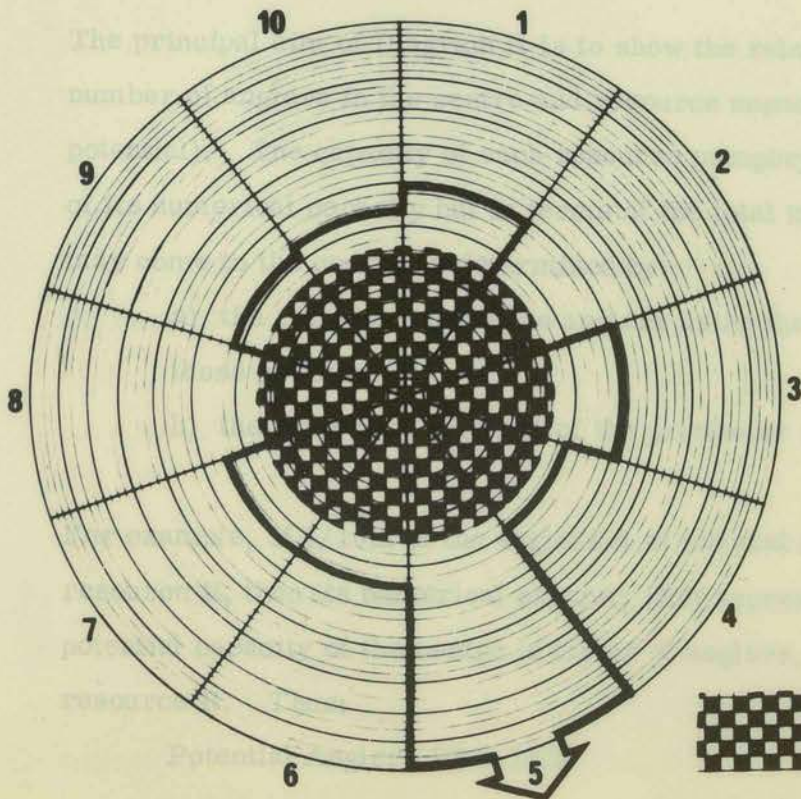


Thresholds imposed by existing capacity



Critical Development Thresholds

Diagram B



Number of anglers using the centre at present



Desired capacity

The resources to be examined are accommodation, fishing resources and utility services. These broad headings are broken down into the following categories:

a) Accommodation;

- 1) all hotels and guesthouses;
- 2) all bed and breakfasts and farmhouses;
- 3) caravans, camping, cabin cruisers;
- 4) rented houses, chalets and all others;

b) Fishing Resources:

- 5) fishing banks within non-walking distance;
- 6) fishing boats within non-walking distance;
- 7) fishing banks within walking distance;
- 8) fishing boats within walking distance;

c) Utility Services:

- 9) water supply systems;
- 10) sewerage systems;

The principal aim of Diagram A is to show the relationship between the number of anglers in the centre and resource capacity (both existing and potential). The capacity of each resource category is shown not in terms of its numerical capacity but in terms of the total number of anglers who may come to the centre as determined by:

- a) the ratio between those anglers using the particular resource and those not using it,
- b) the numerical capacity of the particular resource.

For example, if 1/10th of the anglers A at present coming to the centre use resource R, then its numerical capacity (Rc) represents 1/10th of the potential capacity of the centre in terms of anglers, as determined by resource R. Thus:

$$\text{Potential Anglers PA} = 10Rc$$

Of the two diagrams, the first was based on the existing pattern of use of the resources. The second<sup>(8)</sup> was based on the use of resources that would occur if completely free choice were available. The data for this diagram, B, can be derived from the various questionnaires asking anglers whether they are satisfied, and what alternatives they would have preferred. The first diagram will be inherently more accurate than the second because the first was based mostly on data derived from answers to specific questions such as 'yes' and 'no', or 'a' rather than 'b', whereas the second was based on data derived from more open-ended questions such as 'what improvement would you suggest?'

Nevertheless, a diagram concerned with the present use of resources can only indicate whether a resource is fully used or has spare capacity; it cannot indicate a shortfall of supply (i.e. frustrated demand). Here the second diagram is useful, since the pattern of use that the interviewees would desire given free choice is substituted for the present pattern of use.

Having prepared the diagrams for each of the eighteen centres and placed them on the base map, a picture of the present position (actual and expressed demand) can be set out. The next stage is to discover the significant characteristics that will lead to the formulation of development strategies. The existing potential capacities of each separate resource must first be discovered. Obviously these must relate to the ease with which the resource can be expanded, and at this point the threshold concept is particularly relevant.

Threshold capacities may be plotted directly on to the diagrams by relating them to the present pattern of use and the demanded pattern of use in the first and second diagrams respectively. Once this has been done, it will be possible to see where immediate possibilities exist for expansion and when such possibilities exist after taking into account various threshold constraints.

Critical thresholds will normally be those connected with water supply, sewerage systems, and accommodation. It is unlikely that major thresholds will occur in fishing resources as boats may usually be provided and banks improved or made more accessible, but there may for example be an ultimate capacity in terms of the number of boats that can use a lough at the same time, or critical thresholds may occur when a new harbour installation becomes necessary.

A particular expansion option may be chosen, according to the spare capacities and potential capacities shown in the first diagram; the option is simply represented by a circle of the appropriate diameter. This same option can then be overlaid on to the second diagram, which will show whether it is realistic in terms of expressed demand. Particular options must later be explained in terms of actual resource developments required, and translated into additional investment cost figures, thus providing a basis for a simple economic efficiency analysis.

However, to develop and analyse these options fully it would first be necessary to undertake the second phase of the proposed approach, namely the qualitative approach.

#### Development Incentives

These must be identified and analysed, since they generally represent the assets which increase the attractions of the area in parts or as a whole. They thus provide additional development-generating factors. Some may exist inherently in the natural characteristics of the area, or may be part of the man-made resources; others may be introduced as deliberate Tourist Board policy, or by ad hoc investments.

Analysis should determine those incentives which already exist, define the degree of their significance for the development of angling, and should indicate possibilities for generating additional incentives and their possible influence on development. It should be noted that to formulate a 'realistic strategy', all users of facilities should be considered.

Three major categories of incentive were distinguished:

- 1) For anglers - such as the degree of co-operation of local clubs who may provide maps, information and advice on fishing, bait, and hire of fishing tackle. Convenience of roads to fishing areas was also considered important.
- 2) For non-angling members of parties - such as tourist entertainment and attractions (swimming pools, interesting walks, sunny beaches, etc.)
- 3) For both groups - such as good accessibility for overseas visitors to the area; good quality roads; good service in hotels and restaurants; evening entertainment such as cinemas, night clubs, cafes, restaurants, etc.; outstanding scenic beauty of the natural environment; historical monuments, etc.)

### Development Impediments

Analysis of development impediments was in many ways a simple reversal of that described in the previous chapter: once the incentives have been established it may be said that a deficiency of these would hinder development action. This, however, did not mean that an analysis was unnecessary, for each centre had its own specific character and had to be treated on its merits. There were tourist attractions which in regard to fishing would create insuperable impediments: motorboating, and water-skiing for example. A comprehensive list of such impediments had therefore to be compiled and analysed for the catchment areas of each of the various centres.

### Synthesis

Since this phase of the study is now <sup>(9)</sup> being processed in the Planning Research Unit and may be modified, only a general outline of the proposed course of action will be given here, to present a complete background theory behind the approach devised for this study. The synthesis would in general indicate a phase within which the future prospects of angling should be analysed and development options formulated.

The definition of 'optimised' options is out of the question because of limited time and resources, but it may be possible to develop 'satisfying' options which could be based on a "formulation of alternative courses of actions along the preference scale"<sup>(10)</sup>. From these, a course of action may be taken which would satisfy most needs; the choice is sub-optimal but reasonably satisfactory for this particular exercise. The Irish Tourist Board should then specify the needs required in scale of preference and formulate the most desired objectives for which a hierarchy must be determined. With this information it should be possible to identify the incentives and impediments to which significance should be attached. This would enable a simplified economic analysis to be undertaken by the introduction of a weighting system.<sup>(11)</sup>

The next step in the process of synthesis would be a comparative analysis of the courses of action against the investments, to define the net revenue for any one course of action involved. It is thus possible to define the courses of action which would be economically most satisfactory. In addition, however, less tangible benefits must be analysed. Thus, conclusions can be reached as to which course of action is preferable, and this can be followed by the formulation of recommendations.

As a final stage in this study it might be valuable to consider the set of satisfactory options against the problems resulting from the expansion of

resources beyond their critical thresholds. This would involve the analysis of direct lump sum investment expenditure required; running costs; frozen assets and economies of scale. It is, however, unlikely that this sophistication of analysis would be necessary.

(c) EVALUATION OUTLINE

Any sort of criticism or evaluation of the theoretical developments and practical attempts concerning the direct application of the threshold theory to regional planning problems is difficult as the subject has not generated discussions and comments, for the simple reason that it has not, as yet, been brought into the open through books, publications or professional discussions. The background theory is being printed<sup>(1)</sup>; the first practical test in Yugoslavia could only be described as a result of a direct visit of the author to B. Malisz and the United Nations team in Dubrovnik in 1968; final impact on implementation processes and on the formulation of development strategy is not yet known; and the only test carried out in the Planning Research Unit in Edinburgh had a completion date for the middle of 1971.

Nevertheless, it seems worth while to try to formulate initial impressions and evaluation of this very promising development in overall planning methodology.

From a purely theoretical viewpoint, it must be pointed out that the introduction of the threshold concept into regional analyses is an essential step towards their rationalisation. It allows the provision of new parameters of critical importance in economic efficiency studies since these are always one of the cornerstones of any reliable regional plan or development strategy.

The problem of how to put to the best use a limited endowment of regional resources is where the notion of thresholds may be of particular use; it must however be pointed out that the simplicity and clarity of basic theoretical ideas behind the proposed approach makes its practical application not only possible for sophisticated analyses undertaken by highly qualified experts, using computers, but also for those numerous development studies which are often hampered by lack of time and manpower necessary to undertake a fully comprehensive planning investigation.

Such a simplified approach will be an insufficient tool for the analysis of complex, multi-function regions and it is fair to say that the higher the degree of complication the lower the possibilities of its wide practical applicability. This cannot, however, be considered a deficiency of the method since it is an open-ended one allowing the introduction of computers and mathematical models and able to take on a sophisticated form. It thereby loses a great deal of its simplicity as a practical planning tool but will become more satisfactory as a tool of economic appraisal involving a wider range of disciplines which use or bear upon operational research. The main theoretical doubts arise over the claim that the method has general validity for development analysis of such compound economic activities as industry. The supporting arguments must therefore be examined before the formulation of tentative conclusions.

Any industry, like tourism, must be based on particular resources: transport, water and power facilities, raw materials, and many others. Each specific branch of industry will require various amounts of different resources and any assumed industrial complex will use a certain quantity of resources and will produce a definable income. In countries in which there are still unexploited raw materials it is a relatively easy task to indicate the type of industries which should be developed; in Great Britain however there are practically no unexploited natural resources and the situation at the initial stages of any analysis is much more difficult. As the general aim is merely to point out directions for more expanded studies, it is possible to allow for a general assumption that in most cases encountered in reality a situation may occur which would produce some preferences. If for example in the analysed region an important port is in operation, this would generate the development of particular industries and influence their location. Re-exporting industries should be encouraged, because transport costs and loading of goods is minimised and this type of industry would thus have an economic advantage if placed at the port. Such opportunities and of course constraints should in most cases allow one to

find a 'tying' factor which allows the establishment of the most likely industrial mix for each particular case.

If, as another example, industry is taken as the only function to be developed in a particular region analysed, the resources involved must be examined. Perhaps the available water supply is used to capacity and can only be increased by the implementation of a new water supply system; the clear conclusion is that only 'low water-consuming' industries should be encouraged to develop in the region. At the same time another analysis may reveal that a certain amount of bauxite may still be unexploited, and that there is a vast potential for power supply in the region; the production of aluminium may then appear the optimum recommendation.

This oversimplified analysis example is given to point out that by analysing resources whose capacity can be expanded in lump sums, or in other words by defining their thresholds, important implications can be found which may lead to the establishment of an optimum programme for development: an industrial complex which will use all available resources to the best advantage and will produce relatively the biggest revenue.

The evidence is not convincing enough since it relies on specific instead of general assumptions. In the case of regions whose development is based on 'foot-loose' type industries and in free market economies the number of foreseeable combinations and the amount of data required may be so high that to prepare them for computer processing would take so much time that it would defeat the purpose of the whole exercise. In any case, knowledge of detailed location considerations and input-output relationships between economic units is limited to a few case studies. One can however assume that even then some other factors exist, allowing the reduction of these combinations to a reasonable number of analysed options and to sieve them out by means of threshold constraints.

This leads to the general conclusion that the threshold concept may play an important, and often a critical role, in any regional analyses (including of course industrial development), but that there would exist cases where its significance and usefulness would only be marginal. This does not invalidate the approach as such but indicates the existence of some sort of 'theoretical thresholds' limiting the scope of its applicability. It would be impossible to define these limits in an abstract way, since they would depend on the particular characteristics of the region concerned. Thus in any regional planning exercise an attempt should be made to introduce a threshold concept in the course of analysis and dropped only when proved beyond doubt that in some particular case it would neither have a critical impact on development strategy nor provide essential parameters for economic calculations.

The notion of thresholds in the regional context has been limited by B. Malisz to define constraints connected with indivisible investments needed for their overstepping. This is a deviation from the original threshold concept which also contained limitations determining areas in which additional cost would be spread over the whole implementation period, thus raising unit costs. It seems that in the regional context there would be corresponding threshold costs affecting the extension of various resources and that there is no reason why these should not be considered within the course of a regional threshold analysis.

To assess the validity of the threshold concept in the field of its practical application to regional studies looks even more difficult than an evaluation of its theoretical formulations.

The two cases presented certainly proved that the proposed approach can be put into practice, particularly when one dominant economic activity is the subject of development analysis. It should be noted, however, that the first study was led by the originator of the theory and the second was only

possible because of the direct contact maintained by the Planning Research Unit team with all research and development concerning threshold theory and analysis. In this light it seems unlikely that others will follow up these examples.

Since both cases can be considered successful to a certain extent, and as furthering the threshold of knowledge in the field of applied planning methodology, the main conclusion emerges that similar attempts may lead to significant improvement and development of this new tool which in turn can have a considerable positive impact (if not a breakthrough) on the background theory of regional and sub-regional planning. Even if considered an overstatement this conclusion calls for research to be undertaken towards the preparation of a workable model method - an indispensable starting point allowing for the introduction and critical appraisal of these new ideas in overall planning practice in Britain and elsewhere. However, on balance it would appear that specialised economic, social and planning techniques will have to be brought to bear in an ad hoc fashion. Regional studies will tend to retain an individual character in order to cope with the great diversity of regional problems and constraints.

#### 4. CRITICAL ASSESSMENT OF THRESHOLD THEORY IN THE LIGHT OF ITS PRACTICAL APPLICATION

##### (a) Merits and Demerits

Basic merits - ambiguity of threshold definitions - difficulties of future cost estimation - allocation of threshold costs - significance of threshold costs - problems in defining thresholds - threshold and other development costs - aspects of economies of scale - deceptive attractiveness

After listing the basic merits of threshold theory and analysis its deficiencies are discussed: the ambiguities of threshold definitions which ought to be more clearly formulated; doubts arising as to the validity of costs calculated for long-term periods (although it can be argued that in threshold analysis cost indices serve different purposes than in purely economic studies); the need to eliminate from threshold cost calculations development costs connected with 'externalities' and with raising existing urban standards; significance of threshold costs which may represent only a fraction of total development costs; difficulties in defining thresholds in practice due to their overlapping or to the need to foresee future decisions; lack of 'exploitation costs' and 'frozen assets' in threshold calculations which must be rectified as it greatly reduces their validity; aspects of economies of scale ostensibly indicating conclusions opposed to those from threshold analysis; and finally to the changing significance of some thresholds and to the dangers latent in the attractiveness of the threshold concept which could be overemphasised by enthusiastic planners.

##### (b) Implications for Further Research and Development

Most of the deficiencies identified in the critical assessment of threshold theory and analysis can be removed or at least explained by clarifying basic theoretical assumptions and refining the process of practical application. The full contribution of threshold analysis should be seen in combination with other quantitative methods so that the whole planning process is satisfactorily covered and rationalised. The four most promising directions for further research to be set up in consequence are: refinements of the background theory, comprehensive analysis, application to regional analyses and towards integration with other methods.

(a) MERITS AND DEMERITS

This assessment evolved from the tentative list of pros and cons which served as a starting point for more comprehensive research and constructive criticism of threshold theory and analysis and which was presented in Part 2, Chapter 2.

Basic Merits

As so far formulated and applied the theory reveals advantages valuable enough to justify further discussion and study of this new approach to urban development and its planning. As these advantages have been pointed out several times previously and will be dealt with in the general conclusions, it seems appropriate to concentrate here mainly on a critical assessment of the theory and analysis and at the same time to indicate possible arguments in defence.

However, major positive factors or basic merits of threshold theory and analysis as so far recognised ought to be briefly enumerated and characterised, by pointing out that:

1. The introduction of the threshold concept may help towards a better understanding of the mechanism of the development of towns.
2. The stimulus towards quantification, even in the simplified form of threshold analysis, provides a bridge between economic and physical planners and a 'feedback' between local and regional planning levels.
3. The definition of thresholds and calculation of threshold costs makes objective comparisons possible among all logically devised variants of a town development.

4. Similarly, it may also be possible to compare development potential among various towns, although this is open to considerable dispute. There is a conditional case as to which town to develop by showing how to optimise the distribution of population increase if this increase is known and if the location of employment has been established.
5. 'Threshold logic' represents the development of a new way of thinking in planning methodology, opening prospects for further research and more extended applications.

As far as demerits are concerned, it is intended to bring forward a number of important criticisms and to set up defending arguments derived from discussions and from this research. The primary concern is to find out either if the weaknesses are inherent in the threshold theory itself or whether they characterise imperfections of its conceptual formulations and deficiencies of threshold analyses in this form which have been carried out. This assessment should identify those aspects of threshold theory and analysis which are worth developing as offering promising prospects of progress in the evolution of planning methodology.

#### Ambiguity of Threshold Definitions

The basic definitions on which the whole theory has been founded have never been formulated with wholly satisfactory precision and accuracy, thus leaving a relatively wide margin for interpretation.

In considering the possibility of further research on the development of this theory, it seems necessary first to establish precisely what 'threshold' means. Careful investigation of the way in which the term

has so far been interpreted has disclosed no very informative definition: "disproportionately high cost" and "a radical reconstruction of existing systems" are some of the phrases used by B. Malisz in defining the notion of the threshold. Doubts are bound to arise when one tries to define precisely what these terms mean; when are costs 'disproportionately' high, and what criteria determine whether a reconstruction is a 'radical' one? As the whole threshold concept has been so logically developed by Malisz himself, in the course of practical application few doubts arose as to which limitations to urban expansion were to be identified as of a threshold character. Nevertheless, what may be considered sufficient for the initial, simplified applications of threshold theory may not be satisfactory when its more comprehensive forms are to be applied. Even in the simplified form an explicit definition of a 'threshold' is required, which after all is the cornerstone of the whole theory.

Ambiguity of threshold definition affects the definition of threshold cost, which can generally be considered in three groups:

- (i) Costs which produce no effects until the whole investment is complete (e.g. money must be invested in the construction of a bridge, but no return is possible until the bridge is completed), and a graph of total costs would show these costs rising vertically.
- (ii) Costs which are spread over the whole period of implementation, producing immediate partial effects. These are usually proportional to the expenditure (e.g. when developing land with a limited load-bearing capacity, additional money must be invested in the foundations of any new construction).

- (iii) Costs which are a combination of (i) and (ii). These involve some spending at the beginning of the implementation process, but allow the spreading of the remaining part over the whole period (e.g. when constructing a sewerage network, the treatment plant and main collectors must be built first, the remaining parts of the system being implemented in phases).

To accept this type of subdivision, one must be certain whether it is proper to put such different types of costing as (i) and (ii) under the same heading of threshold costs; this reflects the need to re-analyse the initial definition of a threshold and to formulate it, if possible, in precise mathematical language. This may eventually lead not only to the clear characterisation of threshold costs but also towards classification of various types of thresholds faced by expanding settlements and regions. This classification would help in many practical cases where it is difficult to decide which of the encountered limitations should be treated as thresholds and what degree of significance should be attached to them in relation to the particular settlement involved.

#### Difficulties of Future Cost Estimation

The value of threshold cost calculations was subject to severe criticism, particularly in economic circles; it is difficult to deny that cost indices calculated for long periods ahead are of only relative value, and when a period of 30 to 40 years is concerned the calculations can hardly be said to be founded on a scientifically warranted basis rather than on "prophecies".

Some long-term predictions can be defended on the grounds of logic, but it is clear that "there is yet to be discovered a well-founded methodological basis or rules of approach for truly scientific predictions ..."<sup>(1)</sup> as stated by

Kolipinski who returns repeatedly to this problem, particularly when discussing the difficulties inherent in long-term calculations where he states that: "in economics we have been considering the calculation of a perspective plan (to what extent and how existing prices ought to be altered), taking into account structural changes in the whole economy, changes in relations, changes in technical knowledge, etc."<sup>(2)</sup> It must be admitted that no satisfactory answer has yet been found.

There will be ready agreement among economic planners that long-term plans should not use current prices but 'shadow' prices which reflect the changing composition of demand and new production techniques.<sup>(3)</sup> However, the problems of creating accurate prices for a future as long-term as the horizon normally associated with physical planning decisions are immense. Not only is the perspective of the physical planner long-term, but the costs of reversing decisions is large. Physical planners are bound to use a distant horizon since they must take decisions of an irreversible character<sup>(4)</sup> with far-reaching consequences. This is acknowledged by Kolipinski who states that: "unfortunately it must be admitted that planning for 40 to 50 years ahead, even limited to an assumed growth of gross national product ... cannot claim to be based on any scientific arguments. However, there are situations in the life of persons or communities where decisions are needed, the consequences of which reach many years ahead and are often practically irreversible. These decisions, however, are bound to be taken when there are alternatives of choice ... it is important to limit the number of such fundamental decisions to the really indispensable ... and consistently to minimise the degree of subjectivity."<sup>(5)</sup>

The conclusion need not be a complete rejection of long-term threshold cost calculations as inaccurate, as until there has been no better practical method of tackling this problem worked out, its replacement by conventional, available and fully intuitive "guessing methods" does not appear a sensible suggestion. Admitting all the difficulties, positive

conclusions must be sought for and "we have to remove deficiencies both on the side of town- and economic- planning".<sup>(5)</sup>

It should be pointed out here that by using indices calculated in the same way for all areas or towns involved, mistakes can be greatly reduced. The main aim of Threshold Analysis is not a direct study of investment costs, but rather their comparison to detect the 'least-cost' directions of growth from the angle of land availability; as B. Malisz states clearly: "the aim of Threshold Theory and Analysis is not the evaluation of the functional efficiency of a settlement system, but only the evaluation of the efficiency of taking these or other areas for the further expansion of a town . . .".<sup>(6)</sup> It is therefore unfair to criticise threshold analysis on the grounds that it does not produce accurate information for long-term economic-efficiency calculations of urban development possibilities, as it is impossible to undertake these calculations due to the present state of economic theories and methods related to this question. Long-term threshold cost calculations can be put forward as an instrument providing a common denominator for comparisons and a general 'warning device' for all analyses of long-term development possibilities.

The situation in short-term planning is one in which calculations of economic efficiency can be made. Threshold analysis in its developed, or 'comprehensive' form may produce vital parameters which make such calculations possible. Close co-operation with economic planners would be necessary in order to undertake research into the formulation of appropriate methods applicable to 'everyday' planning practice. A simplified solution indeed, but if developed and applied with caution, it would provide, for the time being, the only way of pushing ahead the 'threshold' of knowledge in quantitative planning methods on a really wide front.

The Allocation of Threshold Costs

An important difficulty in cost calculations is the problem of what should be taken into account: which costs connected with a new transport system should be considered as the cost of town expansion and how much should be allocated for improvements of a regional system, for instance. The town which takes its water from a big inter-regional reservoir must be analysed in a different way from that which has a water supply of its own. How can the expansion of a treatment plant for residential uses be compared with one serving a big industrial complex as well as local population? Even the few examples quoted indicate that the place and role of so-called "externalities" in threshold analysis must be clarified and established. In this analysis that part of investment costs which is directly involved with servicing of the town's future population must be considered separately from that part necessary for development of its regional or national functions, as the case may be.<sup>(7)</sup>

The danger of mixing threshold costs with other costs lies in the fact that existing standards of servicing vary from town to town, and it often happens that an important part of an ostensibly 'pure' threshold investment would not be designated for new inhabitants but for the existing (under-served) population. Kolipinski thinks that "levelling, in a given town, for calculation purposes, of the existing standards concerned with servicing and consumption, cannot be ignored in comparison of costs among various towns, or development alternatives"<sup>(8)</sup> Regulski and Wyganowski place particular emphasis on the aspects of existing equipment of a town, as can be seen in the chapter on the Warsaw Province Development Study.<sup>(9)</sup> Gliszczynski<sup>(10)</sup> is also quite explicit on this point and argues that in aggregated cost indices concerning allocation of new inhabitants there is "... no subdivision as to which part of investment expenditure is to be used for upgrading existing levels of the town's economy and which should be seen as directly involved with the population increase ..." Malisz

concludes: "This may be particularly misleading in cases when a threshold has occurred and no outlays were made to overcome it. It is a fact that a town in such a situation may be treated as "expensive" for its further development although this would result only from the necessity to repair former negligence. Therefore the index W (cost per new inhabitant in threshold analysis) should be investigated together with the index of threshold costs calculated for all inhabitants. The difference between these two indices in various towns should become the subject of detailed analysis before conclusions concerning the further development of these towns are drawn."<sup>(11)</sup>

This problem is a significant one and the answer seems to be twofold. Firstly continuous research is necessary, coupled with practical testings in order to sort out the problems, to define the common cases, and to indicate the most appropriate way of obtaining the 'purified' cost per inhabitant, that is, the way to identify and eliminate costs involved with 'externalities' and costs necessary for the improvement of existing standards up to an acceptable level by some prearranged target date. Secondly, the current shortcomings in the technique must be kept in mind in its application to act as a safety valve against the danger of an over-confident planner overlooking the critical factors distorting the reliability of the final result, which would require correction before any comparisons may be undertaken and conclusions drawn.

#### Significance of Threshold Costs

The fact that threshold costs represent only a fraction of total development costs has led to a number of critics discounting the significance of threshold analysis studies. Threshold analyses in planning studies usually concern selected groups of constructions and specific types of costs, and as a result the average ratio would be about 5% of the total development costs, only

in special cases amounting to 30% or more.

Malisz subdivides investment expenditure for town development into two groups (according to official classifications):

- 1) Investment expenditures concerning industry, agriculture and forestry, construction firms, administration, inter-city communications, sources of electric power, gas and heating for industries;
- 2) Investment expenditures concerning direct living standards of citizens: residential, community services (education, telecommunications, etc.), recreation and green space, transport and urban communications, water supply, sewerage treatment, power networks.

J. Kowalski <sup>(12)</sup> contests this division and states: "Comparing figures quoted by B. Malisz with data included in 'Annual Statistics' which subdivide investment expenditures in a different way, one can find that the first group includes about 2/3 of investment expenditures and the second about 1/3. Thus the more detailed subdivision of investment expenditure can be presented as follows:

**Investment Expenditure for Town Development:**

First Group - 66.6%

Second Group - 33.4%

Including:	(1) housing	16.5%
	(2) community services	7.5%
	(3) greenery	0.4%
	(4) communications	3.7%
	(5) water supply	1.3%
	(6) sewerage treatment	1.6%
	(7) power supply	2.4%

'Studies investigating town development possibilities (i.e. threshold analysis) only consider investment expenditures concerning urban communications (4), water supply (5), sewerage treatment (6), land improvements, compensation costs and compensation investments.

"Threshold analyses are mainly concerned with those expenditures which are directly connected with making particular areas suitable for development. Usually, however, they exclude expenditures for rising living standards in existing parts of the town, and those which are not connected with the location of new development areas. Summing up, one can assume that it deals with about 2/3 of sections (4), (5) and (6) (3.7%, 1.3% and 1.6% respectively, totalling 6.6%), i.e. constituting approximately 4.5% of the total investment expenditures involved in the development of a particular town". Kowalski later concludes: "since only part of these expenditures would be variable one may conclude that the biggest savings would never exceed 1% to 2%."

This reasoning, however, ignores the aspect of operating costs and draws conclusions from average statistics. Three important points which put Kowalski's criticism in a somewhat different light may be emphasised. Firstly, threshold analysis is also concerned with part of (1) and (2) investment expenditures in Kowalski's second group: for example foundation costs are often affected by threshold limitations. Secondly, threshold costs represent those costs which are "location-bound" and are therefore directly dependent upon planning decisions and can be greatly reduced by improved and rationalised design. This is not the case when other costs are concerned since these are beyond the planner's control and represent independent variables. The costs of construction, for instance, depend on the technology applied, materials used, standards desired by the community, the authority, or a 'client'; the planner can scarcely question these and certainly cannot change the resulting costs by his design.<sup>(13)</sup> Thirdly,

threshold analysis must not be looked upon through average statistical figures since by its nature it is oriented towards detecting significantly atypical situations, that is where costs in groups like (4), (5) and (6) jump 'disproportionately' over and above average level. Threshold costs may therefore very often represent much more than a mere fraction of the total development costs. If however it is found that there is only perhaps a 2% saving from the aggregated results of threshold analysis, it almost certainly implies that some average statistic index has been calculated on a regional or even national scale. In such cases, total development costs represent a particularly large amount of money and even a modest 2% is a significant saving worth undertaking, especially since these savings may be effected without detriment to the basic objectives of planning - "man and his environment".

#### Threshold and Other Development Costs

The success of threshold theory, its immediate application and the lack of criticism in this initial period produced side effects; it now seems that this was the reason Malisz considered it unnecessary to develop and strengthen the main theoretical assumptions and formulations. This becomes particularly apparent when one realises that such important aspects as the impact of frozen assets, economies of scale or exploitation costs were almost ignored in the theory itself and not mentioned at all in the instructions for threshold analysis. Direct discussions with Malisz and to some extent his comments during various conferences, and finally his later papers concerning the theory leave no doubts as to his awareness of these problems. So far, however, he has not satisfactorily developed the theory in this direction.<sup>(14)</sup> There is a danger of overlooking these important aspects which is of particular significance when any new application of the threshold theory to planning practice is considered; one of the most important conclusions deriving from the critical

assessment of the threshold analysis (as so far applied) is that the degree of its simplification is too high and tends to invalidate the claim that the analysis is a sound tool for comparison of various development possibilities among the towns within a regional or national range. The essential weakness of the practical approach lies in the fact that cost calculations and resulting indices have been mainly concerned with 'initial investment costs', which in many cases certainly must have produced a distorted picture of the real situation and its economic conditions. The awareness of the possible significance of these other costs is absolutely crucial in any further applications of threshold analysis.

For instance, exploitation costs should be taken into account: the selected solution which would be most efficient in respect of initial investment costs may well involve substantial increases in the operating or running costs of the developing area.<sup>(15)</sup> It is obvious, therefore, that these costs should also be introduced into the scope of the analysis for any comprehensive calculations. This was not the case in Poland, where these costs have been considered in only a few cases and never fully examined.

The difficulty in introducing 'exploitation costs' appears to be twofold. First, they will immediately complicate a relatively simple and straightforward calculation of initial investment costs; and second, it is hard to assess exploitation costs particularly of public utility services, as these costs are so often concealed in municipal joint accounts, making their identification wellnigh impossible. These difficulties are by no means irremediable; they require theoretical research into possible simplifications of equations concerning exploitation costs (which are widely applied in economics) in order to make their use feasible for an average physical planner. Separate analysis of methods by which these costs are usually counted on the various levels of administrative structure should indicate their separation for the purposes of accountants' balance sheets.

Analysis of initial and exploitation costs only is not enough; returning to the main question of what should be included in threshold cost calculations, the results from the simplified type of threshold analysis may be significantly altered if the impact of frozen assets is also investigated, in particular when large scale investments, spread over many years, are involved. The losses resulting from frozen assets can be calculated and the importance of such calculations should not be underestimated since the sum involved is frequently a substantial one.

A useful illustration is provided by an analysis concerning two alternatives for the railway system for Cracow in Poland. One alternative was to modernise the main line and its central station, and the other involved re-alignment of the railway line and shifting the station into a much better location in relation to the future expansion of the town. Since the operation was on a large scale, it was decided to analyse the economic efficiency of both alternatives. Phase one of the study concerned initial investment costs only, and this revealed that the total costs of the two solutions was more or less equal; but the analysis of frozen assets as an important factor of economic efficiency showed the two alternatives in an essentially different light.

Continuous improvements and electrification of the existing line and improving the functioning of existing facilities would show immediate partial effects in consequence of any investment expenditure allocated. For the second alternative, however, the new lines would have to be completed before any effects were possible and accordingly during the whole period of its implementation the old line would have to be maintained. When all these costs were calculated it was found that the second alternative was over 50% more expensive than the first, which was much more than the community could afford for the provision of an improved transportation

system for the town's expansion. This practical example confirms that the losses deriving from frozen investments may represent a significant sum, and that frozen assets must be calculated if a sound basis for comparison and choice among various alternatives is to be provided.

Analysis of frozen assets is essential not only because their impact may be significant for development strategies, but also because, once identified, it is possible to reduce their influence. Two possibilities would be seen immediately: first the feed-back of information obtained to the regional planning authorities, indicating the need to speed up population increase in the town concerned in order to shorten the period in which investment is frozen (i.e. to reduce the time needed to make full use of the investment) and second, subdivision of the implementation process into phases, so that respective segments of the construction involving freezing of capital could be working in a relatively short period of time, thus providing an early return from the expenditure.

These two possibilities would occur only in a simple case of "to cross or not to cross" a particular threshold. In normal practice, however, there can be various thresholds limiting possibilities for town expansion. It must also be remembered that in most cases the character of threshold costs is compound: part of these costs has to be spent initially (thus producing the phenomenon of frozen assets) and part is spread over the whole period of development of the analysed area. The calculation of threshold costs must, clearly, include the impact of frozen assets and of exploitation costs. Only then may development alternatives be properly compared and reliable conclusions drawn to influence planning decisions.

To be practically applicable, calculation of frozen assets should be simplified since in its original form applied by economists, it would be confusing for physical planners who are usually unfamiliar with this type of calculation. One simplification may be to apply an interest rate to the calculations which may then reveal the range of money lost through freezing with enough accuracy in most cases to be adequate for comparison, and only in the most complex problems would it be necessary to go into more intricate calculations.

### Aspects of Economies of Scale

Unfortunately, further complications arise, since any analysis of frozen assets and any attempts to assess their importance in threshold cost calculations are bound to raise the problem of economies of scale, as the two phenomena are closely related. Economies of scale, in simple terms, represent the effect of a decreasing capital requirement index (initial investment cost calculated per head of population to be served or per unit of production) as the size of the construction in question increases.

Analysing some of the facts revealed by Polish research<sup>(16)</sup> into the economic efficiency of various investments necessary for expanding towns, it can be seen that in most cases if there is a comparison between a small construction in the public utility networks serving a small number of people, and a large construction for a large number of people, then the initial investment costs for one inhabitant tend to be lower in the case of the large construction. This difference widens if exploitation costs are included in the analysis. This means that economic efficiency in relation to initial investment costs improves when the magnitude or size of constructions (treatment plants, water supply networks, power stations, etc.) increases. Each construction also has its own 'magnitude threshold' occurring for instance when its implementation results in technical difficulties prohibiting any further increase without a complete change

of construction technology, or the use of new materials.<sup>(17)</sup> This phenomenon, which may be defined in any particular case, represents another limit within which the question of to cross or not to cross should be analysed.

The concept of economies of scale seems at first glance to disqualify the meaning of thresholds in town expansion. According to threshold theory, the growth of a town should be kept within a threshold limitation until the substantial amount of money needed for its overstepping is fully justified in terms of urban growth economics. On the other hand, as shown above, a large expenditure may ultimately result in lower costs of servicing the new population. It may thus be postulated that to cross a very costly threshold is justified because the larger and more expensive the construction, the better the per capita return. This criticism is weak on two grounds: (a) the larger project is justified only if it can be fully utilised, e.g. by accommodating a large influx or growth of population and (b) the large initial costs, even if eventually justified, pose a short-term problem, because of the frozen assets phenomenon (the larger the construction the longer it takes for full exploitation).

Thus it can be seen that only when frozen assets and exploitation costs are taken into account, all parameters necessary for proper comparisons and conclusions are provided. It is obvious that the aspects of time and of frozen assets must be an inherent part of any comprehensive cost analyses and that the relations between these two factors and the economies of scale should lead to optimised decisions, especially since separately they represent exactly opposite directions.

### Problems in Defining Thresholds

Planners frequently complain of the difficulties connected with precise definition of threshold lines or figures, which in practice are rarely clearcut: this is sometimes a surprise to those who expect to encounter in reality the same simplicity as in theoretical presentations of abstract cases. Kolipinski states that thresholds in one system will seldom coincide with thresholds in another, which may result in the obliteration of threshold lines.<sup>(18)</sup> This phenomenon, called "braided threshold lines" was pointed out by B. Malisz<sup>(19)</sup> and discussed by others.<sup>(20)</sup> All this reflects the well-known fact that reality is far from simple, and does not invalidate the basic theory formulations.

The possibilities of an objective definition of successive threshold lines were also questioned by some critics<sup>(21)</sup> who rightly argue that successive thresholds depend upon the volume of reserves created in works when overcoming the previous threshold. Constructing a new sewerage network, main collectors may be laid deeper to serve a large area, or shallower for a small area. In the first case more money would be spent, greater reserves created and the next threshold pushed back, while in the second the threshold would be nearer since reserves would be smaller. From this observation Regulski and Wyganowski<sup>(21)</sup> draw the conclusion that only the nearest threshold is definable and that successive thresholds will result to a great extent from investment policy, thus an objective definition of their position is impossible.

It ought to be kept in mind, however, that threshold analysis indicates the implications from existing conditions. B. Malisz makes it clear that the analysis was not formulated for assessing the consequences of all possible future situations. It may of course be feasible in some cases but it is hardly a fault of the theory that this assessment cannot be done in a fully objective and comprehensive way. Even the acceptance of only

the nearest threshold as objectively definable entails the qualification "in a particular system", since in most cases successive thresholds for an analysed town are imposed by other factors identified from the analysis of existing conditions in all groups concerned.

#### Changing Significance of Some Threshold Limitations

Oversimplification in the application of threshold analysis is partly to be blamed for shortcomings in the assessment of the weight to be attached to various thresholds. It has often been overlooked that the significance of a threshold does not depend solely on the cost of its overstepping, but that there are other criteria, often difficult to measure, which may considerably influence the financial judgments. The main factor (so far nearly totally ignored in threshold considerations) is the process of change; if considered as continually occurring in time this may throw an entirely different light on the established significance based on cost indices of certain development thresholds, which is particularly important because in the majority of cases the significance of these thresholds in a long-term period will be the subject of concern. Progress in technology or an improving national economy may, over time, greatly reduce the significance of particular thresholds: new ways of treating sewers or new techniques of piling may make 'sewerage thresholds' or 'low bearing capacity thresholds' irrelevant limitations to future implementation processes. Conversely, due to different factors, the importance of other thresholds may change and their impact on future development may be much more critical than indicated in analysis solely of their current position. Some of these aspects have been brought out by J. Jezierski and B. Szermer<sup>(22)</sup> in their interesting article on the role of thresholds in sewerage systems, where they state that in the practical

application of threshold analysis in Poland essential and less essential thresholds were equally treated without proper consideration of their changing significance in the course of time. They provide an explicit example, arguing that: "even ignoring incorrect assumptions that watersheds always define the boundaries of areas suitable for the provision of a sewerage network based on gravity, it must be stated that the problem of constructing a pumping station - in cases where the altitude to be overcome and the amount of sewers are not excessively high - does not involve an increase in cost such as to justify the consideration of this limitation as a town's development threshold. Parallel to this clear overestimation of the significance of some technological thresholds, very little attention has been attached to thresholds resulting from biological conditions. A characteristic example here is the problem of disposal sewers, or more precisely, the problem of the biological capacity of sewage-receiving bodies. This problem, already important today, will become more so and more difficult to overcome due to further unavoidable development of towns and industries which will cause an increasing threat to the biological balance of rivers and other water reservoirs." It can thus be clearly seen that while the significance of thresholds defined by watersheds will be diminishing in time, thresholds related to the biological balance of the natural environment will be continually growing in significance.

Similarly, thresholds may become either nearer or further away. Considering, for instance, the capacity of an existing road system, taking into account the time factor, it can be seen that this system, due to increased car ownership, will be able to accommodate proportionally fewer new inhabitants in twenty years' time than in five years' time. It is also important that such a 'moving forward' of thresholds occurs at different rates in various parts of the country. True enough, threshold analysis is not concerned with differences resulting from changing standards, but the significance of the described phenomenon for calculating

a 'threshold potential' must not be ignored. The whole problem may create considerable difficulties in practice particularly in the case of attempts to unify threshold approach for regional or inter-regional comparisons, when it will acquire a critical significance although even if a single town is considered it will greatly influence indices reflecting urban development possibilities. It is of course essential to approach and tackle this problem adequately in the course of threshold analysis.

Discussing the relative significance of respective thresholds in time it is appropriate to indicate other possible circumstances in which two nearly identical thresholds may exert a widely differing impact on development in two respective localities (providing the sizes, functions or rate of growth of these localities are not the same). It is much easier for instance to build a new treatment plant in a fast-growing industrial town than in a slowly developing rural one, although both may be of the same size; it is also a fact that the larger a town the bigger (usually) its development budget and in consequence it would be much easier for its authorities to give the 'green light' for the implementation of costly operations. The latter situation becomes quite distinct in the free market economy conditions of Great Britain where most threshold costs would have to be accommodated by the community itself: eventually inhabitants, through increased rates, cover threshold expenditure. Clearly, the larger the town the smaller the burden on each inhabitant and vice versa - and similar circumstances may influence the changing weight to be attached to similar types of thresholds faced by towns of different sizes. Credit should here be given to B. Malisz who has in his theoretical discussions noted the existence of the problem, but since unfortunately he has not expanded upon it, the problem has been rather overlooked in practical applications of threshold analysis.

Concluding, further research into aspects of relative and changing significance of thresholds is necessary to identify the most common cases, to build a prognosis indicating the possible trends affecting particular types of thresholds by either reducing or increasing their significance, and to specify those thresholds. The relation between town sizes, rates of growth and thresholds should also be investigated as it seems possible that some general interdependence can be discovered and ways of meeting this problem in comparative studies formulated.<sup>(23)</sup> In any case, it should be emphasised that, as in a number of previous cases, the awareness of the existence of the whole problem of relativity and change is a basic 'safety valve' in any immediate applications of threshold analysis, since most of the doubts and questions involved can to a great extent be sorted out by commonsense reasoning coupled with the necessary degree of technical knowledge.

#### Deceptive Attractiveness

It should be pointed out that the danger connected with the attractiveness of the threshold theory is that it often seems to be presented by some planners as a new, simple and logical 'gimmick' to impress a client or fellow professionals. In consequence, assuming that in the case of any individual town no thresholds occur, or that they are very unclear, the danger arises that the planner would try to invent non-existing thresholds in order to fulfil his expectations linked with the use of a new planning technique. As this in fact has taken place in some cases and obviously has detrimental effects both for planning decisions and on the development of planning research itself, it is considered necessary to draw attention to this danger inherent in applying threshold analysis in a hasty and ill-conceived way.

(b) IMPLICATIONS FOR FURTHER RESEARCH AND DEVELOPMENT

An explicit conclusion emerges from the critical assessment, namely that deficiencies are not inherent in threshold theory and that, in consequence, its basic assumptions are correct in principle. Most of the weaknesses and discrepancies discovered are due to the relatively high degree of simplification caused by hasty practical application of threshold analysis and by the need to elaborate the working instructions on a fairly elementary level.

No obstacles prevent systematic examination of the roots of these problems in order to clarify basic assumptions of threshold theory and to refine the process of its practical application. These objectives can generally be fulfilled by clear formulation of the basic definitions on which the whole concept has been based and by incorporating in the analysis all and only those costs reflecting the impact of threshold phenomena on development possibilities of expanding towns.

The 'simplified' threshold analysis as developed so far should be superseded by its more sophisticated, 'comprehensive' form; only then a number of possibly serious mistakes and shortcomings can be eliminated from all final conclusions and in particular from those connected with economic aspects.

In any refinement and development of threshold theory and analysis it is important to avoid extremes and in consequence "throw out the baby with the bath water"; threshold theory is a very useful practical tool mainly because it is simple to understand and to apply. Thus while further evolution of the theory should be continued it would be a serious mistake if threshold theory and analysis were eventually transformed into a highly sophisticated form which while impressive and theoretically

faultless would be of little use to planners in the field (as are so many interesting and progressive planning methods owing to their complicated approach).

If problems become too complex it should be advocated that the increased number of variables, unavoidable in any significantly extended form of threshold approach, should be adequately dealt with in an 'optimisation' methodology<sup>(1)</sup> further removed from the threshold concept. This point may have wider implications since analysing all the criticisms so far discussed it can be noted that the theory has often been blamed for not providing solutions to problems clearly beyond the scope of the whole threshold approach. These apparent misunderstandings seem to be caused either by confusion as to the place and role of threshold analysis in the overall planning process, which must then be further clarified, or by awareness of significant gaps still left in this process after threshold analysis has been applied: the latter observation led to false conclusions implying that threshold analysis should have covered these gaps with the only possible outcome being a general abuse of the method. The point has rightly been made, since it is far from satisfactory if only some parts of the planning process are rationalised - the quality of the final results, their comprehensiveness and degree of accuracy are always determined by the weakest part of the whole range of analytical proceedings and investigations. One of the possible answers to this problem seems to be that the full contribution of threshold analysis should be seen in combination with the other complementary methods which would thus cover the whole cycle of the planning process, or at least the most significant gaps in it. In this context the information deriving from threshold analysis may even function as parameters to the other methods.

Summarising all that has been said so far it seems possible now to conclude that there exists considerable scope for development and refinement of threshold theory and analysis which require much further research aiming towards:

1. Refinements of the background theory in its present form by:
  - a) formulation of precise definitions (regarding the notion of the threshold itself and threshold costs) together with the more exact and unequivocal classification of all kinds of thresholds;
  - b) widening its scope to open possibilities for analysis of initial investment costs together with frozen assets and exploitation costs, considering their interrelations with the economic efficiency of large-scale investments. At the same time theoretical guidance must give an indication of how threshold costs can be isolated in their purest form from all other costs involved in urban development.
  
2. A 'comprehensive' threshold analysis by:
  - a) devising a refined framework for a practical method of the analysis which would correct its basic deficiencies and would enable the investigation not only of initial threshold costs but also of all other relevant costs involved;
  - b) analysing the possibility of applying computer techniques to threshold proceedings to allow for significant increase of the number of variables to be handled and for the introduction of mathematical models adequately to cope with more complex cases.
  
3. A fuller development of direct application of the threshold concept to regional analyses by:

- a) devising workable models of this approach to characteristic types of regions and by
- b) testing the models on a number of life projects to reveal the degree of their practical validity, to indicate critical deficiencies and to allow for step-by-step verifications and refinements of this new, promising, but still untested planning tool.

4. Towards the integration of threshold analysis with other quantitative methods and their clear allocation into one comprehensive model of the planning process, developed by:

- a) research into the background theory concerning the overall design processes;
- b) selection of complementary planning methods;
- c) formulation of a model of an 'Integrated Planning Process' comprehensive and flexible enough to enable the introduction of any relevant techniques or methods which should then be tested and verified in the field.

As already pointed out, a great deal of research and discussion would be required if these aims are to be achieved. Some will be taken as the main themes for successive chapters in the following section<sup>(2)</sup> dealing with the development of threshold theory and analysis in a modest attempt to push out the 'threshold' of knowledge in the field of applied planning methodology.

1. APPLICATION OF THE THEORY OF ...

(a) Canadian Case

1. It should be pointed out that the ...
2. The network of ...
3. Even so ...
4. A. ...
5. The official rate of exchange in 1970 was ...

APPENDIX: FOOTNOTES

(b) Abstracts of Urban Development Proposals for the Warsaw Voivodeship

1. Done by E. Brodzinski, K. Hutegalski, M. ...
2. J. ...
3. Mrs B. ...

(c) Footnote Details

1. ...

1. APPLICATION OF THE THRESHOLD THEORY IN POLAND(a) Nationwide Test

1. It should be pointed out that this practical approach proceeded simultaneously with the development of the theoretical formulations. In fact these multidisciplinary discussions and first 'laboratory tests' were used by B. Malisz for the final refinements of the background theory which was published in its full version in 1963. (B. Malisz 37 and 38)
2. The network of Town Planning Offices is a part of the country's planning machinery. These Offices, attached to the National Voivodship Councils, are responsible for the preparation of statutory urban plans for all towns in the Voivodship concerned (Poland is administratively divided into 17 Voivodships each containing from one to three million inhabitants). Regional Planning Offices are formed as separate bodies also attached to the same Councils but responsible for elaborating regional plans of the whole Voivodships. A lower rung in the planning ladder is represented by Planning Offices attached to the National Powiat Councils (each Voivodship is divided into a number of administrative districts called powiats) and dealing with statutory planning for small towns, villages and parts of the powiats' capitals.
3. Even so outstanding a scientist as J. Kolipinski fell into this trap in his very interesting publication. (J. Kolipinski 24).
4. B. Malisz (40).
5. The official rate of exchange in 1970 was approximately 60 zlotys to £1.

(b) Analysis of Urban Development Possibilities for the Warsaw Voivodship

1. Done by K. Brochocka, K. Konopkova, B. Maliszowa, I. Poniatowicz and J. Regulski within the Town Planning Office for the Warsaw Voivodship.
2. J. Regulski and S. Wyganowski (53).
3. Mrs B. Maliszowa (46).

(c) Evaluation Outline

1. This was particularly important since the theory itself had only recently, and thus not fully, been developed. This point was stressed by some scientists such as K. Dziewonski who wrote: "the so-called Threshold Theory, the new and not yet developed theory though interesting, and in its basic principles at least partially properly founded . . ." (K. Dziewonski 9).

(c) Evaluation Outline (continued)

2. This different approach applied by respective Town Planning Offices and above all the various degrees of accuracy on which calculations were carried out was later pointed out, among others, by F. Gliszczynski (12) who argued that usefulness of cost indices for any sort of comparative studies was, therefore, extremely limited.
3. This was noted and emphasised by B. Ledworowski (31).
4. J. Kolipinski (23).
5. S. Wyganowski (58).
6. This was later taken into account in Scottish applications where it was emphasised that any conclusions drawn from simplified threshold cost indices must be regarded with great caution.
7. Particularly in B. Malisz (42).
8. J. T. Hughes and J. Kozlowski (17).
9. This was later confirmed by other authors such as J. Marshall who pointed out the possibilities of linking the computer mapping technique SYMAP (developed at Harvard by the Laboratory of Computer Graphics) with threshold analysis (J. Marshall 47) and J. Forbes who argued that threshold analysis is particularly suitable for computer graphics (J. Forbes 11). Specific research has also been undertaken in this context by R. Brown of the Planning Research Unit, Edinburgh University, which is due for publication at the end of 1971.
10. Under the direct guidance of B. Malisz, by the French-Yugoslav team led by C. Sauer (C. Sauer 57).
11. Initiated and described by R. Charles (5 and 6).
12. By T.M. Vinod Kumar of the School of Planning and Architecture, New Delhi.
13. Introduced by M. Safier (M. Safier 56).
14. In which W.C. Cunningham on the basis of selected threshold cost indices tested possibilities of applying threshold analysis to probabilistic simulation models, trying to forecast from 1948 data for Cincinnati its growth up to 1960. Comparisons with factual situations revealed about 40% of conformity - quite a success taking into account the simplification of the exercise.
15. Among others, CODA (Community Design Associates) of New York, Montreal University, Royal Institute of Technology in Stockholm, CINAM (Compagnie d'Etude Industrielle et d'Amenagement du Territoire), Paris, the Instituto di Studi per la Programmazione Economica in Rome, and numerous bodies in the United Kingdom.

## 2. TESTING AND DEVELOPMENT OF THE THRESHOLD THEORY IN SCOTLAND

### (a) Grangemouth/Falkirk Sub-Regional Plan

1. A full and detailed description of this application and its role can be found in (60). Large parts of those sections which give an outline of the method applied were published by J. Kozlowski (26).
2. After it had been explained and introduced by J. Kozlowski in 1965, who supported this introduction by a 'mini' pilot study for one of the towns in the area.
3. D. Harris (15) argues strongly for the introduction of a sub-regional planning level as an independent planning level.
4. This problem was exposed by J. Gorynski (13), and after practical experience confirmed by K. Miller (48), who states that "in the plan of a town the possibility of maintaining its model purity would be quite exceptional".
5. Problems connected with the formulation of the model method and its analysis and further development are the subject of Chapter 3 of Part 3.
6. J. Kolipinski (22).
7. The step by step process of this type of simplified method was described by J. Kozlowski (29).
8. 'Model Structure Research' was in fact carried out parallel with threshold analysis and included the study of environmental structure, road systems and recreational networks. Results from these studies were eventually superimposed on and integrated with results derived from threshold analysis, thus forming the basis on which final development plans and long-term directions for growth were constructed. This Model Structure Research was presented in detail in (60).

### (b) Central Borders - A Plan for Expansion

1. (59)
2. The second being a development study for Perth carried out by the Scottish Development Department in 1966/67, to be published by HMSO.
3. (64)
4. This was the first time that intangible factors had been introduced into the main course of the analysis and an 'amenity threshold' identified.

### (c) Evaluation Outline

1. This Scottish version of a simplified threshold manual was published as a separate section of the article by J. Kozlowski and J. T. Hughes (29).

(c) Evaluation Outline (continued)

2. Some critics apparently held similar views; for instance the reviewer of the Central Borders publication (in the Architect's Journal, 21 August 1968, p. 321): "the most interesting thing about the plan is the conception on which it is based - what the planning team has called 'threshold analysis'". In the study itself the outstanding Scottish economist Professor J. N. Wolfe after criticism of the analysis stated that it "deserves some attention as a forerunner of the coming technical-economic innovation in planning concepts" since it has "great potentiality because of its explicit principle of cost minimisation as a necessary part of any central goal of planning procedure". (59)
3. This list was first formulated by J. Kozlowski (26).
4. This was the main criticism of the economic team involved in the Central Borders study where it was stated that "threshold analysis fails to embrace all the relevant costs ... the data ... exclude(s) the costs of increased road congestion, the running and maintenance costs and the costs associated with different industrial distributions" (59). In fact, industrial cost should not be on this list since threshold analysis in the study dealt only with residential development.

3. INTRODUCTION OF THE THRESHOLD CONCEPT INTO REGIONAL ANALYSES(a) Tourist Development Possibilities in the South Adriatic Region in Yugoslavia

1. (63)
2. During the U.N. sponsored planning operation for the South Adriatic region in Yugoslavia (1968), where he was the expert adviser responsible for regional planning methodology.
3. B. Malisz (44).

(b) Assessment of Angling Potential in the Republic of Ireland

1. C. Buchanan (4).
2. Data from (62).
3. The matrix of such a balance is given by Z. Chojnicki (7).
4. Since the main concern of this study was angling, 'existing capacity' means 'existing capacity for angling' and so on. It was clearly impossible, however, to isolate this problem entirely, so while the greatest emphasis was laid on angling development, all related and interconnected problems of other tourist activities were also considered.
5. Some tourist facilities such as restaurants, sports grounds, etc., although quantifiable, were purposely allocated to the qualitative analysis since their influence on angling development was not critical.

(b) Assessment of Angling Potential in the Republic of Ireland (continued)

6. J. Kozlowski and J. T. Hughes (29).
7. As already stated (in Chapter 3 of Part 1 and Chapter 3 of Part 2), this depends on whether a particular resource is one which can be developed proportionally or not.
8. Initially proposed by T. M. Pharoah of the Planning Research Unit.
9. At the beginning of 1970.
10. P. Haggett (14).
11. W. Isard (19).

(c) Evaluation Outline

1. As mentioned in Chapter 3 of Part 1.

4. CRITICAL ASSESSMENT OF THE THRESHOLD THEORY IN THE LIGHT OF ITS PRACTICAL APPLICATION(a) Merits and Demerits

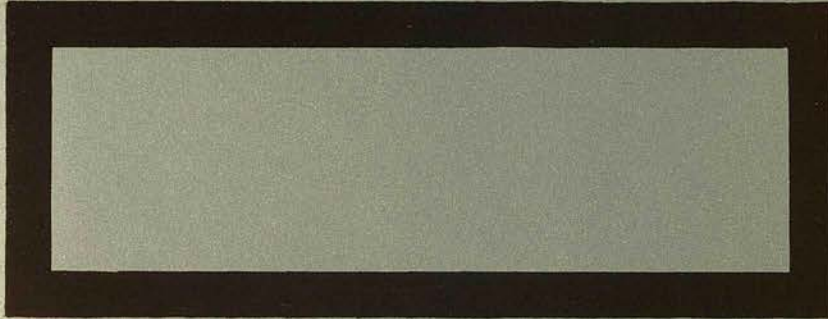
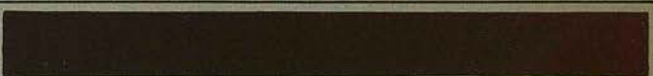
1. J. Kolipinski (22).
2. J. Kolipinski (24).
3. One of the possibilities could be 'dual' prices proposed by K. Porwit (50).
4. This most typically applies to decisions concerning development of infrastructure and road systems since these determine directions of growth for long time periods and cannot be easily altered.
5. J. Kolipinski (22).
6. B. Malisz (42).
7. F. Glisczczyński (12) put forward ways of carrying out this subdivision, based on an analysis of the ranges and proportions in which respective infrastructures or facilities serve towns and regions.
8. J. Kolipinski (24).
9. See Chapter 1 (b), Part 2.
10. F. Glisczczyński (12).
11. B. Malisz (42).
12. J. Kowalski (25).
13. To highlight this important problem, of which many physical planners and their critics are unaware, one may refer to a significant contribution by R. L. Ackoff which stresses the importance of distinguishing the benefits of controlled variables (i. e. within the influence of the decision maker) and uncontrolled variables. R. L. Ackoff (1). J. Regulski and S. Wyganowski have also emphasised the significance of the fact that there are many problems in the planning process beyond the influence of planners.

(a) Merits and Demerits (continued)

- J. Regulski and S. Wyganowski (54). Finally W. Lean presents a list of constraints "that are outside the control of the planner" and concludes that "the planner is governed by decisions that have been made in the past, and he has to try to devise a plan that will assist the efficient economic functioning of the area within these constraints beyond his control" (W. Lean, 30).
14. In his most recent book in which a whole chapter is dedicated to the discussion of various aspects of threshold costs; problems of frozen assets and economies of scale are only outlined and suggested solutions are not elaborated in any detail. B. Malisz (45).
  15. B. Ledworowski (31) emphasises that "costs of building a town - even most correctly and critically calculated after analytical investigations - are only one of the elements of economic justification for selected development directions of a settlement network. These elements, even if only economic (and 'economic' does not cover all aspects) must embrace, apart from initial investment costs, exploitation costs, proper juxtaposition of the two (as they are not spent simultaneously) and their proportional relation to effects obtained".
  16. Undertaken by M. Roman at the Warsaw Polytechnic.
  17. This is in fact a well-known phenomenon of 'diseconomies of scale' - a problem similar to the 'magnitude' threshold was analysed by Klaasen (21) who from studying curves of per unit income and of operating cost defined so-called 'maximum disposable income'.
  18. J. Kolipinski (24).
  19. B. Malisz (41).
  20. J. Regulski and S. Wyganowski (53) among others point out the practical difficulties in defining thresholds due to overlapping of many small thresholds, resulting in 'braided' patterns of threshold lines.
  21. J. Regulski and S. Wyganowski (55).
  22. J. Jezierski and B. Szermer (20). J. Regulski and S. Wyganowski (53) noted the varying significance of thresholds in time, indicating that current difficulties involved in sewerage treatment may be reduced in twenty years' time in connection with technological progress, cheaper electricity, etc.
  23. The fact that thresholds of the same value represent different burdens to large or small communities may be met in a number of ways, e.g. by specifying comparisons not between the actual numbers of population increases, but between fixed percentage levels of expansion in relation to the magnitude of the settlements analysed, or by establishing a threshold cost ceiling and finding which percentage of growth can be accommodated within this limit in which community.

(b) Implications for Further Research and Development

1. J. Kozlowski (27).
2. Excluding the development of a direct application of the threshold concept to regional analyses, since this problem has recently been studied by B. Malisz himself and the results of this research are shortly to be published. See also B. Malisz (44).

	<b>Part Three</b>
<b>DEVELOPMENT</b> 	

## 1. TOWARDS REFINEMENTS OF THE BACKGROUND THEORY

### (a) Definitions

Mathematical characterisation of development and development cost - normal, additional and dwelling unit costs - relationships between cost and development functions - basic definitions - major types and character of threshold limitations - conclusions

Ambiguities in the threshold definitions can best be removed by formulating these definitions in mathematical parlance. Therefore processes of development and of spending development costs must be considered as functions so that their interrelationships can be mathematically characterised. From this a number of basic definitions are formulated, covering the definition of the threshold itself, being now called A NUMBER OF CONSTRUCTED DWELLING UNITS  $n_1$  SUCH THAT THE NEXT UNIT CANNOT BE CONSTRUCTED AT PREVIOUS UNIT COST and followed up by definitions of threshold cost, threshold time, threshold area, and three types of thresholds (stepped, grade and combined). As all these definitions are now expressed in mathematical terms, often by the use of equations, and exemplified diagrammatically also, a sound platform has been created to help in elimination of confusion and misinterpretation in the further development and application of threshold analysis.

### (b) Classifications

Classification I - Classification II - Classification III -  
Classification IV - Classification of Threshold Costs - summary

It is important to set a logical and open-ended framework for classification of thresholds. There are four basic criteria by which thresholds can be classified, namely by cost consequences, (to reveal the character of respective thresholds) by cause, by planning level and by significance for urban development processes. All thresholds can be classified in a univocal way by any of these criteria and the classification of threshold cost follows. It is believed that this classification, once set up, will help communication during the process of threshold analysis and will introduce clarifications in any future writings or discussions dealing with the threshold concept.

(a) DEFINITIONS

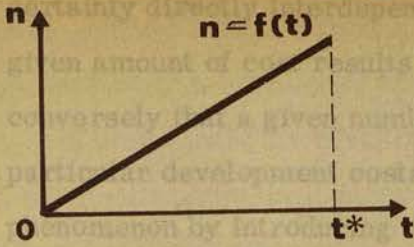
In an attempt to move towards a more precise definition of the basic terms on which the threshold theory is based and towards doing this by the use of mathematical parlance which seems essential if definitions are really meant to be precise, it is necessary first to state and tackle the problem in its most simple form. An elementary case of urban growth in a self-contained area will be analysed assuming that both development and costs increase linearly through time. From an analysis of the interdependence between the development and cost functions, particularly with respect to normal and additional expenditures, mathematical definitions of a threshold, of threshold costs, threshold areas and threshold time will be formulated. Finally relationships between thresholds, total development costs, unit costs and average cost per unit will be characterised in mathematical terms in the hope that all this will help to eliminate a number of confusions and misinterpretations which have arisen in connection with the development and application of threshold theory and analysis so far.

Mathematical Characterisation of Development and Development Costs

It can be said that observations of urban expansion disclose that it is basically characterised by an increase in built-up environment over time as a direct result of spending a defined amount of money for this purpose. In the case of residential expansion (as the subject of threshold analysis investigation) this expansion is characterised by an increase in dwelling units and by a corresponding increase in the cost of building successive dwelling units and of providing them with necessary utilities.

Expressing this in mathematical terms does not present difficulties. To make the problem as straightforward as possible, suppose that a self-contained development area A is the subject of consideration. The growth of population in the area A is accompanied by a corresponding increase in the number of dwelling units through time (if predetermined living standards are to be maintained).

Diagram 1



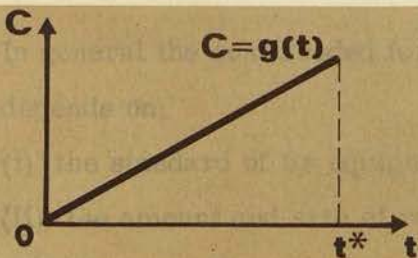
Development Function

This increase can be represented by the graph of a function  $f$ , where for any time  $t$ ,  $n = f(t)$  is the total number of units constructed by time  $t$  (see diagram 1).

The recording of the function  $f$  begins at time  $t = 0$  and the number of units constructed by time 0 is taken to be 0, so that  $f(0) = 0$ . The function  $f$  can be called the DEVELOPMENT FUNCTION for A for the time period from 0 to  $t^*$  (where  $t^*$  is the last time for which Development Function  $f$  is defined). By the nature of development, the function  $f$  is always continuous and non-negative and will also be non-decreasing, if it does not record the destruction of dwellings. Although the values of Development Function  $f$  are discrete, they may be smoothed out so that it is possible to talk about the continuity of  $f$  and about the continuity and existence of its derivative  $f'$ , which measures the rate of development.

In a similar way the increase in development costs can be presented for the area A in the time period from time 0 to time  $t^*$ . The total cost spent on residential development in this time interval, where  $0 \leq t \leq t^*$ , is a function of  $t$  and may be written as  $C = g(t)$  in order to exhibit this relationship (see diagram 2). This function can be called the COST FUNCTION for A for the time period from 0 to  $t^*$ .

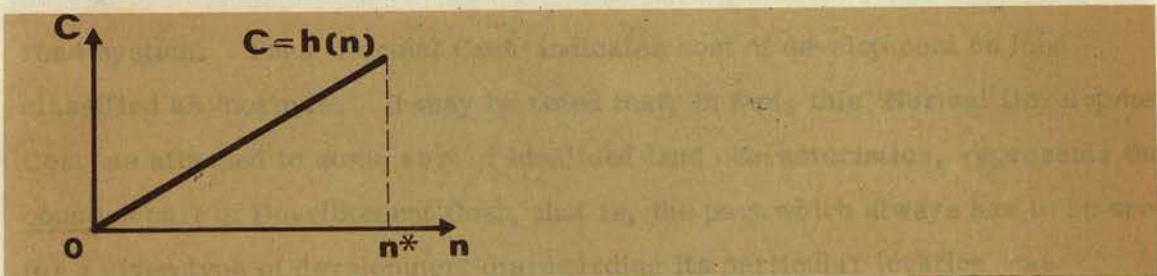
Diagram 2



Cost Function

The two functions, that is the Development Function and the Cost Function, are certainly directly interdependent and if jointly considered they show that a given amount of cost results in a corresponding increase in new dwellings and conversely that a given number of dwellings to be constructed always involves particular development costs. This can be displayed mathematically as a single phenomenon by introducing the COST-DEVELOPMENT CURVE indicating the relationship between total costs and total number of dwelling units constructed. More precisely, a point  $(n, C)$  lies on the cost-development curve if, for some time  $t$ ,  $n = f(t)$  and  $C = g(t)$  (see diagram 3). This relationship between costs and units is also expressed symbolically by writing  $C = h(n)$  even though, strictly speaking, development cost  $C$  need not always be a function of the number of units  $n$ .

Diagram 3



Cost-Development Curve

The relationship between an increase in the number of dwellings and an increase in the required costs is a complex one since it is influenced by various factors. Since most of these factors are beyond the scope of Threshold Analysis it is necessary to make, at this stage, a few additional assumptions.

#### Normal, Additional and Dwelling Unit Costs

In general the cost needed for the construction of a particular dwelling unit depends on:

- (i) the standard of its equipment,
- (ii) the amount and size of rooms,
- (iii) the cost of materials and labour,
- (iv) the construction technology applied, and
- (v) the physical characteristics of its location.

It is clear that threshold analysis deals only with the last variable although all of these variables cause significant fluctuations in the cost of dwellings constructed in the analysed area. In order, therefore, to study only those aspects of the problem which are directly relevant to threshold analysis, with all other disturbing influences removed, it is necessary to introduce a 'ceteris paribus' assumption, meaning that the factors specified under (i)-(iv) should be considered as constant in the area A.

It is convenient to assume that development starts from that part of the area A where building conditions (and therefore development costs) can be regarded as NORMAL. 'Normal conditions' for the development of land, in this context, indicates land being relatively flat, having good bearing capacity of soil, being served by basic public utility networks and having direct access to an existing road system. Thus 'Normal Cost' indicates cost of development on land classified as 'normal'. It may be noted that, in fact, this 'Normal Development Cost' as attached to some sort of idealised land characteristics, represents the constant part of Development Cost, that is, the part which always has to be spent for a given type of development disregarding its particular location - as previously mentioned, this part of Development Cost can fluctuate only if the type of development, its technology or cost of labour and materials are changing. If however normal (or ideal) conditions of the land being developed change, then the cost of development will rise and 'Additional Cost' representing the variable part of Development Cost, directly depending on the location of a given development type, will have to be introduced. Certainly, the distribution of Development Cost between constant and variable costs lies at the root of threshold theory, but its univocal definition is a necessary starting point to this phase of research.

At this stage it is worth clarifying what should be understood here by 'dwelling unit cost', which always represents all basic costs involved in elements linked directly with the construction of and designated only for a particular dwelling unit, that is: cost of construction, cost of providing a site and a dwelling with necessary utilities, cost of access road and cost of site preparations.

Conversely, the cost of those elements which are only indirectly connected with the construction of a particular dwelling and which, even partly, are designated for general public use should not be considered as included in the 'dwelling unit cost' (e.g. cost of a trunk collector, cost of a water pumping station, etc). It should be noted that it is easy to pass from 'dwelling unit cost' to 'per capita cost' which represents 'dwelling unit cost' as defined above subdivided by the average number of inhabitants occupying a particular type of dwelling unit involved. This is an important observation since nearly all writings and formulations concerning threshold theory and analysis have used 'per capita cost' as their basic notion. It seems, however, and this research confirms that it is easier to discuss, develop and apply the theory by replacing 'per capita' by 'dwelling unit' costs.

#### Relationships between Cost and Development Functions

Returning to the Cost Development Curve, it may be pointed out that, within the set of assumptions so far specified, the curve will be linear and therefore continuous. This means that for the same amount of money the same amount of dwellings will always accrue. This relationship between cost and development, however, need not remain unchanged indefinitely but only as long as 'normal' conditions exist in the development area. If the physical character of the area varies there will always occur a moment in time when the relevant 'normal' cost is not sufficient to construct some particular new dwelling unit and then 'additional' cost has to be introduced which implies that the relationship between cost and development has changed. This will also clearly indicate that the varying physical character of the land within the discussed area imposes a sort of LIMITATION upon further continued development. It can thus be said that a LIMITATION to development occurs when the relationship between the cost and development functions reaches its breaking-point.

It is this particular phenomenon which indicates what has been called a THRESHOLD to physical urban expansion. Threshold theory accordingly has concentrated on attempts to explain this phenomenon and, above all, to indicate

its consequences for further urban growth in an analysed area.

Summarising, the theory deals with situations where there is:

- (i) discontinuous decrease in the rate of development at times when the rate of expenditure is constant (see diagram 4) and
- (ii) discontinuous increase in expenditure at times when the rate of development is constant. (see diagram 5).

Diagram 4

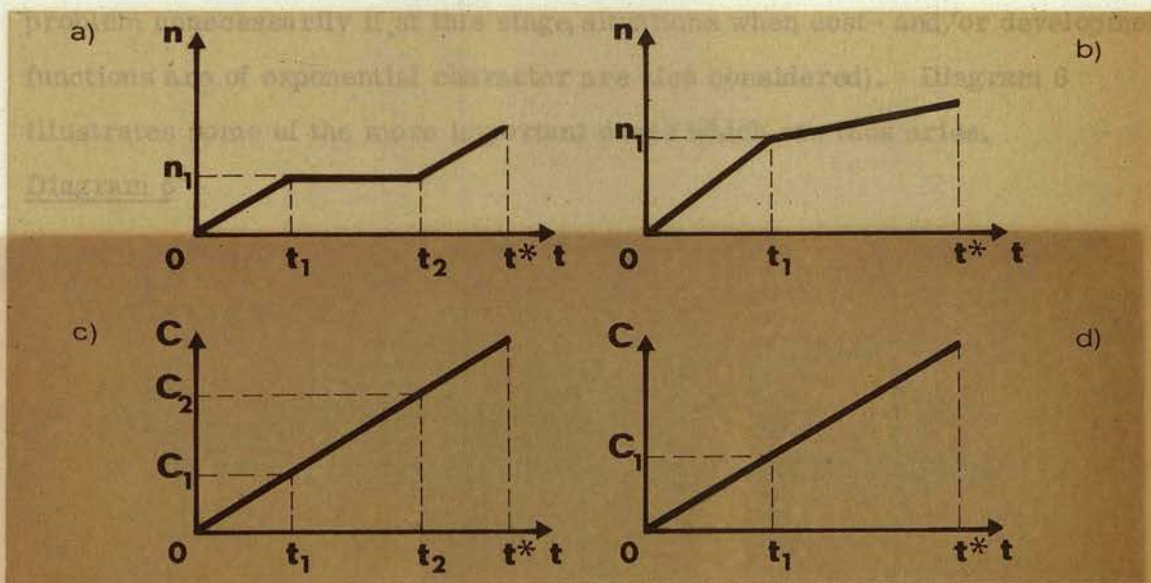
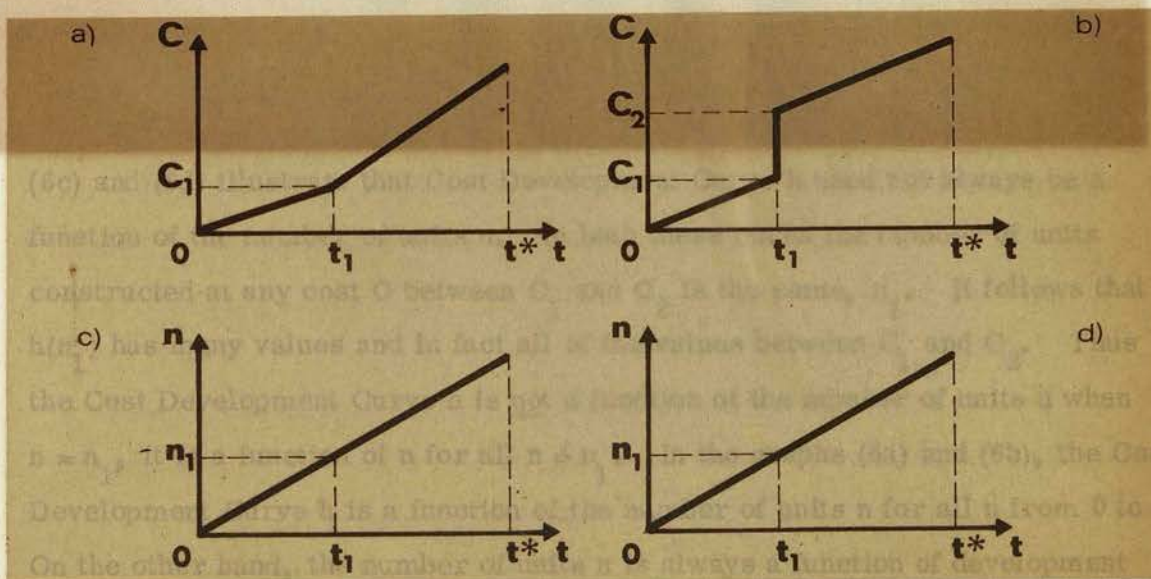
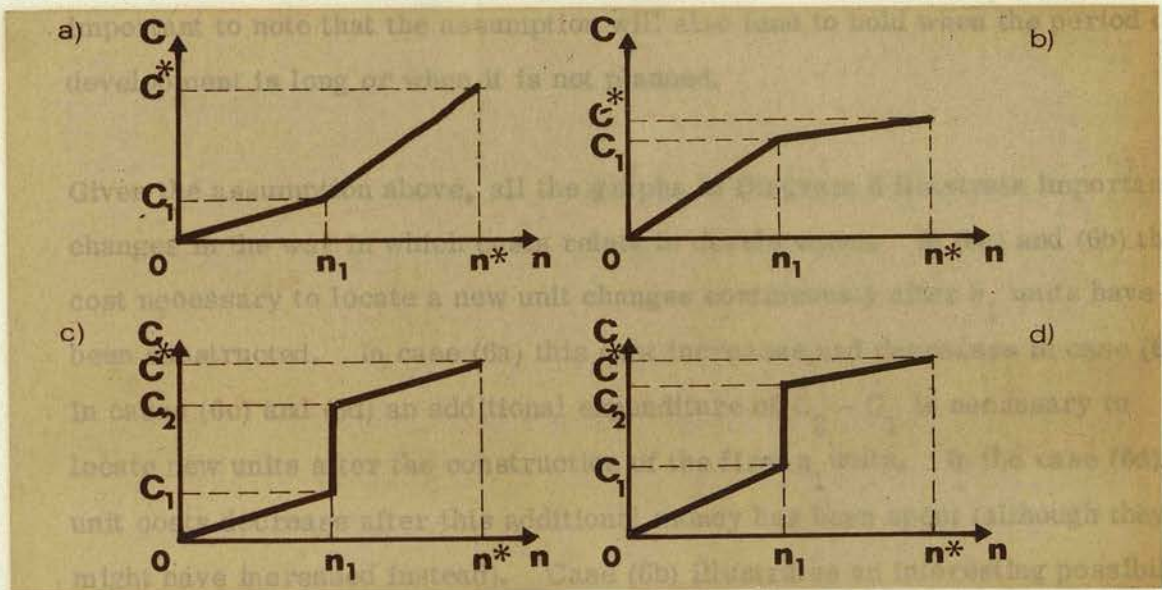


Diagram 5



It can now be quite clearly seen that in both cases 'additional' cost needs to be expended if the relationship between cost and development is to return to its previous character. It is possible to define thresholds in precise mathematical terms and to indicate the consequences of their overstepping. This can best be done by looking at the Cost Development Curve which displays the relationship between total cost and total number of units constructed. The Cost-Development Curve  $h$  is piecewise linear when the Development Function  $f$  and the Cost Function  $g$  are (as previously stated, it would complicate the problem unnecessarily if, at this stage, situations when cost- and/or development-functions are of exponential character are also considered). Diagram 6 illustrates some of the more important cases which can thus arise.

Diagram 6



(6c) and (6d) illustrate that Cost Development Curve  $h$  need not always be a function of the number of units  $n$ . In both these cases the number of units constructed at any cost  $C$  between  $C_1$  and  $C_2$  is the same,  $n_1$ . It follows that  $h(n_1)$  has many values and in fact all of the values between  $C_1$  and  $C_2$ . Thus the Cost Development Curve  $h$  is not a function of the number of units  $n$  when  $n = n_1$ , it is a function of  $n$  for all  $n \neq n_1$ . In the graphs (6a) and (6b), the Cost Development Curve  $h$  is a function of the number of units  $n$  for all  $n$  from 0 to  $n^*$ . On the other hand, the number of units  $n$  is always a function of development cost  $C$ , since for any given amount of money  $C$  there is a unique number  $n$  of

units which are constructed for that cost. In order to interpret Diagram 6 it is necessary to make another important assumption on the way in which total costs relate to the total number of units constructed at the same time. The same assumption is necessary in order to characterise and classify thresholds by means of the Cost Development Curve  $h$ .

Assumption: At every time  $t$ ,  $C = g(t)$ , includes all and only the total costs necessary to construct and equip with basic utilities the first  $n$  units,  $n = f(t)$ .

This assumption will be violated if the Cost Function  $g(t)$  includes any costs related to the construction of units which are constructed after time  $t$ . The assumption will automatically be satisfied whenever, for all  $t$ , the Cost Function  $g(t)$  is the minimum cost necessary to construct the first  $n = f(t)$  units. It is important to note that the assumption will also tend to hold when the period of development is long or when it is not planned.

Given the assumption above, all the graphs in Diagram 6 illustrate important changes in the way in which costs relate to development. In (6a) and (6b) the cost necessary to locate a new unit changes continuously after  $n_1$  units have been constructed. In case (6a) this cost increases, and decreases in case (6b). In cases (6c) and (6d) an additional expenditure of  $C_2 - C_1$  is necessary to locate new units after the construction of the first  $n_1$  units. In the case (6d) unit costs decrease after this additional money has been spent (although they might have increased instead). Case (6b) illustrates an interesting possibility which is unlikely to occur often in real practice. Because of its rarity, threshold theory does not deal with this possibility and it will be ignored in future considerations.

It should be noted that the Cost Development Curve of (6c) can arise in two distinct situations. The rate of development may be constant and continuous (as in (5d)) in which case expenditure increases discontinuously by the amount  $C_2 - C_1$  at time  $t_1$  when  $n_1 = f(t_1)$  units have been constructed (as in (5b)).

Alternatively, the rate of expenditure may be constant (as in (4c)) in which case no new units after the first  $n_1$  are constructed until the necessary amount of money  $C_2 - C_1$  has been accumulated (as in (4a)). Both these situations result in the same phenomenon on the Cost Development Curve  $h$ . As a curve,  $h$  is always continuous and, as a function of  $n$ ,  $h$  may not always have a unique value. A similar observation holds for the Cost Function  $g$ . In order to simplify terminology, in both these cases  $h$  or  $g$  is said to increase discontinuously at a point when in fact they are many-valued at that point. Thresholds occur when new units cannot be constructed and equipped at previous unit costs. Thresholds will be identified here as a number of units  $n_1$  which is such that the construction and equipment of additional units after the  $n_1$ -th requires additional and abnormal expenses.

#### Basic Definitions

Thus the first definition of a THRESHOLD can be spelled out as follows:

DEFINITION ONE - A THRESHOLD FOR THE AREA A DURING THE PERIOD FROM 0 TO  $t^*$  IS A NUMBER OF CONSTRUCTED DWELLING UNITS  $n_1$  SUCH THAT THE NEXT UNIT CANNOT BE CONSTRUCTED AT PREVIOUS UNIT COST. This definition is a general one since, although based initially on an ideal situation, it covers cases in which development takes place on land that cannot be characterised as 'normal'<sup>(1)</sup>. Thus to overcome a THRESHOLD 'additional cost' has to be introduced and this can also be defined.

DEFINITION TWO - IF  $n_1$  IS A THRESHOLD THEN THE COST IN ADDITION TO PREVIOUS UNIT COST, NECESSARY FOR CONSTRUCTING THE NEXT USABLE DWELLING UNIT, IS THE THRESHOLD COST FOR OVERCOMING THE THRESHOLD  $n_1$ .

The Cost Development Curve also makes it possible to obtain precise

definitions of threshold times and threshold areas.

DEFINITION THREE - IF  $n_1$  IS A THRESHOLD AND  $t_1$  IS THE EARLIEST TIME SUCH THAT  $f(t_1) = n_1$ , THEN  $t_1$  IS THE THRESHOLD TIME CORRESPONDING TO THE THRESHOLD  $n_1$ .

DEFINITION FOUR - IF  $t_1$  AND  $t_2$  ARE THRESHOLD TIMES AND IF NO TIME BETWEEN  $t_1$  AND  $t_2$  IS ALSO A THRESHOLD TIME THEN THE GEOGRAPHICAL LOCATION OF ALL UNITS THAT COULD BE CONSTRUCTED BETWEEN TIME  $t_1$  AND  $t_2$  (AT PREDETERMINED DENSITY STANDARDS) FORMS THE THRESHOLD AREA.

It will be seen that two major variants of threshold overcoming may occur at the threshold time  $t_1$  depending upon the CHARACTER of the threshold limitation encountered. To explain and characterise mathematically this important phenomenon it is necessary first to formulate definitions of the two remaining basic terms involved in threshold theory, namely UNIT COST and AVERAGE COST PER UNIT<sup>(2)</sup>.

As previously mentioned, dwelling UNIT COST includes all and only those costs involved in construction and depending upon the construction site but not upon its location with respect to utilities or road networks. Mathematically, unit cost can be identified by means of the derivative of the Cost Development Curve, and accordingly defined:

DEFINITION FIVE - DWELLING UNIT COST AT TIME  $t_1$  IS THE VALUE OF THE FIRST DERIVATIVE OF THE COST DEVELOPMENT CURVE AT TIME

$$t_1 \quad h' (f(t_1))$$

AND, EQUIVALENTLY, UNIT COST OF THE  $n_1$ -th UNIT IS THE VALUE OF THE FIRST DERIVATIVE OF THE COST DEVELOPMENT CURVE AT  $n_1$

$$h' (n_1)$$

It is proposed to call the curve  $h' (n_1)$  the UNIT COST CURVE.

AVERAGE COST PER UNIT needs to be carefully distinguished from UNIT COST (and also from AVERAGE UNIT COST). Average cost per unit

includes a contribution for all development cost (thus both types of threshold cost) incurred during the given time period. This again can be mathematically defined:

DEFINITION SIX - AVERAGE COST PER UNIT FROM TIME  $t_1$  TO TIME  $t_2$  IS THE TOTAL COST INCURRED FROM TIME  $t_1$  TO TIME  $t_2$ , THAT IS INCURRED FOR CONSTRUCTING THE CORRESPONDING AMOUNT OF DWELLING UNITS  $(n_2 - n_1)$ , DIVIDED BY THE TOTAL NUMBER OF UNITS CONSTRUCTED DURING THIS TIME PERIOD, i. e.

$$\frac{h(n_2) - h(n_1)}{n_2 - n_1}$$

where  $n_1 = f(t_1)$  and  $n_2 = f(t_2)$

It should be pointed out that for planning purposes the most important case of average cost per unit is for the time period from 0 to t since this is helpful for identifying when development costs are spent most efficiently. The average cost for developing the first n units is therefore

$$\frac{h(n) - h(0)}{n - 0} = \frac{h(n)}{n}$$

where  $h(0)$  may be assumed to be zero.

It is proposed to call the function  $\frac{h(n)}{n}$  the AVERAGE COST DEVELOPMENT FUNCTION. It should be pointed out that this function is of significance in illustrating consequences of threshold overstepping and that its analysis may help to formulate important conclusions in the course of threshold analysis.

Major Types and Character of Threshold Limitations

It is now possible to define two major types of thresholds (and threshold costs) and to characterise different consequences of their overstepping.

One type of threshold requires an additional investment cost to be spent before proceeding with the construction of new dwellings. This expenditure is not connected with the unit cost of dwelling construction. Thus after overcoming this threshold it is possible to continue with the expenditure of previous unit costs in the process of successive dwelling construction. A simple case of this type of limitation occurs when a bridge must be completed before the first dwelling can be built on the other side of a river.

The second type of threshold occurs when an extra cost per unit is spread over the whole period of implementation on the area affected. Not only the way in which this cost is spent differs from the previous type, but also the character. In this case the unit cost of each dwelling in the affected area rises. This case may be exemplified by an area within which the foundation cost rises due to the decreased bearing capacity of the soil.

The third type of threshold occurs when the two previous types overlap at the same time and place.

The three variants can most simply be defined in mathematical terms:

DEFINITION SEVEN - THE CHARACTER OF THE THRESHOLD  $n_1$  IS INDICATED BY THE IMPLICATION OF ITS OVERCOMING WHICH IS SUCH THAT EITHER:

- (a) THE COST DEVELOPMENT CURVE  $h$  INCREASES DISCONTINUOUSLY AT  $n_1$  OR
- (b) THE COST DEVELOPMENT CURVE  $h$  IS CONTINUOUS AT  $n_1$  BUT ITS DERIVATIVE  $h'$  INCREASES DISCONTINUOUSLY AT  $n_1$ , OR
- (c) BOTH  $h$  AND  $h'$  INCREASE DISCONTINUOUSLY AT  $n_1$ .

It is proposed here to define case (a) as a STEPPED THRESHOLD, case (b) as a GRADE THRESHOLD and case (c) as a COMBINED THRESHOLD.

Corresponding types of threshold costs can also be defined:

DEFINITION EIGHT - IF  $n_1$  IS A THRESHOLD THEN THE THRESHOLD COST INVOLVED IN OVERCOMING  $n_1$  IS:

(a) IN CASE  $n_1$  IS A GRADE THRESHOLD, THE GRADE THRESHOLD COST  $g_t$  IS THAT PART OF NEW UNIT COST WHICH IS ADDITIONAL TO PREVIOUS UNIT COST.

$$g_t = h'(n_1 + 1) - h'(n_1)$$

(b) IN CASE  $n_1$  IS A STEPPED THRESHOLD, THE STEPPED THRESHOLD COST  $s_t$  IS THE ADDITIONAL COST, OVER AND ABOVE UNIT COST, WHICH IS NECESSARY FOR THE COMPLETION OF THE NEXT UNIT.

$$s_t = \lim_{n \rightarrow n_1^+} h(n) - \lim_{n \rightarrow n_1^-} h(n)$$

(c) IN CASE  $n_1$  IS A COMBINED THRESHOLD, THE COMBINED THRESHOLD COST IS THE PAIR OF COSTS  $(g_t, s_t)$  NECESSARY FOR COMPLETION OF THE NEXT UNIT.

The different character of the three kinds of thresholds can be illustrated by examining the cost consequences of their overcoming. Suppose that  $n_1$  and  $n_2$  are successive thresholds and that  $n_1$  is the first threshold. Then for any  $n < n_1$  the total cost for developing the first  $n$  units is

$$C = C_0^n = cn$$

(where  $c$  is the dwelling unit cost).

For  $n$  between  $n_1$  and  $n_2$  ( $n_1 < n < n_2$ ) let  $n'$  be the number of units constructed between  $n_1$  and  $n$  ( $n' = n - n_1$ ). If  $n_1$  is a grade threshold then the total cost for developing all the units between  $n_1$  and  $n$  is

$$C = C_{n_1}^n = (c + g_t) n'$$

If  $n_1$  is a stepped threshold then the total cost for developing all the units between  $n_1$  and  $n$  is

$$C = C_{n_1}^n = s_t + cn'$$

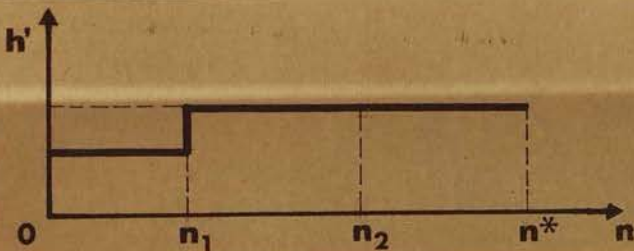
If  $n_1$  is a combined threshold then

$$C = C_{n_1} = S_t + (c + g_t) n'$$

The consequences of overcoming all three types of thresholds are explicit when graphical presentation of the UNIT COST CURVE and of the AVERAGE COST DEVELOPMENT FUNCTION is considered.

If  $n_1$  happens to be a grade threshold then the Unit Cost Curve  $h'(n_1)$  is not defined but presented on the graph (graphically the derivative  $h'(n)$  is the tangent of the angle made by the tangent to the curve  $h$  at  $n$ ); unit cost before and after this threshold indicate its character by showing the changing value of the unit cost. It must be remembered however that by definition unit cost embodies only grade threshold cost and therefore the Unit Cost Curve does not show the stepped threshold encountered subsequently at  $n_2$  (see Diagram 7).

Diagram 7



Unit Cost Curve

The situation is different when AVERAGE COST DEVELOPMENT FUNCTION is considered. This function indicates both stepped and grade thresholds and clearly reveals their different characters. Thus as previously mentioned, its analysis may help to formulate important conclusions in the course of threshold analysis.

Graphically, the average cost per unit for time  $t^*$  can be obtained from the Cost Development Curve by connecting the point  $(n^*, h(n^*))$  with 0 by a straight line. The tangent of the angle  $\alpha$  made by this line and the  $n$  - axis is

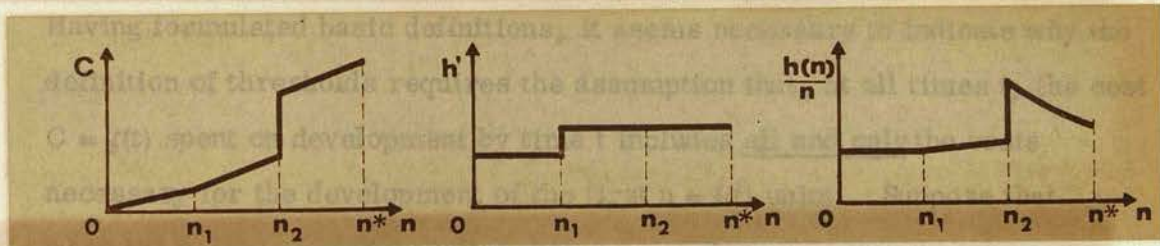
the average cost per unit (see Diagram 8).

Diagram 8



From this a graph of the Average Cost Development Function can easily be obtained. Its significance appears when it is considered jointly with the graphs of the Cost Development Curve and of Unit Cost (see Diagram 9), since it indicates clearly the different consequences of overstepping grade and stepped thresholds (at  $n_1$  and  $n_2$  on the diagram) and illustrates well the phenomenon of 'frozen assets' inherent in a stepped threshold overstepping.

Diagram 9



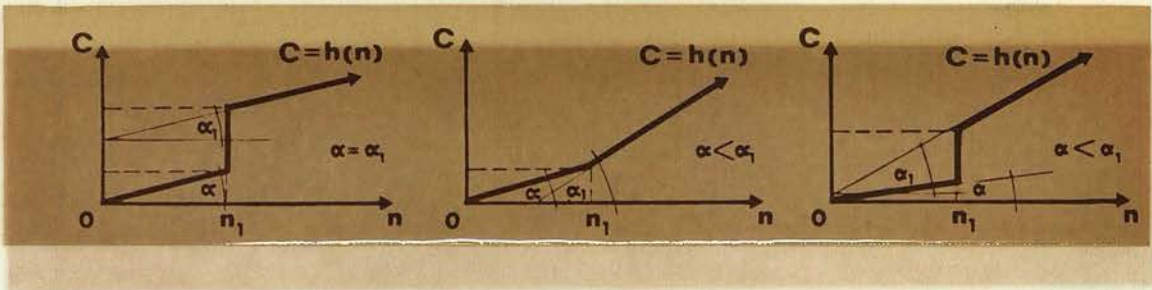
Cost Development Curve

Unit Cost Function

Average Cost Development Function

Finally, the three types of thresholds and differences between them can be shown on the Cost Development Curve (see Diagram 10). It is interesting to note that for mathematically piecewise linear cost development curves  $h$ , a stepped threshold is the limiting case of a sequence of grade thresholds whose grades are of increasing steepness. Diagram 11 illustrates this fact. The cost development curves  $h_1, h_2 \dots$  all display a grade

Diagram 10



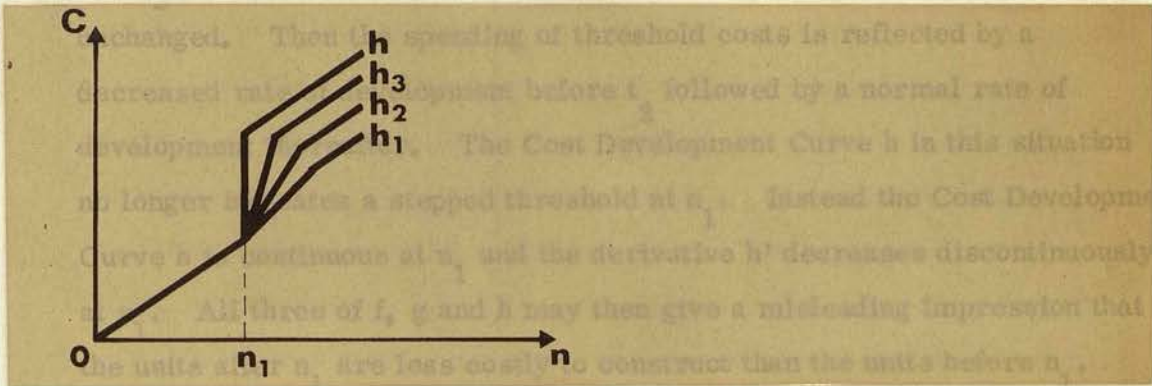
Stepped Threshold

Grade Threshold

Combined Threshold

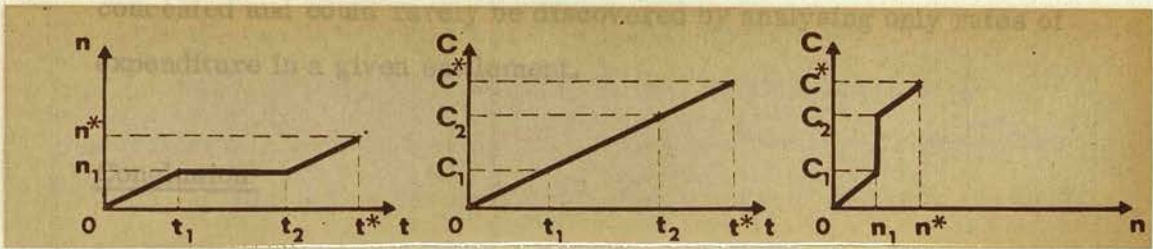
threshold  $n_1$  and approach, in the limit, the curve  $h$  which displays a stepped threshold at  $n_1$ .

Diagram 11



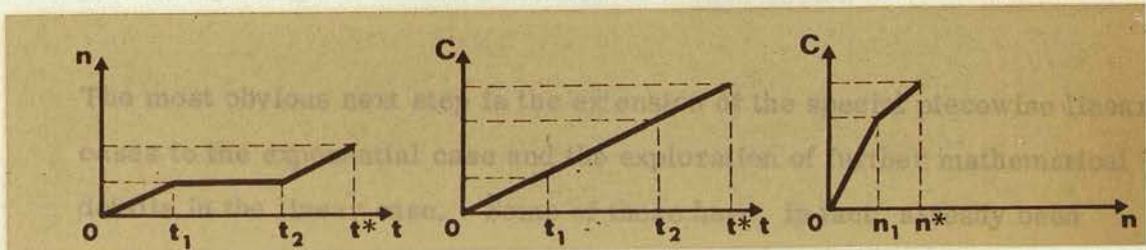
Having formulated basic definitions, it seems necessary to indicate why the definition of thresholds requires the assumption that, at all times  $t$ , the cost  $C = g(t)$  spent on development by time  $t$  includes all and only the costs necessary for the development of the first  $n = f(t)$  units. Suppose that when the assumption is satisfied then  $n_1$  is a stepped threshold for an area  $A$ . Suppose that the rate of expenditure is constant and continuous from 0 to  $t^*$ . Then development must be stagnant for some time period, say from  $t_1$  to  $t_2$ . Suppose that before  $t_1$  and after  $t_2$  the rates of development are constant and equal. The situation is illustrated in Diagram 12.

Diagram 12



Suppose that the development costs  $C_2 - C_1$  necessary to cross the threshold  $n_1$  were spent and distributed over the entire time period from 0 to  $t_2$ , in violation of the assumption. Assume that the cost function is unchanged. Then the spending of threshold costs is reflected by a decreased rate of development before  $t_2$  followed by a normal rate of development thereafter. The Cost Development Curve  $h$  in this situation no longer indicates a stepped threshold at  $n_1$ . Instead the Cost Development Curve  $h$  is continuous at  $n_1$  and the derivative  $h'$  decreases discontinuously at  $n_1$ . All three of  $f$ ,  $g$  and  $h$  may then give a misleading impression that the units after  $n_1$  are less costly to construct than the units before  $n_1$ . (See Diagram 13).

Diagram 13



It may be worth noting that the case described might very much reflect the way in which money is usually spent in a real situation - proper investment planning might not be able to afford sudden jumps in spending

and would require that the cost of anticipated threshold overstepping be phased in over certain time periods. Thus thresholds would be concealed and could rarely be discovered by analysing only rates of expenditure in a given settlement.

### Conclusion

At first glance this chapter may seem a little esoteric and with limited practical conclusions. However, it should be pointed out that the formulation of precise mathematical definitions and characterisation of the basic notions involved in threshold theory and analysis will avoid much of the misunderstanding and confusion resulting from its practical experience and criticism, both in the future development of threshold methodology and in its practical application in the field. Due to the precision of the mathematical language little ambiguity remains in definitions of a threshold, threshold costs, threshold areas or threshold time, and the introduction of clearly defined Unit Cost and Average Cost per Unit greatly helps in explicit characterisation of the two major types of thresholds indicating the consequences of their overcoming.

Definitions and mathematical characterisation of basic terms and notions of threshold theory should, however, be considered only as a starting point for putting the threshold theory on a firm basis.

The most obvious next step is the extension of the special piecewise linear cases to the exponential case and the exploration of further mathematical details in the linear case. Some of these have, in fact, already been tackled but to avoid undesirable overloading of this chapter, as already mentioned, an appendix "A" with extended and more sophisticated mathematics has been attached at the end of this dissertation. So far the functions  $f$  and  $g$  and the curve  $h$  have been assumed to be obtained from observing development and its costs within a given area  $A$  and over a given period from  $0$  to  $t^*$ . Relative to the resulting definitions it is now possible

to obtain a more precise classification of thresholds and threshold costs. By putting the theory on a mathematical basis a new avenue of research towards the use of computers for threshold analysis has also been opened up. Finally, it ought to be pointed out that in the planning stages of development it is often possible to produce projected cost development curves for alternative development possibilities within a planning area. Indeed this activity lies at the foundation of threshold analysis. For a given  $h$  obtained in this way, several functions  $f$  and  $g$  will be compatible. The Development Function  $f$  or constraints upon  $f$  are often fixed in advance by administrative bodies. Similarly Cost Function  $g$  or constraints upon  $g$  are fixed by financial authorities. Obtaining the Cost Development Curves  $h$  is the responsibility of the planner; mathematical relationships among functions  $f$ ,  $g$  and  $h$  exist and imply that corresponding relationships should exist between the administrator, financial officer and planner.

(b) CLASSIFICATIONS

The classification of thresholds is a problem which produces some confusion. Since its inception, threshold theory has been discussed in numerous papers and articles in which different terminology was frequently applied and as a result it is often difficult to be sure what particular terms used in publications or discussions meant precisely, which of them named the same thing in a different way and which introduced new subdivisions.<sup>(1)</sup> For the sake of future research, practical applications and critical discussions, it seems important to set the classification of thresholds in proper order and within a logical framework so that further confusion and misinterpretation can be, if not completely avoided, at least reduced to a minimum while possibilities for the introduction of new terms, or refinements of the old ones, remain entirely open.

It is appropriate to start by distinguishing the main ways in which thresholds can be classified according to different criteria. Four of these can be fairly clearly specified:

Classification I: thresholds classified by the cost consequences of their overstepping;

Classification II: thresholds classified by the causes, that is by the character of physical factors imposing threshold limitations;

Classification III: thresholds classified by the planning level on which they would have to be dealt with; and

Classification IV: thresholds classified by the specific significance they would acquire in relation to urban growth.

This type of subdivision clearly represents an open-ended framework, and possibilities remain for refinement of the existing terms and for the introduction of new ones, providing they are properly located within this

framework.

Another problem is represented by the classification of threshold costs, which will be covered subsequently.

### Classification I

As has been indicated in the previous chapter three major types of thresholds can be distinguished when the cost consequences of their overstepping are considered;

STEPPED thresholds which require additional lump sum investment to be spent on their overstepping. This means that the total stepped threshold cost is incurred before the first dwelling unit can be built after the threshold has been encountered.<sup>(2)</sup>

GRADE thresholds which require the additional costs be spread among all new dwelling units built on an area affected by this type of threshold, which means that the overall new dwelling unit cost is greater than previous unit cost. This indicates that to overcome grade thresholds and to construct the first new dwelling unit after such a threshold has been faced only involves increments in those unit costs.

COMBINED thresholds which require that both the total stepped threshold cost be incurred and that the unit cost increase. Only then can the first new dwelling unit be constructed.

### Classification II

More careful scrutiny of the "classical" subdivision into quantitative, physical and structural thresholds reveals that this classification may be somewhat misleading, since it implies that physical and structural thresholds are not quantitative, while in fact all thresholds can be

presented in quantitative form. This is implicit in the definitions formulated in the previous chapter where a threshold was defined as a number of units. Thus thresholds, by definition, are always quantitative and the main difference between them is that while all thresholds can be presented on graphs expressing urban growth and/or development cost, only some of them can also be marked cartographically on base maps either as areas (in the case of grade thresholds) or as lines (in the case of stepped thresholds) or both (in the case of combined thresholds). As it would be useful to have separate self-explanatory terms for these different kinds of thresholds, it is suggested, first that the distinction between 'physical' and 'quantitative' thresholds be abandoned as misleading, and second, that this be replaced by naming those thresholds which can be defined on the base maps FOOT-BOUND thresholds, and those which can only be expressed in figures (population, dwelling units, etc.) and not necessarily connected with any specific area FOOT-LOOSE thresholds (most commonly these will be thresholds indicating capacity limits of central works or components of infrastructure systems). This initial classification clears the ground and helps to subdivide the various kinds of thresholds in relation to their origin and cause.

Thresholds result directly from differences in the location of development, which can be caused by various factors and consequently it seems that the subdivision into major kinds of thresholds should be based on allocating these factors into distinct groups and accordingly classifying thresholds into:

PHYSIOGRAPHICAL thresholds: those imposed by the natural characteristics of the analysed area;

TECHNOLOGICAL thresholds: those imposed by the technology of public utility networks and transport systems;

STRUCTURAL thresholds: those imposed by existing built-up areas (i.e. town structure);

FUNCTIONAL thresholds: those imposed by existing functions of land or land uses;

SERVICES thresholds: those imposed by the capacity of existing basic facilities, such as schools and shopping centres.

### Classification III

Difficulties often arise when there is a need to define which thresholds identified in the course of threshold analysis are of significance for the settlement analysed, and which, in consequence, warrant further investigation. Analysing the original formulation of the theory, it is obvious that only those limitations which present real problems for the particular town are considered to be its thresholds and in consequence should be more carefully analysed. This is implied by such formulations as the need for 'disproportionally high investment costs' or for 'radical reconstruction of existing systems', indicating that a threshold has been encountered. These definitions, as has been shown, leave a fairly wide margin for interpretation. To overcome this ambiguity it has therefore often been maintained that "a threshold is not any limitation faced by the expansion of a town, but only a major one which poses a serious problem and which has a marked effect on the cost per head of population. Its wider significance derives from this feature. When a town meets this type of threshold, or there is a prospect of one occurring in the near future, the time has come for a reappraisal of the pattern of development to ensure that a more efficient pattern does not exist".<sup>(4)</sup>

Problems met in attempts to distinguish clearly when a particular limitation should and when it should not be considered as a threshold exactly indicate the main difficulties connected with defining thresholds.

A threshold can never be seen as an abstract notion; it is always related to a particular settlement, settlement system, region or even to the country as a whole. A village will find that almost any obstacle will produce serious limitations to its further expansion and therefore the necessity to build a new treatment plant or a bridge will be considered its development threshold. The threshold, however, for a large city will occur on a completely different investment level, imposed by, for instance, the need to construct a new underground traffic system. This is why it has never been possible to prepare a comprehensive list of thresholds. The mathematical definition of thresholds formulated in the preceding chapter helps to solve this problem once and for all since it allows the previous statement to be corrected and for it to be accepted that in fact a threshold is ANY LIMITATION to urban growth, providing it meets clearly specified conditions and assumptions. To determine which of all the thresholds identified in the course of threshold analysis have a marked influence on the urban growth of a given settlement, they should all be classified into categories related to various planning levels. It is proposed that the following general categories of thresholds be introduced:

- NEIGHBOURHOOD thresholds;
- TOWN (or LOCAL) thresholds;
- REGIONAL thresholds;
- NATIONAL thresholds.

With this classification it is possible to relate the significance of any threshold encountered to the level which is dealt with in a particular planning exercise: the threshold concept should not necessarily be limited to the local and regional levels but can usefully be introduced at any level to any planning exercise in which problems of physical development are considered. This means that new categories can easily be introduced (e.g. subregional thresholds, agglomeration

thresholds) providing that they are consistent with the principles of this general classification orientated to the levels of planning.

The means of distinguishing which threshold belongs to which category seems to be inherent in the definition of thresholds previously established. It has been stated that a threshold limitation is one which requires 'additional' investment costs to be introduced in order to proceed with urban development; this additional cost seems to provide the key to allocating thresholds to their relevant categories. Suppose, for further clarification, that an analysis of development possibilities for a town is carried out and that the threshold limitation to its development has been identified on a neighbourhood level. The category of this particular threshold can be found by further analysis, that is of the whole town concerned, or if necessary of the whole region (theoretically even of the whole country) to establish whether there is any other area in the town (region, country) where urban development can proceed without this particular additional cost (indicating a threshold) being involved. If expansion elsewhere in the town is possible without introducing this additional cost it will mean that a 'local' threshold has been encountered. If, however, there is no other area in the town which can be developed without incurring threshold costs first, it will mean that the 'town' threshold has been met. This sort of investigation can also define the point where a 'regional' threshold has been met, and even in the most extreme cases a 'national' one.

The proposed classification does not imply that, for instance, town thresholds should be totally ignored in regional analyses, but it helps in establishing both the relevance of all identified thresholds to the subject of study and the priorities in which these thresholds should be analysed. No rules are laid down but it may be noticed that if a threshold is two levels below the level analysed in a particular study,

then this threshold can most likely be ignored; there is certainly no need to bother with neighbourhood thresholds in regional analyses, although there might of course be exceptions. It can also be seen that if there are no possibilities for the further development of a small town (without substantial investment) when the only treatment plant has reached its working capacity, this will become the 'town' threshold, whereas in a larger conurbation, the same problem will be less important and will fall into the category of 'local' thresholds since there will certainly be more than one treatment plant involved in a conurbation sewerage system.

Thus by accepting this kind of classification it is always possible to discover the significance of threshold limitations for any analysed settlement or settlement system whatever its size without giving up the clarity of the definition of the threshold itself and still remaining in accordance with the original formulations for the theory. It is obvious that any limitation affecting the whole settlement, settlement system, region and so on will always impose a serious problem and will have a marked effect on the cost per head of population irrespective of the type or size of urban system that is the subject of analysis.

#### Classification IV

This section attempts to classify thresholds according to their specific significance in relation to urban development processes. This significance, in general, depends on:

- (i) the place of a threshold in the development sequence;
- (ii) the mutual interdependence between overlapping thresholds;
- (iii) the unusual difficulties involved in some threshold overstepping.

- (i) The place of particular thresholds in relation to the development sequence can be clearly indentified in most cases, and their resulting different significance can be indicated by subdividing thresholds into:
- (a) FIRST threshold which indicates the limit up to which the existing urban area can expand without the introduction of 'additional' development cost.
  - (b) ULTIMATE threshold which indicates the recommended limit up to which urban growth in an analysed area should proceed within the framework of predetermined development standards, existing technological possibilities, available financial resources, etc. In special circumstances the overcoming of an ultimate threshold can be considered, as it indicates fixed boundaries for a particular run through the process of threshold analysis and is therefore truly 'ultimate' only in that sense.
  - (c) INTERMEDIATE or SUCCESSIVE thresholds which indicate all thresholds between the first and ultimate ones.
  - (d) SECOND threshold, THIRD threshold etc., which indicate the possible or recommended sequence of overcoming particular intermediate or successive thresholds.
- (ii) The mutual interdependence between thresholds appears in areas where several of them overlap totally or partially, as there is usually a clear hierarchy in the sequence in which relevant threshold areas can be opened up. The hierarchy is due to the fact that in most cases one or more of the thresholds is dominant or more significant in relation to the others. It is very important to identify this interdependence in the course of analysis by a subdivision of thresholds into:

- (a) DOMINANT thresholds which indicate that their overcoming is a precondition for making the areas involved suitable for development.
- (b) SUBORDINATE thresholds which indicate that their overcoming would open up only part of the areas involved and then only when the dominant threshold is also overcome.

To explain more fully, a dominant threshold is one whose outline is not divided by any other threshold line and which is not the sub-part of any other threshold area, although it may be subdivided internally into parts which have other threshold costs. If the pattern of thresholds is complex and many are overlapping, stepped rather than grade thresholds can be considered as dominant as there are strong reasons for considering the areas opened up by crossing them as whole units. The average cost per unit decreases as more of the capacity of the investment is taken up, whereas the average cost per unit of grade threshold areas does not vary with the proportion of the area developed. If two stepped thresholds overlap they can either be taken together as one dominant threshold area or as several dominant threshold areas, depending on the circumstances.

To exemplify this an area which requires a new sewerage system in order to open it up for urban development can be considered. Supposing that part of this area is also characterised by very low bearing capacity of soil, it is obvious that this part cannot be made suitable for development solely by meeting its own threshold cost but only if the sewerage threshold is also overcome. Thus the physiographic threshold represents the subordinated threshold here and the technological represents the dominant. The relationship between these particular kinds of thresholds may well be inverse elsewhere as it depends on the existing features of a particular area.

The meaning of this interdependence is of importance for the process of successive eliminations of areas and narrowing down the field of study, which is an essential aspect of a rationalised threshold methodology. In this process the analysis of the consequences of overcoming dominant thresholds should be given priority (at this stage subordinated thresholds would be taken into account only as factors increasing the overall additional cost of opening up the dominant threshold area). Only at a later stage, if necessary, should more detailed analysis of various combinations or sequences of opening subordinate threshold areas be undertaken.

- (iii) The unusual difficulties connected with some threshold overstepping may be of critical significance in the formulation of development strategies. It is, therefore, essential that these thresholds be identified by threshold analysis and it is proposed to classify them as CRITICAL thresholds, which indicate that there are exceptional difficulties involved in their overstepping and that they impose development constraints of a critical character for the analysed area. It is impossible to present a clear and unequivocal definition of a critical threshold in abstract theoretical terms, since this specific type of threshold will always be strongly tied to a particular situation and area. Its identification will therefore basically rely on skilful interpretation of the results of threshold analysis. Some guidelines can, however, be indicated.

Generally speaking, the term 'critical threshold' implies one which imposes distinctly greater constraints on further urban growth in an analysed area than those imposed by other identified thresholds. The overstepping of a critical threshold raises particular difficulties for the authorities involved - difficulties mainly, but not only, resulting from the excessively high cost of threshold

overstepping. A critical threshold would also be one whose overstepping results in specific consequences; for instance the determining of a certain direction in the long-term expansion of an analysed settlement, or the final elimination of some future development alternatives. A situation can also exist where a decision (or possibilities) concerning the overstepping of a particular threshold is beyond the range of the level for which the analysis has been carried out. This is the case when a particular threshold is also a threshold at an upper planning level. For example, it might be discovered that lack of water will not allow expansion of a particular town and that a town threshold has been faced. The character of this threshold will however require further investigations which should reveal whether and how it might be overcome. Thus it may occur that: (a) there is plenty of water in the surrounding region, in which case the solution should lie within the framework of the plan for the particular town involved; or (b) there is no available water in the whole region, which would mean that without regional analysis and decisions no economically reasonable solution is possible at the town planning level. This latter case will indicate that since the threshold encountered coincides with the upper level one it is a 'critical' one and until regional analysis is undertaken it indicates the ultimate limit to the expansion of the analysed town. This limit, of course, will not be of an absolute character but it will in any case impose a serious and 'critical' constraint on urban development possibilities.

#### Classification of Threshold Costs

As seen from an economic point of view<sup>(5)</sup> the cost  $T_i$  necessary to house one new inhabitant in an expanding town may be divided into three categories,  $a_i$ ,  $b_i$  and  $c_i$ , so that  $T_i = a_i + b_i + c_i$ .

These categories represent:

$T_i$  = the total cost of the project  $i$  needed to accommodate a particular number of new inhabitants in an expanding town;

$a_i$  = the overhead or fixed cost of project  $i$  (cost of land, engineering services and headworks, e.g. trunk sewers, water mains, access roads, bridges, sewage treatment, reservoirs, etc.) These costs, as will readily be appreciated, are not entirely invariable; but they are relatively inflexible over wide ranges of population targets. The smaller the area under examination the more fixed they will tend to be. The main feature of these costs is that they will decrease as a cost per household (or per person) as the scale of development increases, and they will generally have to be undertaken before there are any returns in terms of numbers housed. One point may arise: whether it is better to consider average cost as per person or per household (i.e. in effect per dwelling). The advantage of using the latter is that it is not affected by changes in sizes of households.

$b_i$  = the direct cost of constructing buildings, including 'normal' site preparations, 'normal' foundations, and 'normal' costs of shell construction. These costs are relatively standard and will usually not require close or original investigation; they will generally be constant for each building type except when density increases, especially when high-rise building is involved. The type of dwelling, namely its expense, may be a factor in determining the significance of threshold costs; briefly, an additional threshold cost per dwelling may be more significant (i.e. as a proportion of total cost) to a proposal to build £3,000 houses than £6,000 ones.

$c_i$  = a group of special costs associated with developing area  $i$ . These would include costs involved in working on an existing site with steep gradients, unusual foundations, perhaps even design costs to deal with troublesome features of the site. The problem here is to decide

what are 'special' costs; to some extent this must be arbitrary but it is believed reasonable to assume that there will be a consensus of opinion about the nature and extent of special costs when the cost of certain operations is higher than normal. This group is identified because (a) a change may indicate a higher level of development costs as the expansion of a town leaves the originally favourable sites, and (b) they bear a very close relationship to physical characteristics, such as gradients and subsoil.

In an attempt to relate these economic subdivisions more closely to threshold analysis and to the definitions so far formulated<sup>(6)</sup> the following classification of total development costs necessary to construct one dwelling unit as seen mainly by the physical planner is proposed:

- (i) Normal Investment Costs - all costs connected with constructing dwellings and providing them with necessary utilities as they occur on sites where building conditions are normal. Thus these costs cannot, by definition, reflect any physical development constraints.
- (ii) Additional Investment Costs - all costs which must be spent in addition to 'normal costs' and which are due to the particular constraints imposed by the characteristics and location of the land involved. They will always reflect thresholds to continued development. Related to the threshold concept they fall into three distinctly different categories:
  - (a) STEPPED threshold costs, representing 'initial investment costs' necessary to open a particular area for urban expansion. Once spent, they will not affect unit costs since they are not connected with the unit costs of dwelling construction. The important characteristic of these costs is that they must

always be spent in lump sums or in a discontinuous way. This may occur in phases but it will not be possible to spread the spending of these costs evenly over the whole implementation period.

- (b) GRADE threshold costs, representing additional costs to the construction of each dwelling unit on the land affected by a particular grade threshold. They are directly connected with dwelling unit cost, which would always rise as a result of grade threshold overstepping. The important characteristic of these costs is that they must be spent in a continuous way, spread over the whole period of implementation.
  - (c) COMBINED threshold costs, representing Stepped and Grade cost jointly.
- (iii) Special Investment Costs - all costs which do not fall into one of the above categories. These may represent costs imposed by outside bodies for political, social or other reasons, or costs involved with unusually troublesome designs, for instance.

In addition to the above subdivisions there is a need to distinguish another category of costs which, while not directly involved, would often be derived from threshold overstepping: running costs, or cost of freezing capital assets would fall into this category and the influence of these 'indirect' costs would usually be felt over long time periods.

Threshold costs may therefore be alternatively classified into:

- a) DIRECT threshold costs, representing those costs that must be spent to cross a particular threshold;
- b) INDIRECT thresholds costs, representing costs deriving from threshold overstepping but being incurred over time;
- c) COMPREHENSIVE threshold costs, representing both 'direct' and 'indirect' costs in cases where they are jointly analysed.

Summary

It is thought that the outlined framework would be more practical if particular descriptive features could be attached to the respective groups so that any one can be easily identified - an important point both in writings and discussions concerning threshold analysis. It is proposed therefore that classification I indicates the CHARACTER of thresholds, classification II their CAUSES, classification III their LEVELS and classification IV their SIGNIFICANCE.

In conclusion, the following general and open-ended framework for the CLASSIFICATION OF THRESHOLDS may be outlined:

CHARACTER of thresholds, that is:

- 'stepped' thresholds
- 'grade' thresholds
- 'combined' thresholds

CAUSES of thresholds, that is:

- 'physiographical' thresholds
- 'technological' thresholds
- 'structural' thresholds
- 'functional' thresholds
- 'services' thresholds

LEVELS of thresholds, that is:

- 'neighbourhood' thresholds
- 'town' thresholds
- 'regional' thresholds
- 'national' thresholds

SIGNIFICANCE of thresholds, that is:

(i) according to sequence:

'first' threshold

'second' threshold

'intermediate' thresholds

'successive' thresholds

'ultimate' threshold

(ii) according to mutual interdependence:

'dominant' thresholds

'subordinated' thresholds

(iii) according to unique importance:

'critical' thresholds

Classification of threshold costs follows, by distinguishing:

'stepped' threshold costs

'grade' threshold costs

'combined' threshold costs

and

'direct' threshold costs

'indirect' threshold costs

'comprehensive' threshold costs.

## 2. TOWARDS A COMPREHENSIVE THRESHOLD ANALYSIS

### (a) Outline of a Model Process

Problem setting - Analysis Phase I - Analysis Phase 2 -  
Analysis Phase 3 - Analysis Phase 4 - Analysis Phase 5 -  
Interpretation

Development of threshold analysis calls for the widening of its scope by incorporation of such factors as frozen assets, running costs, etc., and for the construction of a 'model' process of this expanded approach. This model should allow the application of a method of approach which can narrow down the field of analysis while simultaneously increasing its complexity. Thus it will be possible to introduce new complicating factors into the analysis without the fear that it may be transformed into a tool of such sophistication that its further application in everyday planning practice would no longer be possible. In the first outline of the model process it is proposed that this be subdivided into PROBLEM SETTING where aims, assumptions and study area are defined, ANALYSIS proper including several phases characterised by an increased degree of complexity and decreased field of search, and INTERPRETATION, where the most significant conclusions from the analysis are formulated. A number of diagrams explain these proceedings in more detail.

### (b) Frozen Assets and Exploitation Costs

Impact of the time factor on costs and benefits - frozen assets  
in relation to threshold analysis - exploitation costs

It is important to realise the significant influence of the time factor on the effectiveness of initial costs as an accurate reflection of the true costs of alternative development possibilities. Frozen cost is a measure of the waste created by the fact that it takes time to build and use to full capacity large units of social capital. Exploitation costs represent another kind of indirect cost resulting from threshold overstepping which may alter the indices of the effectiveness of initial cost. Therefore it is important that they should not be overlooked in the course of threshold analysis.

(a) OUTLINE OF A 'MODEL' PROCESS

The evaluation of threshold analysis so far has clearly implied that its further refinement and development calls for the widening of the scope of analysis by the incorporation of several important complicating factors. It also seems necessary to construct a 'model' process of this expanded or 'comprehensive' threshold analysis. The process should firstly enable the full rationalisation of all analytical proceedings by subdividing these into successive phases so that each phase is based on results derived from the one directly preceding (this principle would not only guarantee internal coherence of final results but would facilitate any necessary verification of the final or intermediate findings), and secondly, allow for the narrowing down of the field of analysis, while increasing the degree of its complexity, so that the most difficult and time-consuming phases would be only of the most limited and necessary scope.

So defined, the problem of developing threshold analysis would require two basic questions to be answered: (1) which additional aspects or complicating factors must be incorporated in the comprehensive form of the analysis to maximise the reliability of its results, and (2) which criteria should provide a datum point in the analysis for carrying out this process of narrowing down the field of analysis, eliminating undesirable variants and formulating final conclusions.

The answer to the first question is relatively simple as it emerges almost directly from the 'critical assessment of threshold analysis'. The consequences of freezing capital assets, exploitation cost, and economy of scale should be taken into account as a first priority. In this manner calculations of threshold costs would become much more comprehensive and in consequence resulting indices would be more reliable as a basis for

formulating conclusions. It also seems obvious that once it is decided to move towards an expanded form of the analysis, investigations concerning direct threshold costs would have to be developed accordingly and their compound character (stepped and grade threshold costs) would in most cases be recognised.

It is clear that although a list of complicating factors can be compiled it is much more difficult to provide fully satisfactory methods indicating their treatment in the course of the analysis - there is still scope for further research in this field and the refinement of emerging theoretical concepts. Such a task in its entire complexity obviously goes beyond the framework of this particular research, and only a limited contribution concerning frozen assets and exploitation cost will be presented in the final part of this chapter.

The second question is directly linked with the problem of evolving a model process of comprehensive threshold analysis (which is the object of the chapter). The answer is ostensibly straightforward since narrowing the field of analysis and formulating conclusions cannot be done in abstract but must be related to a concrete datum point. This datum point must be the AIM of threshold analysis, that is characterising the urban growth potential of an analysed area by identifying the threshold limitations and the consequences of overcoming them.

It may be recalled that in the simplified form of threshold analysis<sup>(1)</sup> this aim was to be attained by defining threshold limitations and calculating additional per capita cost (for new inhabitants) of fully developed threshold areas. These indices allowed the definition of the most appropriate population increase, or, if this increase were previously determined, for its verification; the follow-up phase indicated the best distribution of the increase in the light of threshold cost minimisation. The simplified

form described was the one commonly applied; however, the general aim of threshold analysis, if specified in a more detailed way, can contain numerous other variants which may require that the course of the analysis, its degree of accuracy, ways of narrowing down the field, or methods of formulating conclusions must be altered or adjusted. In this light the simplified form of the analysis so far applied may very often be no longer satisfactory and the need to formulate an expanded 'all-purpose' process of threshold analysis can clearly be seen.

The emerging consequences are plain: in certain cases a particular variant of aims will call for full cost calculations and for a comprehensive form of threshold analysis, while for a different variant the answer might be found solely on the basis of physical analysis of threshold areas' population potential, or by identifying the consequences of threshold overstepping without undertaking any cost calculations. These variants may often be connected with assumptions deriving from the general objectives of development strategies in the analysed area, necessitating for instance the elimination of land which in the case of the simplified and 'fixed' approach would have to be considered as the most suitable for development.

It is unnecessary to multiply the arguments stating that threshold analysis must always be preceded by an initial stage dealing with PROBLEM SETTING. In this stage all criteria relevant for carrying out the ANALYSIS must be established. These should specify basic assumptions, or imply a type of parallel additional studies needed to achieve a fully satisfactory solution from the analysis. Above all, however, particular care should be attached to establishing criteria for successive approaches which through eliminations narrow down the field of research and set out the implications from successive intermediate phases of the analysis.

The ANALYSIS proper should in turn be subdivided into several phases that are characterised by an increased degree of complexity. This enables the introduction of a DECISION POINT at the end of each phase of the analysis where a confrontation of the results achieved so far with the aims formulated in the initial phase should take place. The confrontation may reveal that the results of a particular phase have solved the task in a satisfactory way and that it is no longer necessary to carry out the next phase (always more complicated and time-consuming) as it is possible to move straight to the formulation of conclusions, which should in fact become the subject of a separate final stage of threshold analysis concerned with the INTERPRETATION of results of the whole analytical procedure.

Thus by suggesting the subdivision of the process of threshold analysis into PROBLEM SETTING, several phases of the ANALYSIS proper, and INTERPRETATION, it is possible to overcome an important difficulty resulting from the introduction of additional factors. The outline of this 'model' process of comprehensive threshold analysis is shown diagrammatically (see Diagram 1 - Outline of the Model Process of Threshold Analysis) and constitutes the starting point for the presentation of a more developed succession of phases.

#### Problem Setting

This stage, which is a necessary introduction to the analysis, should be divided into three operations: defining aims, formulating assumptions, and delimiting the study area.

Defining the Aims: it should be borne in mind that threshold analysis is only one component of the planning process and its basic input must not only be

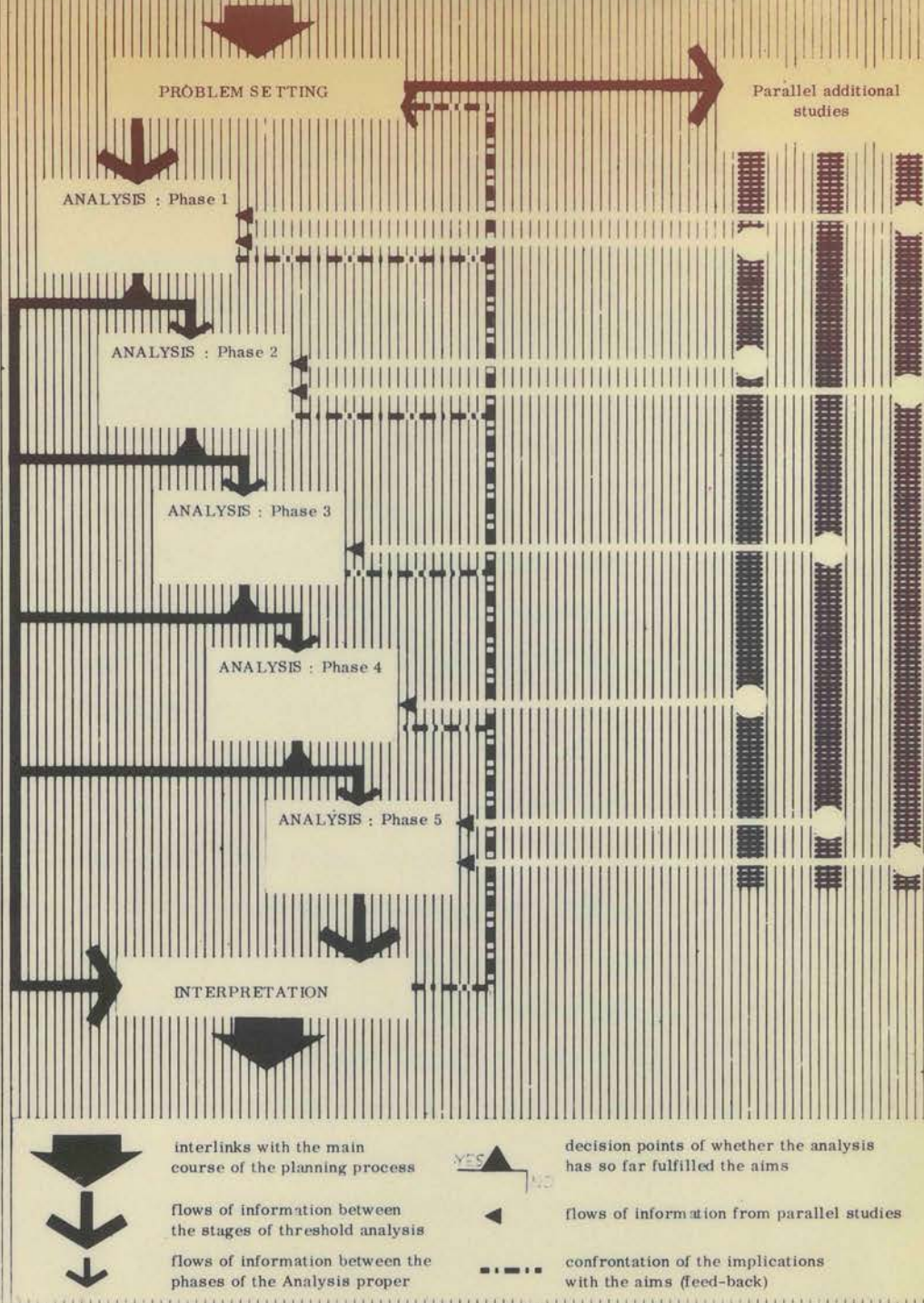


Diagram 1: Outline of the Model Process of Threshold Analysis

in accordance with the principal assumptions of the analysis itself, but must always be contained within the general policies and objectives determined by the 'client' (e.g. the local authority) for the whole planning exercise involved. This problem will be dealt with in the next chapter, in which an overall model of the planning process is discussed.

For accordance between a task put before a given run of threshold analysis and the principal assumptions upon which the analysis rests, it must be ascertained that threshold analysis would serve the purpose for which it was created; as already shown in former parts of this research, numerous criticisms of the analysis were due to overlooking this elementary fact.

The development of different variants of aims within such established boundary frameworks depend on which 'independent variables' provided by the client are fixed and which are left for the planner to find. Three basic cases may be distinguished: (1) where the amount of development money available is given and rationalised population distribution within this cost ceiling is necessary, (2) where the population increase is fixed and minimisation of the cost of its accommodation is expected, and (3) where neither of the two is determined beforehand so that optimising interrelations between cost, distribution and ranges of the population increase would have to be found.

Considering these in a more detailed way, a further breakdown of case (1) is possible since either a fixed amount for some target year may be provided or a given rate of expenditure on an annual or quinquennial basis. In the first situation the problem would be to define such a combination of population target and standard of environment which would create a socially meaningful cost-minimisation problem. In the second situation the problem is infinitely more complex if a properly dynamic

view is to be taken of minimising the present value of the time stream of costs and to take into account the unfortunate social consequences of a widely fluctuating rate of population growth. The main determinants of the cost of residential development in a dynamic setting for a given population depend upon;

- (i) location;
- (ii) density of development;
- (iii) standard of design and environment;
- (iv) rate of development, both the average rate and the extent to which it can be varied, which will influence the extent of frozen costs;
- (v) size of population units which will determine the extent to which economies of scale are available.<sup>(2)</sup>

The primary aim of threshold analysis is to assess the importance of alternative locations (i. e. item (i) above). However, possible developments of the technique may be used to examine other causes of cost variation; it will be suggested later, for example, that a fairly simple methodology may be used to take account of frozen costs.

Similar problems would be encountered in case (2) because a fixed population figure may also be given either as (a) a final one for a target year of (b) as an expected yearly increase. And again, for (a) the best and most economic distribution would be critical whereas for (b) an 'optimum' development trajectory would be the basic target.

Case (3) would be the most complex one and require much more sophisticated analytical proceedings than the two previous ones. The searched parameters should (i) define that population increase which would permit the most effective use of investment costs within identified threshold limitations or (ii) detect that rate of growth which would allow the

following of a relatively optimum development trajectory defined by analysing the consequences of overstepping those limitations. It might be thought that with no predetermined limits either for investment money available or for the population growth, and assuming that densities are left open, it would be impossible to undertake such an analysis without involving complicated mathematical equations which would to a large extent destroy one of the most valuable characteristics of the threshold ideology, that is its clarity and wide practical applicability. One of the main objectives of the model process of threshold analysis discussed here is to provide a solution to this problem.

Thus in defining the aims (or the task) of threshold analysis it is always necessary to take into account both variable aims depending on specific situations and the general aim, that is the minimisation of threshold costs involved in urban development of the analysed area.

Formulating Assumptions: this 'follow-up' operation should allow the formulation of a set of assumptions necessary for a full run of threshold analysis. These assumptions should be related to the particular circumstances of the case analysed, and should specify: locational preferences for dominant land uses (e.g. residential, industrial, agricultural); average densities essential for growth potential calculations; the most common type of construction (e.g. type of houses) needed to establish criteria for defining first and ultimate thresholds; and the basic criteria for elimination of areas (e.g. cost ceilings, scenic assets, historic values). Emphasis should be given to aspects which are not an inherent part of threshold analysis and therefore their significance in a particular case must be indicated (e.g. land tenure, cost effectiveness studies of technical alternatives). It can be seen that the assumptions are to play a double role - to provide necessary parameters to allow the analysis to be carried out,

and to indicate the need to undertake certain parallel complementary studies, the results of which may be required at various stages of the analysis. At this stage, the possibility of more than one run through threshold analysis and introducing alternative assumptions may be considered.

Delimiting the Study Area: there are two main factors to be balanced in this process: there is the need to make the study area large enough to be certain to contain the area most suitable for the expansion of the core settlement in the ways envisaged in the aims of the study, and in contrast the need to make the area small enough to keep the time spent on data collection down to a reasonable level. The balance between these conflicting aims will be affected by the quantity and character of resources available and the degree of accuracy required.

The area of study can be delimited by any method thought appropriate, but it may be useful to indicate criteria which seem to be particularly relevant for this operation. These are as follows:

- (a) functional criteria allowing the outlining of an area from an assumed optimum commuting time (in given circumstances);
- (b) geographical criteria allowing the identification of distinctly homogenous physical areas or entities;
- (c) administrative criteria linked with existing administrative boundaries;
- (d) criteria allowing the immediate elimination and exclusion of certain areas from further analysis.

Analysis: Phase 1 (see Diagram 2)

This phase should lead to the definition of the first and ultimate thresholds. The basic aim of this phase is accordingly to discover the overall population potential of the study area and to subdivide the land into that which can be developed without threshold costs, that which requires some such costs to permit development, and that which can be considered as unsuitable for development.

The first operation is to collect and analyse data in such a way as to divide the land into these three categories of suitability. This operation should be carried out separately for each distinguished group of threshold limitation causing factors. Within each of these groups first and ultimate threshold lines must be defined.

The first threshold line depends on which factors cause threshold cost in each of the groups concerned. The position of the ultimate threshold line, in turn, depends on accepted criteria (either assumed or resulting from additional studies) which indicate factors qualifying land as unsuitable for development. As in fact there are no 'absolute' development thresholds the possibility of revising criteria defining an ultimate threshold exists and another run through threshold analysis based on alternative criteria can always be undertaken.

There are many ways of isolating homogenous groups of threshold-causing factors, but for practical reasons it seems most appropriate to form such groups that it would be possible to record the synthesised results for each group on a single map. It is therefore recommended that threshold-causing factors should be subdivided into six basic groups:

- (i) physiographic or natural features;
- (ii) land uses and built-up areas;
- (iii) drainage systems;
- (iv) water supply systems;
- (v) transport systems;
- (vi) others.

From results derived from each of the groups the first and ultimate threshold lines for the study area can be found by the use of overlaying techniques. The lines can be corrected on the basis of information fed in from additional studies (e.g. information on legal difficulties connected with land tenure). It is clear that all land beyond the ultimate threshold lines should then be eliminated from further consideration during the particular run through threshold analysis.

It is then necessary to calculate population potential within the first and ultimate threshold lines by applying a density ratio either assumed in the Problem Setting or provided by additional studies.

Parallel to the described process of defining 'foot-bound' thresholds, 'foot-loose' thresholds must also be identified. These latter cannot be located on the ground, as they mostly reflect reserves and limitations of capacity or yield of various infrastructure systems and components of those systems, such as central works or networks. Reserves and limitations to public facilities also fall into this category.

To define such reserves and/or limitations and to express them in numbers of inhabitants (or dwelling units) usually requires assumptions indicating average standards of service and supply to be provided. If these assumptions are not determined in the initial phase of the analysis and there are no commonly recognised standards, additional studies might be needed to formulate these important criteria.

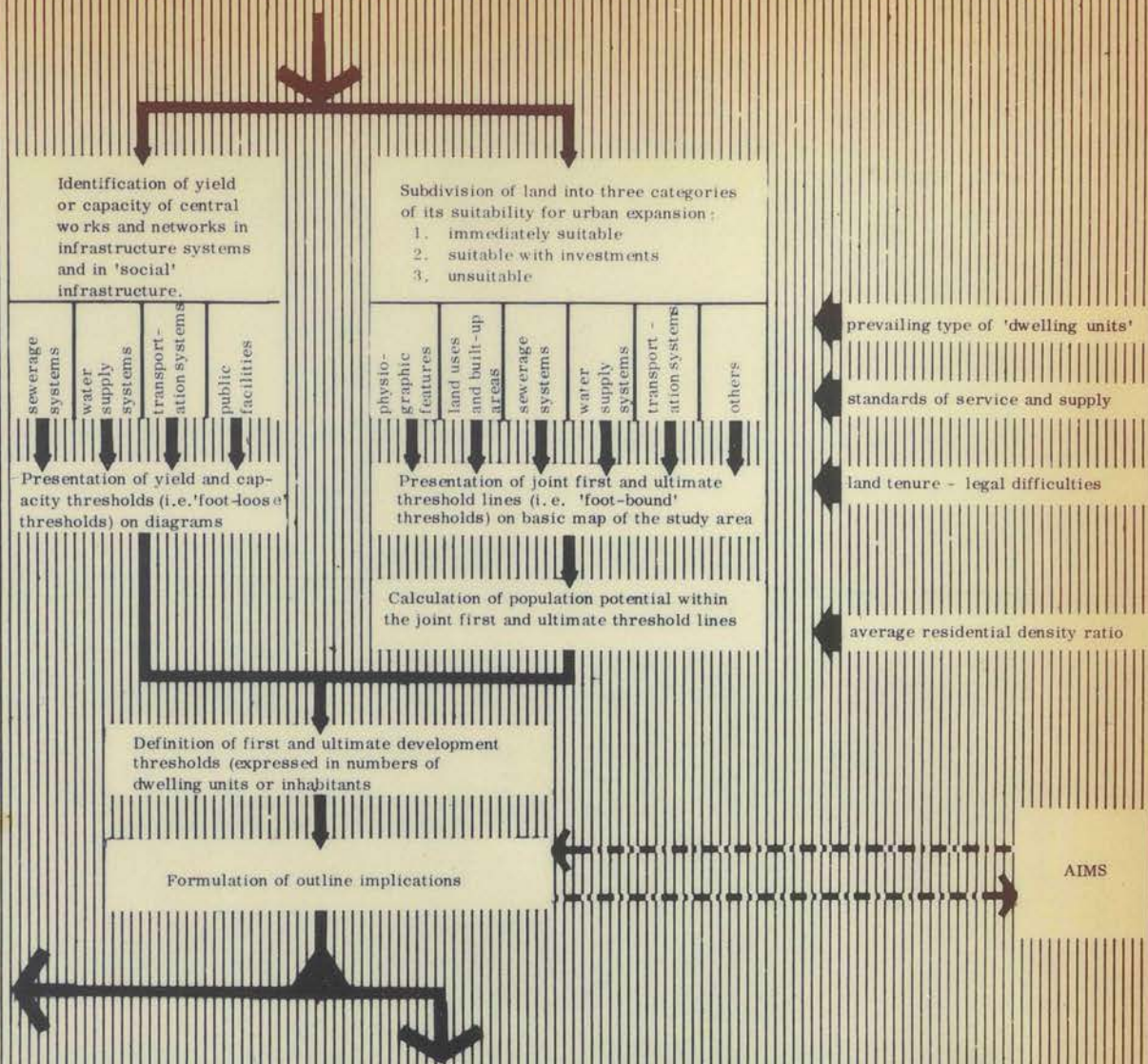


Diagram 2: PHASE 1 - Definition of the First and Ultimate Thresholds

'Foot-loose' thresholds are then recorded on diagrams to indicate their location in relation to the numbers of existing population.

Synthesis of the two so far parallel analytical streams should now be undertaken to allow for an unequivocal definition of the first and ultimate thresholds expressed according to the previously established definition of a threshold in numbers of inhabitants and/or dwelling units.

The results obtained should be recorded preferably on maps or diagrams and their implications for the urban development of the study area related to the aims of the particular analysis should be outlined. A decision can then be made on whether there is a need to proceed to the second stage of threshold analysis, or whether, if the aims have been fulfilled, it is possible to formulate final conclusions.

Analysis: Phase 2 (see Diagram 3)

This phase should lead to the definition of intermediate thresholds and to the identification of any main directions of growth. Its basic aim is to subdivide the land between the first and ultimate threshold lines into homogenous intermediate threshold areas and to calculate their population potential. It may also be detected whether particular groupings of these areas indicate distinctly different development possibilities which can be considered as main directions of growth.

The definition of intermediate thresholds should take place separately within each of the groups distinguished in the former phase. All the foreseeable intermediate thresholds should first be divided into those which can be uniquely defined and those which can take more than one alternative form. There may be one fixed physical location for most

of the grade and some of the stepped thresholds which is unrelated to the methods applied to open up the areas defined by those thresholds. A typical example is a threshold caused by slopes of certain gradients, or a threshold delimiting land that may obtain water from an existing pressure tank. To define intermediate and 'uniquely defined' thresholds is a relatively straightforward exercise and can be done at this stage. Apart from these 'uniquely defined' thresholds, most stepped thresholds can have alternative values and different physical locations. These alternatives depend on certain initial assumptions which must be formulated to allow for definitions and quantification of 'alternatively defined' thresholds. The assumptions should in general concern: ranges of expected population increase (necessary to establish size and/or location of central works for new infrastructure systems); location of probable concentrations of dominant economic activities (to assist in a more accurate isolation of land most suitable for residential uses); and general patterns in which infrastructure systems may be developed allowing the establishment of their ranges and calculation of their costs.

Problems arising from the need to introduce such assumptions look rather alarming when considered purely on theoretical grounds <sup>(3)</sup> as it is obvious that the full information necessary for these assumptions cannot be provided at the early stage of the planning process in which threshold analysis is introduced. Without them, however, even straightforward definition of intermediate thresholds and calculation of costs involved in their overstepping would hardly be possible. On the other hand, by building in assumptions about, for instance, population size and industrial location, predetermined values are introduced which in fact ought to be derived from results of threshold analysis.

Ostensibly therefore the problem is a vicious circle; if however it is recalled that the main aim of threshold analysis is to be achieved from the implications of existing conditions (e.g. road systems, industrial

concentrations, demographic structure and natural growth) all previously specified assumptions imply how existing may most likely influence future conditions. It is quite appropriate that the most probable future conditions are therefore investigated in the course of threshold analysis in order to provide premises necessary to define and evaluate intermediate threshold limitations.

These investigations are therefore not only in accordance with the theoretical background of the analysis but should in fact become an inherent part of it, and it is proposed that this process be called DEVELOPMENT OF PROBABLE FRAMEWORKS<sup>(4)</sup>. Formulation of the frameworks in the course of threshold analysis should cover:

- (i) Demographic framework, indicating the most probable boundaries within which the population increase of the analysed area should be considered;
- (ii) Zoning framework, indicating preferences and alternatives for future location and profile of dominant economic activities in the study area;
- (iii) Infrastructure frameworks, for each infrastructure system concerned, indicating alternative physical patterns of the technologically most probable and appropriate ways of developing these systems or their components, and most suitable location and size of their central works or size of other components. These conceptual frameworks should be based principally on the technology of the system involved, premises deriving from existing conditions and information provided by the former frameworks (demographic and zoning).

The main purpose of this stage is thus to establish boundary limitations:

- (a) allowing the selection of the relatively best alternatives for intermediate thresholds in infrastructure systems, and
- (b) narrowing down the field of search for the most efficient ways and means of opening up such defined intermediate threshold areas.

As a result, therefore, all alternatively definable intermediate thresholds should be traced on a base map or marked on a graph.

The next step in the process should be a synthesis of all intermediate threshold areas. The occurrence of large numbers of such areas (which is highly likely in practice) may create difficulties for their analysis in all possible combinations, and further proceedings would be extremely complicated. It is therefore more appropriate to follow general principles and attempt to increase the degree of complication in successive steps, while narrowing the field of analysis.

Hence it is proposed that these numerous intermediate threshold areas be aggregated in a few major groups indicating the possible main directions of growth for the analysed urban settlement, for instance by identifying 'dominant' and 'subordinated' thresholds (defined in the preceding chapter), as areas delimited by dominant thresholds almost always represent main directions of growth within any analysed area. This does not preclude the use of other means to define these main directions - the essential point is that the area should not be partitioned into too large a number of components too soon, as this inevitably leads to the necessity of using highly time-consuming studies or computers.

The next operation should be the calculation of population potential for each of the main directions of growth and the definition of their joint intermediate thresholds expressed in numbers of inhabitants or dwelling

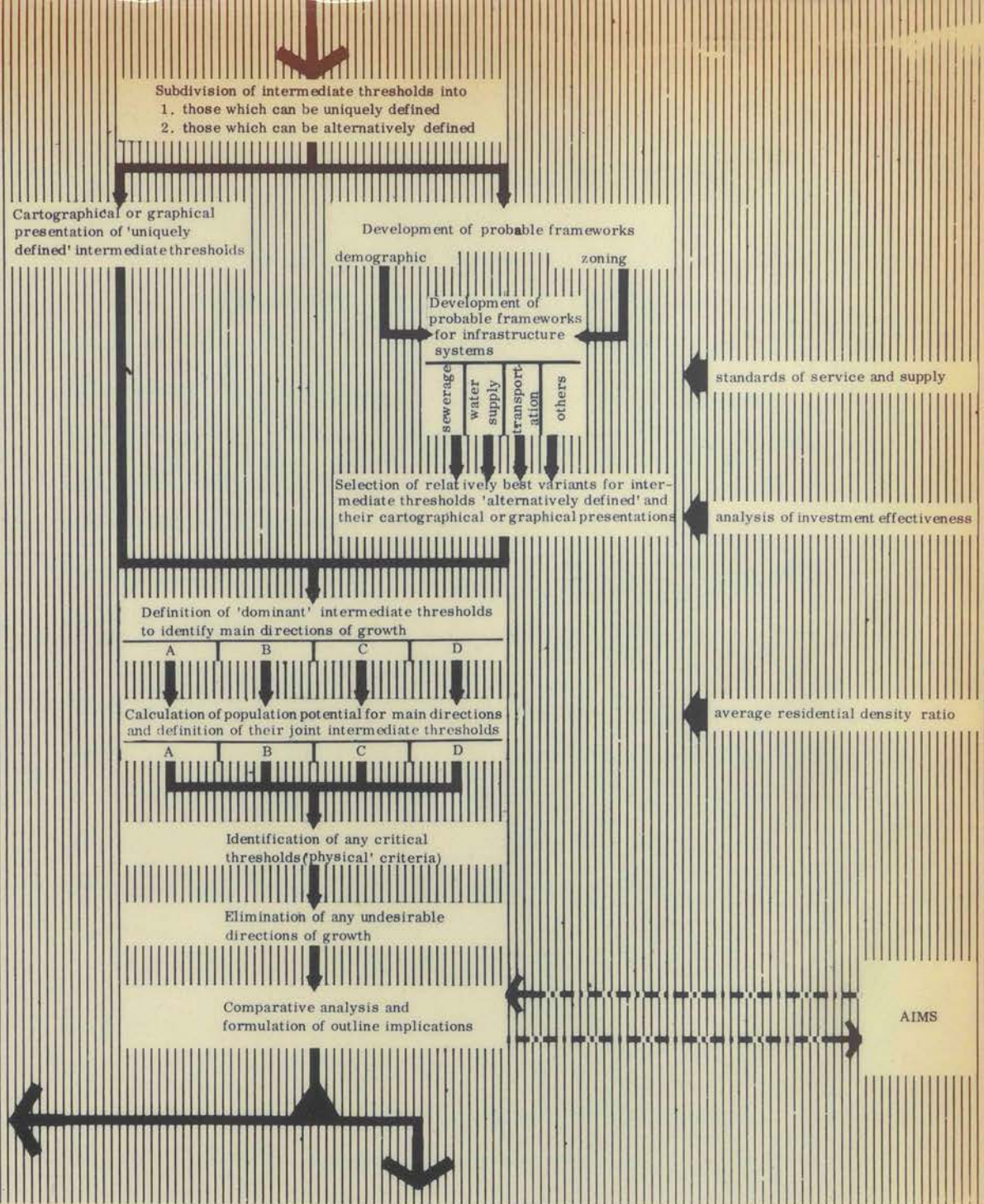


Diagram 3: PHASE 2 - Definition of Intermediate Thresholds

units (thus taking into account all 'foot-loose' thresholds).

Having defined the intermediate thresholds they may be examined to find out if any can be identified as critical (for example the degree of pollution of an existing sewage-receiving water body may impose a development threshold which, to be overcome, would require decisions taken on a regional level - in the case of a small town such a threshold would clearly be a critical one), and whether, in consequence, it is possible to narrow down the field of analysis by eliminating all development possibilities beyond the ceiling delimited by this threshold.

After taking into consideration any other premises which may indicate the elimination of certain directions of growth, comparative analyses can be undertaken and implications formulated in relation to the aims initially defined. As in the first phase, a decision can now be made on whether there is a need to proceed to the next stage or whether it is possible to formulate final conclusions.

Analysis: Phase 3 (see Diagram 4)

This phase should lead to the calculation of direct threshold costs necessary for each of the main directions of growth and a comparison of their development effectiveness on the basis of direct threshold cost indices.

In the course of Phase 2 intermediate thresholds were defined; opening up any intermediate threshold areas necessitates the overcoming of a particular segment of the first threshold and the capital cost involved must be calculated in this phase.

It is necessary to examine first whether any alternative ways of opening up the intermediate threshold areas exist (this should not be confused with alternative locations and magnitudes of intermediate thresholds which were analysed in the preceding phase), which may depend on various possible technical solutions and may in consequence give different costs (for example a bridge of the same length and width may be made of steel or of concrete; resulting costs would differ).

After selection of the relatively best alternatives (or a decision to analyse more than one alternative simultaneously) it is possible to calculate investment costs needed to open up for urban development each of the intermediate threshold areas defined in Phase 2. Results may then be aggregated so that the joint direct threshold cost involved in developing each of the main directions of growth can be found.

To make comparison more meaningful these total threshold costs should be divided by the population potential calculated in the previous stage, separately for each of the directions, to obtain average cost per capita or per dwelling unit. As 'foot-loose' thresholds indicating capacities are not identifiable on the map, it is often necessary to calculate alternative cost indices for certain directions, that is with and without those capacity thresholds.

The information on direct threshold costs should be examined to find whether any critical threshold is indicated and in consequence whether it is possible to eliminate development possibilities that cannot be contained within this threshold.

Comparative analysis of threshold cost indices may also allow eliminations if some indices prove to be exceptionally high relative to other and when the particular direction involved offers no additional tangible or intangible benefits.

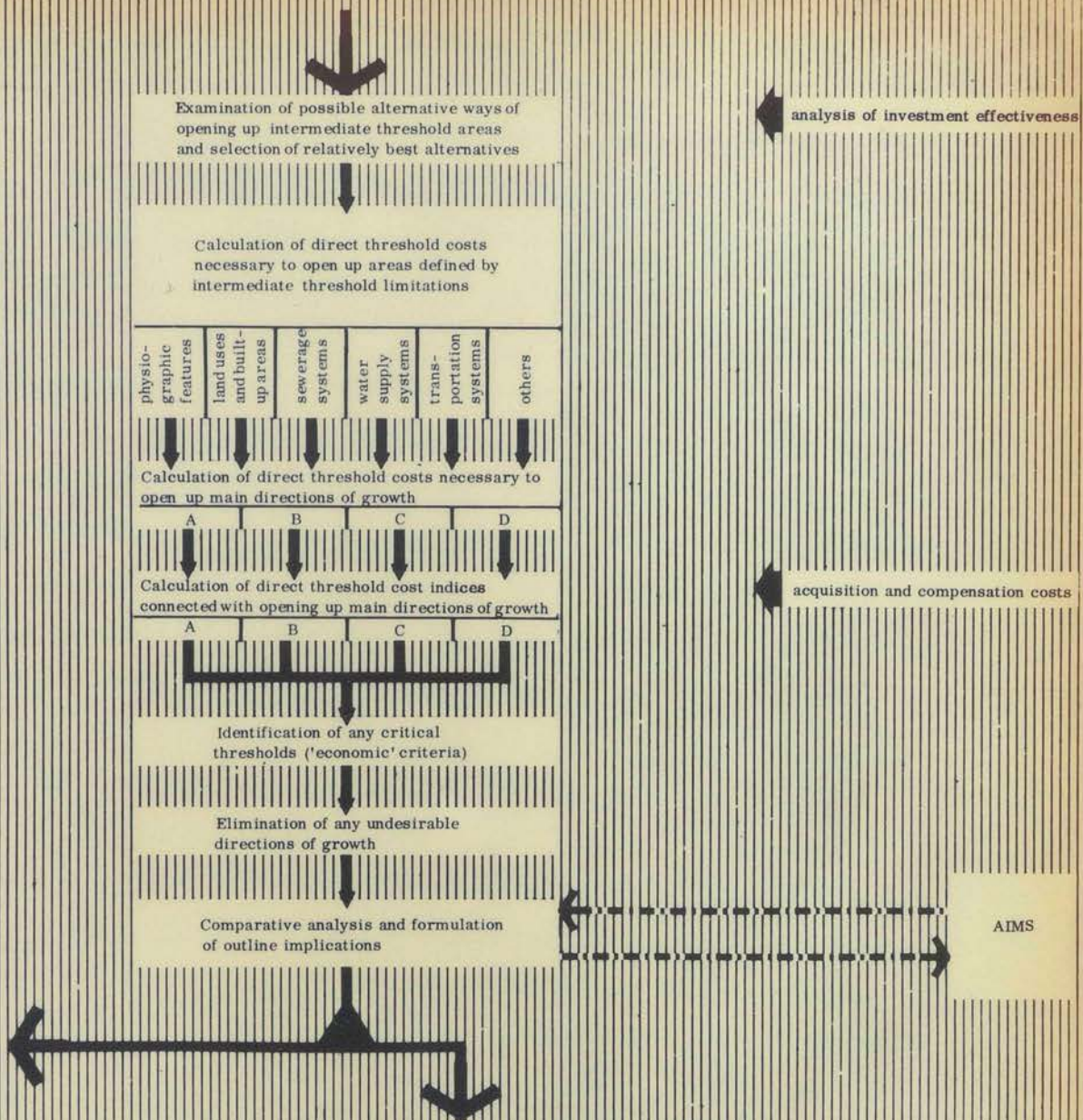


Diagram 4: PHASE 3 - Calculation of Direct Threshold Costs for the  
Main Directions of Growth

Formulation of implications from Phase 3 should be carried out as in the previous phases, that is in relation to the aims of the analysis, and once again a decision must be made as to whether there is a necessity to undertake further analyses to reach a complete and satisfactory solution.

Analysis: Phase 4 (see Diagram 5)

This phase should lead to the calculation of the direct threshold costs needed for opening up any possible combinations in which intermediate threshold areas can be developed. The basic aim of this stage is thus to compare the development possibilities of selected threshold areas or groups of areas on the basis of their population potential, direct threshold cost indices, and other functional or spatial implications so far derived.

Intermediate thresholds and the areas they delimit were defined in the course of Phase 2. The direct cost calculations in Phase 3 were done for individual thresholds and results were aggregated for the main directions of growth. In this Phase the possibilities of developing some of the threshold areas, within or between main directions of growth, are considered. It seems most appropriate to begin by listing all the possible combinations in which intermediate threshold areas, within one direction of growth, can be developed (including single threshold areas as a specific combination) and then either to eliminate obviously unacceptable combinations on the basis of general design criteria, or to choose only the combinations of areas thought most promising. The aggregate direct threshold cost for opening up each selected combination of areas should then be calculated, and converted into threshold cost indices. The possibilities of developing selected combinations of threshold areas can then be compared on the basis of their total threshold cost, their average

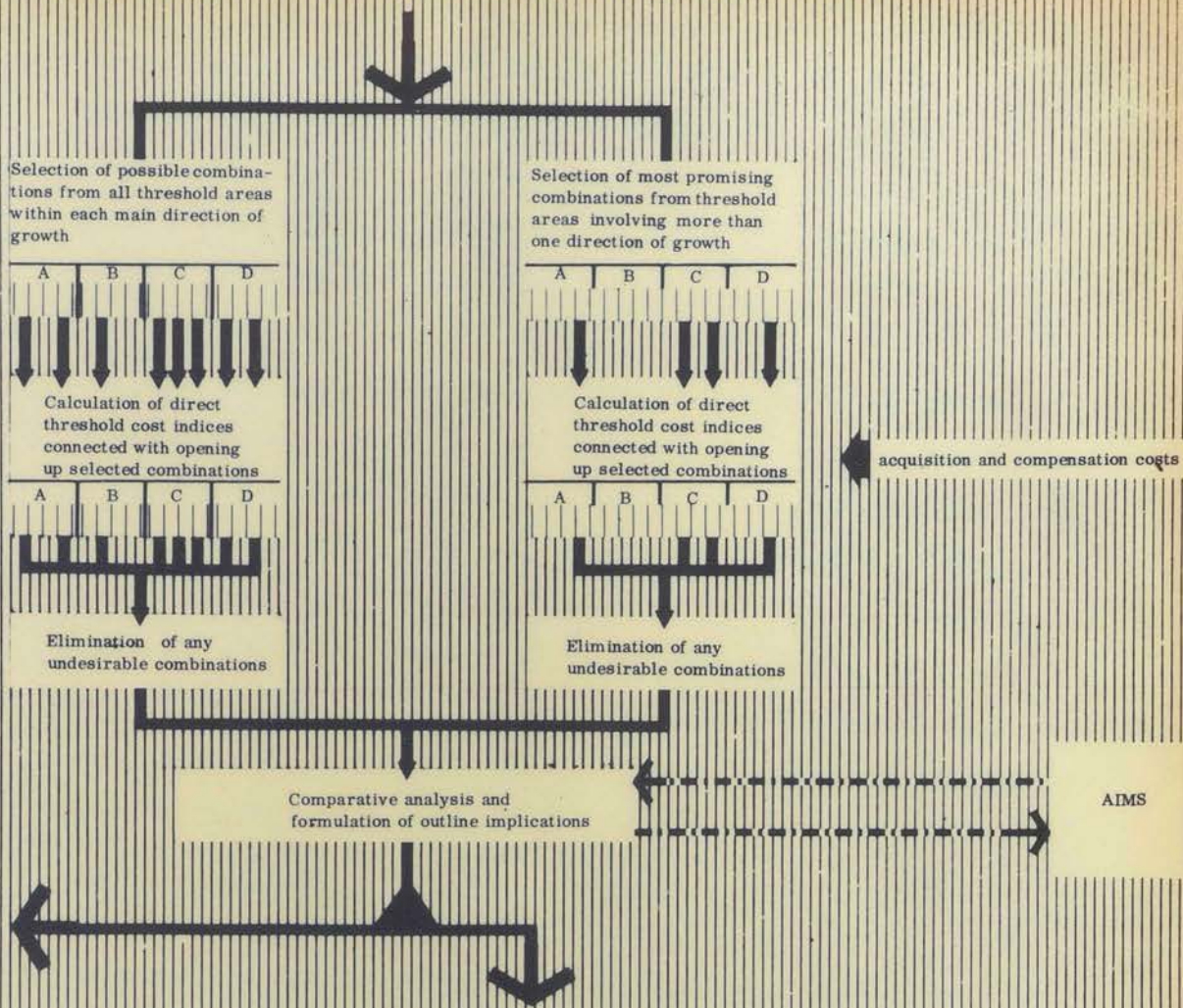


Diagram 5: PHASE 4 - Calculation of Direct Threshold Cost for

Combinations of Intermediate Threshold Areas

threshold cost per capita or per dwelling unit, their population potential and other spatial or functional consequences that may result from their development. The most undesirable combinations can then be eliminated from further analyses.

A similar process can be applied to threshold areas drawn from more than one direction of growth. In this situation it will probably be impossible to consider all existing combinations of threshold areas owing to the large numbers involved, and only the most promising combinations should be indicated and assessed. The selection should not be too difficult, as in principle the concept of opening up two or more main directions of growth simultaneously is contradictory to threshold logic - thus only exceptional (and therefore rare) additional benefits may justify the consideration of such possibilities.

The final stage of this phase should be carried out in the same way as the previous phases and only when it is clear that an adequate solution has not been found is it necessary to continue the analysis by undertaking Phase 5.

Analysis: Phase 5 (see Diagram 6)

This phase should lead to the calculation of comprehensive threshold costs for selected intermediate threshold areas or combinations of those areas. Its basic aim is therefore the introduction of the time factor to the analysis of development possibilities and comparisons on the basis of comprehensive threshold costs, either of respective threshold areas and/or their combinations or of the sequence in which certain combinations of these areas can be developed.

Summarising results so far it may be pointed out that intermediate threshold areas were defined in Phase 2, the direct threshold cost of opening up these areas in Phase 3 and population potential of all intermediate threshold areas in Phases 3 and 4. In this Phase comprehensive threshold costs are calculated for selected threshold areas or groups of those areas. This means that all indirect threshold costs involved (e. g. exploitation cost, cost of frozen assets as a first priority) must be added to known direct threshold costs. These costs must be calculated for each threshold involved in the combination of areas under consideration. Since such a calculation will normally be lengthy and difficult it should be done only for carefully selected threshold areas - as a rule these should be areas where the character of threshold limitations implies that the indices so far calculated may significantly change if comprehensive threshold costs are taken into account.

In some cases important implications can be derived from comparisons on the basis of comprehensive threshold costs of various sequences in which a particular combination of threshold areas can be developed. Consideration of the order in which capital investment is made in each variant, the point at which running and maintenance costs are incurred and the effect of frozen assets related to the process and rate of accommodating new inhabitants may indicate the most effective ways in which development can be phased, or may show the advantages resulting from a particular sequence in which a given combination of threshold areas can be developed, although this combination might have looked unpromising only in the light of direct threshold cost indices.

The results of Phase 5 may allow the elimination of some of the possibilities considered but their main role is to enable comparative analyses of high complexity to be undertaken and the implications to be formulated so that a basis for the final stage of threshold analysis is provided.

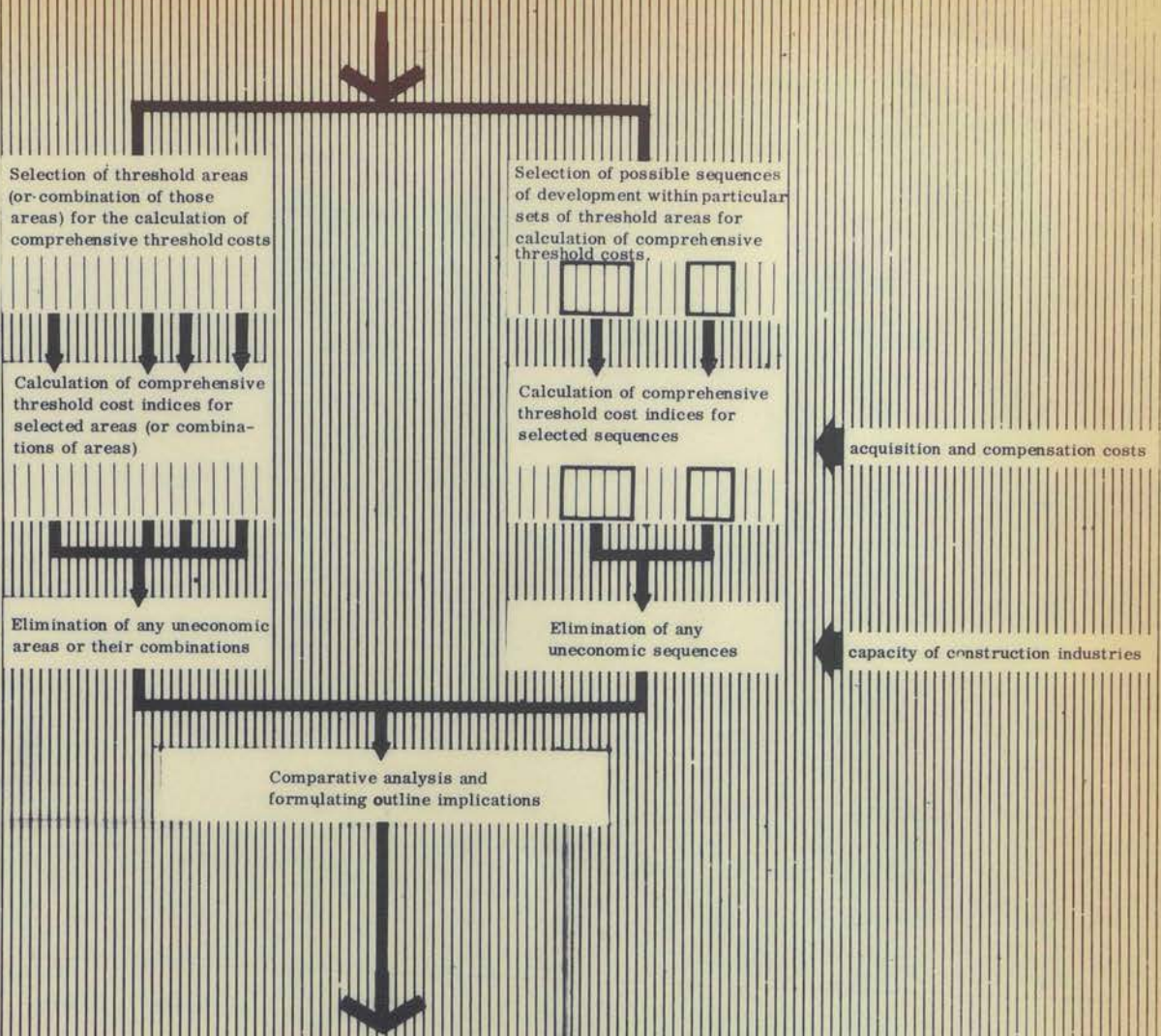


Diagram 6: PHASE 5 - Calculation of Comprehensive Threshold Cost for Selected Combinations of Intermediate Threshold Areas

### Interpretation

This final stage should present general implications from threshold analysis related to the initially defined aims and indicating the function they should fulfil in the follow-up stages of the planning and decision-making processes.

It is necessary to concentrate in this stage only on the most significant conclusions from the analysis, to avoid the risk of supplying a planner or decision-maker with an unmanageable mass of information, which may result in confusion over the relative importance of some issues or conclusions.

It seems impossible and inappropriate to establish an 'interpretation recipe' as the ways in which the conclusions are drawn and their reliability or validity will always depend on the experience and skill of the planners involved. Some guidance can, however, be provided from knowledge gained in the practical application of threshold analysis, its evaluation and research.

It can be said that the basic implications deriving from threshold analysis should characterise the following problems of the study area:

- (a) Urban development possibilities in the light of identified threshold limitations;
- (b) Urban development possibilities in the light of threshold cost calculations with indications of the consequences of overstepping various thresholds;
- (c) Locational potential and preferences for dominant economic activities taking identified threshold limitations into account.

In some cases this may allow the indication of particular ways in

which specific types of these economic activities can be attracted to the area;

- (d) Implications of threshold analysis as compared with the planning objectives and development policies being implemented or having been proposed by local authorities involved;
- (e) Interrelationships between thresholds, their overstepping, and aspects of changing standards and norms.

Although, in general, each planning team should be left free to present the results of threshold analysis as it wishes, some degree of uniformity would be useful. It is therefore proposed that the three following THRESHOLD CHARTS be produced at the end of this final stage:

#### Chart No. 1: THRESHOLD LINES AND AREAS

This Chart should include a simplified base map on which the main implications deriving from threshold analysis should be indicated (i. e. finally verified threshold lines, potential of respective threshold areas, areas with dominant economic activities such as town growth generating functions).

#### Chart No. 2: THRESHOLD FACTS AND FIGURES

This Chart should include text and tables outlining basic kinds of threshold cost indices (total, per capita, per dwelling unit, per hectare); the character of elements causing thresholds; alternative ways and sequences in which thresholds can be overcome with the resulting consequences for the development strategy and implementation processes; possibilities of phasing the overcoming of stepped thresholds; characteristics of possible town growth generating functions; and comparison of the implications of threshold analysis with existing or planned development policies.

Chart No. 3: THRESHOLD CURVES AND DIAGRAMS

This Chart should include all basic threshold cost curves and bar diagrams showing the main implications of threshold analysis.

\* \* \* \*

It seems necessary to point out here that threshold analysis in general indicates both growth possibilities which in the light of the aspects analysed appear most suitable, and gives warning of development constraints by revealing all positive and negative consequences of threshold overstepping. It must be stressed that no planning policy decisions are to be made in the course of threshold analysis, which is clearly a 'problem-identifying analysis' and provides only a basis for future decision-making and designing processes.

The method chosen to carry out threshold cost calculations is of critical importance for increasing the degree of accuracy and thus the degree of objectivity and rationality in decision-making. It should be noted, however, that the way in which threshold costs are calculated does not change the character or the location of thresholds. Experience from practical application of the threshold analysis both in Poland and in Scotland shows that even in cases of threshold analysis confined to the definition of threshold limitations and their character, without the calculation of cost indices, it is possible to derive significant and accurate implications for decision-making both in the course of formulating the plan and in the process of implementation. This important summary statement would be fully borne out by a thorough analysis of Phases 1 and 2 of the 'model' process of threshold analysis.

(b) FROZEN ASSETS AND EXPLOITATION COSTS

It has already been mentioned that the development of fully satisfactory methods indicating the ways in which frozen assets and exploitation costs can be dealt with during threshold analysis, would require further research, preferably coupled with practical testing; such a task would require economists, quantity surveyors and other experts, and clearly goes beyond the framework of this particular research. However, some aspects of the problem may be outlined to indicate possible directions of approach to frozen assets and exploitation costs and their significance in the context of threshold analysis.

Impact of Time Factor on Costs and Benefits

The essence of the investment decision is that it deals with the distribution of costs and benefits through time. Although the main concern in the evolution and future development of threshold analysis is the rational allocation of economic resources in space, the concepts associated with it have implications for evaluating different time streams of costs. Certainly unless allowance is made for the effects of time the technique will not lead to correct investment decisions. Let this be considered in relation to the characteristics of investment expenditure. Firstly, investment produces benefits over a period of time. The problems of community development are partly derived from the extremely long time period over which the facilities will exist and produce benefits. A benefit of £1,000 in year 20 will not cancel out a cost of £1,000 in year 1 of the project. Secondly, the problem of frozen costs concerns the distribution of costs over time. Again, residential development does not take place instantaneously and planning for the development of major communities will look forward as far as twenty years into the future and even more. The time during which a facility is partly built but not usable is 'wasted' time as far as the community is concerned;

bricks are in place, concrete set and the labour in performing such tasks spent but while the facilities are not in use the resources are 'frozen' until the last stage of construction is complete.

The problem which the introduction of the time factor poses for the rational calculation of costs is that a fixed money cost cannot be considered to constitute the same real burden regardless of the point of time at which it occurred. To take an example, the prospect of paying a bill of £100 tomorrow is a much greater burden than paying it next year. This is a rational reaction on the part of all of us and is called 'time preference'. We prefer spending power and the goods we can thus secure now rather than in the future. The reasons for the existence of time preference are complex, but for instance payment of interest if the money is invested can be one reason.

The significance of the differing burden of costs through time is twofold: (a) if the sequence of costs to be fixed in money terms is considered then the real costs of a development project may be increased or decreased by altering the time structure of this sequence, and (b) if there exist alternative sequences the lowest cost path may not be chosen unless a proper view is taken of the effects of time.

#### Frozen Assets in Relation to Threshold Analysis

In the appraisal of a normal investment decision the effects of time should be taken into account by means of time discounting. The estimated money costs and value of benefits should be discounted by a factor which reflects the lower real value at the present time, i. e. their 'present value'.

In threshold analysis, however, the method has to be somewhat different since it does not explicitly take benefits into account. Were it possible to consider benefits, their largely unquantifiable nature makes discounting inappropriate; if discounting alone is applied in a calculation, the paradoxical result will be that the longer the project lasts the lower the real cost. In fact the benefits are being pushed further off and (unquantifiable as they may be) becoming less valuable.

To solve this problem it will be necessary to return to the more basic reasoning of threshold analysis. It should also be remembered that the impact of frozen assets is most significant when the construction of capital facilities is concerned and this section deals with the two reasons for the freezing of part of these facilities.

Firstly, during the investment period, while there is no utilisation of the facilities since they are not completed, economic resources have been committed to the project<sup>(1)</sup> but are not yet yielding benefits.

Secondly, during the early part of the productive period as development progresses, the level of utilisation may be less than capacity. The point of reference is when frozen costs cease, i.e. when the project is constructed and used to full capacity.

In the first case the total costs to date should be surcharged. In the second case, the proportion of the capital costs to be surcharged should be equal to the degree of underutilisation. In other words, if the total capital costs are £100,000 and in year x are used to 40% of capacity, then 60% of £100,000 at 5%<sup>(2)</sup> would reflect frozen capital. This allows a simple but practical method of reflecting frozen costs to be presented.

An example<sup>(3)</sup> may be used to illustrate these points: a new sewage system is perhaps required to service a prospective new development of 1,000 houses. Supposing that it takes four years to complete the system (year 1 to 4), that the houses are built at a rate of 200 per year (years 5 to 9) and that the cost of the sewage network (excluding local collector networks which will be built at about the same rate as the houses) is £10,000.

Table 1

Year	Total Cost TC	Utilisation U	Annual frozen capital costs F
1	£ 2,000	-	£2,000 x 0.05 = £100
2	£ 4,000	-	£4,000 x 0.05 = £200
3	£ 8,000	-	£8,000 x 0.05 = £400
4	£10,000	-	£10,000 x 0.05 = £500
5	£10,000	20%	£8,000 x 0.05 = £400
6	£10,000	40%	£6,000 x 0.05 = £300
7	£10,000	60%	£4,000 x 0.05 = £200
8	£10,000	80%	£2,000 x 0.05 = £100
9	£10,000	100%	-
			F = £2,200

The total frozen capital costs F represent more than 20% of the total capital cost of the project. At this point some may ask: 'If this is a legitimate cost, then who pays it and to whom?' The answer is that it is not a monetary outlay to anyone but an opportunity cost: the sum of £2,200 is an imperfect measure of the value of goods and services foregone by having economic resources tied up and unproductive. It is 'paid' for by the whole economy.

These costs are of course unavoidable as one cannot expect sewers to be built overnight; the purpose of threshold analysis is to introduce a greater degree of rationality into such investment decisions, and although some frozen capital costs are unavoidable, it is possible to reduce them by adopting courses of action which are well within the bounds of feasibility. The measurement of frozen costs is therefore useful only if it can be used to influence investment decisions in planning. Three possible schemes for the housing project outlined above in Table 1 may be assumed:

Plan A: As described above.

Plan B: Extending the period of sewage construction by one year; rate of housebuilding the same.

Plan C: Sewage construction as in Plan A but rate of housebuilding up to 500 houses per year.

Table 2

<u>PLAN A</u>			
Year	Total Cost TC	Utilisation U	Annual frozen capital costs F
1	£ 2,000	-	£100
2	£ 4,000	-	£200
3	£ 8,000	-	£400
4	£10,000	-	£500
5	£10,000	20%	£400
6	£10,000	40%	£300
7	£10,000	60%	£200
8	£10,000	80%	£100
9	£10,000	100%	-

F = £2,200

PLAN B

Year	Total Cost TC	Utilisation U	Annual frozen capital costs F
1	£ 2,000	-	£100
2	£ 4,000	-	£200
3	£ 6,000	-	£300
4	£ 8,000	-	£400
5	£10,000	-	£500
6	£10,000	20%	£400
7	£10,000	40%	£300
8	£10,000	60%	£200
9	£10,000	80%	£100
10	£10,000	100%	-

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F = £2,400

PLAN C

Year	Total Cost TC	Utilisation U	Annual frozen capital costs F
1	£ 2,000	-	£100
2	£ 4,000	-	£200
3	£ 8,000	-	£400
4	£10,000	-	£500
5	£10,000	50%	£250
6	£10,000	100%	-

---

F = £1,450

Table 2 above demonstrates that frozen capital costs vary directly with the length of the investment period and the length of the period of build-up to final capacity. It therefore seems possible to regard a

reduction in frozen capital as a measure of improved programming. For example, if the first year's provision of housing was constructed in the last stages of the construction period, the degree of utilisation would be 20% immediately upon completion of the sewage system.

Thus:

Table 3

REVISED PLAN A

Year	Total Cost TC	Utilisation U	Annual frozen capital costs F
1	£ 2,000	-	£100
2	£ 4,000	-	£200
3	£ 8,000	-	£400
4	£10,000	20%	£400
5	£10,000	40%	£300
6	£10,000	60%	£200
7	£10,000	80%	£100
8	£10,000	100%	-

F = £1,700

By further examples, it could be shown that the cheapest method where total capital costs are concerned may not be the cheapest when frozen capital costs are taken into account. Thus the ranking of alternative schemes may be altered. Further, if frozen costs are regarded as a legitimate reflection of the opportunity cost of capital, then their inclusion may not only change the ranking of projects but may show certain projects to be uneconomic. This argument will not be developed here since it entails considerable digression because the total formation of social capital in any time period is determined by budget limitation rather than the marginal equation of costs and benefits.

It may also be important to bear frozen costs in mind when considering economies of scale. Large sewage facilities, for example, are associated with economies of scale (larger units usually entail lower costs per household) but may be offset by high frozen costs, a long investment period and a long period at less than full capacity.

In conclusion, it can be stated that, despite objections which are bound to emerge if the problem is discussed in more depth, the methods described in Table 1 are a necessary modification to the comparison of the overhead costs of alternative patterns of development. Further, an awareness of frozen capital costs can lead to improved programming of projects; without these costs and time preference being taken into account there is a constant danger of over-estimating the real value of future cost savings made possible by overgenerous provision of overhead facilities. In practice, frozen costs are likely to be brought into the calculations at a stage in the comprehensive analysis when a large number of alternatives have been eliminated and some consideration given to the time structure of development. The hypotheses should be tested by calculations of frozen costs in case the ranking of preferences is changed. A short preliminary method of estimating the significance of frozen costs may (according to J. T. Hughes) be presented in the following simplified equation:

$F = T \cdot r \cdot z$ , where F is frozen costs,

T is total costs,

r is interest rate, and

z is the average freezing period (normally half the period of construction).

### Exploitation Costs

Exploitation costs should reflect all expenditure in full. Thus the costs concerning capital renovations should be added to the total costs. A comparison should be made between cost of development and cost of modernisation or reconstruction of existing facilities or other urban components - the capital costs of renovation usually increase proportionally to the age of the construction involved, and this must be taken into consideration.

The method of accounting for the time factor is analogous with the definition of the effects of production, and differs only as far as the value of discount rate is concerned, which in the case of exploitation costs may be taken as 3%, according to B. Malisz, who has worked on this problem at some length.<sup>(4)</sup> Generally, there are two possibilities:

(i) If exploitation costs are constant then the volume of annual costs should be corrected by multiplying them using a certain coefficient.<sup>(5)</sup>

(ii) If annual exploitation costs are variable in the course of exploitation, they should be reduced to constant volumes through multiplying by a type of 'transforming' coefficient.<sup>(6)</sup>

There are practical difficulties in introducing exploitation costs: they will immediately complicate a relatively simple and straightforward calculation of initial investment costs, and it may be difficult to obtain the necessary data for a number of public utility services, since these may be hidden in various joint accounts which will make their segregation difficult if not impossible.

These difficulties are by no means irremediable and will require theoretical research towards possible simplifications of the equation concerning the calculations of exploitation costs and to make its use possible in everyday planning, and will call for a separate analysis into the methods in which exploitation costs are counted at the various levels of administrative structure of the country.

### 3. TOWARDS A RATIONALISED PLANNING PROCESS

#### (a) Outline of a Model Planning Process

A simplified model planning process - an expanded form of a model planning process

To find how much the whole planning process can be influenced and rationalised through the introduction of threshold analysis it is necessary first to develop a model of this process. An appropriate starting point is provided by a simplified model planning process devised during the Grangemouth/Falkirk study. In this model the process is subdivided into three main stages: defining the task, process of solution, and interpretation. Within the process of solution, direct physical analysis, model structure research and process of synthesis are distinguished as the three main directions of research. A more comprehensive model can accordingly be proposed. In this model stronger emphasis is put on goals formulation as the necessary starting point of any planning exercise and on ideas of using goals as the sieve at particular critical points of the process. The process is subdivided into eight successive stages: defining the task, formulating methodology, hypotheses, conceptual process, prognosis, optimisation processes, plan, and defining imperatives. Finally the previously established three streams of research are reformulated to embrace socio-economic studies and are labelled: identifying potential, formulating programme and developing models.

#### (b) Threshold Analysis in the Rationalisation of the Planning Approach

Threshold analysis in the Planning Process - complementary quantitative methods - the concept of an 'integrated' planning process

It is important to note that threshold analysis is not a 'panaceum' for all planning problems and that it is mainly confined to a particular early stage of the planning process. It can play a particularly important role in four major fields: formulation of the BASIS for decision-making; evolvment of the FEEDBACK mechanism; supply of PARAMETERS for planning synthesis and for phasing of implementation; and instigation of the INTEGRATION of complementary quantitative methods. Threshold analysis is therefore primarily involved in the early, predesign stage of the planning process but as its full contribution can be more clearly seen when in combination with other quantitative methods, this latter concept leading towards an integrated planning process is discussed in more detail. It is accordingly proposed that the first follow-up technique be an Optimisation Method which may later be completed by a Planning Balance Sheet and a Goals-Achievement Matrix. Basic interrelationships between these methods can then be developed so that parameters provided by one method can be used in another so that eventually a more rationalised form of planning process may be established.

(a) OUTLINE OF A MODEL PLANNING PROCESS

Threshold theory aims towards rationalisation of planning thinking - one of the most important targets of any research and development in the field of applied methodology. By definition, this theory is, however, confined to a particular stage of the planning process, although its influence often goes beyond it. It seems that the wider significance and more general ideas of the threshold theory will be seen if looked at in a broader framework.

One of the main safeguards of a reliable research is after all to carry it out in a comprehensive, and not in a narrow, way, but considerable refinements of some particular phases in the planning process often do not bring corresponding improvements of the resulting final product - indeed many promising and successful methods or techniques leading towards rational reasoning or elimination of subjective judgments in planning work can be enumerated which mostly concern selected aspects, and do not attempt to integrate with the full cycle of the planning process. Even if they did, this would usually be by pointing out the place of a given method in the overall planning process without any indication of how the process could accordingly be modified and refined.

These introductory remarks, together with results from the preceding evaluation and development of the threshold approach, imply that it may be advantageous to analyse how far, through the introduction of this approach, the whole planning process could be influenced and rationalised.

To achieve this aim, however, it seems necessary firstly to discuss some of the basic principles and objectives of this process, which can best be done by developing a model of the process. Only then would it be possible to indicate the role of threshold analysis in its general framework.

This brings rationalisation of planning thinking nearer as it has already been argued<sup>(1)</sup> that at the very foundations of the rationalisation of urban planning lies the need to develop 'models' of the planning process and to introduce into these models 'quantitative methods' as their main safeguard and control device.

#### A Simplified Model Planning Process

During the first testing of the threshold theory by the Planning Research Unit, Edinburgh University,<sup>(2)</sup> the author attempted to build up a simplified model for a typical physical planning exercise; its principles will now be discussed in more detail and suggestions made on how this model could be further developed or refined.

The main function of such a model is to provide a theoretical framework defining the given process of action as simply as possible without internal contradictions. This, in the hands of a planner, becomes a tool to help in the conscious reshaping of the object of planning (that is, the town, region, etc.) on the basis of the assumptions, hypotheses and principles which are the key-stones behind the intellectual formulations of the model.

It must be pointed out here that the enormous complexity of the urban environment makes it almost impossible to conceive a truly optimum solution for it. It can be argued that all new methods leading towards the rationalisation of the planning process should in the first priority ensure that major mistakes can be avoided - a limited, but important, goal if physical planning in a broad context is considered. In this light, it may be said that the main aim should always be to formulate a relatively optimised but at the same time realistic path for any planning exercise being considered.

This is not the place to elaborate theoretical arguments at length and further observations are therefore limited to indicating the mental process adopted as a framework, leading to a logical creative planning method, and to defining its principles.<sup>(3)</sup> To make the model process consistent and as logical as possible, the theoretical basis of the planning process has been analysed and its main stages defined as follows:

Stage I	Defining the Task
Stage II	Process of Solution
Stage III	Interpretation of Recommendations

The subject of Stage I is quite clear and need not be discussed further. Stage III covers first of all the definition of a programme of action and predetermines the co-ordination of legislative, fiscal and administrative measures formulated with a view to achieving the situation represented by the model of settlement structure which is the final product of the planning work at the end of Stage II. Stage II presents the most dynamic part of the whole planning process and demands continuous creative thinking. Since it is very complex, a further breakdown should be made to render the framework of the model method more relevant and theoretically sound. It is possible to define the main directions of research and the adequate classification of the various types of study within this part of the planning process. The process of solution can thus be divided into three main analytical streams which are correlated continuously during the period of work, and integrated successively into the fourth and final stream of synthesis. These are as follows:

- (A) Direct Physical Analysis - this serves to define the character and indicates the implications of the existing conditions both for urban policies and for further physical growth based on direct studies of the existing conditions of the surveyed area.

- (B) Model Structure Research - this is to establish the range of physical development models and to put forward the physical structure of the plan based on comprehensive analysis of the different selected theoretical patterns for both urban settlement structures and their various networks.
- (C) Socio-Economic Studies - these are to establish the overall development programme based on combined information from analyses of socio-economic and political aspects of existing conditions and future requirements.<sup>(4)</sup>
- (D) Process of Synthesis - this is an integration of the results from the three directions in order to formulate a final planning solution by broadly comparing the various possibilities deduced from the rational and scientific analysis of all the problems involved. All these studies are certainly of critical importance and cannot be considered separately. A plan, for instance, derived only from the implications of the existing conditions or trends, would limit planning to a set of extrapolations and thus to the passive acceptance of what is actually happening, but this would hardly be planning. If, on the other hand, a planner detached himself entirely from the reality of existing conditions and possibilities and tried to develop the plan only on the basis of some abstract models and ideas, the results would be no more than a series of pretty pictures on paper. Although this seems obvious, there are still many examples of plans which have been formulated almost exclusively on the basis of only one of these directions, whereas a proper planning solution can only derive from their integration, together with continuous feedback into and from the socio-economic studies.

Diagram 1 - IDEOGRAM

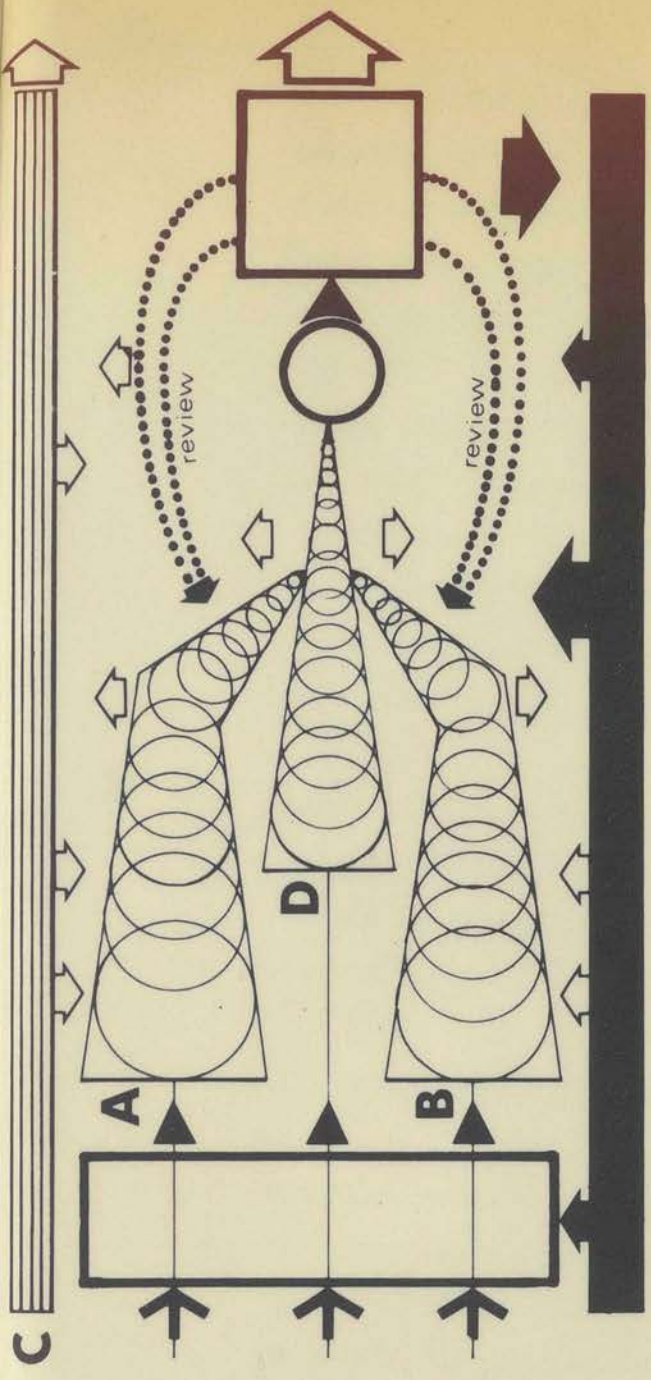
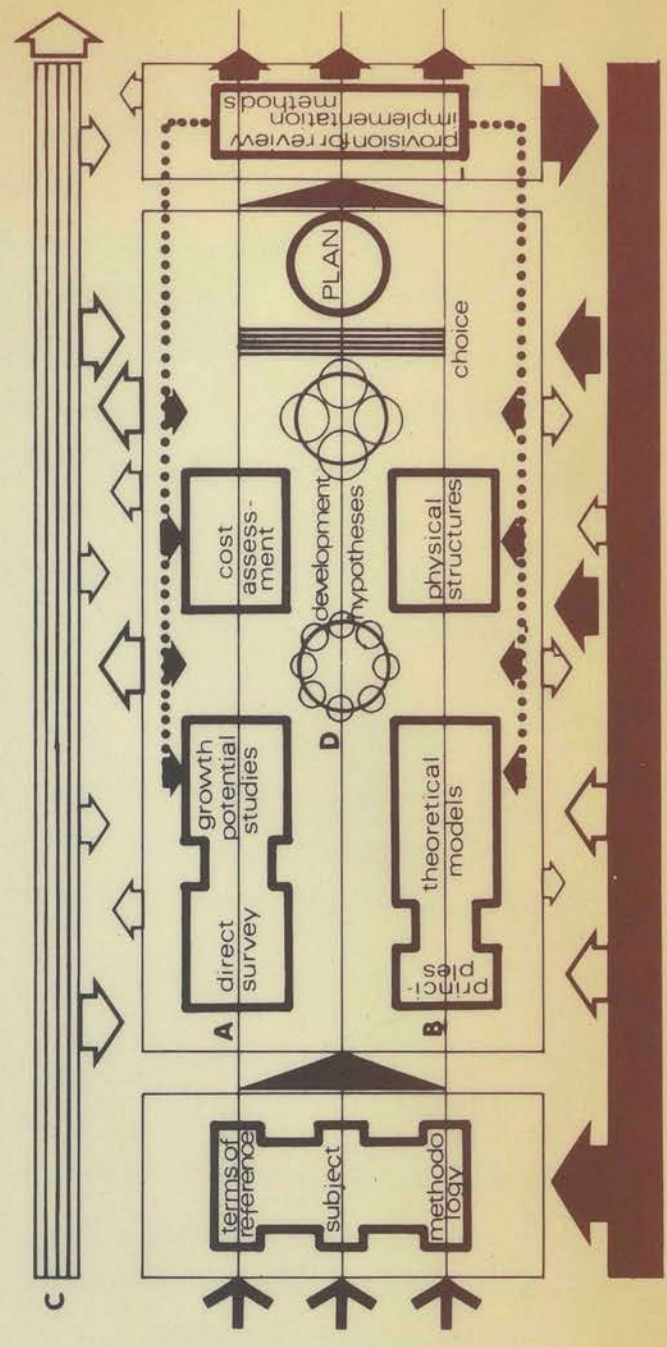


Diagram 2 - SIMPLIFIED MODEL

PROCESS



KEY

- A Direct Physical Analysis
- B Model Structure Research
- C Socio-Economic Studies
- D Process of Synthesis
- Authorities

The mutual interrelation and the structure of the theoretical concepts described above are also presented in graphic form. Diagram 1 (the Ideogram), as the general model of operation, shows the main stages of the process, indicating the dynamic character of Stage II which is subdivided into the main streams discussed above. The 'Authorities' are represented in their twofold role of 'client' and 'consulting (or guiding) body'. They influence the planning process throughout by indicating the main social, economic and political aspects, and by appraising the intermediate and final synthetic results of the work. Diagram 2 (the Simplified Model Process) shows the more detailed application of this 'ideal' framework indicating its key elements.

The simplified model process, while crude, provides a basis for further research which should remove its most apparent shortcomings and develop it into an expanded and more comprehensive form of model planning process.<sup>(5)</sup>

#### An Expanded Form of a Model Planning Process

A critical analysis of the simplified model process reveals that such an important aspect as the formulation of GOALS is hardly noticeable in its overall framework, whereas this is surely an essential task which ought to precede any planning exercise. Its particular significance can be seen in relation to any application of quantitative methods such as threshold analysis because it is impossible to evaluate anything without the appropriate frame of reference. The interdependence between goals and quantitative methods should thus become evident, since the latter would be meaningless without being oriented towards some datum point; in planning usually (and best) provided by the goals, which in fact indicate the expected or desirable EFFECTS.

Goals formulation is also an essential stage in which public participation must be introduced to play an outstanding role in setting up needs, demands and aspirations either directly or through those who represent the interests of the community (politicians, administrators, associations, etc.).

Having established the prime significance of goals, this 'starting point' of any planning work may be discussed in more detail. Following McLoughlin's approach<sup>(6)</sup> the following subdivisions should be introduced: GOALS, having broad, general (and thus somewhat vague) connotations, and OBJECTIVES, representing the sort of operational measures for achieving goals, or allowing for a measurement of the rate of progress towards those goals. Both types are indispensable as frames for decision making, evaluations, eliminations, selections and comparisons during the planning process. Objectives would then mean goals translated into the technical language - they would include all density standards, plot ratios, maximum commuting time, etc. Thus the comprehensive set of objectives would be no more than an urban development programme for the settlement or settlement system which is the subject of the planning exercise. The programme would naturally reflect effects which should be aimed at in the final solution.

In the discussed context, it seems necessary to introduce further subdivisions. The goals, and accordingly the objectives, could be put into the two following categories:

- (a) ABSOLUTE GOALS (and accordingly objectives) which by definition would have to be met by any of the proposed planning solutions. They would represent those boundary conditions within which all methods would have to operate. A great

number of goals and objectives in this group would be connected with a 'planner's workshop' - it is obvious that a primary school must be provided for a certain size of urban community, and so on. It seems that a criterion of cost minimisation may also be included here, since it should be considered as a primary duty of the planner always to aim towards solutions which would fulfil the whole set of absolute goals while economising on the means to be used, and only then trying to meet as many as possible of the goals and objectives specified in the group below.

- (b) DESIRABLE (and therefore variable) GOALS and OBJECTIVES which would be the subject of maximisation and which would therefore provide measures for evaluation and comparison among the various planning options emerging during the planning exercise. This group would thus be essential in the choice operation because only in relation to those goals and objectives is it possible and necessary to look for the optimum variant.

Facing this second group, it would be essential to determine who should be asked to take part in deciding to what extent they have been met in various planning options. In this way, the degree of public participation can be precisely established.

There are obviously many other ways of categorising goals, such as into tangibles (measurable) and intangibles (thus immeasurable), the latter being of necessity the subject of more subjective, qualitative assessments. The goals can also be listed as concerning various aspects, such as aesthetic qualities, sanitary living conditions, economic health and accessibility; or as those which indicate the need to remove existing deficiencies and those which indicate directions for necessary improvements and developments. An even more general subdivision is offered by Hill, who

says that: "goals may involve getting something the actor does not have or giving up something the actor does have."<sup>(7)</sup>

In the context of this chapter the most important conclusions from the arguments above would be that the goals formulation:

- (a) must be the starting point of any comprehensive planning exercise;
- (b) is the best way to protect and express public interest, and
- (c) is an essential frame for effective application of quantitative methods.

It can be clearly seen that the goals should therefore be used also as a 'sieve' through which one stage passes to the next in the planning process, while objectives should be continually evolving and be specified alongside it.

There is yet another aspect which was not discussed in the formulation of the 'Simplified Model Process'. It should be kept in mind that once established, these goals, together with the existing economic potential represent major elements beyond the exclusive control of the planner.<sup>(8)</sup> This does not mean that the planner should accept them blindly: on the contrary, his most important and responsible task will concern their critical review to ensure that they are not contradictory. Two major options may occur - either the goals will have to be adjusted or reduced, according to the possibilities, or ways must be found to increase the possibilities.

It is here that the goals serve to sieve and eliminate partial solutions which are not compatible with these goals. The goals also need to be verified in the light of initial findings and in consequence re-evaluated or modified, as previously explained.

At this necessary stage a revised version of goals, and hence of development possibilities, should be analysed in a comprehensive manner, discussed with the 'client' (i.e. the community) and accepted. This would provide an efficient safeguard to the public interest and would also help in the selection of options to be further analysed and developed. The next sieve in the planning process would take place while choosing the option which would become the basis for final solution and recommendations.

At the very end of the process, approval of the plan would follow, and it seems obvious that this ultimate stage also requires checking in relation to the predetermined goals, that is, in relation to the interests of the community.

All these stages may now be called CRITICAL POINTS in the planning process and specified as:

- Formulation of Goals
- Verification of Goals and Selection of Options
- Choice of Options
- Approval of the Plan

It has here been generally assumed that the analysed process forms part of a fully developed cyclical system on a national scale, so that the goals would be formulated both from interpretation of the input from the upper planning level and as the direct translation of the wishes of the local community. As has been proposed, this wide spectrum of public interest is to influence the planning process throughout, by being generally expressed through the goals and interacting particularly at critical points.

To round off the list of basic shortcomings of the simplified model process it must be noted that socio-economic studies were not an integral part of its framework. To correct this inadequacy the 'model' process offers a revised subdivision into three main analytical streams which, as before, must be continuously correlated during the period of the work, and in which the main course of design work proceeds. The streams are as follows:

- (a) Identifying Potential (corresponding to the previous 'direct physical analysis') - the aim of this stream is to investigate the implications of existing conditions and to define growth potential and its limitations. This is identified by analysing not only physical constraints and possibilities, but also all others resulting from socio-economic conditions, functional requirements, etc.
- (b) Formulating Programme (corresponding to the previous 'socio-economic studies') - the aim of this stream is to establish the overall development programme and policy, mainly obtained from socio-economic analyses, and represented by the translation of goals into a set of objectives to provide operational, technical and quantitative measures guiding and controlling the progress towards fulfilment of those goals during the course of the planning process.
- (c) Developing Models (corresponding to the previous 'model structure research' and 'process of synthesis') - the aim of this stream is to establish, from the analysis of the different theoretical assumptions and patterns and from the synthesis of information provided by the other two streams, the narrowing range of successive development models of urban and community structures.

It is also proposed that the whole planning operation be further broken down into eight follow-up phases:

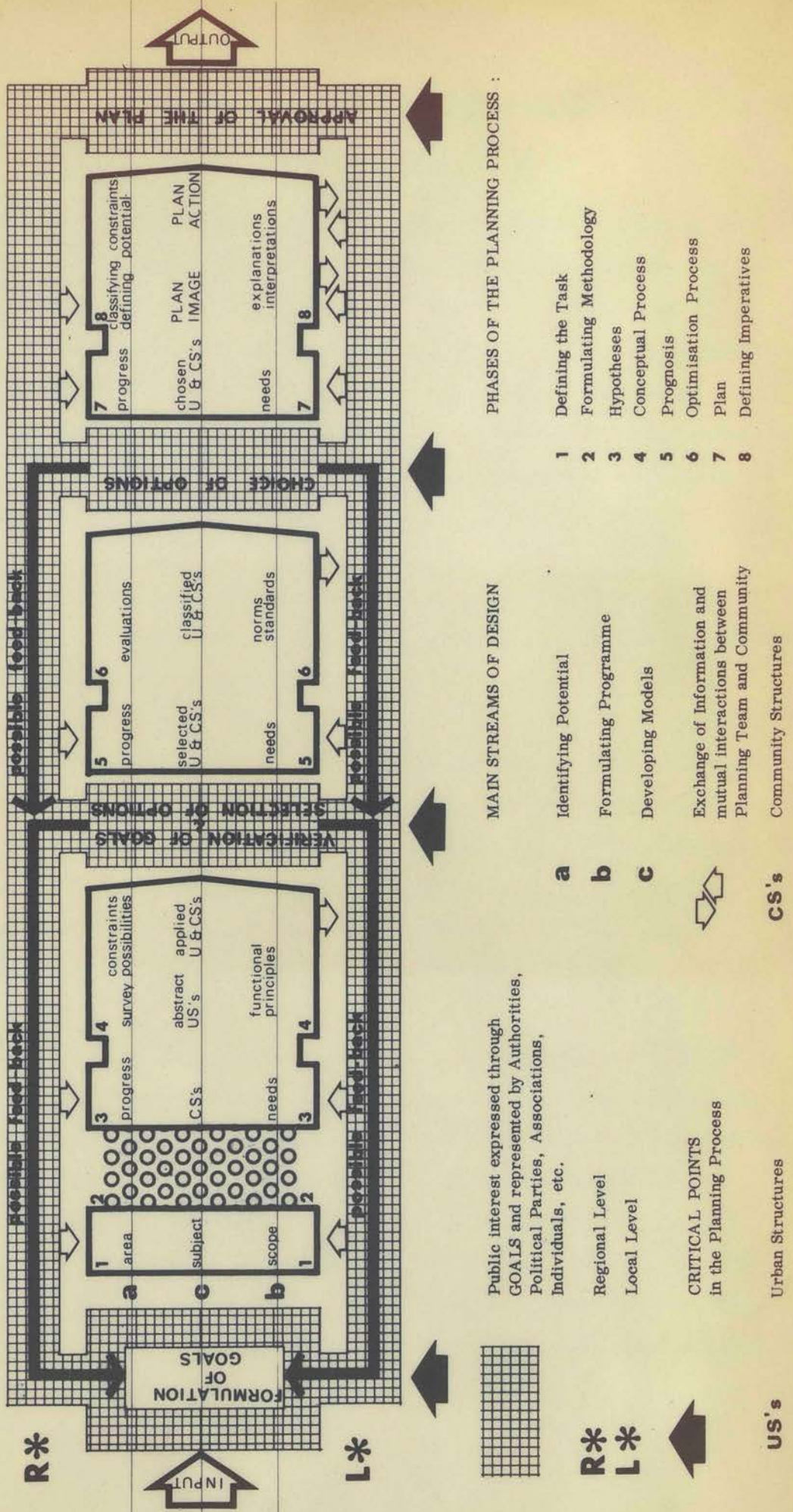
1. Defining the Task - in which the subject, the scope and the areas of the entire exercise should be specified.
2. Formulating Methodology - in which, for the previously defined task, the proposed method of approach has to be determined in the light of the available labour potential, finances designated, time factor, qualifications and experience of the staff involved, etc.
3. Hypotheses - which, in this context, should be understood as development of initial, often long-range, forecasting. This is based on hypothetical fundamental assumptions concerning tendencies of urban growth, which are of necessity difficult to verify scientifically.
4. Conceptual Process - in which, on the grounds of previously formulated hypotheses, a first concept of possible solutions of the task involved should be developed.
5. Prognosis - which in this context should be understood as the formulation of long and short term forecasting, supported by previously determined scientific evidence which would allow empirical and logical verification.

6. Optimisation Process - in which the selected options emerging from the conceptual process are to be optimised in the light of now established prognosis and all other planning factors involved (functional requirements, aesthetic assets, development costs, etc.). Briefly, this phase would concern both minimisation of means and maximisation of effects for all the options concerned.
7. Plan - which in this context should be understood as the finally determined prognosis (for a given planning exercise), to be used as a basis for the design of the development plan.
8. Defining Imperatives - in which the final recommendations in the form of an 'Image'-Plan and an 'Action'-Plan should be established as end products resulting from the whole Planning Process. It should be mentioned that this phase has absorbed all the elements included in the simplified model under the heading of Interpretation of Recommendations.

All these phases represent consecutive and interrelated steps in the planning process, where the starting point for the next phase is always based on results from the previous ones, which helps greatly to increase the overall degree of rationalisation.

This very general concept of the 'model planning process' is presented in the form of a diagram showing its general principles (see Diagram 3).

Diagram 3 - OUTLINE OF THE MODEL PLANNING PROCESS



(b) THRESHOLD ANALYSIS IN THE RATIONALISATION OF THE PLANNING APPROACH

Before discussing the role and potential meaning of threshold analysis in the overall planning process it seems necessary to point out that the method of threshold analysis can deal only with particular aspects of a planning exercise and that it should, therefore, never be considered as a fully sufficient tool in itself. It may, however, constitute a significant part of a comprehensive planning methodology which attempts to integrate the economic and physical aspects of urban development processes.

Four major fields in which threshold analysis plays a particularly significant role in relation to the overall planning process can be pointed out and discussed in some detail.

1. FORMULATION OF THE BASIS FOR DECISION MAKING - generally speaking threshold analysis is like a mental skeleton which allows the consideration of various development possibilities in the light of different presumptions within the planning process; to clarify this, however, the analysis must first be clearly allocated within the framework of the process.

It may be useful to reiterate what threshold analysis is basically for: to identify and to quantify a set of physical constraints or THRESHOLDS; to indicate the consequences of their overstepping and to reveal how this can be done most efficiently; and to evaluate and compare various urban development possibilities on objective, quantified foundations. Primarily, therefore, threshold analysis appears to play a major role at the pre-design stage of the planning process in the growth potential studies and to provide the ground for the calculation of cost indices usefully employed in these studies.

It is important to note that within its framework not only a few intuitive (or semi-intuitive) development models, but all those logically possible, together with their consequences, can be considered. Later in the planning process the technique may help in evaluation of these models but its main task is to rationalise the BASIS upon which they can be developed and to assist in an objective narrowing down of the field of search by reducing the numerous development options to a manageable number, facilitating attempts to find the relatively 'optimum' one.

Clearly the analysis represents a simple rationalisation and minimisation of capital outlays in the early stages of the planning process and it operates within a set of boundary conditions, expressed in general by some predetermined goals or objectives.

2. EVOLVEMENT OF THE FEEDBACK MECHANISM - as was stated at the very beginning of this research<sup>(1)</sup> the very essence of planning is the formulation of the programme and the location of its components into some physical area. It has also been emphasised that two-way relationships between the programme and the location of its components are an absolute necessity in any rational planning approach. This approach must be supported by feedback from locational analyses to programme setting which in consequence must also operate between various planning levels. The parameters necessary for the proper functioning of the feedback machinery within the whole integrated planning system can be obtained only through quantitative methods, so their potential contribution in this field seems self-evident.

Threshold analysis, by allowing for calculations of cost indices characterising various development possibilities, thereby fulfils another important role - it provides necessary information for feedback relationships

between the formulation of a programme and the location of its components in physical space allowing in consequence objective verification of this programme (and hence also of goals) and for the development of a dialogue between the various planning levels.

3. SUPPLY OF PARAMETERS FOR PLANNING SYNTHESIS AND FOR PHASING OF IMPLEMENTATION - threshold analysis can also, though less directly, influence later stages of the planning process, as it usually provides parameters for the final synthesis and for long-term development strategies. Its results, in fact, often help in the formulation of the "Image"-Plan itself.

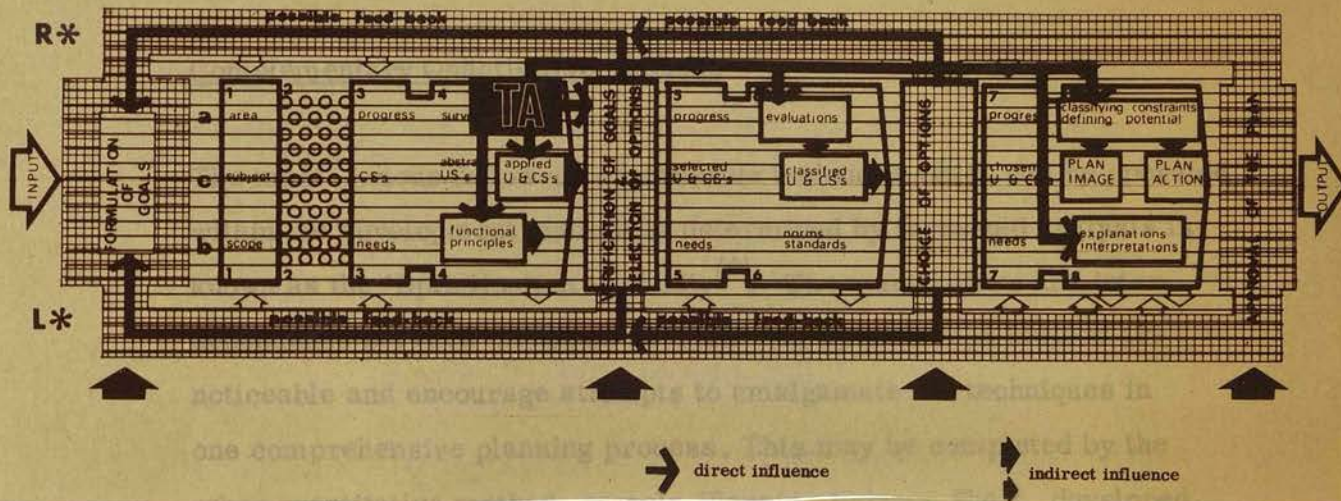
The "Action"-Plan in turn represents a stage in which foundations are set for the best possible implementation of the planning proposals. This process may again be strongly influenced by results from threshold analysis which can (on the basis of cost indices) indicate the correct sequence of urban expansion.

Particular attention here must be given to phasing, that is, to the selection of time periods and their relation to the characteristic stages in which urban structures may most likely develop. These periods often used to be established on an a priori basis and coincided with the real rhythm of urban growth only by accident; a selection of these time periods must therefore be based on an analysis of the development process to detect its 'critical points'<sup>(2)</sup> which represent a much wider notion than that of a threshold itself. It is clear, however, that thresholds have to be identified in order to define some of the critical points and thus the results of the analysis would also be required in this part of the planning exercise. They should, in fact, provide a starting point for it, since threshold theory, by introducing the time factor, allows

for a dynamic interpretation of urban development problems, and throws important light on the mechanism of growth of any urban settlement concerned.

The role and place of threshold analysis within the outline model of the planning process can now be shown in a diagram which contains most of the points discussed so far and which indicates not only the general location of the analysis in the process but reveals its direct and indirect influence on the various phases of this process.

Diagram 1



Allocation and influence of threshold analysis within the 'model' planning process

4. INSTIGATION OF THE INTEGRATION OF COMPLEMENTARY QUANTITATIVE METHODS - yet another important property of threshold analysis is that its wider contribution towards the rationalisation

of the whole cycle of the planning process can be more clearly seen when this method is considered in combination with other complementary methods being integrated into the planning process.<sup>(3)</sup> In this context information provided by threshold analysis functions as parameters to the other methods and the proper balance between tangible and intangible criteria, or between cost and benefits, can be much better safeguarded.

This concept opens interesting and fresh possibilities for rationalisation of the planning process and it seems appropriate to develop it further by looking for suitable complementary techniques which could, together with threshold analysis, form a type of integrated planning process.

#### Complementary Quantitative Methods

The most obvious follow-up quantitative technique which can be operated within the development guidelines determined by threshold analysis is known as the 'Optimisation Method'.<sup>(4)</sup> The mutual links and interdependence between threshold analysis and Optimisation Method are noticeable and encourage attempts to amalgamate the techniques in one comprehensive planning process. This may be completed by the other quantitative method, namely Planning Balance Sheet, developed in Britain by N. Lichfield,<sup>(5)</sup> which seems to fulfil extremely well the gaps left by the two previous methods.<sup>(6)</sup> The 'Goals-Achievement Matrix' evolved in the U.S.A. by M. Hill<sup>(7)</sup> offers additional and promising advantages in this context, although it has not been checked in practice as thoroughly as have the other three techniques. It is suggested that an amalgamation of all these methods may contribute to the significant rationalisation of the whole planning process.

Optimisation Method clearly represents a more sophisticated quantitative analysis, allowing choice from a large number of possible 'types' and 'intensities' of use to be optimised. The technique aims towards minimisation of costs together with maximisation of effects, and requires a comprehensive list of instrumental goals to be established beforehand. Since the Optimisation Method considers all possibilities and allows for their classification according to cost (while making sure that the goals are safeguarded) it represents an important tool optimising the way in which final planning models are constructed. Its application greatly reduces the danger of overlooking important development possibilities during the designing process .

The Planning Balance Sheet may prove an extremely helpful tool after this process if accomplished (or nearly accomplished), since it would enable an analysis to be made of the number of alternative planning models resulting from the previous stages, based both on threshold analysis and on Optimisation Method. The Planning Balance Sheet "cannot confidently optimise among alternatives to give the undeniably best solution (but here the two previous methods would make a certain contribution), because of the various unsolved problems, but it can satisfy by identifying the alternative which would appear on the evidence to be the best, or at least good enough."<sup>(8)</sup>

This method sets out "in a synthetic way the different advantages and disadvantages to each relevant sector of the community, and thereby to the community as a whole, of the alternative plans or parts of plans being compared, whether the plans be at regional or local level, and it is certainly an improvement above the over-simple advantages and disadvantages methods because it uses the rigours of economic analysis to make comparisons which are meaningful."<sup>(9)</sup> The Planning Balance

Sheet represents a mature method of evaluating final solutions and trying to bring together various costs and benefits by asking "who pays?" and "who benefits?" - "who decides?" can be added to cover all the main aspects of the problem.

This method therefore goes further than threshold analysis and Optimisation Method, in which intangible benefits were not included in any weighting operation and the community was treated as one entity. The Planning Balance Sheet disregards the way in which planning solutions (subject to comparison) were developed, and thus does not give any guarantee that there were no other better solutions overlooked in the Planning Process.

In this light the assumption that attempts towards amalgamation of the three methods into one 'Integrated Planning Process' should be undertaken seems to be justified. Each of them provides a means for the rationalisation of the planning work and each is based on a quantitative approach. Apart from some overlapping, they tackle distinctly different phases of the planning process and all have well-established theoretical bases and have passed through a number of practical testings in 'life-projects'. This last important asset cannot be ascribed to the Goals-Achievement Matrix, but in spite of this disadvantage, it presents a very promising approach worth serious consideration in this context. It concentrates the focus of attention on goals, stating rightly that all costs and benefits should always be evaluated in terms of goals achievement. According to Hill<sup>(10)</sup> a major criticism of the Planning Balance Sheet is "that it does not appear to recognise that benefits and costs have only instrumental value. Benefits and costs have meaning only in relation to a well defined objective. A criterion of maximising net benefits in the abstract is therefore meaningless."<sup>(11)</sup>

The Goals-Achievement Matrix goes far to solve this inadequacy - it introduces a weight with which each goal is provided. Various groups of people or establishments are also identified as affected by planning solutions and a relative weight is determined for each group, either for each goal individually, or all goals together. The technique calls, however, for an extremely complex and time-consuming task and has been mainly devised for the evaluation of plans for development in a single functional sector. In its present form, therefore, it is not suitable for evaluation of multi-sector development plans. Its approach is nevertheless very stimulating and it seems that once it is considered together with the three previous methods, important progress would inevitably follow. In any case the method, though initially designed to assess final solutions, may also perhaps be applied throughout the planning process as a complementary tool, helping to evaluate particular aspects outside the scope of the other methods.

#### Integration and Interrelations

The last problem to be discussed at the end of this chapter concerns the mutual interdependence between these methods, since possibilities not only for straight follow-up relationships, but for the feedback of information between them are opened up. It might thus be helpful to look again from this viewpoint at the four methods concerned.

Threshold Analysis - would operate essentially within the framework set up by the Absolute Goals and, if required, also by the Desirable Goals (which means that the analysis may be undertaken for different purposes). Its importance would therefore depend on where the emphasis in the Goals would lie. The parameters from threshold analysis would be of importance for the Optimisation Method, since they would define some sort

of boundary conditions within which the optimisation process would take place. In addition, they would provide information concerning development cost involved in indivisible types of investment. This information would also be an essential element in the course of evaluation by the Planning Balance Sheet and/or the Goals-Achievement Matrix.

Optimisation Method - would operate within the framework of Absolute Goals while aiming towards maximisation of Desired Goals (and accordingly Objectives) but within the field already narrowed down as a result of threshold analysis. In certain phases and to specific aspects, the Planning Balance Sheet technique and particularly the Goals-Achievement Matrix as geared mainly towards single sector evaluations may be applied here. Specifically, the Planning Balance Sheet seems to be useful in Stage Two of the Optimisation Method (i. e. when urban structural units are designed), while the Goals-Achievement Matrix may help in phases dealing with optimisation of various utility networks and communications systems.

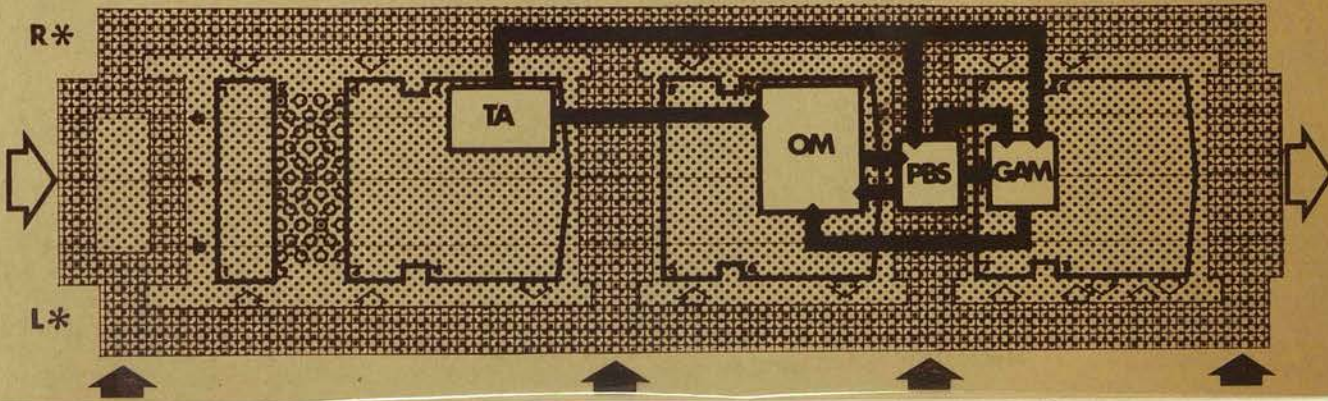
Planning Balance Sheet - would be used mainly in the later stages of the planning process when the final choice among various solutions emerging from the Optimisation process is faced. It should concentrate mainly on full analysis of additional benefits (but only those contained within the list of Desirable Goals) and according to the costs involved; and on evaluation of the costs necessary to fulfil a set of Absolute Goals, since they would usually be varied in the analysed solutions. As previously mentioned, the Planning Balance Sheet would take into account a number of information and cost indices provided both by threshold analysis and by the Optimisation Method.

Goals-Achievement Matrix - would serve mainly as a complementary tool in various stages of the planning process but particularly in the final choice operation to provide additional parameters in cases where no satisfactory answers would be obtained from the Planning Balance Sheet investigations. It may also be used for additional comparative analysis concerning selected important aspects, such as to assess (in various solutions) the degree of achievements of Goals, which is particularly important in the analysed settlement. It is also anticipated that the introduction of the Goals-Achievement Matrix with its very interesting theoretical background would lead to the modification and refinement of the three other methods involved.

\* \* \* \* \*

Basic relationships, which may develop between the four methods and their allocation within the framework of the Integrated Planning Process, have been diagrammatically indicated (see Diagram 2).

Diagram 2



Threshold Analysis, Optimisation Method, Planning Balance Sheet, Goals-Achievement Matrix and their interdependence within the framework of an Integrated Planning Process

It is hoped that the general concept of an Integrated Planning Process with the four methods merged together has been backed up with enough supporting arguments to stimulate critical comments and discussions, which may in turn lead to practical testing of the whole idea - the most important step for its eventual refinement and reliable development.

APPENDIX, CONTINUED

1. THE STATE OF THE ART

1.1. Introduction

In the development of the present invention, it was found that the use of a certain type of material in a certain way was not known in the prior art. This is particularly true in the case of the use of this material in the construction of a certain type of device. It is therefore the object of the present invention to provide a device of the type mentioned which is improved over the prior art.

If the device of the present invention is used in a certain way, it will be found that it is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

1.2. Description

The device of the present invention is of the type mentioned in the foregoing. It is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

**APPENDIX: FOOTNOTES**

1. The device of the present invention is of the type mentioned in the foregoing. It is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

2. This is a new type of device, the use of which is not known in the prior art. It is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

3. F. J. Smith and J. D. Jones (1950)

4. This is the first step in the process of developing a certain type of device. It is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

5. Part 3, Chapter 1 of the present invention is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

2. THE STATE OF THE ART

2.1. Introduction

The present invention is of the type mentioned in the foregoing. It is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

6. The present invention is of the type mentioned in the foregoing. It is particularly well adapted for the purpose mentioned. It is therefore the object of the present invention to provide a device of the type mentioned which is particularly well adapted for the purpose mentioned.

## 1. TOWARDS REFINEMENTS OF THE BACKGROUND THEORY

### (a) Definitions

1. In his criticism of threshold cost calculations K. Gliszczynski (12) points out that "so far only new construction has been taken into account. Thus, in calculating total costs, outlays needed for renewal are ignored while replacements of old construction are calculated" although quite often they are of the same magnitude. It is worth pointing out that the definition proposed also eliminates this objection since all purely descriptive elements are removed from it.
2. If the discussed functions are not piecewise linear, unit costs change, so that one will also have to distinguish AVERAGE UNIT COST - detailed discussion of this problem is, however, beyond the scope of this research.

### (b) Classifications

1. For instance, to mention a few doubts from many which may arise: Is a structural threshold also a physical one? Is a capacity threshold part of a technological threshold or do they represent different categories? Why is a quantitative threshold supposed to represent a separate category while other thresholds are also, as a rule, presented in quantitative terms?
2. In some cases where threshold investment is liable to phasing this cost can be subdivided into smaller parts but this does not affect the general character of this limitation.
3. This is a new type of threshold, so far not considered either in the theoretical background or in the practical application of threshold analysis - it seems, however, that the 'service' threshold should be introduced since it has marked effects on the continuity of urban growth and since it derives from existing conditions of an analysed area.
4. J. Kozlowski and J. T. Hughes (17).
5. This is an initial approach to the problem of classifying threshold costs, outlined by the economist J. T. Hughes of Glasgow University in his research related to threshold theory.
6. Part 3 Chapter 1 (a) where the character of 'normal' and 'additional' cost was also discussed in more detail.

## 2. TOWARDS A COMPREHENSIVE THRESHOLD ANALYSIS

### (a) Outline of a Model Process

1. Which provided the basis for the majority of cases where threshold analysis was applied in practice (both in Poland and Scotland). A simplified method of threshold analysis was presented by, among others, J. Kozlowski (29).
2. Compare the more static, though more detailed enumeration of factors which affect the costs required for the construction of dwelling units specified in Part 3, Chapter 1 (a).

(a) Outline of a Model Process (continued)

3. This ostensible contradiction was in the past criticised by some authors as the 'theoretical inconsistency of the threshold analysis'.
4. The more obvious term MODELS was purposely discarded to distinguish these investigations from the development of comprehensive urban models which should be developed in the later stages of the planning exercise.

(b) Frozen Assets and Exploitation Costs

1. The value of work in progress.
2. This is an arbitrarily chosen figure; at current rates 8% would probably be more accurate.
3. Proposed and developed by J. T. Hughes during his joint research with J. Kozlowski (sponsored by the Centre for Environmental Studies) on threshold theory and analysis.
4. B. Malisz (39).
5. This coefficient, according to B. Malisz (39), can be calculated as follows:

$$Y_n = \frac{\sum_{K=1}^{ns} Kst \frac{(1)^K - 1}{(1+c)}}{\sum_{K=1}^{ns} Kst \frac{(1)^K - 1}{(1+c)}} = \frac{1 - \frac{(1+c)^n}{(1+c)}}{1 - \frac{(1+c)^{ns}}{(1+c)}}$$

where:

- $Y_n$  is a coefficient correcting exploitation costs
- $Kst$  is constant per annum exploitation costs
- $n$  is the period of investment exploitation
- $ns$  is the base period of exploitation
- $c$  is the discount rate (3%)

6. The magnitude of constant costs will be as follows : (B. Malisz 39)

$$Kst = rk \sum_{K=1}^n K_k \frac{1 - (1+c)^{-K}}{(1+c)}$$

where:

- $Kst$  is the annual exploitation costs
- $K_k$  is the annual exploitation costs in a K-year
- $rk$  is the transforming coefficient
- $c$  is the discount rate (3%)
- $n$  is a period of investment exploitation (20 years)

### 3. TOWARDS A RATIONALISED PLANNING PROCESS

#### (a) Outline of a 'Model' Planning Process

1. In Chapter 1 Part 1.
2. (60) and J. Kozlowski (26).
3. This method was further improved and developed in (59).
4. In the case of Grangemouth/Falkirk, these studies were undertaken by the team led by Professor D. Robertson of the Department of Social and Economic Research, Glasgow University, and were therefore a concurrent and not an inherent part of the Planning Process as applied by the 'physical' planning team.
5. First outlined by J. Kozlowski (28).
6. J. B. McLoughlin (39).
7. M. Hill (16).
8. This problem has already been discussed in the chapter on Critical Assessment (see Part 2, Chapter 4 (a))

#### (b) Threshold Analysis in the Rationalisation of the Planning Approach

1. In Chapter 1, Part 1, where general aspects of relationships between the programme and locations have been discussed at some length.
2. J. Regulski (51) in investigating the "efficiency of town planning" has introduced the concept of critical points in urban development processes which he has defined as "moments in which there appears a danger that disproportions would arise between the required standards of use and their fulfilment by the existing (in that period) standards of the town".
3. As has already been suggested in Chapter 4 (b), Part 2.
4. An outline of this method has been given by J. Kozlowski (27), and by S. Broniewski and B. Jastrzebski (3).
5. N. Lichfield (32).
6. This idea was first mentioned by J. Kozlowski (27).
7. M. Hill (16).
8. N. Lichfield (33).
9. N. Lichfield (33).
10. M. Hill (16).
11. M. Hill (16).



## CONCLUSIONS

### Fulfilment of Initial Research Objectives

In summary, it can be stated that the whole research has been an attempt to prove that through the introduction and development of threshold analysis the overall planning process could be rationalised in general and in particular in its early analytical part. An additional, but by no means less important task, was to support the claim that because threshold analysis was based on scientifically sound and logical assumptions, all its major shortcomings and deficiencies found in its practical applications, pointed out by its critics, and emerging directly from practical testings carried out during this research, can be removed.

Both these general aims have provided the main guidelines for the evaluation and development of threshold analysis presented in parts 2 and 3 of this research.

In the Evaluation section, main emphasis was put on implications from the test cases which were subject to careful scrutiny. As a result it has become possible to evolve a list of shortcomings and deficiencies of the approach and to indicate ways in which these could be either totally removed or partially remedied. Thus directions for further research were formulated, which provided the starting point and the platform for follow-up research dealing mainly with the Development of the technique, concentrating on;

- (1) The refinement of basic definitions upon which the analysis was founded and the setting up of an organised framework for threshold classifications which helped greatly in clarifying the ambiguities and confusions previously indicated.
- (2) The formulation of an expanded comprehensive process of threshold analysis which has created an open framework allowing for incorporation into this process all elements previously missing (which thereby made the results of the analysis not fully reliable in numerous cases). Thus the ways of improving the whole threshold approach were not only exposed but to a great extent realised, described and diagrammatically presented.
- (3) The possible influence and role of threshold analysis within the overall context of the planning process which was finally examined. The outline model of this process was first developed and then the role of threshold analysis alone and in combination with other complementary quantitative methods was presented, providing supporting evidence for the initial hypothesis that this technique can and should help to rationalise not only a specific part of the planning process but also its entire framework.

## General Remarks

The major conclusions of this research are thus inherent in the findings of parts 2 and 3. It would, however, be inappropriate if at the end it was not stated clearly the general view of threshold analysis as it appears at this point in time, so that emphasis may be put on its most significant attributes which otherwise might be overlooked.

In the preceding discussion of threshold theory, there are three strands which ought to be identified if confusion as to these conclusions is to be avoided. Firstly, there is the concept of a threshold or discontinuity in development, which would be valuable in itself even if it did not lead to the development of a system of analysis. Thresholds help in comprehending the growth of urban settlements and in focussing attention upon the points in the development of an area when a genuine choice exists.

Secondly, there is threshold analysis as developed in Poland and applied in Britain. Having identified points of decision, it is possible to develop a form of analysis which lays emphasis on these factors.

Thirdly, the development of a quantifiable, objective analysis technique naturally leads to further refinements and a more ambitious scheme which corrects the inadequacies of the original technique but at the same time is less closely related to the original concept. It is believed that planning would benefit from further research into and application of variants of threshold-optimisation methods, but the view in these general conclusions applies to what might be called the 'threshold approach' to planning problems.

The major contribution of threshold approach lies in four main fields, which will be dealt with in turn.

1. An Improved Planning Methodology. Perhaps the major current problem for the planning profession is the question of the period of time for which a plan should be prepared. Traditionally plans have been drawn up for a period of twenty years or for a specific date such as 2000 A.D. These periods do not coincide with the natural growth cycles of an urban community, and plans which have been produced in this way seldom take account of the process by which the community grows to the size and pattern outlined in the plan, even if it is assumed that the goals are fulfilled. In addition, the plans for the target year tend to present an 'ideal' arrangement as though the town must grow to this form, whereas if it is developing successfully it will grow beyond the target almost immediately.

Threshold is a more dynamic approach to planning in that time is explicitly introduced as an integral element in the plan. It can be used to identify the natural phases of growth and planning instead of an arbitrary time period associated with a population target. These advantages can be gained by the use of the threshold concept and simplified threshold analysis, although the use of time discounting in comprehensive analyses considerably improves the treatment of future benefits and costs.

Another important problem for planners in the future lies in the need for effective planning to encompass a much larger area. It is likely that the current review of local government in Great Britain will result in the creation of larger planning areas. There is also a need to relate physical planning to other forms of economic and social planning at regional levels. The results of threshold analysis,

quantitative and comparable in smaller areas, can create information for choices at a higher level of decision-making. The data for threshold analysis and its results can provide a vehicle for feedback between regional and local levels which will contribute to a further refinement both at the lower and regional level.

The development of computers has made it possible for all types of planning to handle a considerably enlarged quantity of data. However, if physical planning is to reap the benefits of this revolution it must develop a framework which lends itself to quantification in the analysis and data processing stages. Threshold analysis is a quantitative technique which is related to other techniques; the data and results can provide inputs to further stages of analysis. Also, having established the framework of data collection and generated the information necessary for threshold and optimisation analysis, this work will continue to produce results in two respects. Firstly, future analyses will use the same material and, secondly, threshold costs can provide the information needed for detailed implementation, for example in drawing up a capital budget.

The advantages of quantification have previously been dealt with; in brief, it is believed that it provides a method of development appraisal which does not prematurely eliminate alternative schemes and allows comparisons in a much more objective manner than current intuitive methods.

2. A Measure of Efficiency . A quantitative technique such as threshold or optimisation analysis reduces many planning variables to a common denominator, which in this case is the money cost of developing certain areas for certain functions at certain rates of growth. This of itself does not make it a technique of economic appraisal although the use of

money costs clearly facilitates comparison with economic analysis. However, the crossing of a threshold not only has significance for the growth of a town, but also involves the additional commitment of economic resources. Indeed, a very large part of gross fixed investment is taken up by threshold-related expenditures. The economist can therefore regard the crossing of thresholds as similar to an investment project, with which he is accustomed to dealing, and for which his techniques of analysis are designed. At the risk of confirming the worst fears of many planners, the development of an area of barren land bears many similarities to the choices involved in constructing a factory to produce any article.

On a more general level, the methodology in the threshold approach embodies the twin concepts which lie at the bottom of the 'economic approach' - whether economists are directly involved in the project or not;

- (a) by comparing the costs of alternative forms of development, threshold analysis reflects the notion of opportunity costs, that is, the real cost of undertaking a course of action is the alternatives which thereby have to be foregone;
- (b) the concept which is necessary to optimisation is the margin; that is, the question of efficiency does not deal with questions such as "should we expand Town A or not?" but "is it cheaper to expand A by x% or by y%?", or "should the expansion of A be in area b or c or both?" In other words by comparing alternative combinations of development proposals (combinations which become more complex in progress from simplified threshold to optimisation analysis) it is possible to identify the optimum much more clearly.

3. A Basis for Improved Interdisciplinary Co-operation. Planning requires the co-operation of many disciplines, and any technique which encourages this co-operation has considerable advantages. It has already been mentioned that the threshold technique facilitates economic analysis, and encourages the co-operation of economists and physical planners; the analysis represents a common language which should lead to improved communications between the professions, both of which are dealing with the same phenomena - the physical planner with threshold lines on a map and the economist more interested in steps in a cost curve. More important, there may be greater clarity about the goals and purposes on the part of each discipline.

4. Improved Links with Executive Functions. Not only will threshold create links between disciplines, it will also bind the planning function more closely to the decision-making process at the authority level and the departments responsible for running the functions involved in development. The analysis makes it easier for planners to keep open alternatives which can be presented to decision-makers to give them a more effective choice, and it can also be argued that the language and criteria of threshold analysis are more comprehensible to non-planners. The threshold approach allows a plan to be worked out in such a way as to make explicit the requirements of the engineering, power and transportation services; this should reduce the period of co-ordination and negotiation which follows the acceptance but precedes the implementation of the planning recommendations.

## Summary

It should once again be emphasised that threshold analysis is neither a complete planning theory nor a panaceum for all kinds of planning problems. No planning policy decisions are to be made in the course of the analysis as it attempts only to provide a more objective basis for design and decision-making processes. Clearly, threshold analysis represents a 'problem-identifying technique' and embodies only some of the parameters of a planning strategy. There always remains a strong need to balance its results with results of other complementary techniques covering together the whole spectrum of comprehensive objectives and goals which are to be fulfilled in the course of the planning process.

The purpose of the analysis should always be remembered so that its misuse or abuse can be avoided. In the most general terms, the analysis does not measure the benefits of alternative urban forms, but indicates the costs of these forms and thus helps to identify the factors which cause variations in these costs. It does not replace other judgments in the planning process but it puts these judgments on a sounder and more objective foundation.

Above all, the advocacy of threshold analysis places a responsibility upon the shoulders of its proponents to test their statements and assumptions in the real world both to discover the behaviour of costs in practice and to ensure that the admitted bias in the technique does not lead practising planners to reach erroneous conclusions.

These final remarks may be concluded by pointing out that theories do not have to be 'dead right' to be enormously useful and the usefulness of threshold analysis, with all its admitted or latent shortcomings, seems to be adequately proven by the evidence and arguments presented in this research.

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