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STUDIES IN APPLIED REGIONAL SCIENCE

18

POPULATION GROWTH AND URBAN SYSTEMS DEVELOPMENT

A Case Study

G.A. van der Knaap

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Rotterdam

CONTENTS

POPULATION GROWTH AND
URBAN SYSTEMS DEVELOPMENT

1. INTRODUCTION AND FRAMEWORK OF ANALYSIS

1.1 Scope and method

The spatial behaviour of man in a regional context and the spatially varying aspects of this behaviour have been since long the concern of geography as a discipline, albeit with changing emphasis on the two components. Already in the first quarter of this century De Geer[1.] wrote that the "chorographical way of thinking i.e. areal philosophy is, as a rule, the essential thing in geographical research". In his use of the term chorographical he summarized the classical dichotomy in geography between uniqueness and generality, which in about the same period is also discussed by Hettner[2.]. Through time there has been a varying emphasis on these two aspects and about forty years later Berry[3.] again stresses the same point as the authors mentioned above, viz. that these approaches within geography are not conflicting but complementary and aimed at a synthesis. The goal of the present study is partial in this respect, because it is proposed to study some spatial aspects of the Dutch economy in more detail. These aspects relate specifically to the evolution of the urban system and they will be integrated using the general principles discussed later in this introductory chapter.

Although the scope of geography has not changed, as has been indicated above, the method and methodology used in the subject have changed considerably over this time period, because of the changing scale of the phenomena studied and the appearance of a whole new set of phenomena with different types of spatial relationships created by the industrial revolution[4.]. A related important aspect in this process of change is the changed position of population in geographical studies, which can be partly explained by the increased market orientation of

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[1.] De Geer, S., On the definition, method and classification of geography, <u>Geografiska Annaler</u>, 1923, Arg.v.Haft 1, pp.1-37, see p.11.

[2.] Hettner, A., <u>Die Geographie: Ihre Geschichte, Ihr Wesen, und Ihre Methoden</u>, Breslau, 1927, pp.221-224.

[3.] Berry, B.J.L., Approaches to regional analysis: a synthesis, <u>Annals of the Association of American Geographers</u>, 1964, Vol.54, pp.2-11.

[4.] Wrigley, E.A., Changes in the philosophy of geography, in <u>Frontiers in Geographical Teaching</u>, R.J. Chorley and P.Haggett, eds., Methuen and Co. Ltd., London, 1965, pp.3-19.

industry[5.] and, as Wrigley[6.] argues, this consequently makes it better sense to begin with the analysis of the population distribution, in order to explain the distribution of economic activities rather than vice versa.

A somewhat different argument for the study of population as an initial point of departure was put forward by Hägerstrand[7.], when he stated that "a geographical study which places its emphasis on quantitative results should use the population distribution map and links with the other social sciences as points of departure". Man being the bearer of a wide range of dissimilar functions, reflected in his various types of space use, provides the natural bond between them. By his collective action, whether or not in unison, he changes and structures the face of the earth. The resulting spatial structure may be conceived as originating from a complex set of individual actions, which can be considered as mutually compensatory.

It is thus possible to define a spatial structure as the temporal equilibrium situation of a set of highly interdependent processes. This type of formulation enables a statistical description and analysis of these processes by introducing stochastic processes possessing ergodic properties as tools of analysis[8.]. By using probability theory in this way the various stages of the development of a spatial process can now be compared, in respect of their changes and rate of change as well as the expected final equilibrium state.

Because of the generality of stochastic process theory it has been applied to a wide range of problems in spatial analysis, for example, in the analysis of the spatial diffusion of an innovation, in which the shape of the frequency distribution of the acceptance ratio tends towards a normal distribution, which property has been used for analyzing, modelling and forecasting spatial diffusion, or in the input-output analysis of the movement of goods between firms, plants or regions focussing on equilibrium solutions, as well as in the analysis

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5. McCarty, H.H. and J.B. Lindberg, A Preface to Economic Geography, Prentice Hall, New Jersey, 1966.

6. Wrigley, E.A., Geography and population, in Frontiers in Geographycal Teaching, R.J. Chorley and P. Haggett, eds., Methuen and Co., Ltd., London, 1965, pp.62-80.

7. Hägerstrand, T., Innovation diffusion as a spatial process, translated by A. Pred, from 'Innovation forloppet ur korologisk synpunkt', Gleerup, Lund, 1953, University of Chicago Press, Chicago, 1967, see p.9.

8. Kemeny, J.G. and J.L. Snell, Finite Markov Chains, Van Nostrand Reinhold Company, New York, 1960.

of the movement of migrants, the distribution of city sizes, etc.[9]

According to Vining[10] it is now possible to describe the essential features of a spatial structure (of an economic system), which does not involve the idea of bounded (economic) regions, by two types of distributions. One of the distributions is based on the population system and its form and stability are population characteristics. The other type of distribution describes the origin and/or destination of flows of materials, goods, people and ideas from each point within the area. It is through the parameters of these distributions and additional cartographic analysis[11] that changes of conditions over time can be studied.

The theoretical framework which relates the population distributions to the distributions of their interaction patterns is incomplete. However, in the next two sections of this chapter, a few related theories will be briefly discussed. These will provide the common basis for the various aspects under examination, e.g. the population distribution, the role of transportation in an expanding economic system, the emergence of urban centres as nodes in an evolving urban system and interaction patterns in this system. Notwithstanding the incompleteness of both the theoretical framework and the aspects under examination, in the sense that they do not represent all the elements which are essential in the study of an urban system, they contribute towards the understanding of the operation of such a system from a spatial point of view.

1.2 Two conceptual models of economic development

A long existing concern with the process of economic development and growth has created a vast body of literature related to the mechanisms involved

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[9] Olsson, G., Central place systems, spatial interaction and stochastic processes, Papers and Proceedings of the Regional Science Association, 1966, Vol.18, pp.13-45.
Olsson, G. and S. Gale, Spatial Theory and human behaviour, Papers and Proceedings of the Regional Science Association, 1968, Vol.21, pp.229-242.
Gale, S., Explanation theory and models of migration, Economic Geography, 1973, Vol.49, No.3, pp.257-275.

[10] Vining, R., An outline of a stochastic model for the study of spatial structure and development of a human population system, Papers and Proceedings of the Regional Science Association, 1964, Vol.13, pp.15-40.
Vining, R., A description of certain spatial aspects of an economic system, Economic Development and Cultural Change, 1955, pp.147-195.

[11] c.f. Board, C., R.J. Davies and T.J.D. Fair, The structure of the South African Space Economy: An integrated approach, Regional Studies, 1970, Vol.4, pp.367-392

and the spatial and temporal sequences of the process itself[12.]. In as far as the mechamisms of growth and change have been the focus of interest, the resulting concepts are highly partial in character, but some concepts like the multiplier concept have enjoyed considerable success.

The regional multiplier concept, for example, relates a rise in income, production or employment in one group of economic activities, through the increased demand, to the expansion of an other group of economic activities, and growth is occurring relative to existing threshold levels. This concept has been incorporated in an export-base model, in which all the economic activities are classified as either engaged in the production of goods in response to local demand (so-called non-basic activities) or in producing goods as a reaction to externally originated demand (the so-called basic activities)[13.]. The demand for goods produced by the basic activities is considered to be the cause for internal growth, but it originates from somewhere outside the region. The region itself is conveniently viewed in isolation from the rest of the world, except for its trade relations, which is also the case for the regional concept in the closely related growth pole concept.

This consideration led Lasuen[14.], among others, to develop a conceptual framework that incorporated the concept of a growth pole and the many regional interdependencies from geographical diffusion theory. The appeal that the classical multiplier and growth pole theory has had on politicians can be explained partly by the direct localized effects suggested by it and partly by its direct applicability without guaranteeing success though, by not taking into account interregional effects.

Complementary to the ideas behind the export-base theory are the concepts

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12. See, for example, the review by Keeble in which he discusses a large variety of models, Keeble, D.E., Models of economic development, in Models in Geography, R.J. Chorley and P. Haggett, eds., Methuen and Co. Ltd., London, 1967, pp.243-302.

13. North, D.C., Location theory and regional economic growth, Journal of Political Economy, 1955, Vol.63, pp.243-258.
Tiebout, C.M., Exports and regional economic growth, Journal of Political Economy, 1956, Vol.64, pp.160-164, p.169.

14. Lasuen, J.R., Multi-regional economic development, An open-system approach, in Information Systems for Regional Development, T. Hägerstrand and A.R. Kuklinski, eds., Lund Studies in Geography, Ser.B., No.37, 1971, pp.169-212.
Lasuen, J.R., On Growth Poles, Urban Studies, 1969, Vol.6, pp.137-161.

of the sector theory, originally formulated by Fisher[15.] and Clark[16.], in which the internal development of a region is emphasized. The development sequence is supposed to start from an agricultural subsistence economy and leads through intra-regional specialization in primary activities and interregional trade with accompanying investments in transportation facilities, to the introduction and growth of secondary industrial activities. The latter are most likely to develop in places with the best access to markets and raw material sources in varying combinations, according to the locational pull related to the requirements for the particular type of production involved[17.].

These urban-industrial centres will form the nuclei in which further development may take place through diversification and specialization in manufacturing. In the final stages of this process industrial complexes and a well developed tertiary sector that provides high quality services will emerge in a small number of these places. The latter centres have thus become the major nodes in a gradually emerging urban system and do possess a high information potential as well as powerful managerial and control functions[18.].

These changes have also been operative in the Dutch economy, which can be inferred from the development of the occupational structure in the Netherlands since 1850 (see fig. 1.1.1). It was around 1900, that the rapidly declining share of the primary sector came to equal the share of the slower growing secondary sector, which encompasses employment in manufacturing, construction and energy production. Although the growth rate of the tertiary sector roughly parallels the rate of the secondary sector, its composition is rather complex, while the declining share of the domestic services since 1860 hides the growth of employment in the other components of the service sector, especially the increased rate of growth after 1930 (see fig. 1.1.2).

A basic element of the sector theory is that there exists an excess population with a high fertility rate in the agricultural areas. This population can flow to the developing secondary sector activities located at some places with-

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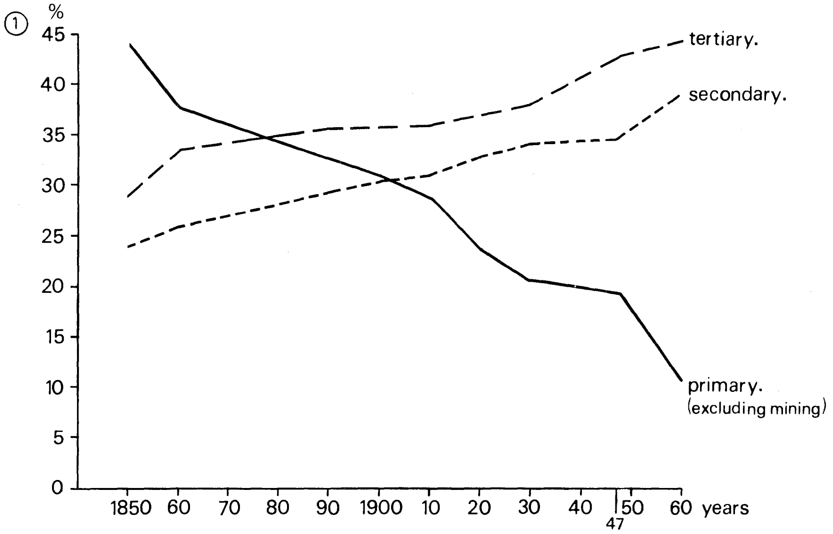
15. Fisher, G.B., Production, primary, secondary and tertiary, Economic Record, 1939, Vol.15, pp.24-38.

16. Clark, C., The conditions of economic progress, MacMillan, London, 1940.

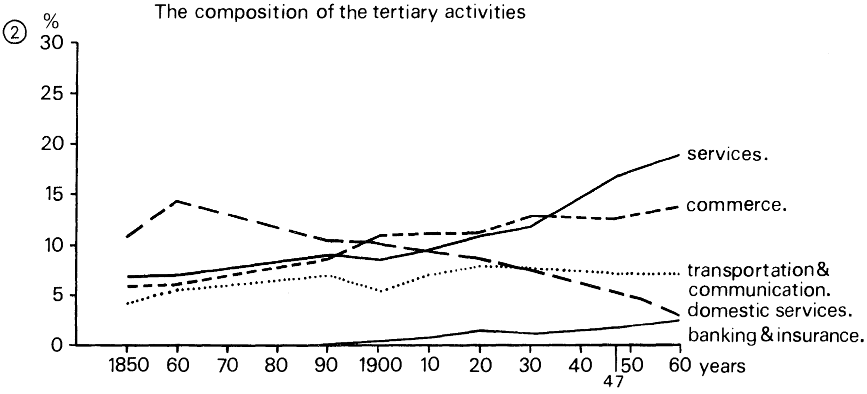
17. Hoover, E.M., The location of economic activities, McGraw-Hill, New York, 1948, see pp.186-196.

18. Gottman, J., Megalopolis, the urbanized northeastern seaboard of the United States, M.I.T.Press, Cambridge, Massachusetts, 1968.

fig 1.1 The development of the occupational structure in the Netherlands by group of economic activitities (1850–1960)



The composition of the tertiary activities



in these areas. Ultimately such a development will lead towards a relocation and reorientation of the population within a country and, consequently, a change in the regional pattern of population growth will occur and will be accompanied with a change in areal specialization and increasing regional inequalities.

The possible outcome of the process just described is shown in fig.1.2, in which the regional share is mapped relative to the national sector composition in agriculture (10·7%), industry (41·0%) and services (46·9%) in 1960. The contrast between the Northern and the Southern part of the Netherlands is striking by the near absence of a larger than average share (coefficient of localization > 1) in the North and the dual occurrence of both agriculture and industry with a larger than average share in the South. The predominance of the service sector is notable in the city-rich Western part of the country.

Another important assumption in the sector theory is the creation of an interregional transportation system in the early stages of development, because of the increased variety of the commodities produced by the different sectors. This development leads to an increased demand for various modes of transport and results in investments in new transportation systems, like railways and improvements and extensions of existing ones, like rivers, canals and roads, but investment decisions of this type have other far reaching implications, because these are decisions that influence the future spatial organisation of society and at the same time reflect changing spatial structures.

Lachene[19.] pointed out two essential functions of transport networks : (1) the short-term function of providing the necessary network for the flows of transport and (2) the long-term function in orienting the location of installations by their shape and capacity. Related to the first function is the possibility that, once a network is put into service, the capacities offered are in excess of actual demand. This leads to the construction of a network in areas with the highest expected economic growth and thus stimulates a further development in these areas by offering them low-cost transportation and a widening of the markets.

Because the physical life of a transport network is in principle unlimited, provided proper maintenance, the economic effects may accumulate over time. As maintenance costs are only a fraction of total investment costs, a network once established reinforces both the existing regional economic structure and the communication network itself, thus creating a high degree of rigidity in the spatial

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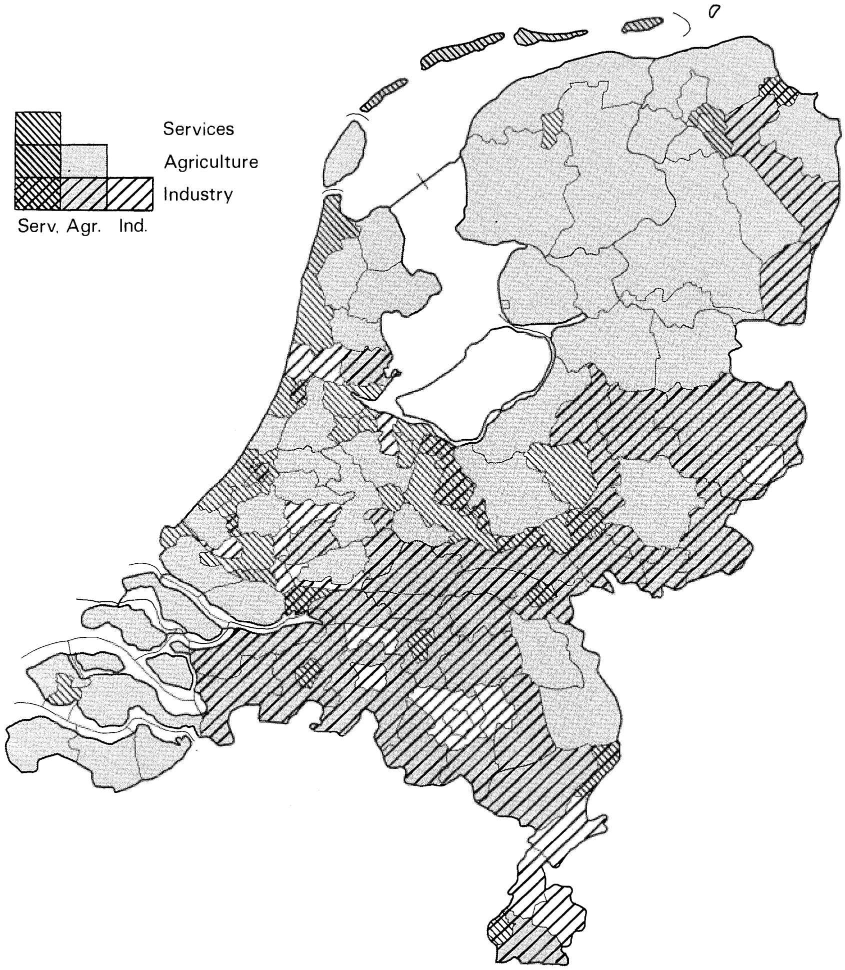
[19.] Lachene, R., Networks and the Location of economic activities, Papers and Proceedings of the Regional Science Association, 1964, Vol.14, pp.183-196, see p.184.

Fig. 1.2 The dominant structure of the economic geographic areas by economic activity in 1960



Only sectors with a location quotient larger than one are represented. *Source:* C.B.S. census 1960 investment pattern. In reality, however, we can observe that some of the early constructed networks have become obsolete and in disuse, because of technological changes which influenced the capacity carried, travel time involved and thus the importance of existing linkages, both direct and indirect. In this process of on-going technological change some cities still experience a continued rate of growth, while others decline or grow at a much more moderate rate.

Various authors have attached a different importance to the role of transportation in the development process and Gauthier[20.], basing himself on a review of the literature, suggested that three possible relationships are advocated.

First of all, the most common view is that the relationship is positive, implying a causal chain of events in which the provision of improved transportation facilities is considered to be a prerequisite for the expansion of the directly productive activities. This viewpoint is based on the analysis of the economic history of the United States and is in particular related to the development of the railways. A re-examination of the role of the railways, by Cootner[21.], in terms of causal association, suggests that railways in the U.S.A. were built to demand and not in advance of demand. However, generalizations of this kind are hardly applicable to a vast country like the United States, and it is much more likely that both processes occurred at the same time, having, at the one hand, a moving resource frontier while, on the other hand, a more organized population settlement scheme existed.

This dual occurrence of both schemes of explanation is also relevant to the development of the economy of the United States as a whole where both the sector theory and export-base theory can serve as modes of explanation. In the early stages of development of the U.S. economy, its trade pattern was dominated by exports to Western Europe and the local markets were small. According to Gottman[22.] and Pred[23.] the internal industrial development took place in the 19th century when the growing cities on the Northeastern seaboard of the U.S.A. gradually replaced Western Europe by becoming the largest market. This development created the

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20. Gauthier, H.L., Geography, transportation and regional development, Economic Geography, 1970, Vol.46, pp.612-619.

21. Cootner, P.H., The role of the railroads in United States Economic Growth, Journal of Economic History, 1963, Vol.23, pp.477-521.

22. Gottman, J., op.cit.18.

23. Pred, A.R., The spatial dynamics of U.S. urban-industrial growth, 1800-1914: Interpretive and theoretical essays, M.I.T. Press, Cambridge, Massachusetts, 1966.

occurrence of the sequence of events described by the sector theory in the North-eastern part of the U.S., while the export-base theory was still applicable in the more Westerly located towns. In Europe, however, the urban-industrial development started in England in the second half of the 18th century from a mixture of an existing subsistence and mercantile economy, which has much more relevance for the application of the sector theory as a single mode of explanation in the early stages of development. A combination of both theories together with concepts from central place, communications and organisation theory[24.], to be discussed in the next section, is often used to gain insight in the later stages of the process.

The second point raised by Gauthier is the stimulating effect the development of a transportation system has on the increase in the level of economic growth. From a West-European point of view, this may be much more the case than the causal mechanism of growth mentioned in the previous paragraph. This is because the already existing communication network, inherited from centuries of interregional trade, means there is no urgent drive for 'opening up the country' and a stable population distribution may be assumed.

Finally, it is possible that investments in transportation have a negative effect on economic growth. This could be especially the case in regions with a very restricted potential to invest, in which an investment in transportation can very well block a development of the directly productive activities, by draining too much of the total available capital for investment in this single sector. The case of Caracas in Venezuela may serve as an example[25.], where, until the 1960s, the only large investments outside the Caracas region, based on government revenues from oil, was put in road construction and all the newly built roads led again to Caracas so favouring the capital city which already possessed an initial advantage. This kind of development process has not only been observed in developing countries, but also in an earlier period in industrializing nations like the United States, where Chicago is the classic case of a railway centre enjoying an initial advantage and which was then able constantly to grow because of the agglomeration economies based on this advantage at the cost of other locations[26.]. The dominant position of

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[24.] Pred, A.R., The growth and development of a system of cities in advanced economies, in Systems of Cities and information flows, two essays by A.R. Pred and G.E. Törnqvist, Lund Studies in Geography, Ser.B., Human Geography, No.38, Gleerup, Lund, 1973, pp.1-85.

[25.] Odell, P.R. and D.A. Preston, Economies and Societies in Latin America, John Wiley and Sons Ltd., London, 1973, see pp.196-198.

[26.] Pred, A.R., op.cit. 23, see pp.54-55 and also p.78.

Chicago is also emphasized by the favourable rate structure of hauls to and from this Midwestern "capital", which in turn reinforces its position creating even larger regional imbalances.

In conclusion it can be said that sector and export-base theory may fruitfully be used as 'genetic models' of explanation in the description of the process of the changing importance of the sectors of economic activities in the national or regional economy, the effects of technological innovations and the consequences of the investments in transportation. In this perspective the interrelationship of these elements and their impact on the larger whole of spatial interdependencies can best be discussed by considering them from the wider view of the spatial organisation of society, as formulated in central place models, which refer to systems of cities in a spatial context.

1.3 A functional view on the evolution of central place models

In stressing the importance of the spatial organisation of society as the framework for analysis and explanation, the emphasis has shifted from a sectorial towards a functional approach. This change in scope ties in with the views expressed in the first section of this introduction, in which the changed position of population in geographical studies is discussed. Philbrick[27.] states, in this respect, three important principles affecting the spatial organisation of human activity : (1) human activity is focal and localized in character, (2) the basic unit of human focality is the establishment, e.g. home, farm, factory, 'office' individually located in a specific place and (3) in the normal course of human activities establishments become more interconnected. Once proximity between the establishments is assumed, it is possible to formulate a theory of the development and organisation of the city[28.]. If one assumes, in addition, a certain degree of specialization in at least one of the functions carried out by the establishments in such a centre, a system of cities will emerge by emphasizing the organizational aspects of the establishments with respect to their external functional ties[29.].

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27. Philbrick, A.K., Areal functional organization in regional geography, Papers and Proceedings of the Regional Science Association, 1957, Vol.3, pp.87-98, see p.88 and 89.

28. c.f. Van Paassen, Chr., Geografische structurering en oecologisch complex, een bijdrage tot sociaal-geografische theorie-vorming. (Geographical structuring and oecological complex, with summary in English), Geografisch Tijdschrift, 1962, pp.215-233.

29. Wärneryd, O., Interdependence in urban systems, Regionkonsult Aktiebolog, Göteborg, 1968.

The creative forces that establishments have in organizing themselves in their surroundings, with respect to both internal and external linkages, is also expressed by Hägerstrand, quoted by Törnqvist[30], when he stated that "the principle of horizontal linkage, and thus urbanization itself, is based on the art of moving materials, people and information".

The increase in size and consequently the changing organizational structure of some of the establishments, e.g. the factory and the office, has undoubtedly influenced the organizational structure of the urban system since the industrial revolution. In an analysis of the changing position of the urban centres in the United States, over this period, Borchert[31] has found that both the migration networks and banking networks became more national than regional in character and concluded that the metropolitan centres are less important as regional capitals than they are as major components in the national system of markets, suppliers of labour, entrepreneurship and capital.

It is the changing organizational structure of the national urban system that is of particular interest for the general theoretical background of the present study. This changing organizational structure can be partly explained by changes in the functional and organizational structure of the establishments and the capability (over time) in dealing with the movements (over space) of materials, people and information within this system. The system of movements defined by external contacts between individuals and groups of individuals is called a contact system[32]. Within this context, Thorngren[33] indicates as groups of special interest for regional analysis, "those individuals that are employed at the same site, and in the same firm, authority, research body etc.". It is evident that his concept of "organizations", in which these groups are active on different levels of aggregation, and Philbrick's concept of "establishment" are closely related. They differ, however, in their operational quality in the sense that the former starts from individual observations or form a very detailed job function classification, while the latter uses census information based on economic activities, which distinguishes much of the functional organizational aspects inherent to the various activities.

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[30] Törnqvist, G., Flows of information and the location of economic activities, *Geografiska Annaler*, 1968, Ser.B., Vol.50, pp.90-107, see p.100.

[31] Borchert, J.R., America's changing metropolitan regions, *Annals of the Association of American Geographers*, 1972, Vol.62, pp.352-373, see p.365.

[32] Thorngren, B., How do contact systems affect regional development, *Environment and Planning*, 1970, Vol.2, pp.409-427.

[33] Thorngren, B., *op.cit.*32, p.411.

An organisation or activity system, as defined above, embodies a number of functions related to its survival, operation and growth and this feature gives rise to a number of different contact systems. Each of these systems does have different tasks and a different structure. Consequently a different type of space use is involved, related to varying combinations of material and information exchange. A large number of studies have been carried out in this area by Swedish geographers (they have been reviewed by Pred[34].) and these studies have contributed to a better understanding of the spatial aspects of an activity system of job functions connected by links and flows[35].. The schematic representation of such an activity system in fig.1.3 reveals two distinct but connected hierarchies. One of them ranges from primary to administrative functions, while the other hierarchy - which runs parallel with the first and expresses its communication activities and related linkages - starts with the transportation of goods and proceeds to 'face to face' contacts, which is related to information exchange only. The vertical linkages arise from internal flows, while the horizontal ones indicate external flows. The differences between the flows of information and flows of material are emphasized by the distinction between an organizational unit (A) and a production unit (P). The latter unit deals with the processing of goods ranging from primary to tertiary production and causes the transportation of mainly material goods to and from the production unit, which is not necessarily one physical unit in one location, because a number of plants at different locations can be involved. In the case where a number of production units are involved a part of the administrative section has to be located at the same place and most of the times in the same physical unit and these various organizational combinations create a number of possible locational alternatives[36]..

When an organisation becomes spatially dispersed, the highest administrative functions, as indicated in fig.1.3 by A1 and A2, may be located in the main urban areas and they are involved in the processing of non-material goods from the type related to the control and direction of production to decision-

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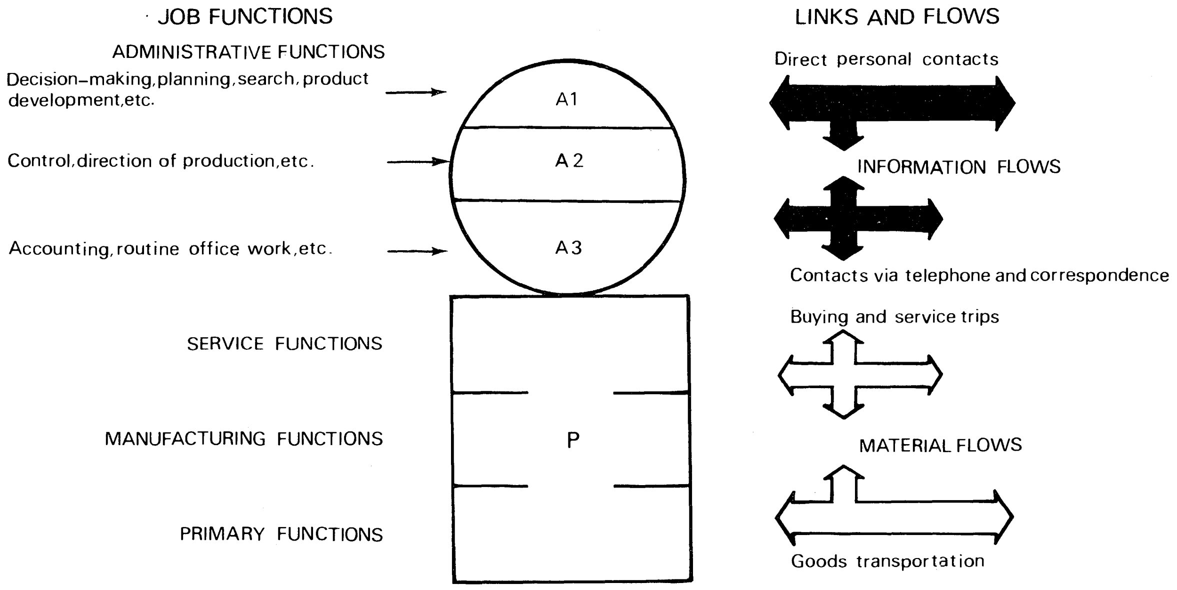
[34]. Pred, A.R., Urbanization, domestic planning problems and Swedish geographic research, in Progress in Geography, Chr. Board, R.J. Chorley, P. Haggett and D.R.Stoddart, eds.,1973, Vol.5, pp.1-76.

[35]. Törnqvist, G., Contact requirements and travel facilities, in Systems of cities and information flows, two essays by A.R. Pred and G.E. Törnqvist, Lund Studies in Geography, Ser.B., Human Geography, No.38, Gleerup, Lund, 1970, pp.85-121, see p.87.

[36]. Törnqvist, G., op.cit.30, p.103.

fig.1.3 An activity system consisting of job functions connected up by links and flows.

[after G.E.Törnquist (op.cit.35)]



making, planning and search activities. The latter type of function deals with, what Thorngren[37], following Ehrlemark, terms orientation processes and these are heavily dependent on information and thus close contact to, or proximity with, the relevant information sources is required, in order to be able to control and scan the environment. According to Meier[38] and others, these functions which are dependent on non-standardized flows of information are the source and the cause for future urban growth. The other functions can be classified in two types of processes, viz. the programmed processes and the planning processes and they have become much more standardized and consequently developed a lower need for access to, or the proximity of, concentrations of information and control functions. The first type of process is directly related to routine transactions and production and is the least sensitive for non-standardized information flows, while the planning processes are controlling the changes in the first process varying from changing type of production to entering new markets.

The organizational structure described above indicates a spatial concentration and dispersal which not only involves the same organisation but which also affects a different locational pattern of the various types of functions. This gives rise to different spatial patterns when movements of material or information are concerned. The forces behind these movements are generally originating from and between the same centres, because every flow of materials is based on some kind of non-material contact flows, which are described by Dunn[39] as creating dual or shadow networks. The different types of networks, however, are not spatially isomorphic, because there are limits to functional coincidence based on the difference in the kind of function operating through these networks. More important though, is the different location in space of the functional units themselves engaged in this twofold type of exchange involving varying combinations of material and information flows. The emerging spatial pattern combines both elements of central place development and changing locational characteristics of the firm.

The development of the organizational structure of the firm since the industrial revolution, arising out of technological changes and innovations affecting modes of communication, scales of production, etc., did change its locational requirements at the same time leading towards an organizational structure like the one portrayed in fig.1.3 in which different sets of location factors are important

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[37] Thorngren, B., op.cit. 32.

[38] Meier, R.L., A communication theory of urban growth, M.I.T. Press, Harvard, Massachusetts, 1962, see pp.40-44.

[39] Dunn, E.S., A flow network image of urban structures, Urban Studies, 1970, Vol.3, pp.239-258, see p.253.

for different parts of the organisation. In a tentative conceptual description of this development Lasuen[40.] discussed three important aspects, viz. the number of plants, the number of locations with respect both to places of production and to the number of markets for the finished products, and the type of process in combination with the number of products. It will be evident that a spatial dispersion can be observed with an increasing number of plants at different locations having access to a large number of markets. On the other hand, a concentration may occur at points of production dependent upon the type of production and the goods produced, because of the growth of linkages between plants, which belong either to one organisation or to different ones. The incorporation of these elements in classical central place theory[41.] requires an expansion of this theory because of the sole emphasis on tertiary production in the original formulation. In addition to this the formulations of central place theory are essentially static and cannot cope with changes in the system over time. However, there have been some attempts to describe the spatial distribution and development of settlement patterns by using simulation models of the Monte Carlo type, which are only quasi-dynamic because of the fact that the structural properties of the simulated world do not change over time.

In the model developed by Bylund[42.], in which he simulates the distribution of rural settlements in Northern Sweden, the behaviouristic assumptions are translated into a distance variable and some consideration is given to functional aspects by incorporating a weighing factor for the distance to a church and market-place. The functional characteristics are much more explicitly dealt with by Morrill[43.] when he discusses the economic and social conditions, which

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40. Lasuen, J.R., Multi-regional economic development. An open-system approach in Information systems for regional development - a seminar. T.Hägerstrand and A.R. Kuklinski, eds., Lund Studies in Geography, Ser.B., Human Geography, Gleerup, Lund, 1971, pp.167-229, see p.186.

41. See for an extensive review and bibliography Berry, B.J.L. and A.R. Pred, Central Place Studies: A bibliography of theory and applications, 2nd ed., including supplement through 1964, by H.G. Barnum, R. Kasperson and S. Kiuchi, Regional Science Research Institute, Philadelphia, 1965. Bibliography Series No.1, 1965.

42. Bylund, E., Theoretical considerations regarding the distribution of settlement in inner North Sweden, Geografiska Annaler, 1960, Ser.A., Vol.23, pp.225-231, see also p.227.

43. Morrill, R.L., The development of spatial distributions of towns in Sweden: an historical-predictive approach, Annals of the Association of American Geographers, 1963, Vol.53, No.1, pp.1-14.

enable a concentration of economic activities in towns and cities, as one of the major factors to be taken into account in a study of the spatial distribution of towns. Although Morrill recognizes the need for an expanded central place theory[44.], he treats the concepts from Christallerian central place theory, industrial location theory, (which he then terms non-central place activities) and migration theory, including "information fields". He sees these only as partially related elements in the sequence of influences causing the development and spatial distribution of towns.

Based on an initial population distribution, the location for new transportation links is determined. This sets the stage for the assignment of manufacturing and other non-central place activities, which in their turn provide the basis for the location of central place activities. The consequently changed economic landscape then stimulates migration to restore the equilibrium in the spatial allocation of activities. Of interest in the operation of this model is the complete dependence of each fase in one development cycle upon the previous fase in this cycle, so preventing a direct interaction of the forces at work, while the process starts with the assignment of transportation links. The emphasis on the latter element clearly indicates the classical North American view on the role of transportation as a prerequisite in the process of spatial development. As regards the development of a system of cities an allowance is made, as indicated above, for internal dynamic aspects but in most cases these are operative within a fixed and rigid central place structure. Hägerstrand's observation that the diffusion of an innovation follows the urban hierarchy[45.] can now be considered as a classical comment. It has, however, been interpreted by various authors, like Brown[46.] and Hudson[47.], solely in terms of a central place system of the Christaller type[48.]. Only the more recent attempts towards a more integrated dynamic

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[44.] Morrill, R.L., op.cit.43, p.3.

[45.] Hägerstrand, T., Aspects of the spatial structure of social communication and the diffusion of information, Papers and Proceedings of the Regional Science Association, 1965, Vol.16, pp.27-42, see p.40.

[46.] Brown, L.A., Diffusion Dynamics, A review and revision of the quantitative theory of the spatial diffusion of innovation, Lund Studies in Geography, Ser.B., Human Geography, No.29, Gleerup, Lund, 1968.

[47.] Hudson, J.C., Geographical diffusion theory, Department of Geography, Northwestern University, Evanston, Illinois, 1972, Studies in Geography, No.19.

[48.] Christaller, W., Die Zentralen Orte in Süddeutschland, Gustav Fischer Verlag, Jena, 1933.

formulation of central place development, of which the author is aware, are those of Wärneryd[49.] and Pred[50.]. This is illustrated by Pred's discussion of the development of a system of cities, in which he takes explicitly into account factors like : (1) non-local multiplier effects and the spatial structure of organizations, (2) the inter-urban diffusion of growth inducing innovations and (3) the accumulation of operational decisions made by organizations[51.]. A full discussion of Pred's ideas is beyond the scope of this introduction. However, the realization of the static nature of the various central place formulations is very pertinent, because it poses limitations on the usefulness of central place theory in the description of the historic process of changes in locational patterns. The analysis of the locational behaviour and locational pattern of e.g. organisations in terms of a 1930 originated and hardly changed central place concept, is anachronistic in terms of contemporary economic geographic analysis. This comment does not imply that a Christallerian concept cannot be used any more, but that its relevant context has changed through time and therefore it can only be applied successfully after careful examination of the spatial context of interest, which appears to be in most cases the distribution of retail stores and functions within a city.

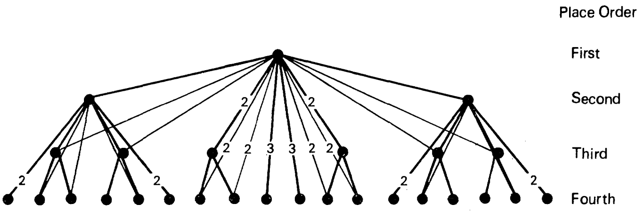
One of the most characteristic features of the development of a system of cities is the growing number of interdependencies between its constituent parts. These interdependencies may be measured by the flows of materials, people and information in such a system. When a central place system is classified according to the nature and content of the flows in the system, then it appears that a Christallerian market system (K = 3) represents an agricultural economy with a predominance of primary functions. Consequently, the emphasis in such a system is on the movement of materials. Although Christaller also discussed other principles of spatial organisation, such as the transportation system (K = 4), this is of little interest here. The spatial impact of the application of this principle is a reorientation of the hexagonal network to minimize transport cost (distance). The geometry of this network is the same as for the market principle, leading only to somewhat larger hinterlands. The functional relationships and structure are much clearer understood in the case of the market system and this system gives rise to the kind of relationships as presented in fig. 1.4.1. Here one can note the complete hierarchical structure of the urban system and the absence of any horizontal linkages in the urban hierarchy.

[49.] Wärneryd, O., op.cit. 29.

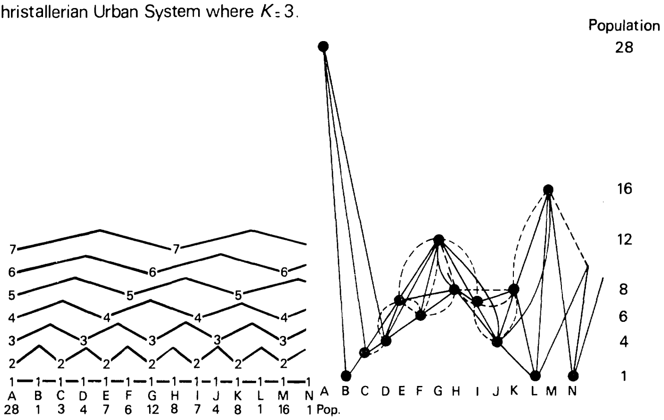
[50.] Pred, A.R., op.cit. 24.

[51.] Pred, A.R., op.cit. 24, p.47.

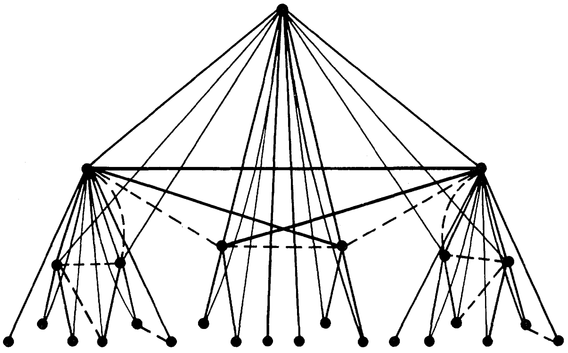
Fig.1.4 The evolution of functional interdependence in central place models. (after Pred op.cit.58)



① Christallerian Urban System where $K=3$.



② Location, market areas and flows in a Löschian Urban System.



③ One permutation of an Urban Information System.

Christallerian dyads (larger to smaller dyads)
Löschian dyads (lateral and smaller to larger dyads)
High-order interdependence dyads

The flow structure according to the market system can be described by primary goods which move up in the hierarchy to their respective markets. This type of movement is also applicable to the people in the system who move upwards to consume services offered in higher order centres, while information about the nature and availability of these services moves down in the hierarchy. The implication of this model is that places having roughly the same population size, i.e. occupying the same level in the hierarchy, have the same functions. This feature of the model prevents the occurrence of interaction between centres (markets) of the same order, because there is no reason for exchange when the same set of goods is produced. Each of these markets is occupying a monopolistic position within its own region as far as primary goods are concerned and a monopsonistic position with respect to the services offered. In addition to this phenomenon, a higher order place produces a wider range of goods than the centres being one step lower in the hierarchy and this creates completely closed subsystems.

These subsystems will be spatially isolated from each other when transport costs are minimized, which is usually the case. The spatial organisation of such an economic landscape will give rise to an accumulation of capital in the highest order centre of the urban hierarchy, because of the monopolistic position of the centres in the system. A chronic desequilibrium in the balance of payments of the highest order centre and the other centres will then occur. This situation is prevented if one assumes a trade pattern in which larger centres buy non-agricultural products from smaller centres. In such a situation there can be a back flow of capital to the lower order places in the system, which can in turn be used to buy services in a higher order centre[52.]. This is the case in the system of cities hypothesized by Losch[53.], in which there is made an explicit allowance for a differentiation of functions between places having about the same population size. Such a system is characterized by more complex patterns of flows of goods and capital and a more integrated system of cities and market areas.

The functional variation between places in a simplified Löschian landscape is represented in fig. 1.4.2, where the places are located at an equal distance - all offering the same type of lowest order goods - in an one dimensional landscape in principle stretching in all directions[54.]. Here the location of seven

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52. Stolper, W., Spatial order and the economic growth of cities: a comment on Eric Lampard's paper, Economic Development and Cultural Change, 1955, pp.137-146, see p.144.

53. Lösch, A., The economics of Location, translated by W.Stolper, Yale University Press, 1954, see p.140.

54. Stolper, W., op.cit. 52, p.140.

orders of activity, as indicated by numbers, is shown and these are produced by the same number of places as in the Christallerian case. Concomitant with this diversification is the variation in population size between the places (designed by letters), being proportional to the size of its industry - in terms of the market area it covers. The interaction pattern between the places in a Löschian landscape has become more complex now in comparison with the previous case, because exchange of goods can occur between places having about the same population size, e.g. between E., F. and H., thus expressing lateral non-dominant interaction patterns. However, the higher order places in this system, e.g. G. and M., have no exchange at all with the largest centre, while at the same time each branch (one dimensional subsystem) is completely closed for interaction with like subsystems. This is due to the fact that Lösch employs general equilibrium analysis for the solution of his system in which the elements of interdependence are minimized and the space economy as a whole is treated as consisting of several major sectors[55.].

In comparison with the urban system described by Christaller, explicit allowance is made for the occurrence of industry in the Löschian scheme, albeit under very restrictive conditions, i.e. raw materials are equally and adequately present at any site, the population is uniformly distributed and having like tastes, the existence of a homogeneous transportation surface. Isard[56.] relaxed some of these assumptions and tried to resolve some of the apparent inconsistencies, like the uniform population distribution assumption, by introducing urbanization, localization and scale economies as specific subsets of agglomeration economies. The consequence of the assumptions related to the distribution of raw materials is the exclusion of that type of industrial production, which are heavily influenced in their location decision by the strong locational pull exerted by raw materials. According to Törnqvist[57.], the latter factor seems to loose some of its significance by the decreasing importance of transportation costs in total production costs in advanced industrial economies. This development increases the relevance of the Löschian scheme with respect to the description of inter-urban communication flows, but it does not allow for the existence of a considerable degree of information ex-

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55. Isard, W., Location and Space-Economy, M.I.T. Press, Cambridge, Massachusetts, 1956, see p.48.

56. Isard, W., op.cit.55, pp.269-281.

57. Törnqvist, G., Transport costs as a location factor for manufacturing industries, Lund Studies in Geography, Ser.B., Human Geography, No.23, Gleerup, Lund, 1962.

change between very high order places, i.e. amongst places just below the highest order centre and with the centre itself[58.]. In fig. 1.4.3 these linkages are incorporated and they express the functional ties related to the operation of tertiary and higher order administrative functions, which are becoming increasingly important in post-industrial societies. Though, it must be noted that Pred[59.] also observed this type of interaction on the basis of analysis of innovation paths in the pre-industrial period in the United States. He concludes that "the locational pattern of inventive activity for any pre-electronic year suggests that, at least in the early stages of the diffusion processes, spread [of information] frequently occurred between large cities and from smaller to larger places". If this finding holds in general, then it indicates that these types of interaction patterns are omitted from the models discussed earlier.

Summarizing the above argument, a rough identification of the schematic models of spatial functional interaction, as represented in fig. 1.4, may be made, each one emphasizing one particular aspect of the spatial organisation of the economy. The Christallerian urban system, based on studies in Southern Germany pre-dating 1930, may be identified with economies based upon primary production, while the Löschian urban system, mainly illustrated with examples from the U.S., is expressing characteristics of economies with primary and secondary functions. Each type of economy has its own related type of service activities. The linkages which exist in these systems reflect the kind of movements of goods to be dealt with according to the degree of complexity and the needs of each particular system.

The urban communication structure discussed by Pred is shown in fig. 1.4.3 and reflects one possible combination of linkages between higher order activities carried out in the largest centres of the urban system. These linkages indicate the need for external contacts, that is external to the cities, between higher order service and managerial functions. The main commodities to be transported through the system then consist of non-material goods, such as information. The urban system then contains three types of flow structures, which are related to particular aspects of the urban and regional economy. The degree in which the communication paths in this flow network are used, with respect to the intensity and quality of the exchange, will vary according to the state of the development of the economy. This view also allows a modification of the rigid hierarchical

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58. Pred, A.R., Large-city interdependence and the pre-electronic diffusion of innovations in the U.S., Geographical Analysis, 1971, Vol.3, pp.165-181, see p.175.

59. Pred, A.R., op.cit.58, p.179.

formulation, in which a directional flow between a specific pair of nodes is suggested and opens possibilities for the circulation of goods, both material and non-material, throughout the network as a whole.

1.4 Conclusions and research strategy

Conclusions

The general background to this study of the evolution of a national urban system covers a broader area than will be dealt with in the following chapters. The main purpose of the above discussion though is the provision of a theoretical framework within which the aspects under examination can be related. The two general research questions, which can be formulated, focuss upon : (1) the variables that account for the growth and development of an urban system, and (2) the relationship between urban systems development and national development. The present study is more limited in scope and the nature of these questions will be studied by concentrating on the structural growth of the urban settlements being part of an urban system and measured by population and the volume of economic activities. The changes in the urban system occur within a growing economy, developing from a rural-commercial towards an urban-postindustrial structure. The way in which this growth has been transmitted through the national urban system and in which it did affect various regions in a different way then becomes a question which is extremely relevant in the context of this study.

Open or closed systems

From the above discussion it emerges that the focus of the analysis should be oriented on the structure of the urban system and the way in which the urban and regional economy are related. First of all, the systems approach raises questions about the general nature of the urban system. Is the system open or closed in space and time. Although the Dutch urban system is a part of the larger Northwest European urbanized area it will be conceived as a national urban system. This view implies a closure of the system as far as its individual elements are concerned. The changes in the system will be interpreted as being caused by the changes in the national (economic) development, which, of course, is sensitive to the changes in the Northwest European space. The extent to which, for example, port-development is stimulated by demand in the German hinterland will be ignored to be able to concentrate on general aspects within the national space.

The urban system will also be closed in time. This issue is discussed at some length in chapter 2. The implication is that the same group of cities is analysed over the study period. Thus, birth (entry) or death (dropping out) of cities to the group is not possible and consequently also the number of cities remains constant at the same time. This will enable us to concentrate upon the development of the system as one entity.

The structure of an urban system

The study of an urban system involves the analysis of the two basic elements of this system : (1) the urban centres conceived of as nodes, and (2) the linkages of the urban network, representing the interdependencies between the nodes.

The size and the order of the nodes in an urban system are important elements for the understanding of the structure of the system as a whole. Order is related to size but cannot be equated with size in a real world situation, because it expresses both internal structure (of a city) and external relationship with other cities in the system. In order to gain further understanding of this relationship the internal structure of the main cities of the system is examined in more detail in chapter 4. It are those cities which are the most influential in structuring the system. The size aspects of the urban system are studied in chapter 2, both for the urban system at large as for the centres.

The second component of an urban system is given by the linkages in the system. The nature of these linkages are reflected in two ways, viz. the physical networks, like roads, canals, railways etc. (see chapter 3) and the non-physical networks, like personal communication networks. The latter can only be studied in their spatial reflection when they materialize in the most literal sense. An example in this case is provided by the study of the diffusion of an innovation of a material good, such as the diffusion of television sets in chapter 5. The object of such an analysis is to examine the functional and hierarchical aspects of the interurban linkages as opposed to the physical linkages, although these two linkage structures can coincide at times. Variation in the functional nature of the relationships can be caused by variations in socio-economic conditions, which are not incorporated in a theoretical central place model structure. This type of variation, such as income differences or household structure, may act as a barrier, speed up or divert the diffusion process for some places in the system. The study of those variations will reveal whether they have a general or only a specific effect upon the structure of the interurban linkages.

Systems behaviour over time

The second main theme of this study is to incorporate explicitly the factor time in the analysis. The time span is such, viz. it encompasses fully the industrial revolution, that structural changes in the system have occurred from a sectoral point of view. The behaviour of the urban system during this period thus can be studied on the basis of a number of questions :

(1) What is the spatial stability of the system with respect to the changes in the organisation of economic activities? Spatial inertia may play an important role in a seemingly stable but changing organizational structure.

(2) Is there a steady state or an allometric growth of the system as a whole or is growth occurring in different parts of the system in different ways? This question refers directly to size properties of the system, but ignores structural properties of which size is only one expression.

(3) What is the nature of structural change for parts of the system, as the spatial basis is non-homogeneous? A development from a uniform basis may even lead to structurally different subsystems.

On the level of the urban system as a whole it has been argued that there are different modes of explanations, viz. three types of central place models. Each central place model represents a temporal equilibrium solution for a specific type of spatial economic organisation. Although these explanations are conceptually related, there does not exist a direct measurable relationship between the three types of central place models. This poses operational problems in terms of the way in which one system replaces the other, as these three systems represented also a different stage in the development process as a whole. Besides operational problems, problems of explanation in terms of the traditional models remain, because the explanatory alternative is not only one of complete or incomplete replacement of a central place system, but at the same time the joint occurrence of the various types of relationship (as expressed by the three central place models) in space.

The research results for the various periods can only be compared with this changing context in mind. It is for this reason that there will be put an emphasis on stability of relations and comparability of data sets over time in order to be able to trace some of the changes which do occur over the period.

Research strategy

The aim of this study is thus to analyse, within the framework summarized above, and discussed in more detail in sections 1.2 and 1.3, a few aspects of the evolution of the urban system in the Netherlands. A central theme in the analysis will be the changes in the spatial organisation and the occurrence of temporal stability of the aspects under examination.

First of all there are three general types of problems which have to be solved and these relate to the definition, measurement and specification of the nodes of the urban network and their inter-relationships. The problems associated with the definition of an urban centre over time are discussed in chapter 2. The operational solution is based upon an areal definition of an urban centre which remains constant over time. The municipal boundaries as defined in 1970 provide the basis for the selection of the urban areas, using a population of 5,000 inhabitants in 1970 as a minimum number. Throughout the study various population levels, all above 5,000, will be applied to take into account differences in threshold levels to incorporate changes in the minimum requirements necessary for the operation of an urban economy. Generally these threshold levels will be different for different periods.

The overall growth and implicitly the redistribution of the Dutch population on a municipal basis will be studied from 1840 to 1970 per decennial period. This period covers completely the occurrence of the industrial revolution in the Netherlands, during which there was a basic change in the structure of the economy from a rural to an industrialized society. Concomitantly a clustering of the population can be observed, from a large number of scattered villages and market towns into a small number of large urban metropolitan areas. The length of the period in combination with the detailed coverage enables a study of the processes of change on different levels of aggregation.

The growth of the cities in the above sense is studied in chapter 2, for the city system as a whole, for size classes of cities and for individual centres. This will reveal the long-term trends in the evolution of the city system at different levels, as well as fluctuations over shorter periods. The combined results will throw light on the evolution of the urban system as a population system over this period.

The definition and measurement of the linkages in the urban network is the second major problem in this analysis. According to the discussion in section 1.3, three types of flows are particular relevant for the study of central place systems, viz. the flow of materials, people and information. In some way this sequence also reflects the changing emphasis over time of these three elements, according to their importance in the understanding of the organisation of a central place system. In this respect flows of materials will be dominant in the early period, and indicate the primary base of the economy. In the period of the industrialization, flows of people reflect not only the redistribution of the population but also point towards demand centres of labour in an evolving urban system. Flows of information gain in importance in an urban-industrial society moving towards a post-industrial structure. Thus, from an evolutionary point of view, the study of the flows of materials or goods will precede a study of information flows.

INTRODUCTION AND FRAMEWORK OF ANALYSIS

The analysis of the flow of materials will concentrate on the physical aspects of transportation, as they are present in the landscape and can be pursued via map analysis. Transportation, when considered as a spatial process, is one of the most influential forces in modifying the face of the earth[60.]. The provision of social overhead capital, i.e. the investment in transportation, is often considered as one of the critical factors in the early stages of economic development from a rural-commercial society towards an urban-industrial society[61.]. This being the case though it is realized that investment in transportation is an expression of a whole complex of decision-making forces and in treating transportation alone in this restrictive manner a gross over-simplification is made.

In view of its above-mentioned importance, the analysis of transportation networks is reported in chapter 3. In this chapter three types of networks are considered, viz. the waterway, the road and the railway network, as these reflect different alternatives in modes of transport. Each alternative is partly constrained by the physical environment and by the nature of the spatial demand patterns. Jointly, the transportation facilities offered are considerable.

In order to examine the relationship between urban size and growth and the transportation network, the analysis will be focussed upon the total influence of the three transport networks together, as well as upon their individual effects. The latter point is of some importance as one may argue that the three modes of transportation belong to three different eras, and this becomes even more the case if one reads instead of road-networks, motor-transportation linkages.

Linkages are identified on the basis of a cartographic analysis of the different types of networks, using maps which are compiled for this specific purpose. In this part of the total analysis there is an emphasis on the growth of the networks over space and time and the relation between network development and urban growth are examined. The total number of linkages is used as a measure of accessibility. This part of the analysis will also be used to study the influence of the definition of different threshold values on the specified relations.

The analysis reported in chapter 2 and 3 stresses the nature of the external relations of the nodes of the urban network and their linkages. However, rapid industrialization and urbanization have been joint features of the process of economic development and both contributed to the creation of the present character-

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[60.] Ullman, E.L., The role of transportation and the basis for Interaction, in Man's role in changing the face of the earth, W.L. Thomas, ed., Chicago University Press, Chicago, 1956, pp.862-880.

[61.] Rostow, W.W., The stages of economic growth, Cambridge University Press, London, 1960.

istic features of the internal structure of the urban centres.

The changes within and between the largest centres, i.e. centres with a population over 50,000 inhabitants in 1960, will be studied in chapter 4. In this chapter, a functional classification of the internal structure of the urban areas is carried out using a common set of variables and the same areal definition for the different time periods involved. This should throw light on the changing structure of the system of cities as it evolves from a rural-commercial towards a fully developed urban-industrial structure.

First of all, the functional structure of the system as a whole will be compared for three time periods, i.e. 1930, 1947 and 1960. This analysis is restricted towards these three periods because of the lack of sufficient data on socio-economic variables for earlier periods. Second, for each period a functional classification of the cities is carried out. The purpose of this classification is a study of the nature of change or lack of change in the internal structure of the cities, which will be then part of sub-groups of cities with the same structure. In addition to this analysis, it should be possible to draw some tentative conclusions about the degree of specialization within the city systems for cities and groups of cities.

Going from chapter 2 to 4, the scope of the analysis narrows from a population system covering the country as a whole to the main centres in the urban system. In the next chapter, chapter 5, the scope broadens again when the diffusion of T.V. ownership will be studied from 1957-1967. As the diffusion of T.V.ownership is thought to be channeled through the urban system, the urban centres discussed in the previous chapter will thus play a key-role in the process of diffusion over the country as a whole. The diffusion of T.V. ownership by municipality concerns not only the movement of a material good, viz. a television set, but also a flow of information about the television as an innovation, which it was in the early fifties. Thus the flow of T.V. sets measured through licensed T.V. ownership, can be regarded as an approximation of one possible flow structure of an information flow within an urban system.

The study of T.V. ownership as an innovation diffusion process will throw some light on the nature of the linkages within the urban system[62.] and will complement in this sense the study carried out in chapter 2 for a more recent view of the state of the system. In addition to a cartographic analysis a quantitative

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62. Brown, L.A., Diffusion processes and Location, a conceptual framework and bibliography, Regional Science Research Institute, Philadelphia, Pennsylvania, 1968, Bibliography Series, No.4.

analysis may reveal the operation of barriers, such as specific socio-economic conditions, which are relevant for the understanding of the process as a whole. As two of the most important ones, one may consider the thresholds created by the price of a television set and the income per household. Over the period 1957-67 one can observe very clearly the variation in threshold levels caused by rising incomes and declining prices. These two elements will obviously influence the map patterns and thus the conclusions, based upon them.

In the final chapter the main findings will be summarized in the context of the discussions in section 1.2 and 1.3 in this chapter. As these findings will relate to the long-term behaviour of the urban system, they cannot be used in a direct predictive sense for policy purposes. However, they could be related to the feasibility of long-term policy goals in terms of future trends, or possible trajectories, of the urban system. Urban system development is usually characterized by a high degree of spatial inertia such that changes in the expansion path of the system will then require considerable efforts at high costs, while goals formulated within the general line of the trajectories will be realized much easier.

2. URBAN POPULATION DISTRIBUTIONS, GROWTH AND CHANGE, 1840-1970

2.1 Introduction

The study of the evolution of an urban system raises a number of practical questions, as to the operational definition of the components of the system as well as to the incorporation of the factor time in the analysis. In this chapter the focuss is on the urban centres, the nodes of the urban system. One of the first problems to be solved now is the definition of such a node. It has been argued above that population size can be used as an approximation of the complexity of the spatial economic structure of a region. The acceptation of this notion makes it possible to study the urban system as a population system. The analysis of the population system over the study period will be pursued from this perspective.

The study period, 1840-1970, covers completely the industrialization and urbanization phase which occurred during the industrial revolution. Over this period the spatial organizational structure of society evolved from a rural-commercial towards a modern urban-industrial state. One of the major events in this period of change is the spatial redistribution of the population and the population growth. This process will be examined below at three levels of aggregation: (1) the population distribution as one frequency distribution, (2) the population distribution disaggregated into a number of size classes, and (3) the individual cities which make up the population distribution. Each of these levels emphasizes a different aspect of the population system. The analysis of the population distribution as a frequency distribution will reveal changes in the size distribution of the cities, which affect the total system. The spatial component, as to the locational effect of such a change, is not incorporated in this part of the analysis. The localization of the growth over time will be studied on the basis of the individual growth path of each city for the length of the whole study period. In this respect the analysis of the population distribution by size class occupies an intermediate position as regards the level of aggregation as well as the length of the period studied. The data for the analysis has been collected for every decade since 1840 and a comparative study of the decennial changes by size class will throw light on the way in which the growth is transmitted through the population system over time.

The description and analysis of the population system in this chapter is thus focussed upon the nature of the process of population growth and distribution. An important question is whether it is possible to identify stable relationships or trends at different levels of aggregation. If this is the case, then to which degree do these trends describe the forces exerted upon the spatial distribution of the cities, their size relationship and their growth behaviour?

2.2 The measurement and classification of an urban centre

The study of an urban system as a population system does not resolve the definition problem of the node, a unit of analysis. Such a node has to be defined both in spatial and in functional terms. Spatially, the population distribution can be studied by means of a dot map. The question then becomes, which dot or which spatial series of dots can be identified as a node of the system. In the case that the study area is completely subdivided in a number of areas, the question may become which areas are urban and which are not. The functional content of these areas then becomes relevant and this introduces the idea of a (minimum) threshold value.

In a macro analysis, starting at the national level, the allocation of each areal unit to its (unique) position in the national urban system will be sometimes difficult, in terms of the urban character of a place. This raises the questions whether a classification of places should be based on an urban-rural continuum or on an urban-rural dichotomy. Davis[1.], in his comparative international study on world urbanization, differentiates between urban population and rural population. He argues in favour of a dichotomy on the basis of practical considerations. Although one can argue that a dichotomy is unrealistic, this is only one extreme point of view. The objections against a dichotomy are not so strong as to force abandonment of a complete data series based on such a classification.

One of the first problems related to the spatial definition of a city is the boundary problem which is most obvious when dealing with large cities, i.e. places with a population of over 100,000, because in most cases there will be population overspill over the political boundaries of the city. It is here that the concepts behind the definitions of a city and an urban area merge and go beyond a simple description of population size within a given area. It becomes necessary to refer to more complex indicators or urbanization. This fact has been widely recognized and the Netherlands Bureau of the Census, like its counterparts in many other countries, emphasizes four major elements relevant to the study and classification of urban areas[2.]: (1) morphological criteria, which are expressions of the physical aspects of urbanization, are measured by the number of inhabitants, population density and the

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1. Davis, K., World urbanization 1950-70, Vol.1: basic data for cities, countries and regions, Population monograph series No.4, Berkely, 1969, pp.10-20.

2. Typologie van de Nederlandse gemeenten naar urbanisatie graad, 31 mei 1960, C.B.S., Zeist, 1964.

degree of nucleation of the built-up area, (2) social-economic aspects, which are related to commuting, commuting patterns and type of employment, (3) functional criteria, which are based on the type of services provided by the central city, and (4) behavioural aspects focussing on the sociological and psychological attitudes expressing an urban way of life. The last mentioned element, though recognized as being important in seemingly rural but yet suburbanized areas, is very difficult to measure through general enumeration procedures. When the behavioural aspects are set aside, other problems arise relating to the spatial extent and shape of the urban labour market as measured by commuting. Unfortunately, information of this kind has only been systematically collected in the Netherlands since 1947. As regards service functions, these may be measured by certain critical population levels based on threshold size notions from central place theory[3.]. However, the rigid imposition of a fixed minimum threshold value is likely to give rise to a rather unrealistic picture, because a relevant minimum threshold is defined on a certain state of the economy in a given period and this may vary throughout the study period.

The lower population limits for defining an urban area vary considerably between countries, as is evident from Kingsley Davis' cross national analysis[4.] in which 59 countries out of 73 have lower limits between 2,000 and 7,500. As the national economies of these countries are at different stages of development, we can expect their urban economies to differ in the degree of minimal requirements necessary for the operation of certain functions. On the basis of this spatial variation in threshold sizes, one may hypothesize that the development of the lower size limits within one national economy will vary through time, i.e. the threshold size will increase progressively, being dependent on the rate at which the urban economy becomes more specialized and complex. As an illustration of this process may serve the changes made in the village distribution plans for the most recently reclaimed polders in the Netherlands, the Northeast polder and Eastern Flevoland[5.]. In the latter polder the size of a central village - the lowest in the urban hierarchy - was planned to be about 5,000 inhabitants. This minimum number was based on the consideration that "due to the continuing development in farming techniques and, consequently, farm employment, the farming community cannot any longer be regarded as the sole basis of building up a village population of a sufficiently high number to justify

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[3.] Berry, B.J.L. and W.L. Garrison, The functional bases of the central place hierarchy, Economic Geography, 1958, Vol.34, No.2, pp.145-154.

[4.] Davis, K., op.cit. 1, p.9, see table 1.

[5.] Van Hulten, M.H.M., Plan and reality in the IJsselmeer polders, Tijdschrift voor Economische en Sociale Geografie, 1969, Vol.40, No.2, pp.67-76.

economically the provision of the village people's present day service requirements"[6]. When services are defined to include those offered by local government, a recent study[7] suggests a minimum population size of about 15,000 for economic operation of these services. The difference between these two figures expresses the problems local governments face in small-scale administrative areas. At the same time it may be argued that this problem, which is also a financial one, operates at both ends of the scale, viz. for the largest and smallest municipalities, but is different in kind because the larger units service the smaller areas contiguous to their boundaries. Despite these problems the administrative area may turn out, in general, to be a reasonable approximation of an urban area from practical considerations. However, a rigorous application of the size criterion will inevitably lead towards the incorporation of municipalities which may have some urban functions but do not possess a complete set, like dormitory villages or small historical towns.

The analysis of a time series, which covers a period as long as a century, puts a severe restriction on the use of more refined indicators developed in recent periods. This limits the number of criteria one can use to those which are measuring the most elementary aspects of a place, like size and density in a defined administrative area and one can only refer implicitly to its functional characteristics. Size, density and degree of nucleation were used by C.M. Law[8] in de definition of an urban settlement for nineteenth century England and Wales. The application of the density criterion has, according to Law, the advantage that suburban areas can be included before administrative boundary changes have been made. The density criterion, however, having a close link with population size, suffers from the same drawbacks as a fixed threshold size. Grytzell[9], using administrative areas, suggests that there exists a simple direct relation between the lowest population density for a city and the square root of its population. The application of this relation gives as the lower density limits for 'Greater Stockholm' 100 inhabitants per sq.km. An increasing density may be noted for comparable urban populations in other cities,

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[6] Van Hulten, M.H.M., op.cit. 5, p.72.

[7] Eindrapport Bestuursonderzoek Oost-Nederland, Van Soest B.V., Amsterdam, 1973, p.45.

[8] Law, C.M., The growth of urban population in England and Wales, 1801-1911, Transactions of the Institute of British Geographers, 1967, No.41, pp.125-143.

[9] Grytzell, K.G., The demarcation of comparable city areas by means of population density, Lund Studies in Geography, Ser.B., Human Geography, No.25, Gleerup, Lund, 1963, pp.64-70.

like 100 for Copenhagen, 200 for Paris and 300 and above for London and New York[10.]. An indication of the great variation in judgement by other authors in this matter may be illustrated by the lowest figure C.M. Law used, 247 persons per sq.km., in his definition for all urban places in England and Wales in the 19th century, compared with the 100 persons per sq.km. for Copenhagen in 1950.

Although one may argue that urban densities are decreasing since the 19th century, the difference remains striking, especially if one takes the difference in size into account as well. The observation of a diminishing density gradient through time is supported by a number of other studies[11.]. This change can be associated with a shift in transportation technology leading towards a rapid, flexible and multi-mode transportation system and this has created possibilities for a more dispersed spatial pattern. The degree of nucleation of the built-up area might be used as a supplementary criterion in this respect and will sometimes change the picture considerably. The Apeldoorn municipality, for example, being one of the largest municipalities of the Netherlands and having a population over 100,000 in 1960, is an extreme case with an average density of 3.3 persons per ha. and 49.9 per ha. for the built-up area. Decisions on the basis of the latter density figure should be supplemented by careful map analysis, because the built-up area does not necessarily consist of one core, but may be a summary figure for a group of scattered settlements ranging from the nuclear to the longitudinal type.

To summarize the above argument, the analysis of the urban population distribution through time raises the question as to which aspect of the total population the urban or the rural population component is emphasized. Consequently, urban definitions become important and the yardsticks which are derived from them, like population size and density levels must be varying, however, in a temporal analysis. This variation is due to changes in socio-economic conditions and technological development in the past century, as well as a subjective appraisal of the influence of these factors and is reflected by the adjustments made in the municipal boundaries over this period.

[10.] Grytzell, K.G., op.cit. 9, p.65.

[11.] Berry, B.J.L., J.W. Simmons and R.J. Tenant, Urban population densities: structure and change, The Geographical Review, 1963, Vol.53, No.3, pp.389-405, see especially pp.396-397.
Berry, B.J.L. and F.E. Horton, Geographic Perspectives on urban systems, Prentice Hall, New Jersey, 1970, chapter 9.

2.3 An operational definition

The emphasis in this study on the city as a major node in a spatially organized system leads towards the exclusion of the smallest municipalities. This exclusion has the practical advantage of considerably reducing the total number of areal units to be studied, while the loss in absolute numbers is small as will be shown below. Nevertheless, as Brian Robson rightly observes 'however a city is defined, all of the operational definitions still leave unanswered the conceptual problem that a city cannot be isolated as a functional operational unit in spatial terms'[12.]. It will be evident from the preceding discussion that it is difficult to define a city satisfactorily with the use of a limited number of criteria, which are mainly related to size and area. Nevertheless, these variables often produce a useful approximation of the urban population.

The first thing one needs in a comparative analysis is a common base, which is hard to find in a cross-temporal analysis of urban population growth, because all the main indicators are relative to time. In this case the smallest administrative area of local government in 1970, the municipality, seems a reasonable basis to start from for two reasons. First, to describe and subsequently gain insight in the historical process which led to the present spatial distribution of the population, a fixed spatial basis is a necessary requirement. This simultaneous comparison in space and time necessitates the incorporation of historical changes in the areal boundaries. Second, the present administrative areas are the result of a process of boundary corrections and the complete legal annexation of contiguous administrative areas which can be considered as an adaptation to the changing urban reality, based on a process of urban population growth in the previous period. Especially in the case of boundary changes, the amount of area added is negligible in most cases, both in terms of the gaining and the losing municipality, but in terms of population change this can affect quite a large number of people, as is indicated in table 2.1. The population concerned will generally consist of the overspill of the largest municipality or in a more indirect way it is generated by the growth induced by the neighbouring areas. In both cases this type of growth can be considered as the natural expansion of the major centre and it will occur in the proximity of this centre especially in the early periods when urban densities were higher as compared to the mass transport and automobile type of urbanization in later years.

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12. Robson, B.T., Urban growth: an approach, Methuen and Co. Ltd., London, 1973, p.12.

table 2.1 Two examples of a municipal demographic accounting system based on boundary changes and/or annexations

Municipality	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970
EINDHOVEN	2,996	3,028	3,083	3,193	3,210	3,768	4,565	4,930	5,715	45,624	89,619	113,126	140,554	166,032	188,631
Gestel	x	1,363	1,357	1,378	1,658	2,320	2,697	3,017	4,110	5,630					
Stratum	x	1,319	1,387	1,467	1,829	2,906	3,526	4,047	5,582	7,587					
Strijp	x	1,040	1,086	1,082	1,272	1,677	1,933	2,221	3,172	7,045	After 1-1-1920 incorporated in Eindhoven				
Tongelre	x	811	847	875	909	1,118	1,057	1,199	1,860	3,207					
Woensel	x	3,337	3,147	3,133	3,766	5,033	5,459	6,110	8,975	15,761					
Eindhoven (total)	x	10,898	10,907	11,128	12,644	16,822	19,237	21,524	29,414	84,856	89,619	113,126	140,554	166,032	188,631
BREDA	13,114	15,399	14,743	14,939	14,765	17,596	22,176	26,096	27,976	30,044	44,112	51,811	89,304	107,127	121,209
Ginneken	x	3,288	3,626	3,774	3,884	4,474	4,904	5,747	7,384	9,603	12,640	16,740	1-1-1942 68.1% to Breda		
Princenhage	x	5,093	5,434	5,648	5,923	6,418	7,153	8,935	10,974	12,658	1-5-1927 33.3% to Breda				
Prinsenbeek	x	At 1-5-1927 the name Princenhage changed into Prinsenbeek									10,882	13,066	1-1-1942 72.3% to Breda		
Nw. Ginneken	x	At 1-1-1942 this municipality is created with Ginneken and Prinsenbeek as components											6,169	7,422	1-6-1961 13.96% to Breda
Teteringen	x	1,013	1,166	1,128	1,188	1,610	2,537	3,701	5,442	6,638	1-5-1927 76.0% to Breda				
The calculated positive shifts are listed below:											2,579	3,289	1-1-1942 43.1% to Breda		
Ginneken	x	2,385	2,631	2,738	2,818	3,246	3,558	4,169	5,357	6,967	9,170	12,145			
Princenhage	x	4,152	4,430	4,604	4,828	5,232	5,831	7,284	8,946	10,319					
Prinsenbeek											7,868	9,447			
Nw. Ginneken													861	1,036	
Teteringen	x	875	1,007	974	1,026	1,390	2,190	3,195	4,699	5,731	1,112	1,418			
Breda (total)	13,114	22,811	22,811	22,855	23,437	27,464	33,755	40,744	46,978	53,061	62,262	74,821	90,165	108,163	121,209

x = figure unknown; for a discussion see text.

Sources for Boundary changes and annexations:

Bijdrage tot de algemene statistiek van Nederland, jaargang 1878, aflevering 1, Van Weelden, 's-Gravenhage, 1880.

Statistiek van de loop van de bevolking van Nederland, 1970, Gebr.Belinfante, 's-Gravenhage, 1908, pp.156-157.

Statistiek van de loop van de bevolking van Nederland, 1921, Gebr.Belinfante, 's-Gravenhage, 1922, p.IX.

Twaalfde Volkstelling, Serie B, deel 1, 's-Gravenhage, 1930, pp.190-193 en deel IX, pp.6-7.

Dertiende Algemene Volkstelling, 31 mei 1947, deel 1, Ser.B., p.187.

Bevolking der Gemeenten van Nederland, op 1-1-1969, table 7, p.20 and table 8, p.28.

Demografische gegevens per gemeente sinds 1880, source C.B.S. kept up to date till 1965 with recent supplements.

One advantage of the proposed accounting system is that an equal number of municipalities is considered, all having the same spatial basis for the whole study period. Another effect of the procedure is the smoothing of the population series, which brings out much more clearly the real growth shocks some places have experienced, because disturbances based on administrative-technical changes have been taken into account. In the case of Eindhoven, the home town of the Philips factories, the population growth in the area is not from 5,715 to 45,624 but starts from the much higher value of 29,414 to 84,856 for the period 1910-1920 when the industry started to grow and expand. An interesting point here is that the corrected figures for Eindhoven indicate an even higher absolute growth but a lower percentage growth than the uncorrected ones do.

Although part of the population growth is due to natural increase in a period with improving medical care and health services, a large proportion of the growth is due to migration and its related demographic effects. This may be illustrated by the rapid growth of the neighbouring municipalities of the city of Breda, which have lost several times heavily in population as a consequence of the subsequent boundary changes. Their population growth due to both factors have been allocated proportionally to Breda by positive shifts throughout the period and to the places themselves by negative shifts, straight to the start of the study period, viz. 1840. For the cases in which there has been more than one boundary change over the period, the corrections made are, of course, confined to the relevant period for which a specific proportion of change is valid.

A second problem is related to the minimum population level, above which a place can be considered as being urban. In the previous discussion the varying threshold problem has been mentioned and two size levels were indicated, one at 15,000 and one at 5,000 inhabitants. The latter value has been used in physical planning projects in the Netherlands in the 1960s. The application of this value as a lower limit reduces the number of municipalities in 1970 from about 940 to 507, while it goes down to 502 when the municipalities on land reclaimed since 1840 are not taken into consideration. An interesting point at this stage of the discussion is the nature of the spatial distribution of the municipalities which are not taken into account. As will be readily seen in fig.2.3, this distribution is by no means random but four distinct areas are shown on the map together with a number of scattered small areas. It is, of course, not surprising that the four areas can be identified with well-known agricultural regions located in the Northern fringe of the Netherlands and the province North-Holland, and also incorporate large sections of the province Zeeland in the Southwest. On the other hand, the striking contrast between the densely populated Randstad and the fourth area, being a relatively vast empty area at a rather close distance, is noteworthy. This area is, however, located farther to the Southeast than the popular conception of the location of the Green Heart, which is the central part of the province South-Holland, together with the Western part of the province Utrecht. One has, of course, to realise that part of the map pattern is influenced by the size of the areas considered, which may be noted in the North of the Netherlands, but the fact that the deleted areas cluster together spatially while none of them can reach a population level above the threshold size, is an indication of the low overall density in these areas.

The delimitation of the units of analysis in the way discussed above has the practical advantage of using the same spatial basis throughout the period and an equal number of municipalities for every decennial cross-section, which is based on the application of a lower limit of 5,000 inhabitants in 1970. A possible drawback of the latter rule might be felt in the early part of the study period, caused by the inclusion at that time of relatively small municipalities which can only be considered as rural, viz. the smallest place in this analysis has a population of 397 inhabitants in 1840. This is, of course, due to the non-linear relationship between the smallest municipality and the lower limit will, however, increase when one approaches the end of the period, while it is unknown to which degree it really deviates from the temporally existing threshold values necessary for the provision of the minimum number of service requirements. As this problem stays unsolved presently, the rules applied provide only a first approximation of the size and location of viable communities, which may have urban characteristics. An inspection of table 2.2 reveals the fact that notwithstanding the number of municipalities has been reduced considerably by about 46%, from 940 to 502, the percentage of the popu-

table 2.2 The growth of population in the Netherlands, 1840-1970

Year	Total population	Per cent considered	Year	Total population	Per cent considered
1840	2,860,559	82.26	1910	5,857,949	88.83
1850	3,056,879	82.29	1920	6,831,231	89.32
1860	3,390,128	82.61	1930	7,832,175	89.44
1870	3,579,529	82.92	1940	8,833,977	90.39
1880	4,012,693	83.98	1950	10,026,773	90.22
1890	4,511,415	84.93	1960	11,417,254	90.90
1900	5,104,137	86.55	1970	12,957,621	90.77

lation considered ranges from 82.26 per cent to 90.77 per cent, showing a steady but expected increase over the period. Thus it may be argued that the proposed delimitation has not been completely successful from a functional point of view, because of size considerations but an increased economy of description has become possible, in addition to a consistently defined set of places over space and time.

2.4 Size distributions and stability

The classification of cities[13.] into size categories is in most cases dependent upon the statistical distribution of the human population system, and the most frequently quoted distributions are either the lognormal or the pareto-type distributions. The empirical distributions are very often portrayed in 'rank-size' graphs such as fig.2.1, which shows 14 plots for every decade from 1840 to 1970, all of which are of a striking linearity. It will be evident that a regularity of this kind has initiated a considerable amount of research. One of the first studies in this field was carried out by Auerbach in 1913 and is principally concerned with German cities[14.]. This study was followed by a 1924 publication of A.J. Lotka[15.] who studied the rank-size regularities of many phenomena from a statistical point of view. Singer's[16.] international comparison of population distributions also contributed to this field, but it was G.K. Zipf's[17.] work published in 1941 which really started the numerous studies of rank-size relationship. The rank-size regularity can be characterized by the equation:

$R.P^q = K$ or $R = K.P^{-q}$, which is linearized by $\log R = \log K - q\log P$

where R = a vector of length n containing the ordered rank numbers of each city i

P = a vector of length n containing the population of each city i in rank-order

and $i = i, \ldots\ldots, n$; n being the total number of cities in the analysis.

[13.] The word "city" or "town" will be used in this section for ease of expression and is not, in a strictly defined sense, referring to population agglomerations in general.

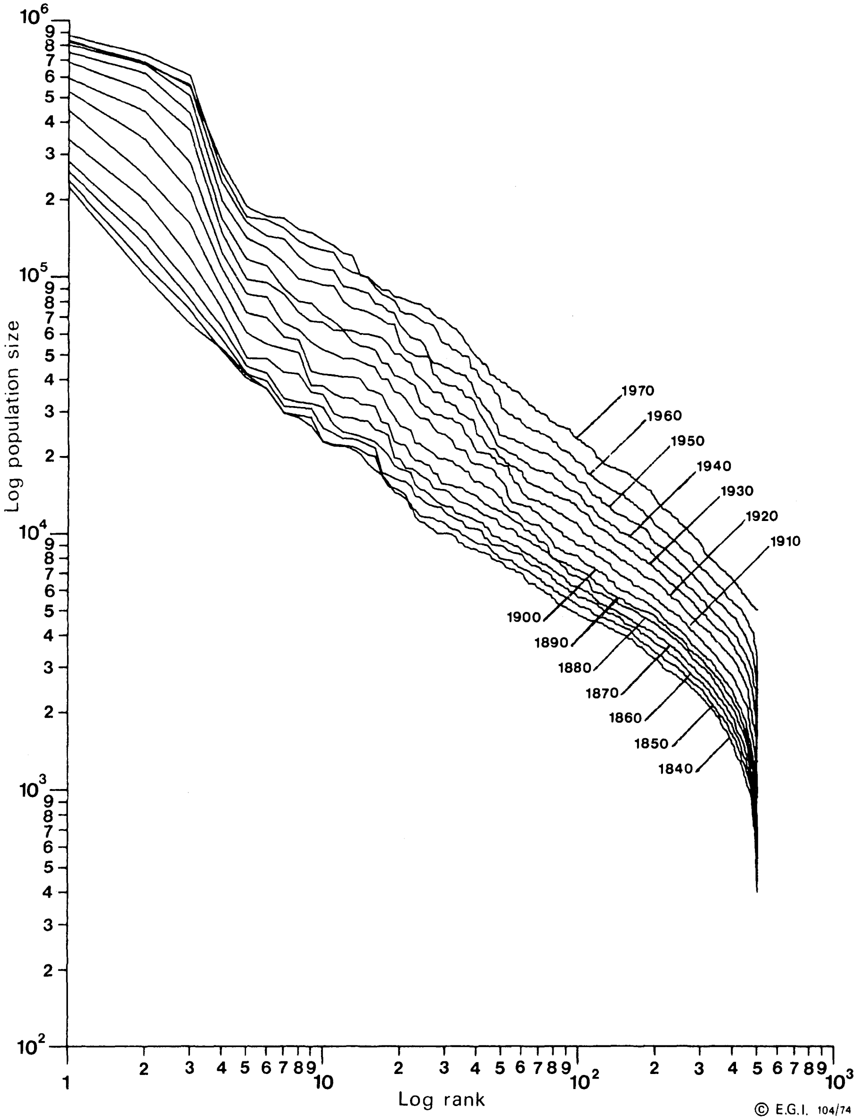
[14.] Auerbach, F., Das Gesetz der Bevölkerungskonzentration, Petermanns Mitteilungen, 1913, Vol.59, pp.74-76.

[15.] Lotka, A.J., Elements of Physical Biology, Williams and Witkins, Baltimore, 1924.

[16.] Singer, H.W., The "courbe des populations". A parallel to Pareto's Law, Economic Journal, 1936, pp.254-263.

[17.] Zipf, G.K., National Unity and Disunity, Principia Press, Bloomington, Indiana, 1941; see also for a more complicated statement
Zipf, G.K., Human Behavior and the principle of least effort, Addison-Wesley, Cambridge, Massachusetts, 1949.

Fig.2.1 Rank size distributions of Dutch municipalities 1840–1970



The estimation of the parameters q and constant K from the above mentioned equation for the case of the Netherlands yields the results listed in table 2.2 and is based on the 502 individual observations without grouping the data into size classes. The classical interpretation of q is, that it can be considered as an index of the distribution of the whole population, both rural and urban places of different size, and as a precise and unambiguous measure of urbanization[18.]. As the index is a measure of the relative frequency of small, medium-sized and large cities, the smaller the value of q is, the greater is the proportion of large cities in a given number of cities. If $q > 1$ metropolitan dominance is existent, a situation often met in developing countries as well as in some economically advanced countries, such as France in which Paris is the major dominating node. The occurrence of a disproportional wide gap between the first ranking city, in most cases the political or economic 'capital' of a

table 2.3 Regression results of $\log R = \log K - q \log P$ for the Netherlands

Year	log K	(st.dev.)	-q	(st.dev.)	R^2	n=502
1840	6.260	(0.050)	-1.154	(0.014)	0.927	
1850	6.340	(0.049)	-1.167	(0.014)	0.930	
1860	6.361	(0.048)	-1.162	(0.013)	0.933	
1870	6.400	(0.048)	-1.162	(0.013)	0.937	
1880	6.420	(0.045)	-1.155	(0.012)	0.943	
1890	6.381	(0.042)	-1.134	(0.011)	0.950	
1900	6.330	(0.038)	-1.108	(0.010)	0.958	
1910	6.378	(0.033)	-1.104	(0.008)	0.968	
1920	6.466	(0.031)	-1.108	(0.008)	0.972	
1930	6.565	(0.029)	-1.116	(0.007)	0.977	
1940	6.610	(0.023)	-1.113	(0.006)	0.985	
1950	6.705	(0.022)	-1.118	(0.005)	0.987	
1960	6.802	(0.019)	-1.123	(0.004)	0.991	
1970	7.049	(0.020)	-1.159	(0.009)	0.991	

[18.] Singer, H.W., op.cit. 16, p.263.

country, and the second in rank was studied by Jefferson[19.] and he termed this phenomenon: the Law of the primate city. The recognition of primacy has given rise to two kinds of city size distributions, i.e. rank-size and primate distributions. Though the latter distribution may be considered as a special case of the first one, since the difference is caused only by the highest ranking cities and 'there are no relationships between type of city size distributions and either relative economic development or the degree of urbanization of countries[20.]. The special case where q=1 is the well-known rank-size rule, in which q is not allowed to vary and logK holds the population number of the largest city, for R=1. Various authors have demonstrated that the rule in its rigid definition must be rejected[21.] and a statistical estimation seems more appropriate. A situation in which the number of intermediate sized cities are relatively overrepresented is indicated by $q < 1$.

The interpretation of the values of q in table 2.3, based upon the above discussion, suggests a decreasing dominance by a few large centres till about 1910 and from that period the picture is reversed by a very gradual increase in the proportion of large centres as compared with the total number of cities, with the exception of 1970 q value, which indicates a rapid increase. A visual inspection of fig.2.1, however, indicates that a different interpretation is possible. First of all the 14 graphs are running nearly parallel, a fact which is supported by the q values which are significantly different from each other, but in most cases not pair-wise and not from all other values either. Another aspect which jumps to the eye is the rapid growth of second and third cities, being Rotterdan and The Hague, with Utrecht, the fourth largest city, following closely behind at a more moderate rate. This process of growth, which started around the turn of the nineteenth century, has led to the occurrence of the three largest cities being about the same size and one may note, though it is hardly discernable in the graph, that the 1970 values for the three of them are below their 1960 level. The third general characteristic of the graphs is the gradual disappearing tail, which roughly consists of the 200 smallest municipalities. This is also reflected by the steadily increasing coëfficient of determination indicating an improving 'goodness of fit' and by the decreasing standard deviations in table 2.3. The downward curvature may be inter-

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[19.] Jefferson, M., The Law of the primate city, Geographical Review, 1939, Vol.29, pp.226-232.

[20.] Berry, B.J.L., City size distributions and economic development, Economic Development and Cultural Change, 1961, Vol.9, p.587.

[21.] See, for example, Rosing, K.E., A rejection of the Zipf model (rank-size rule) in relation to city size, The Professional Geographer, 1966, Vol.18, pp.75-82.

preted economically as an indication of a deficiency of smaller communities or as the demarcation between urban and rural, which is analogous to the minimum threshold requirement[22.].

The problem of finding the appropriate minimum threshold for every period as discussed in the previous section, cannot, however, be solved graphically by using the curvature as a device, because there does not exist one straight line which can be drawn across all the graphs and cut them individually at the right spot. Much more serious is the fact that this curvature may affect the estimated value of q and this raises questions to the nature of the statistical function by which the empirical distribution is described, viz. the lognormal or the Pareto type distribution, together with the identification problem. The consequences of truncation for the estimated value of q become evident when the results derived by Deurloo[23.], calculated for 1935 and 1970, are compared with the corresponding figures in table 2.3. The data Deurloo uses is not corrected for area, as in this study, and he has a varying number of observations for both periods. The q values derived, based on a truncation at 3,452 and 97,024 inhabitants, are -1.210 and -1.108 for 1935 and 1970 respectively and the corresponding values of logK are 6.964 and 6.820. The tabled 1940 and 1970 values for q are -1.113 and -1.159, while the values for logK are 6.610 and 7.049 respectively. Although no standard deviations for these estimates are reported, it is not likely that the difference between these estimates are only due to chance, because of the known values of the tabled deviations, especially for the 1970 case which is the most comparable of the two[24.].

At this point of the analysis it has become necessary to discuss four general aspects relevant to the study of city size distributions in more detail, but no attempt is made to make a complete review, as only recently there have been

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[22.] Richardson, H.W., Theory of the distribution of city sizes: Review and prospects, Regional Studies, 1973, Vol.7, p.241.
In this section Richardson also quotes Zipf's 1949 contribution, op.cit. 17, p.423.

[23.] Deurloo, M.C., De wet der urbane concentratie, Tijdschrift voor Economische en Sociale Geografie, 1972, Vol.63, p.308.

[24.] See also the discussion of Singer's analysis, op.cit. 16, by Allan, G.R., The 'Courbe des Populations', a further analysis, Bulletin of the Oxford University, Institute of Statistics, 1954, Vol.16, pp.179-189, especially p.182.

already three review articles covering the subject from various viewpoints[25]. The four aspects mentioned are: (1) the kind of the statistical distribution chosen to analyse the observed distribution, (2) the spatial nature of the problem and immediately related to these two are (3) the identification of the basic features of the spatial problem with the statistical properties of the selected function, and (4) the usefulness of the parameters derived as summary statistics for descriptive or analytical purposes.

As regards the first point, the commonly selected statistical functions to analyse the distribution of city sizes are the lognormal and the Gibrat distribution, as a special case, on the one hand and the Pareto-type and Yule distribution, as the more general type, on the other hand. If the empirical distribution has been truncated the linear estimates of the parameters for the various functions yield all the same result, which is not surprising as it has been shown that the different equations when redefined on the same basis are all identical[26]. An important difference, however, is the recognition of the structural features, viz. the difference between open and closed systems. Birth and death processes in this context can be associated with the second group of functions[27], which is typically related to threshold requirements in which some cities disappear and new ones enter. The first group of functions may be associated with the study of the population as a whole, without any change in the total number of cities studied, i.e. a closed system approach, as well as regards the considered cities themselves. An interesting application in this context is Champernowne's[28] analysis of income distributions, using Gibrat's law of proportionate effect, which demonstrates that in a process of growth, growth in proportion to size is a random variable with a given distribution which is considered constant in time. This assumption enabled him to specify a matrix with transition probabilities, such as those used in Markov-chain models,

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[25] Dziewonski, K., General theory of rank-size distributions in regional settlement systems: reappraisal and reformulation of the rank-size rule, Papers and Proceedings of the Regional Science Association, 1972, Vol.29, pp.73-86.
Parr, J., Models of City size in an urban system, Papers and Proceedings of the Regional Science Association, 1970, Vol.25, pp.221-253.
Richardson, H.W., op.cit. 22, pp.239-251.

[26] See Richardson, H.W., op.cit. 22, p.240.

[27] Steindl, J., Random processes and the growth of firms, a study of the Pareto Law, Griffin, London, 1965, p.32.

[28] Champernowne, D.G., A model of income distribution, Economic Journal, 1953, Vol. 63, pp.318-351.

where the distribution of the population over the states of the system reaches an equilibrium situation. The analytical advantage of this approach is the possibility of a functional breakdown to study the behaviour of subsystems, as has been demonstrated in the case of income distributions by a specification of the occupational and age structure as the states of the system[29.]. The explicit incorporation of 'birth and death' processes in models of this type has been applied in a study of I.G. Adelman[30.] by the addition of an extra group which acts as a reservoir for the entering and departing units.

A reformulation of this dichotomy in the terminology of system analysis[31.] leads to the consideration of closed and open systems, but does not give much additional insight except another framework of reference and new concepts like the law of allometric growth and the entropy of a system which will be discussed shortly below. Eventually it must be said that most of the applications are more concerned about the mathematical and statistical properties[32.] than with the spatial problem which lies at the heart of them.

The spatial and geographical nature of the problem was explicitly recognized by Dziewonski, who stated[33.] 'that by ordering settlement units according to their size we destroy other existing relations as well as their position in terrestrial space'. The first point here relates to the functional relationships between cities leading towards hierarchical concepts as formulated in classical central place theory. On the basis of two fundamental assumptions: (1) the size of any city is proportional to the population it serves (including that of the city itself), and (2) cities of each order (but the lowest) have a fixed number of satellite cities of the next lower order, Beckman[34.] was able to develop a model from which the rank-size rule could be derived directly. More complicated and sophisticated versions of

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29. Champernowne, D.G., op.cit. 28, pp.334-346.

30. Adelman, I.G., A stochastic analysis of the size and distributions of firms, Journal of the American Statistical Association, 1958, Vol.53, pp.893-904.

31. Berry, B.J.L., Cities as systems within systems of cities, Papers and Proceedings of the Regional Science Association, 1964, Vol.13, pp.147-163, see especially p.149.

32. Chatterji, M., On a class of distribution functions to characterize the growth of some cities in the United States, Paper presented at the Second Seminar in Regional Science, Karlsruhe, August 1972.

33. Dziewonski, K., op.cit. 25, p.82.

34. Beckman, M.J., City hierarchies and the distribution of city size, Economic Development and Cultural Change, 1958, Vol.6, pp.243-248.

hierarchical explanations of rank-size distributions are discussed by Parr, who argues that these distributions provide some indication of the forces of economic-geographic organisation, which operate within an urban system as opposed to non-hierarchical approaches[35.]. Distributions of the rank-size type reflect the equilibrium state of a stochastic process and the theoretical justification for this view is often made by referring to the existence of a complex system with many counteracting forces, like Zipf's forces of diversification (minimizing the cost of the plant) and unification (minimizing transport costs to the market). This rather vague way of reference to an actual spatial process is an indication of the identification problem between the statistical and geographical processes.

As regards the specification of non-hierarchical explanations of rank-size distributions the most complete set of assumptions is given by Simon[36.] in a recent publication, which is an extension of his classic earlier article[37.]. The relevant assumptions for a geographical area with both urban and rural communities are: (1) for the urban population, birth and death rates are uncorrelated with city size, (2) there is migration between cities and net migration from rural areas to cities, (3) out-migration rates from cities are uncorrelated with city size, (4) the probability that any migrant, chosen at random, will migrate to a city in a particular size class, and (5) a constant fraction of the total growth of population in cities above some specified size is contributed by the appearance of new cities, which have grown above that threshold.

The model developed by Simon on the basis of these assumptions leads towards a lognormal distribution of city size, which appears to be nearly linear when plotted on double-log paper because of the threshold requirement. This state of affairs is quite an improvement compared with Madden's statement that there exist, to his knowledge, 'no hypothetical "models" analyzing the process by which an economy develops under assumed conditions, that would lead to the expectations, as limiting distributions, of Pareto or logarithmic normal distributions'[38.]. It has now become

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[35.] Parr, J., op.cit. 25, p.244.

[36.] Simon, H.A., On judging the plausibility of theories, in Logic, Methodology and Philosophy of Science, III, Van Rootselaar and Staal, eds., North Holland Publishing Co., Amsterdam, 1968, pp.145-164, see p.145.

[37.] Simon, H.A., On a class of skew distribution functions, Biometrika, 1955, Vol.42, pp.425-440, see p.437.

[38.] Madden, C.H., On some indication of stability in the growth of cities in the United States, Economic Development and Cultural Change, 1956, Vol.4, pp.236-253, see p.251.

possible to evaluate and test empirically the underlying hypothesis individually, instead of only comparing predicted and actual city size distributions. Haran and Vining[39.] tested recently some of the assumptions made by Simon with respect to intercity and rural-urban migration (hypothesis no.2) and the assumption of the constant birth rate of new cities (hypothesis no.5). The reason for their tests can be found in a noticeable upward curvature of the rank-size plot for the United States in the last two decades, which is thought to arise out of the violation of the inter-urban and rural-urban migration assumption. The latter type of migration flow has been reversed and suburbanization has become a familiar phenomenon, which also affects the reasoning behind the constant entrance of new cities to the system of cities as the rural influx has dried up. These factors lead towards an increased importance of inter-urban migration and the assumption of a closed system of cities becomes increasingly relevant for modern industrialized economies[40.].

A final comment has to be made about the usefulness of the estimated parameters as summary statistics for descriptive and analytical purposes. As will be apparent from the above discussion, the latter purpose can only be pursued when a proper identification has been made. This puts a severe limitation on the usefulness of the parameters relying on concepts from general systems theory, like the measure of entropy[41.], which indicates the state of the organisation of the system

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[39.] Haran, E.G.P. and D.R. Vining, Jr., A modified Yule-Simon model allowing for intercity migration and accounting for the observed form of the size distribution of cities, Journal of Regional Science, 1973, Vol.13, pp.421-437. Vining, D.R., Jr., On the sources of instability in the rank-size rule: some simple tests of Gibrat's Law, Geographical Analysis, 1974, Vol.6, pp.313-330.

[40.] See also Haran, E.G.P. and Vining, D.R., Jr., On the implications of a stationary urban population for the size distribution of cities, Geographical Analysis, 1973, Vol.5, pp.296-308.

[41.] Berry, B.J.L., op.cit. 31, see pp.158-161, and especially his statement on p.161: 'In a systems framework, we should no longer worry about apparent contradistions between the kind of conclusions reached for different subsystems, i.e. between the distribution of city sizes and the functional arrangement of market centres in a hierarchy,....'. In contradiction, however, we have very little understanding of how to put these different patterns together in more general models that are broad in scope'. (sic!)
Curry, L.J., The random spatial economy: an exploration in settlement theory, Annals of the Association of American Geographers, 1964, Vol.54, see p.144-146.
Fano, P.L., Organization, city size distribution and central places, Papers and Proceedings of the Regional Science Association, 1969, Vol.22, pp.29-38.

and the degree of allometry based on the law of allometric growth[42.], in which the relative growth of an individual element is a constant fraction of the relative growth of the entire system. Both types of measurement, at their present state of development, do not provide us with any additional information compared with the traditional rank-size procedures, while the law of allometric growth may be equated with the specification of the Pareto distribution; its only valid application is for closed systems. Thus, despite the considerable effort put in the study of rank-size distributions, relatively little progress has been made and the main use of the parameters estimated for one of the various specifications may still be found in their descriptive value. However, one characteristic is obvious and it is shared with the centrographic measures based on social physics[43.], that is the high degree of generalization as it relates to the total population. The parameters derived can be considered as a summary statistic, which describesthe state of the system at one point in time. In the case where this statistic cannot be interpreted in terms of a relevant process which leads to this state, it still can be used to describe the movements of the system over time relative to a given outcome. The analysis of the results presented in fig.2.1 and table 2.3 suggests a rather stable pattern of city size distribution over time, but there is no basis to say that stability has been proven, either for the overall distribution, or for groups of cities or the individual cities which make up the general pattern.

A first step towards the understanding of the processes behind the overall population distributions is the analysis of the frequency distributions which are at the basis of each rank-size curve. Thus, a more detailed picture of the behaviour of the Dutch system of cities can be obtained by the analysis of the population distribution by city-size class, as is presented in table 2.4. The class division used in this table is based on the usual classification of the C.B.S. of Dutch municipalities and it will be immediately apparent that the size classes used are not proportional. This way of grouping is not felt as a drawback here because its main

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42. Nordbeck, S., The law of allometric growth, Michigan Inter-University Community of Mathematical Geographers, Discussion Paper No.7, 1965.
Nordbeck, S., Urban allometric growth, Geografiska Annaler, Ser.B., 1971, Vol.53, pp.54-67.
Ray, D.M., The allometry of urban and regional growth, in Proceedings of the Commission on Regional Aspects of Development of the I.G.U., Vol.2, Spatial aspects of the development process, F.M. Helleiner and W. Stohr, eds., Toronto, 1974.

43. Stewart, J.Q., Empirical mathematical rules concerning the distribution and equilibrium of population, Geographical Review, 1947, Vol.37, pp.461-485.

table 2.4 The historical pattern of population growth, change and number by size class, 1840-1970

A. total population*	1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970
≤ 2,500	360,873	330,864	311,626	289,426	258,970	232,003	207.404	152,760	89,262	51,622	27,426	1,822	0	0
2,500 - 5,000	651,065	648,242	677,176	703,170	701,853	711,102	677,106	711,792	726,073	688,901	619,552	488,026	290,298	0
5,000 - 10,000	451,700	524,153	551,025	626,793	691,908	729,412	849,337	965,931	1,095,093	1,169,647	1,346,480	1,324,519	1,484,146	1,550,857
10,000 - 30,000	370,544	459,289	493,577	542,426	733,887	721,436	855,109	1,030,584	1,258,888	1,497,342	1,622,441	2,256,498	2,778,255	3,445,049
30,000 - 50,000	78,100	77,466	173,877	217,417	250,615	274,008	384,565	449,723	383,880	488,821	704,729	762,816	676,141	1,159,872
50,000 - 100,000	217,413	126,046	137,636	156,345	74,481	308,506	256,017	455,473	818,672	903,418	1,102,262	1,011,796	1,365,530	1,809,203
100,000 - 250,000	223,381	349,469	131,663	151,024	314,922	407,811	319,096	124,385	147,466	396,633	581,005	1,125,589	1,318,327	1,448,922
250,000 - 1,000,000	0	0	257,078	281,721	343,178	447,045	868,801	1,313,025	1,582,292	1,808,446	1,980,801	2,074,889	2,465,735	2,347,628
B. number of cities														
≤ 2,500	227	205	188	170	148	130	113	80	46	25	12	1	0	0
2,500 - 5,000	184	185	190	195	193	196	189	196	196	181	159	121	68	0
5,000 - 10,000	64	78	82	92	104	111	127	140	156	166	187	191	213	224
10,000 - 30,000	21	28	33	35	47	49	55	64	78	97	104	145	170	208
30,000 - 50,000	2	2	5	6	6	8	10	11	10	13	18	19	17	31
50,000 - 100,000	3	2	2	2	1	5	4	7	12	14	15	14	20	25
100,000 - 250,000	1	2	1	1	2	2	2	1	1	3	4	8	10	10
250,000 - 1,000,000	0	0	1	1	1	1	2	3	3	3	3	3	4	4
C. per cent of total population														
≤ 2,500	15.33	13.15	11.40	9.75	7.68	6.05	4.69	2.93	1.46	0.73	0.34	0.02	0.00	0.00
2,500 - 5,000	27.66	25.77	24.77	23.68	20.82	18.56	15.32	13.67	11.90	9.83	7.75	5.39	2.79	0.00
5,000 - 10,000	19.19	20.83	20.15	21.11	20.53	19.03	19.22	18.56	17.94	16.69	16.86	14.64	14.30	13.18
10,000 - 30,000	15.74	18.25	18.05	18.27	21.77	18.83	19.35	19.80	20.63	21.37	20.31	24.94	26.76	29.29
30,000 - 50,000	3.31	3.08	6.36	7.32	7.43	7.15	8.70	8.64	6.29	6.97	8.82	8.43	6.51	9.86
50,000 - 100,000	9.24	5.01	5.03	5.26	2.21	8.05	5.79	8.75	13.41	12.89	13.80	11.18	13.15	15.38
100,000 - 250,000	9.49	13.89	4.81	5.08	9.34	10.64	7.22	2.39	2.41	5.66	7.27	12.44	12.70	12.31
250,000 - 1,000,000	0.00	0.00	9.40	9.49	10.18	11.66	19.66	25.23	25.93	25.81	24.80	22.94	23.75	19.96

* the total population number is based on the sum total of the 502 municipalities studied

purpose is to draw attention on the size-class boundary of 100,000 (the 'magic' number of city size) and to specify the threshold value of 5,000 explicitly, while in addition comparative possibilities with results published elsewhere are kept. However, a more detailed analysis of the total population in the last decade will be presented in section 2.5 of this chapter. In the analysis of the figures presented in table 2.4 one has to bear in mind the changing proportion of the total population under discussion ranging from 82.26 per cent in 1840 to 90.77 per cent in 1970 and increasing steadily all the time till 1960, where the highest value (90.90) is found, relative to a total population growth from 2,860,559 to 12,957,621 (see table 2.2). The second point of importance is the size class of 5,000 and below containing 35.37 per cent of the total population, while 17.74 per cent have been excluded completely because of the accounting rules discussed earlier. This makes up a sum total of 53.11 per cent of the Dutch population living in municipalities with less than 5,000 inhabitants in 1840 as compared with 9.23 per cent in 1970, indicating the impact of the process of urbanization on the spatial distribution of the population over the past 140 years, caused by natural growth and redistribution. As far as the general pattern is concerned four points emerge from table 2.4. First, the absolute number of people in class, 2,500 - 5,000 (table 2.4A), is rather stable and fluctuating around 700,000 from 1840-1930. As compared with the smallest size class, which shows a relative and absolute decline throughout the period, the decrease in absolute numbers started as late as 1930, while there has been a steadily retreat of the relative importance since the start of the period (see table 2.4C). Contrasting with this development is the increase in the number of places from 184 to 196 (see table 2.5B) but this drops rapidly after 1920 and is probably caused by the overflow from the previous size class causing a net effect in total.

The second point of interest is presented by the development in the third size class, 5,000 - 10,000, indicating both an absolute increase in total population and the number of towns, but a steadily decreasing 'carrying capacity' with regard to the proportion of the population living in places of this size. If we compare this relative decline in importance with the development in the next higher size class, 10,000 - 30,000, the difference becomes striking. This group experienced a stable growing pattern for the three different aspects of table 2.4, viz. the absolute population, the relative population and the total number of cities, and it may be noted that it encompassed the highest total population number of each of the size categories, containing over 25 per cent of the total Dutch population in 1970. Taken all these aspects together it is strongly suggested that this size class, which incorporates the lower threshold of 15,000 discussed earlier, is one of the basic elements of the contemporary Dutch urban system.

As a third feature, the 30,000 - 50,000 size class has to be mentioned, contrasting in many ways with all the other groups. Being the class of the small medium-sized cities, a steady growth in the number of towns can be observed. However, the proportion of the total population dwelling in these places is surprisingly low, having the lowest relative number (9,86 per cent in 1970) of all size classes for many decades, of course with the exception of the bottom class. This indicates an uneven distribution of cities within this size class with a concentration towards the lower boundary, suggesting in combination with the previous size class that a considerable proportion of the Dutch population is living in small medium-sized towns of about 30,000 inhabitants and a lack in the number of 'real' small middle-sized cities. This idea is sustained by a closer inspection of table 2.4 for the period 1950-1970, which shows for the second time in one century, the first being from 1920-1940, a drop in the relative number of people for this size class from 8.43 per cent to 6.51 per cent for 1950 and 1960 respectively. However, the next higher group experienced the same phenomenon in the 1940-1960 period, showing a rapid growth in the number of places from 14 to 20, but a considerable smaller rate of growth as far as the total population is concerned. These developments taken together suggest a crossing of class boundaries for places in the 30,000 - 50,000 size group in the 1950-1960 period and for the next higher size class in the previous decade. This creates a temporal gap in the size distribution of cities in the early 1960s, which is, however, rapidly filled up by nearly a doubling of the total population in the former group from 676,141 to 1,159,872 and the number of cities from 17 to 31 in the last decade.

A final comment has to be made with respect to the two top classes, which suggest to have a rather stable pattern. The major change in the largest size class occurred around the turn of the century, leaving us with three cities above 250,00 inhabitants containing roughly 25 per cent of the total population in 1910. It is interesting, though, to note that at the same time this has been the largest relative share this group has ever had during the whole study period, but is losing gradually since till 1960, notwithstanding the late entrance of a fourth city to this size class in the period 1950-1960. Another feature of a general nature is the constant growth of the second largest group since it experienced its lowest share, compared with all other classes, both in absolute and relative terms over the period 1900-1920 in which it contained only one city of about 130,000 inhabitants. From 1930 onwards, the total number of cities in this size class rose from 3 to 10 in 1960, but even the cities in this group noted a relative decline since 1960, although it is to a lesser degree than the cities in the largest size group, which lost in absolute terms as well.

The above discussion indicates that two time periods have been of considerable importance in the urbanization process, i.e. the turn of the nineteenth century for the largest cities and the period since 1930 reflecting the increasing importance of the large medium-sized towns. The first aspect is also brought out by the analysis of rank-size stability (see table 2.3), although the indication was weakened by other factors. The aggregate level of analysis did not indicate the possibility of the occurrence of temporal gaps in the city size distribution both for different size classes and for different periods. However, the changing contributions of the different size classes with respect to each other raises questions towards the underlying mechanics of the population system. Is the observed stability and change due to geographical factors at work or are the movements within and between classes only due to technical matters based on the classification method used, because a perceived class pattern such as a stable pattern might be caused by changes to and from the next classes. As the comments made above seem to be of immediate relevance for the problem under examination, the latter question will be studied in more depth in the next section. A detailed analysis of the internal structure of the medium-sized and large cities, however, will be presented in chapter four.

2.5 Aggregate growth patterns

The study of city size distributions based on size class analysis is very much dependent on the properties of the cross-sectional approach and the selected class intervals. A cross-temporal analysis of such a classification becomes then an excercise in comparative statistics, with the inherent problem of the evaluation of the class content as has been discussed in the previous section.

An attempt will be made here to introduce a dynamic element in the analysis in two different ways. First of all, the decennial change is studied by making use of the transition matrix concept of Markov-chain analysis by means of which the passage of one city from one size class in a given period to its size class in the next decade is described. It will be evident that this approach involves only a short time period, covering one time interval being one decade. Although a refinement, like extensions over larger periods, is possible, this is not attempted because a more analytic use of the transition matrices within the present context is not allowed on the basis of theoretical considerations, as the rates of change are not stable over the 140-year period. It is shown in table 2.6 that these requirements of a regular Markov-chain are not met by the evidence presented in this table.

The second approach, in contrast with the first, covers the whole period by analyzing the individual growth path of each of the 502 municipalities. Although the summary statistic by which the growth path is described is derived at the expense of the size information available, a considerable positive trade-off is gained by introducing an explicit spatial pattern based on a map of this statistic.

The transition matrices of table 2.5 thus display a set of simple descriptive statistics related to population changes of individual size groups of cities at successive decennial intervals and the concurrent movements of the individual cities between the eight size classes during the same period. The observed rate of change from one size class to all others for each size class, i.e. the empirical transition probabilities, are only dependent upon the elapsed time between transition points and not upon the time when the transition occurs. This implies, that the stability of the transition probabilities is a function of the width of the selected time interval and the structural rate of change of the phenomenon itself, as in urban land use, where major changes sometimes take place only over extended periods of time.

In the case of the analysis of population patterns changes in the underlying structure and behavioral patterns may occur much more rapidly, as will be anyhow the case when dealing with the transition from an agricultural and mercantile economy in the 19th century to a modern industrialized society in the 20th century. This process of change is recorded in tables 2.5 and 2.6 in which table 2.5A illustrates the movement of towns from one size group to another, which may be read along the row. The row total corresponds with the number of places in a size class at the start of the period, while the column total shows the number of places at the end of the period still being in the same size class. The row and column totals, of course, correspond with the values presented in table 2.4 and it is the movement to and from a particular size class which is of specific interest here.

Although table 2.5B is constructed on the basis of the same principles, a major difference with table 2.5A can be noted. Again the column total records the total population within a particular size class at the end of a decennial period, but the row sum figure does not correspond anymore with the total population at the beginning of the period. This difference reflects the dynamic element of the demographic structure of the population in a size class and is due to natural increase and net migration. The first size class from table 2.5B in 1840-1850 may serve as an example, having a population of 330,864 in 1850 and 360,873 in 1840 (see table 2.4). The population of the places in this size class increased to 387,429 inhabitants, being the sum total of 227 municipalities. However, because of this growth 22 places exceeded the maximum requirement and moved into the next class affecting a population of 56,565 in total. This change reduced the total number of people in this size class suggesting an overall decline, while in reality the population grew by 26,556 from table 2.5 Transition matrices of the number of places by size groups and the total population at decennial intervals

	1840 - 1850							
A. size class	1	2	3	4	5	6	7	8
1	323,661	68,501	0	0	0	0	0	0
2	7,203	579,741	112,279	0	0	0	0	0
3	0	0	411,874	76,168	0	0	0	0
4	0	0	0	383,121	0	0	0	0
5	0	0	0	0	77,466	0	0	0
6	0	0	0	0	0	126,046	111,520	0
7	0	0	0	0	0	0	237,949	0
8	0	0	0	0	0	0	0	0

	1840 - 1850							
B. size class	1	2	3	4	5	6	7	8
1	202	25	0	0	0	0	0	0
2	3	160	21	0	0	0	0	0
3	0	0	57	7	0	0	0	0
4	0	0	0	21	0	0	0	0
5	0	0	0	0	2	0	0	0
6	0	0	0	0	0	2	1	0
7	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	0

	1850 - 1860							
size class	1	2	3	4	5	6	7	8
1	304,428	53,699	0	0	0	0	0	0
2	7,198	615,352	74,816	0	0	0	0	0
3	0	8,125	476,209	85,986	0	0	0	0
4	0	0	0	407,591	92,744	0	0	0
5	0	0	0	0	81,133	0	0	0
6	0	0	0	0	0	137,636	0	0
7	0	0	0	0	0	0	131,663	257,078
8	0	0	0	0	0	0	0	0

	1850 - 1860							
size class	1	2	3	4	5	6	7	8
1	185	20	0	0	0	0	0	0
2	3	168	14	0	0	0	0	0
3	0	2	68	8	0	0	0	0
4	0	0	0	25	3	0	0	0
5	0	0	0	0	2	0	0	0
6	0	0	0	0	0	2	0	0
7	0	0	0	0	0	0	1	1
8	0	0	0	0	0	0	0	0

	1860 - 1970							
size class	1	2	3	4	5	6	7	8
1	282,029	56,317	0	0	0	0	0	0
2	7,397	637,097	78,481	0	0	0	0	0
3	0	9,756	548,312	31,868	0	0	0	0
4	0	0	0	510,558	32,644	0	0	0
5	0	0	0	0	184,773	0	0	0
6	0	0	0	0	0	156,345	0	0
7	0	0	0	0	0	0	151,024	0
8	0	0	0	0	0	0	0	281,721

	1860 - 1870							
size class	1	2	3	4	5	6	7	8
1	167	21	0	0	0	0	0	0
2	3	172	15	0	0	0	0	0
3	0	2	77	3	0	0	0	0
4	0	0	0	32	1	0	0	0
5	0	0	0	0	5	0	0	0
6	0	0	0	0	0	2	0	0
7	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1

table 2.5 continued

	1870 - 1880							
A. size class	1	2	3	4	5	6	7	8
1	256,472	62,706	0	0	0	0	0	0
2	2,498	639,147	127,336	0	0	0	0	0
3	0	0	605,950	127,937	0	0	0	0
4	0	0	0	605,950	0	0	0	0
5	0	0	0	0	250,615	0	0	0
6	0	0	0	0	0	74,481	117,563	0
7	0	0	0	0	0	0	197,359	0
8	0	0	0	0	0	0	0	343,178

	1870 - 1880							
B. size class	1	2	3	4	5	6	7	8
1	147	23	0	0	0	0	0	0
2	1	170	24	0	0	0	0	0
3	0	0	80	12	0	0	0	0
4	0	0	0	35	0	0	0	0
5	0	0	0	0	6	0	0	0
6	0	0	0	0	0	1	1	0
7	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1

	1880 - 1890							
size class	1	2	3	4	5	6	7	8
1	232,003	48,832	0	0	0	0	0	0
2	0	643,862	101,589	0	0	0	0	0
3	0	14,601	627,823	98,428	0	0	0	0
4	0	3,807	0	623,008	198,233	0	0	0
5	0	0	0	0	75,775	219,039	0	0
6	0	0	0	0	0	89,467	0	0
7	0	0	0	0	0	0	407,811	0
8	0	0	0	0	0	0	0	447,045

	1880 - 1890							
size class	1	2	3	4	5	6	7	8
1	130	18	0	0	0	0	0	0
2	0	174	19	0	0	0	0	0
3	0	3	92	9	0	0	0	0
4	0	1	0	40	6	0	0	0
5	0	0	0	0	2	4	0	0
6	0	0	0	0	0	1	0	0
7	0	0	0	0	0	0	2	0
8	0	0	0	0	0	0	0	1

	1890 - 1900							
size class	1	2	3	4	5	6	7	8
1	200,220	53,643	0	0	0	0	0	0
2	7,184	613,572	138,804	15,814	0	0	0	0
3	0	9,891	700,608	85,608	0	0	0	0
4	0	0	9,925	753,687	65,354	0	0	0
5	0	0	0	0	319,211	0	0	0
6	0	0	0	0	0	256,017	107,256	0
7	0	0	0	0	0	0	211,840	341,028
8	0	0	0	0	0	0	0	527,773

	1890 - 1900							
size class	1	2	3	4	5	6	7	8
1	110	20	0	0	0	0	0	0
2	3	167	25	1	0	0	0	0
3	0	2	101	8	0	0	0	0
4	0	0	1	46	2	0	0	0
5	0	0	0	0	8	0	0	0
6	0	0	0	0	0	4	1	0
7	0	0	0	0	0	0	1	1
8	0	0	0	0	0	0	0	1

table 2.5 continued

			1900 - 1910					
A. size class	1	2	3	4	5	6	7	8
1	150,306	94,402	0	0	0	0	0	0
2	2,454	617,390	142,650	0	0	0	0	0
3	0	0	816,421	159,034	0	0	0	0
4	0	0	6,860	871,550	100,570	52,251	0	0
5	0	0	0	0	349,153	106,154	0	0
6	0	0	0	0	0	297,068	0	0
7	0	0	0	0	0	0	124,385	277,431
8	0	0	0	0	0	0	0	1,035,594

			1900 - 1910					
B. size class	1	2	3	4	5	6	7	8
1	79	34	0	0	0	0	0	0
2	1	162	26	0	0	0	0	0
3	0	0	113	14	0	0	0	0
4	0	0	1	50	3	1	0	0
5	0	0	0	0	8	2	0	0
6	0	0	0	0	0	4	0	0
7	0	0	0	0	0	0	1	1
8	0	0	0	0	0	0	0	2

			1910 - 1920					
size class	1	2	3	4	5	6	7	8
1	84,797	95,997	22,700	0	0	0	0	0
2	4,465	625,709	178,814	0	0	0	0	0
3	0	4,367	893,579	210,488	0	0	0	0
4	0	0	0	1,036,042	134,380	84,856	0	0
5	0	0	0	0	249,500	275,883	0	0
6	0	0	0	12,358	0	457,933	0	0
7	0	0	0	0	0	0	147,466	0
8	0	0	0	0	0	0	0	1,582,292

			1910 - 1920					
size class	1	2	3	4	5	6	7	8
1	44	33	3	0	0	0	0	0
2	2	162	32	0	0	0	0	0
3	0	1	121	18	0	0	0	0
4	0	0	0	59	4	1	0	0
5	0	0	0	0	6	5	0	0
6	0	0	0	1	0	6	0	0
7	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	3

			1920 - 1930					
size class	1	2	3	4	5	6	7	8
1	49,138	64,432	0	0	0	0	0	0
2	2,484	619,487	206,054	11,852	0	0	0	0
3	0	4,982	963,593	301,824	0	0	0	0
4	0	0	0	1,183,666	238,990	0	0	0
5	0	0	0	0	249,831	214,097	0	0
6	0	0	0	0	0	689,321	228,098	0
7	0	0	0	0	0	0	168,535	0
8	0	0	0	0	0	0	0	1,808,446

			1920 - 1930					
size class	1	2	3	4	5	6	7	8
1	24	22	0	0	0	0	0	0
2	1	158	36	1	0	0	0	0
3	0	1	130	25	0	0	0	0
4	0	0	0	71	7	0	0	0
5	0	0	0	0	6	4	0	0
6	0	0	0	0	0	10	2	0
7	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	3

table 2.5 continued

A. size class	1930 - 1940							
	1	2	3	4	5	6	7	8
1	24,964	38,087	5,061	0	0	0	0	0
2	2,462	581,465	191,405	0	0	0	0	0
3	0	0	1,130,989	177,832	0	0	0	0
4	0	0	19,025	1,444,609	239,730	0	0	0
5	0	0	0	0	464,999	101,677	0	0
6	0	0	0	0	0	1,000,585	113,126	0
7	0	0	0	0	0	0	467,879	0
8	0	0	0	0	0	0	0	1,980,801

B. size class	1930 - 1940							
	1	2	3	4	5	6	7	8
1	11	13	1	0	0	0	0	0
2	1	146	34	0	0	0	0	0
3	0	0	150	16	0	0	0	0
4	0	0	2	88	7	0	0	0
5	0	0	0	0	11	2	0	0
6	0	0	0	0	0	13	1	0
7	0	0	0	0	0	0	3	0
8	0	0	0	0	0	0	0	3

size class	1940 - 1950							
	1	2	3	4	5	6	7	8
1	1,822	29,782	6,005	0	0	0	0	0
2	0	445,586	277,953	0	0	0	0	0
3	0	12 658	1,040,561	497,466	0	0	0	0
4	0	0	0	1,759,032	133,381	0	0	0
5	0	0	0	0	629,435	172,214	0	0
6	0	0	0	0	0	839,582	444,011	0
7	0	0	0	0	0	0	681,578	0
8	0	0	0	0	0	0	0	2,074,889

size class	1940 - 1950							
	1	2	3	4	5	6	7	8
1	1	10	1	0	0	0	0	0
2	0	108	51	0	0	0	0	0
3	0	3	139	45	0	0	0	0
4	0	0	0	100	4	0	0	0
5	0	0	0	0	15	3	0	0
6	0	0	0	0	0	11	4	0
7	0	0	0	0	0	0	4	0
8	0	0	0	0	0	0	0	3

size class	1950 - 1960							
	1	2	3	4	5	6	7	8
1	0	2,539	0	0	0	0	0	0
2	0	287,759	303,055	0	0	0	0	0
3	0	0	1,171,105	365,157	0	0	0	0
4	0	0	9,986	2,413,098	244,101	0	0	0
5	0	0	0	0	432,040	511,316	0	0
6	0	0	0	0	0	854,214	312,527	0
7	0	0	0	0	0	0	1,005,800	254,186
8	0	0	0	0	0	0	0	2,211,553

size class	1950 - 1960							
	1	2	3	4	5	6	7	8
1	0	1	0	0	0	0	0	0
2	0	67	54	0	0	0	0	0
3	0	0	158	33	0	0	0	0
4	0	0	1	137	7	0	0	0
5	0	0	0	0	10	9	0	0
6	0	0	0	0	0	11	3	0
7	0	0	0	0	0	0	7	1
8	0	0	0	0	0	0	0	3

table 2.5 continued

A. size class	1960 - 1970 1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	376,422	20,914	0	0	0	0
3	0	0	1,165,564	684,121	0	0	0	0
4	0	0	8,871	2,740,014	657,823	0	0	0
5	0	0	0	0	502,049	295,577	0	0
6	0	0	0	0	0	1,413,834	101,221	0
7	0	0	0	0	0	99,792	1,347,701	0
8	0	0	0	0	0	0	0	2,347,628

B. size class	1960 - 1970 1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	66	2	0	0	0	0
3	0	0	157	56	0	0	0	0
4	0	0	1	150	19	0	0	0
5	0	0	0	0	12	5	0	0
6	0	0	0	0	0	19	1	0
7	0	0	0	0	0	1	9	0
8	0	0	0	0	0	0	0	4

size class	class boundaries
1	≤ 2,500
2	2,500 - 5,000
3	5,000 - 10,000
4	10,000 - 30,000
5	30,000 - 50,000
6	50,000 - 100,000
7	100,000 - 250,000
8	250,000 - 1,000,000

360,873 to 387,429.

The proportion of the population moving from one size class to another size class may be expressed by calculating the ratio of this population with the row total, which is in this case 0.15. Consequently every row sum total of ratios is equal to one and a stochastic process may be described by giving these ratios a probability interpretation. These ratios are summarized in table 2.6, in which only the probability of staying within one's size class has been recorded, enabled by the fact that not one transition matrix showed a retardation to a previous size class and the forward movement comprised in any case only one size class leaving the difference of the tabled figure with one, to its next higher size class. Analysis of table 2.6 indicates: (1) that the pattern displayed by the transition probabilities over time is of a rather fluctuating nature, and (2) that it is not possible to enter every other state (size class), given a certain passage time, from any initial state, which is a feature of an absorbing Markov-chain. The latter condition is partly reflected by the ones in table 2.6 indicating the probability of staying within a size class once entered and the fact that it is not possible to move from a larger size class to a smaller one. These two features of the transition possibilities are in contradiction with the necessary requirements for regular Markov-chain analysis[44.], as is used quite often in demographic analysis[45.]. Although extension to other Markov methods is possible by using a function allowing for variable transition probabilities[46.], both the absorbing characteristics and the emphasis on process description and not on projection may be used as arguments against further explorations along this avenue.

In a joint interpretation of tables 2.5 and 2.6 one has to bear in mind, that the transition probabilities related to the number of towns by size class are of about the same order of magnitude as the transition probabilities related to the population within these places, recorded in table 2.6. The mere difference in numbers may be striking, but at the movement of one town, a concurrent movement occurs of a population number of at least the size of the lower boundary of the next class.

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44. Kemeny, J.G. and J.L. Snel, Finite Markov Chains, Van Nostrand Reinholt Company, New York, 1960.

45. Rogers, A., Matrix analysis of interregional population growth and distribution, University of California Press, Berkeley, 1968.

46. Gilbert, G., Two markov models of neighborhood housing turnover, Environment and Planning, 1972, Vol.4, pp.133-146.
Bell, E.J., Stochastic analysis of urban development, Environment and Planning, 1975, Vol.7, pp.35-39.

table 2.6 Transition ratios of the population by size class, indicating the probability of staying within one size class at successive time periods *

Size class**	1840/50	1850/60	1860/70	1870/80	1880/90	1890/1900
1	0.83	0.85	0.83	0.80	0.83	0.79
2	0.83	0.88	0.88	0.83	0.86	0.79
3	0.84	0.83	0.93	0.82	0.85	0.88
4	1.00	0.81	0.94	1.00	0.76	0.91
5	1.00	1.00	1.00	1.00	0.26	1.00
6	0.53	1.00	1.00	0.39	1.00	0.70
7	1.00	0.34	1.00	1.00	1.00	0.38
8	0.00	0.00	1.00	1.00	1.00	1.00

Size class**	1900/10	1910/20	1920/30	1930/40	1940/50	1950/60	1960/70
1	0.61	0.42	0.43	0.37	0.05	0.00	0.00
2	0.81	0.77	0.74	0.75	0.62	0.49	0.00
3	0.84	0.81	0.76	0.86	0.67	0.76	0.63
4	0.85	0.83	0.83	0.85	0.93	0.90	0.80
5	0.77	0.47	0.54	0.82	0.79	0.46	0.63
6	1.00	0.97	0.75	0.90	0.65	0.73	0.93
7	0.31	1.00	1.00	1.00	1.00	0.80	0.93
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00

* see text for explanation

** the same class boundaries have been used as in table 2.5

Thus, a careful interpretation of these figures is necessary, even in cases where large numbers are involved[47].

Three points emerge from the analysis of tables 2.5 and 2.6 sustaining the interpretation of table 2.4. First, the observed stability (in table 2.4) of the number of towns in the second size class is caused by transitory movements of about the same order of magnitude to and from this class till about 1930, while already two decades earlier the rate of growth increased and this is reflected by the decreasing probabilities in table 2.6.

Second, the same decrease may be noted with respect to the transition ratios in the third size class since 1930, but the same order of magnitude in the transition rates for both size classes is more surprising, especially if one takes into account the difference in width of the two size classes. The number of places joining the fourth size class (10,000 - 30,000) is, however, about three times as large as the number moving up to the next higher size class. Notwithstanding this contrast in numbers, the total population affected by this growth process is often in the same order of magnitude, because the cities joining have the smallest size and those leaving, the largest. These two different processes with respect to this size class balance each other and suggest a stability in the aggregate analysis. The stability of the contribution of this class to the total population (see table 2.4) until 1900 indicates a rate of growth which is parallel with the national growth rate. This congruent growth rate changes after 1900 and decreases even more rapidly since 1940, probably accounting for the somewhat higher transition ratios in the next size class, because a lot of small towns have joined from the bottum up.

A comparison of the transition probabilities of the third class with those of the fourth (10,000 - 30,000) indicates a higher overall mobility in the former size group, which is rather interesting but this might be due to a smaller width of the interval of the third size group. An argument which can be sustained by recalling the discussion on proportional growth in the previous section, in which it is stated that (for closed systems) the rate of growth is unrelated to size or may be even negatively correlated[48].

A third point of interest is the rate of depletion of the first and the fifth size class, which speeded up after 1900. The latter size class shows a very contrasting picture with the first part of the whole period with a rather stable pattern, as compared with the highest transition rates of all size classes in the

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[47] Wrigley, N., The use of percentages in geographic research, Area, 1973, Vol.5, pp.183-186.

[48] Kalecki, M., On the Gibrat distribution, Econometrica, 1945, pp.161-170.

second part, of course with the exception of the first size class. The transition probabilities are even lower than those of the second size class, which has to be empty at the end of the period. These observations sustain the conclusions made earlier, about the instability of the size class of places having a population between 30,000 and 50,000 inhabitants.

In conclusion it can be said that both the analysis of the cross-sectional information and the analysis of transition ratios together with the transition matrices of absolute change indicate: (1) the existence of two periods of acceleration in growth rates. First of all, the turn of the century characterized by an overall increase in growth rates and secondly, the period 1920-1930 after which the whole process gained even more momentum. (2) The strong position of the fourth size class (10,000 - 30,000) as a stable class in the lower size brackets, and the contrasting weak position of the next higher group of 30,000 - 50,000 which may be characterized by high transition ratios in combination with a relatively small proportion of the total population within its class boundaries.

2.6 Individual growth paths

A common criticism of a classification using size classes is the arbitrary nature of the selected class boundaries, which imposes a certain rigid structure on the data analyzed. In his study of city distributions, Tiedemann[49.] proposed a division into equal size categories around each city and allowing cities of approximately the same size to fall into the same size class. As his procedure is applicable to all cities within the considered total range, the class boundaries are not mutually exclusive any longer and a city can belong to more than one size class. This leads, in the final analysis, to as many classes as there are cities taken into account and consequently each city creates its own unique class with flexible boundaries on both sides. From such a categorization scheme towards the analysis of individual growth rates of cities one has only to take a small step.

An idealized growth pattern of city growth is often discussed in terms of logistic growth, which is graphically depicted by a S-shaped curve. From a preliminary investigation, which is reported below, it appeared that this type of growth path is, however, not existent for the 502 municipalities under study, while the other general type of growth curve, describing exponential growth, seems to be the prevalent type. The latter growth curve emerged as possessing the closest degree of

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49. Tiedemann, C.E., On the classification of cities into equal size categories, Annals of the Association of American Geographers, 1968, Vol.58, pp.775-786.

fit with the actual growth pattern from three types analyzed. The first type is the logistic growth curve in which the decennial growth rates are of interest[50.] and these are related to the population at the beginning of each decade. Instead of an emphasis on relative change, the second focusses on the absolute change per decade which is related directly to time. A comparison of these two growth patterns revealed a considerable better 'goodness of fit' by least-square estimation procedures for the second approach. The exponential growth equation of the third type, $y = be^{\alpha t}$, showed the best performance for all 502 municipalities, by which only the growth path of 16 municipalities is poorly described, all having correlation coëfficients below 0.80.

An analysis of the individual growth curves and the size of these 16 places indicates that they all belong to the smallest size class (5,000 - 10,000), with the exception of two municipalities in the province of Friesland which are just above the upper limit and two distinct growth patterns may be identified. A convex growth path emerged for 7 municipalities located all in the province of Friesland, having their maximum population in the period 1890-1900. The total area of each of these municipalities is probably the cause for their incorporation in this study as they are all situated in the Northern and Western fringe of Friesland, having the lowest growth rate (see fig.2.3) and being contiguous to the smaller areas in the North which are not considered. The other nine municipalities are scattered over the map possessing a near stationary population number over time, and they experience a very rapid population growth in the period 1950-1970, when their population doubles, in some cases even triples. The parameter α from the exponential growth equation, $y = be^{\alpha t}$, may be considered as a generalized growth statistic and thus can be used to describe the growth for each municipality based on its own individual time series. To use the estimated value for α for other than descriptive purposes is completely unjustified, because of the systematic nature of the deviations in the residuals when actual and 'predicted' values are compared. Both the left hand and the right hand tail of the fitted curve show positive residuals, while the middle values show negative signs for the nearly all time series considered, implying a non-linearity of the log-transformed data and the function used is consequently a poor predictor[51.].

The plotted values of α do not display a tendency towards clustering on a scattergram, but show instead a rather uniform distribution, which has been divided

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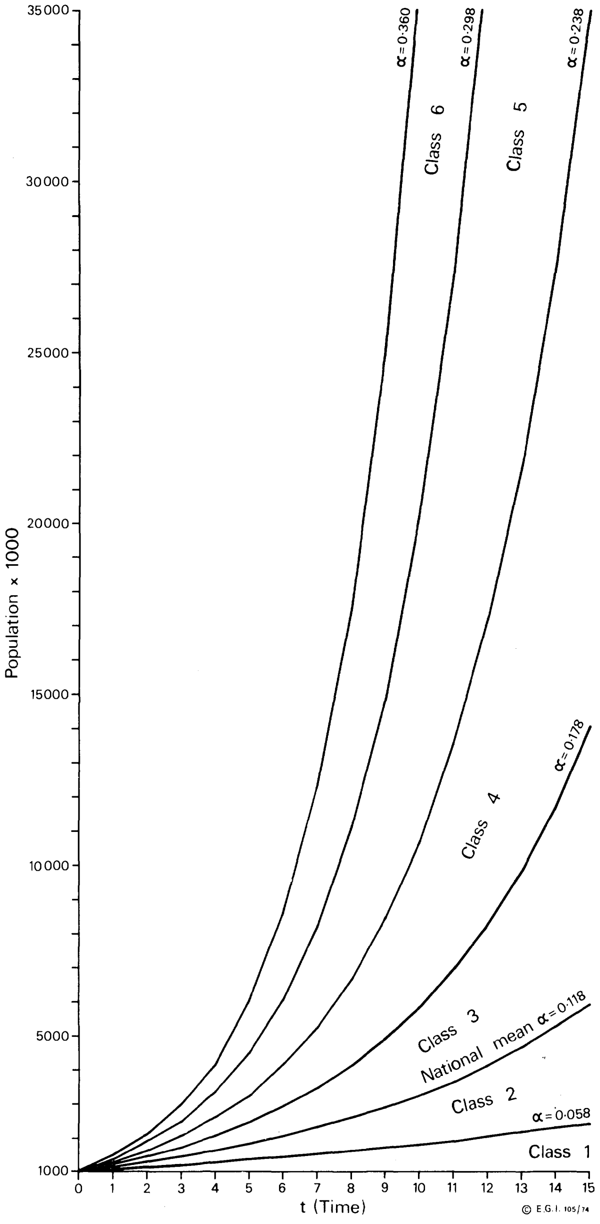
50. Goris, H., Inleiding in de econometrie, Oosthoek, Utrecht, 1972, pp.26-37.

51. Related problems are discussed in Taylor, P.J., Distance transformation and Distance Decay Functions, Geographical Analysis, 1971, Vol.3, pp.221-238.

Fig. 2.2 Exponential growth behaviour for different values of α ($y = be^{\alpha t}$; b = 1000)



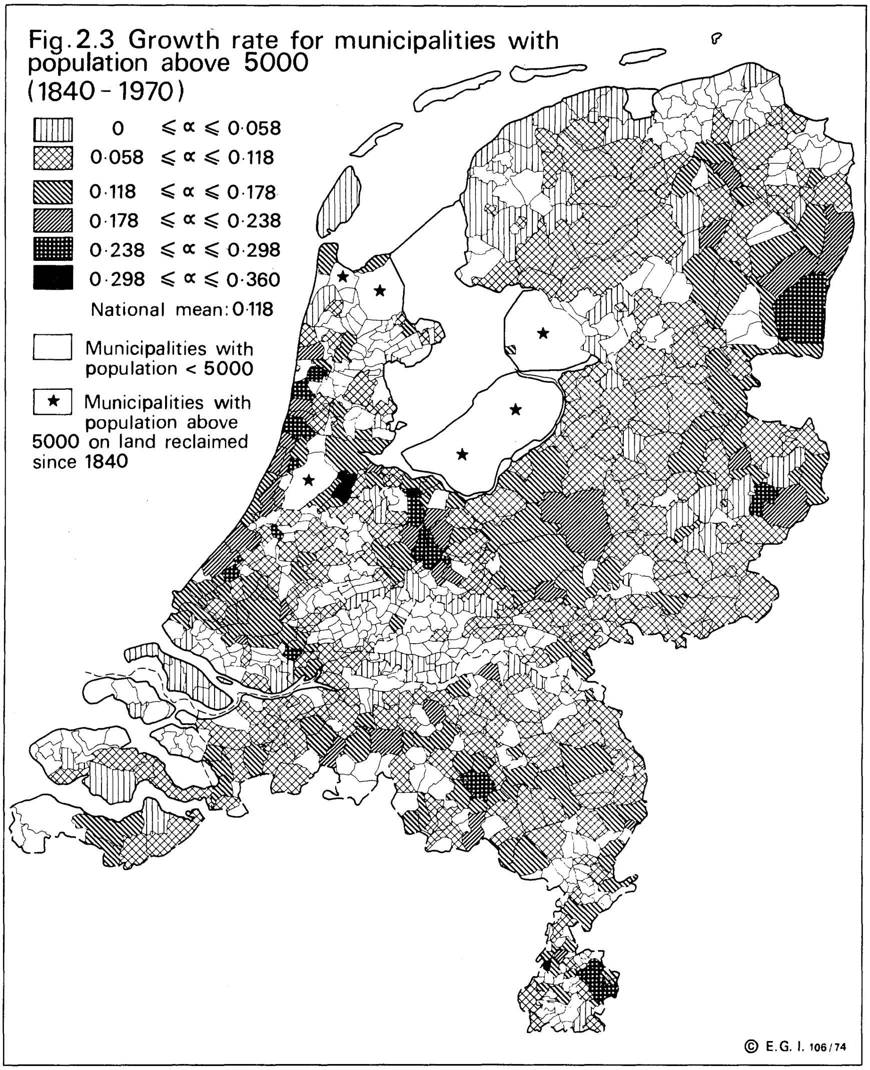


Fig.2.3 Growth rate for municipalities with population above 5000 (1840-1970)

into six equal size categories with the average national growth rate as one of the boundaries. The interval width of 0.06 is on average at least five times as large as the estimated values of the standard deviations of the α-values and the six classes thus derived may be considered as meaningful units for the description of the individual growth behaviour of the municipalities. The resulting types and associated growth patterns are shown in fig.2.2 for a place with 1,000 inhabitants in 1840, while the national figure is also shown being the upper boundary of the second class. When the six classes are mapped two patterns emerge (see fig.2.3): (1) The areas with a 1970 population below 5,000 are mainly concentrated along the Northern edge, in the central area and the Southwest of the country, as discussed earlier above. The total population of these 'white' areas is less than 10 per cent of the total population of the Netherlands, but they cover quite a larger proportion of the national area, indicating a considerable concentration of the rest of the population in more urbanized areas. (2) A number of major growth areas is closely associated with both the main urban centres themselves and heavily suburbanized areas, but these two components cannot be directly separated from the map alone.

The fastest rate of growth of the whole country occurs in the surroundings of the Amsterdam area with the two municipalities from the top class, Amstelveen and Bussum[52.]. These places are of a completely different nature, where Amstelveen, situated on the Southern border of Amsterdam, may be conceived as an example of a town growing because of overspill of population and employment, while Bussum is much easier identified with a dormitory suburb. The latter municipality is part of a larger area, which is mainly devoted to residential land use and related developments and is shown on the map by relatively high growth rates.

The second area of high growth rates stretches along the North Sea coast and is a mixture of large city growth located in this area, e.g. Rotterdam, The Hague and Haarlem, related suburban development as in Rijswijk, Heemstede and Castricum in the Northern part, and industrial development as occurred in Velzen, with its related iron and steel industry. The three main centres of rapid growth outside this area are situated in the Eastern half of the country and its growth is also related to industrial development, which started in these areas after the beginning of the 20th

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52. The third place with the highest growth rate is Elsloo in the province Limburg, but this rate is due to a misfit as discussed earlier, because of its slow near linear growth till 1950 and a sudden doubling of the population in the last two decades.

century[53.]: (1) the resource-based coal-mining and carbo-chemical industries of Southern Limburg, (2) the manufacturing industries of the Eindhoven area based on electric engineering, textile and metal industries, and those of Eastern Overijssel, and (3) the stimulated industrial development in the North, in which the Emmen municipality has been the most successful 'growth pole' in attracting industry, especially metal and textile manufacturing. Already developing in the late 19th century, the latter type of industry has also been very important until recently in the growing centres of the province Overijssel, making up a semi-circle in the Eastern part of this province and the urban-industrial development in the Western part of the province North-Brabant.

Although quite a large proportion of the growth pattern shown on the map may be associated with the growth of urban areas, not all urban areas fall in the higher growth categories, like the city of Leiden in the province South-Holland or Leeuwarden, the provincial capital of Friesland, which show a growth rate below the national average. Another important feature of this map is the coincidence of two different growth patterns at the same time, i.e. the long-term pattern of urban growth and residential suburban development, which is a well-known feature of the area Southeast of Amsterdam, for example, and the much more recent general process of suburbanization. The spatial separation of these two trends is not a simple matter, because the same areas may be affected by both types of developments and the observed growth is induced by decentralization of both industrial and residential land use.

2.7 Conclusions

The description and analysis of the evolution of the urban system as a population system has been the major research question in this chapter. To study this question effectively over a period as long as a century, both the spatial and functional characteristics of a city were considered. It was decided that for the purpose of understanding the present state of the system a retrospective analysis was most appropriate. Thus, the urban system was defined as a closed system on the basis of the areal definitions of 1970 and the lowest (functional) threshold size, viz. the 1970 municipal boundaries and a minimum population size of 5,000 inhabitants.

[53.] See for a recent statement of the industrial structure of the Netherlands Hauer, J., G.A.van der Knaap, M. de Smidt, Changes in the industrial geography of the Netherlands during the sixties, Tijdschrift voor Economische en Sociale Geografie, 1971, Vol.62, pp.139-156.

POPULATION GROWTH AND URBAN DEVELOPMENT

The urban population system was studied at three levels of aggregation to examine the degree in which the spatial distribution of the city changes with respect to their size and their growth behaviour within the system of cities. Changes in the state of the system as a whole were analyzed on the basis of the decennial rank-size distributions. It appeared that there was a decreasing dominance of the largest cities in the system until 1910. This was partly caused by the rapid growth of the population of the smallest cities over the period 1840-1910. A subsequent cross-temporal comparison revealed that the nature of the population redistribution within the system was such that the three largest cities contained about 25 per cent of the total population in 1910. Thus, over the first part of the period the total growth effect was felt in a different way in the largest and the smallest centres of the city system. The latter centres grew at a higher rate than the system as a whole, while the former experienced the largest increase in total population.

In the cross-temporal analysis of the urban population system by size class we dealt with both the number of cities by size class and the total population of these cities for each size class. The changes over time were studied by a cross-sectional comparison of each decennial distribution and by the analysis of the rates of change between decades. The combined results of these analyses indicated two important features of the size distributions, viz. one was related to the dynamics of the growth process and the other pointed at a distributional characteristic. The growth process seemed to have accelerated twice. This happened for the first time around the turn of the century and for the second time after 1920. When the size distributions were examined from this perspective, the fourth size class (10,000 - 30,000) emerged as a stable class over time. Its neighbouring class (30,000 - 50,000), however, appeared as a class which is characterized by rather small transition ratios, indicating a rather unstable class structure.

Finally, the spatial distribution and allocation of the population growth over the period was studied by considering the centres individually. Each centre was classified according to its rate of growth over time based upon an exponential growth path. When these classes were mapped a number of growth areas emerged, which can be identified as containing the main urban centres and the heavily suburbanized areas. It appeared that two different growth processes are reflected in the parameters which gave rise to this spatial pattern, viz. the long-term pattern of urban growth and the more recent general process of suburbanization.

The analysis of the evolution of the urban population system focusses on the spatial outcome of a highly complex process of urban systems growth. Considering the results summarized above, a question of immediate relevance can be raised as to the way in which this process of growth is initiated, stimulated and distributed through the urban system. More specifically one can raise questions about the linkage structure in the urban system, the kind of linkages, their evolution, as well as about the role of the provision linkages, e.g. physical infrastructure, and their impact upon the process of urban growth. It will be those questions which are the subject of the analysis in the next chapter and in this respect these two chapters are fully complementary to each other.

3. THE DEVELOPMENT OF TRANSPORT NETWORKS AND URBAN GROWTH, 1840-1970

3.1 Introduction

Many sectors of the national economy have experienced an era of unprecedented growth over the period 1840-1970. This process of growth is reflected in the changing nature of the relations between towns and their rural hinterlands, as well as in the relations between towns and cities. Initially, one notes the increasing 'agriculturization' of the countryside as the traditional cottage industry collapsed under the heavy competition of the fast growing urban manufacturing industries and changes occur in the traditional trade relationships. Concurrently, rapid urban growth can be witnessed both in the old established and in the new emerging industrial towns, concomitant with increasing levels of production[1].

One of the consequences of changing trade patterns and higher levels of production is an increasing demand for transportation, which cannot always be met by the existing transport system. An increase in demand for transportation within the same spatial structure requires an increase in transport capacity. Initially, an extension of transport capacity can be provided by increasing the trip frequencies between points of origin and destination. However, because of the physical nature of transport systems, the latter solution can only provide temporary relief. In a situation of sustained higher demand levels an increase in capacity per haulage will be offered and lower prices per ton/mile will be the consequences. In addition to this development the network itself may need adjustments to meet the increase in transportation. These changes do not take into account important factors like the possible competition with other modes of transport, a changing technological environment and the introduction of innovations in transportation. Each of these elements influence both the nature of the transport system as a whole, its spatial orientation, and the structure of the urban system, as the external exchange between elements of this system is an important feature of its coherence.

The relationship between transportation, regional development and urban growth is usually discussed within this context, but there still does not exist a clear and consistent theory of transport structure and development. "What we have are a few puzzling and often contradictory glimpses of spatial structures and processes that seem to be related to each other in something more than a random

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[1] Pred, A.R., The spatial dynamics of U.S. urban industrial growth, 1800-1914, Regional Science Study Series, No.6, Cambridge, Massachusetts, 1966.

fashion"[2]. In the following discussion some of the questions indicated above will be analysed in more detail. First of all, the nature of the investments in transportation is of interest. Is there a difference over space and time with respect to the various modes of transportation? Are these differences associated with the availability of technological innovations and their different rate of occurrence over space and time? The second type of questions tries to relate urban population growth to the development of transport system. This analysis will be partly based on the discussion and material presented in the preceding chapter.

3.2 Investments in transport networks

The effects of investments in transportation cannot only be related to the different purposes they serve, but they are also associated with the spatial context in which they are made. Sometimes investments in transport serve to create new economic opportunities, while on other occasions they may enlarge existing ones in response to economic change, or reduce levels of economic activity in some regions. The first type of investments are often made to increase the existing resource base of a country by opening up new territories for exploitation by reducing existing transport costs or by increasing the accessibility of economically depressed areas. The attempt to improve a regional economy by investments in transportation is by no means always stimulating to the economic development of the depressed areas themselves[3]. These areas cannot be considered as isolated regions, but are components of a larger regional system with an already existing communication structure.

The strong emphasis on transport investments one find in many development programs nowadays is based on the rather restrictive set of assumptions of classical location theory[4], in which the dynamics of urban-industrial growth and agglomeration economies are not incorporated. This argument can be extended to central place theory from which a spatial system of cities can be derived making use of the assumption that accessibility to all points in the system is equal in all

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[2] Taaffe, E.J. and H.L. Gauthier, Geography of transportation, Prentice-Hall, Englewood Cliffs, New Jersey, 1973, p.72.

[3] Hale, C.W. and J. Walters, Appalachian regional development and the distribution of highway benefits, Growth and Change, 1974, No.1, p.9.
Kühn, J.A. and J.G. West, The Ozarks, Highways and regional development, Growth and Change, 1970, No.1, p.23.

[4] Hansen, N.M., How Regional Policy can benefit from Economic Theory, Growth and Change, 1970, No.1, p.23.

directions. Thus, such a structure does not allow for variations in mode of transport for different directions, which in turn influences the spatial structure and distribution patterns[5.]. A relaxation of the classical assumptions by introducing behavioural ones will give rise to a distortion of the theoretical identical communication/information structure. Incomplete information and different attitudes towards economic change by the decision takers are then becoming important factors influencing decisions in new transport capacity. This is reflected through differences in the evaluation of its potential, the availability of finance and the magnitude of possible benefits relative to alternative investments[6.].

At present, investments in transport infrastructure are generally considered as a component of social overhead capital provided by the government. This view on the financial source of infrastructural investments is less valid in the more liberal 19th century with its emphasis on private enterprise. In the first period of the development of the railway network in the Netherlands, for example, all investments and the exploitation were entirely dependent upon the initiative of the private entrepreneur. This situation changed after 1857, because in the previous twelve-year period about one hundred concessions for railway development were granted, but none of the entrepreneurs appeared to be successful in the construction of the planned railroads[7.]. This being the case, the Dutch government decided to take the responsibility for the construction of an integrated network covering the whole of the Netherlands. The operation of the railway, however, was carried out by private enterprise.

The construction of tramways, having a much more regional character, started around 1880 and this was carried out by a host of small regional and local companies. Some of these disappeared rapidly again, while others were taken over by their competitors or more profitable companies[8.]. By now, very little is left from this development as most regional tramways disappeared in the late 1940s.

The development of the water-transport system is and has always been much more a matter for the national government that took initiative and was financially

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5. Johnston, R.J., Railways, urban growth and central place patterns, Tijdschrift voor Economische en Sociale Geografie, 1968, Vol.59, p.33.

6. Wilson, G.W., Towards a theory of transport and development, in Transport and Development, B.S. Hoyle, ed.,MacMillan, London, 1973, pp.210-216.

7. Jonckers Nieboer, J.H., Geschiedenis der Nederlandse Spoorwegen, Tjeenk Willink en Zn., Haarlem, 1907.

8. Sluiter, J.W., Beknopt overzicht van de Nederlandse spoor- en tramwegbedrijven, Brill, Leiden, 1961, pp.73-99, in which dates of the opening and closures of tramways and their routes are listed.

responsible directly or indirectly for investments in this sector. This may be illustrated by the construction of the Noord-Hollands canal in 1825 and the Voornse canal in 1831 to improve, respectively, the connections of Amsterdam and Rotterdam with the open sea. The North Sea canal and the New Waterway were constructed later to serve the same purpose.

In general one can state that the influence the national government exerted on the provision of social overhead capital grew rapidly since the second half of the 19th century. This influence was also extended into other sectors of the economy after the end of the first world war[9]. On the basis of the above argument it seems justifiable to use government expenditures for the construction and maintenance of transport facilities as a first approximation of the total amount of investments in this sector of the economy. In addition to this assumption, it can be argued, that the difference between the total amount invested in transport infrastructure and the government expenditures for this sector of the economy is decreasing over time. To make the investments in the various transport systems comparable with each other as well as over time, they have been expressed as a percentage of the total national budget over the period of interest[10] (see fig.3.1). Although these figures are only a reflection of the amount spent on the provision of physical infrastructure, they provide a means of evaluating their relative importance within a national context.

An examination of fig.3.1 indicates that for a period of fifty years (1860-1910) at least 5 per cent of the national budget was spent on the construction of transport networks. The greatest effort was made over the period 1860-1890, in which investments levels reached between 15 and 20 per cent of the national budget. As these figures represent the total relative amount of the investments in physical infrastructure, the contribution of the various subsectors is obscured. A question of considerable interest is, whether it is possible to differentiate between periods as regards subsectors of the transport system.

A decomposition of the total investments into three main subsectors, eg. roads, railways and waterways, reveals a distinct separation of these sectors over

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9. Keesing, F.A.G., De conjuncturele ontwikkeling van Nederland en de evolutie van de economische overheidspolitiek, 1918-1939, in Van stapelmarkt tot welvaartstaat, P.W. Klein, ed., Universitaire Pers Rotterdam, 1970, pp.94-108.

10. Handelingen der Staten Generaal, annual records of the national budget for the Ministry of Inland Affairs and the Ministry of Transportation, 1850 till 1970. From these records only the data pertaining to the maintenance and construction of railways, waterways and roads have been considered. Physical infrastructure in this respect relates only to the transport routes themselves, not to the rolling stock as well.

Fig. 3.1 Government expenditures in transportation (roads, railroads and canals) as a percentage of the national budget 1850 - 1970.

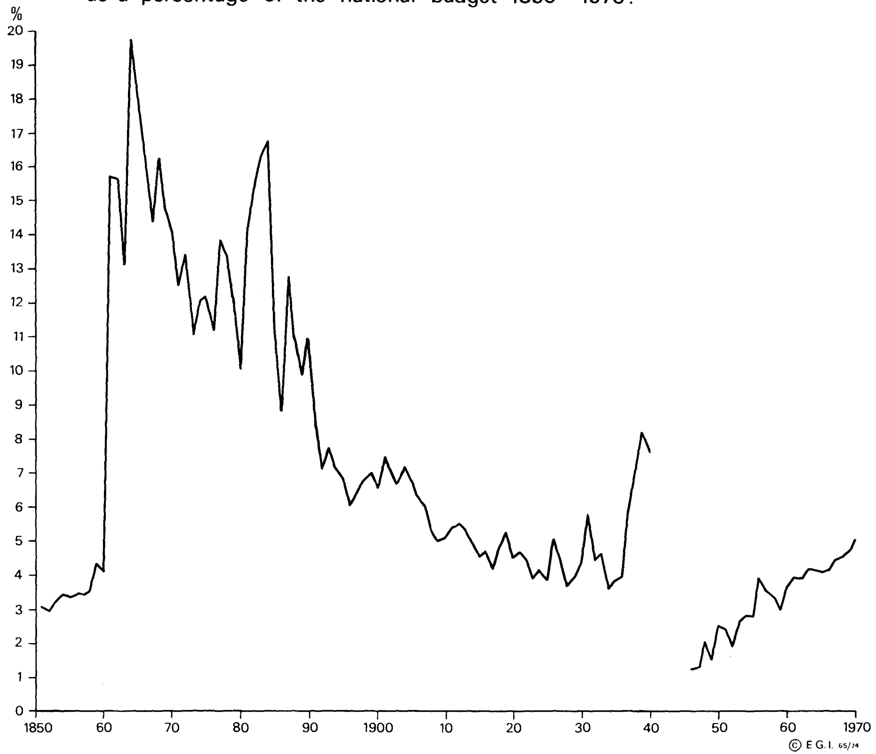
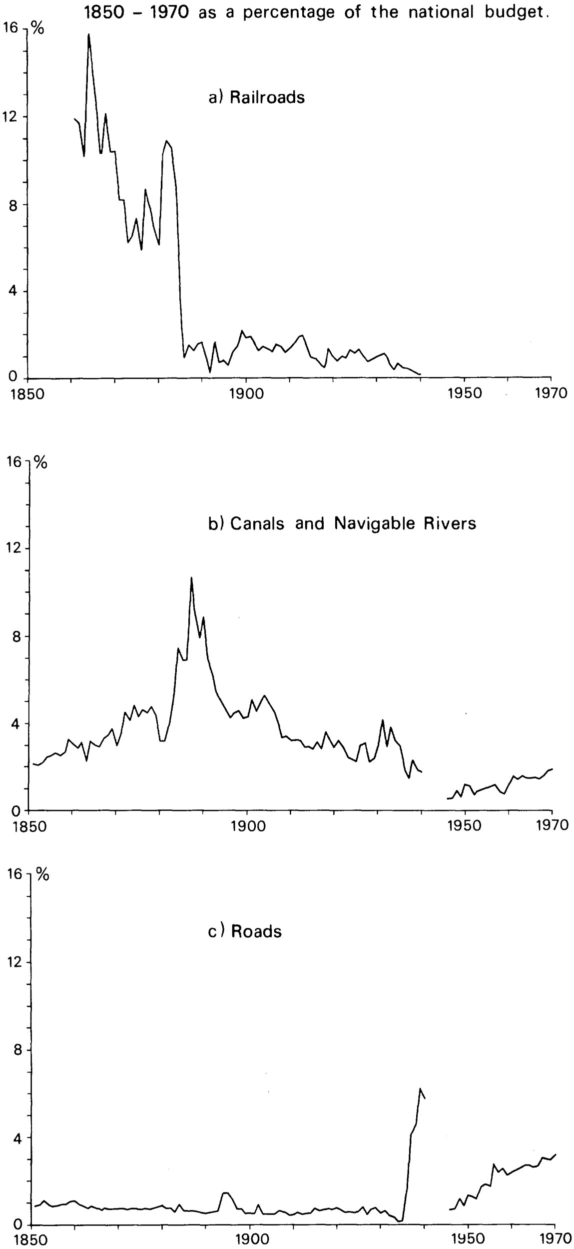


Fig.3.2 Government expenditures in transportation by sector, 1850 - 1970 as a percentage of the national budget.



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time (see fig.3.2), although some overlap is noticeable in the period 1880-1885. This decomposition suggests the occurrence of four relevant investment periods: (1) a railway period, 1850-1885, (2) a waterway period, 1885-1910, (3) an intermediate period, 1910-1935, in which investments in railways and waterways were relatively low, when compared with the previous periods, and (4) a road period, 1935-1940, although investments increased again after 1945 they never reached the pre-war level. In general it can be observed that the investments in the period 1945-1970, for all sectors together, have been lower on a percentage basis than those in almost any other year in the preceding century.

3.3 Innovations and periods

The introduction of innovations in transport technology and the periods identified in the previous paragraph are closely associated. Borchert emphasized in his study of the American metropolitan evolution three major innovations which can be associated with these periods[11.]: (1) the use of the steam engine in water and land transportation, (2) the appearance of abundant and low-priced steel, and (3) the introduction of the internal combustion engine in transportation. In the West European context the railroads were already known in the mining areas of Germany (Harz) and Austria (Tirol) from which already in the 17th century the principle diffused to England carried by migrating German miners. The diffusion of the railways, as a transport system, started after the famous locomotive competition at Rainhill near Liverpool in 1829, which marked the end of a period of experimentation on locomotive steam engines. Shortly thereafter, one can notice the construction of railways in a number of different locations on the European continent, like the lines between Prague and Lahna in 1830, Lyon - St.Etienne and Linz - Budweis in 1832, while in the low countries the line Brussels - Mechelen was opened for the public in 1835[12.].

The appearance of a railway line in the Netherlands does not occur before 1839, when a service between Amsterdam and Haarlem started operating. The earliest applications of steam engines in transportation, however, can be found in water transportation. This development occurs at the same time as the application of steel

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11. Borchert, J.R., American Metropolitan Evolution, Geographical Review, 1967, Vol.52, pp.301-332.

12. Godlund, S., Ein Innovationsverlauf in Europa, dargestellt in einer vorläufigen Untersuchung über die Ausbreitung der Eisenbahninnovation, Lund Studies in Geography, Ser.B., Human Geography, No.6, Gleerup, Lund, 1952, pp.3-4.

in the construction of Rhine-barges and tugboats. These inventions were introduced by a Dutch naval officer, Roentgen, who lived in Rotterdam and they have had a considerable impact on the evaluation of land against water transportation. Thus influencing the availability of risk capital in favour of the more traditional water-transport system. It is only the heavy competition of Belgium for the same hinterland trade with Germany, through the Antwerp - Cologne line, 1844, that serious efforts were made to build an Amsterdam - Cologne line[13.].

The absence of a process of rapid development in the Netherlands is probably due to the lack or, at least, the slow rate of economic growth in the first half of the 19th century[14.]. There is, however, a difference of opinion amongst economic historians about the occurrence of the "take-off" period of the Dutch economy. Some historians, like Brugmans, Pen and Bouwman, argue that this period occurs between 1850 and 1870, while others like Van Dillen and Wieringa consider the period 1895-1914 as the crucial period[15.]. The latter viewpoint is also dealt by De Jonge[16.], who analyzed the industrial development of the Dutch economy over the period 1850 to 1914. His emphasis was on the analysis of potential "leading" sectors in the take-off period, based on the stages theory formulated by Rostow. One of the pre-conditions for "take-off", according to this theory, is the investment in social overhead capital, while investments in this period may be already above 5 per cent of the national income[17.]. If one inspects fig.3.1 with Rostow's theory of economic growth in mind, then it is rather tempting to suggest that the period 1895-1905 is the base period before the "take-off", although it must be emphasized that such a situation is only one of the pre-conditions for "take-off". This period coincides with views hold by some Dutch economic historians as well as the increasing concentration of the Dutch population in a few urban centres as observed in the previous chapter.

[13.] Keuning, H.J., Het Nederlandse volk in zijn woongebied, Leopolds, Den Haag, 2nd edition, 1965, pp.477. See also, op.cit. 7, Jonckers Nieboer's account of the Dutch-Rhenish Railway Company from 1845, p.37 and p.52.

[14.] Van Stuyvenberg, J.H., Economische groei in Nederland in de negentiende eeuw, in Van Stapelmarkt tot Welvaartstaat, P.W.Klein, ed., Universitaire Pers Rotterdam, 1970, p.52.

[15.] Van Stuyvenberg, J.H., op.cit. 14, pp.59-60.

[16.] De Jonge, J.A., De industriële ontwikkeling van Nederland tussen 1850 en 1914, gezien in het licht van enkele facetten van de theorie van Rostow, in Van Stapelmarkt tot Welvaartstaat, P.W.Klein, ed., Universitaire Pers Rotterdam, 1970, p.81.

[17.] Rostow, W.W., The stages of economic growth: A non-communist manifesto, Cambridge University Press, London, 1960, pp.5-40.

The four periods which are identified on the basis of fig.3.1 and 3.2 will be used as a basis for further analysis in the rest of this chapter. First, the analysis of the spatial allocation of the investment in transportation may indicate the nature of the diffusion of the technological innovations over space. In using the intervals, which mark the beginning and the end of each period, emphasis is put on the overall development of the different transport subsectors and to a lesser degree on the spatial variations within one subsector. Second, the analysis of urban population growth and the investments in transportation can be associated with the particular feature of each period. In addition to this, the effect of the various subsectors will be studied over the whole period with respect to their possible differences in impact.

3.4 Spatial characteristics of network development

In the allocation of transport investments two kinds of spatial competition are of immediate relevance: (1) the competition between the various modes of transport, and (2) the competition between centres for access to the newly offered or improved modes of transportation. These two points are closely related as generally investments in new or improved transport systems require higher capital expenditures than a comparable development of existing transport systems. The analysis of the introduction of a new transport system and the improvement of existing transport structures, however, cannot be carried out within the same framework, as there are basically two different kind of processes under consideration. The introduction of a railway system, for example, can be considered as a diffusion process of which the railway network is the spatial outcome. The increase in barge capacity is, however, the result of changing economic conditions causing the marginal shipper to increase his minimum-sized transport capacity or else he has to leave the market. The same set of forces is also reflected spatially in an increase in the capacity of a section of the water-transport system. The expansion of the maximum capacity offered by a section of this system will finally reduce the total extent of the system as an economic system, because other sections will not be improved. Thus, contrasting to the case of the railway network, the diffusion of a technological innovation ultimately leads here to the retraction of the water-transport system.

In the description of the spatial development of a transport network one may recognize a number of typical stages as the network grows. Such a framework of reference is given by the ideal-typical sequence of events as discussed by Taaffe, Morrill and Gould, although the authors did not claim a universal validity for their model[18.]. The first phase of this sequence starts with the creation of a frontier line along the coast based upon small ports and trading centres. The next stage is the invasion of the interior by the creation of one or more penetration lines to interior centres. This stage is the most critical as it gives some coastal locations an initial advantage by reducing hinterland transportation costs and a process of regional specialization is initiated. Small centres begin to develop at intermediate locations along these lines and start to enlarge at the expense of other ports by the creation of feeder lines. In the next two stages the penetration lines become interconnected and some of the intermediate centres have grown and emerge as modes with a large number of interconnections.

The 'natural' regional economic environment for this type of model is the export base or the resource oriented type of regional economy[19.]. Such an economy is a characteristic feature of many regions in which the development of a transport network has been studied, such as North America, Australia[20.] or New Zealand[21.] In Europe, however, the growth of the economy was not dependent upon external demand, but more internally induced and the European situation can be characterized as a process of gradual growth from an agricultural towards an industrial economy. Such a process of growth is described by the term, sectoral growth[22.]. The evolution of the Dutch economy can be studied from this perspective and provides the relevant background for the discussion of the development of transport networks in the Netherlands. As with the introduction of a new transport system, such as the railways, one has to consider the existence of an already developed transport system and large mercantile cities. This situation provides the basis for a strong competition between transport systems and between cities.

[18.] Taaffe, E.J., R.L. Morrill and P.R. Gould, Transport expansion in underdeveloped countries: a comparative analysis, Geographical Review, 1963, Vol.53, pp.503-529.

[19.] North, D.C., Location theory and regional economic growth, Journal of Political Economy, 1955, Vol.63, pp.243-258.

[20.] Rimmer, P.J., The search for spatial regularities in the development of Australian seaports, 1861-1961/2, in Transport and Development, B.S. Hoyle, ed., MacMillan, London, 1973, pp.63-86.

[21.] Badcock, B.A., Central place evolution and network development in South Auckland, 1840-1968: A systems analytic approach, New Zealand Geographer, 1970, Vol.26, pp.109-135.

[22.] Tiebout, C.M., Exports and regional economic growth, Journal of Political Economy, 1956, pp.160-169, together with the rejoinders by North and Tiebout.

Railways

The initial emphasis on railway development, when compared with governmental expenditures in other transport sectors, reflects the complementary nature of the newly developing transport network. The growth of the network over the four periods under discussion is shown in fig.3.3 to fig.3.7. In Appendix I there is a brief discussion on the construction of the networks. The ring type structure, one observes in fig.3.3, connects the established urban centres in the Western part of the country, as Amsterdam, The Hague, Rotterdam and Utrecht and coincides approximately with the present-day shape of 'Randstad Holland'. The feeder line going east is developed to duplicate the existing water connection with the German hinterland. The initial development thus reflects the reinforcement of the existing urban structure[23.], which is also indicated by the fact that the Western part of the 'ring' was constructed first. The early location of the main centres on the new transport network created in this way an additional advantage, when compared with the other urban centres.

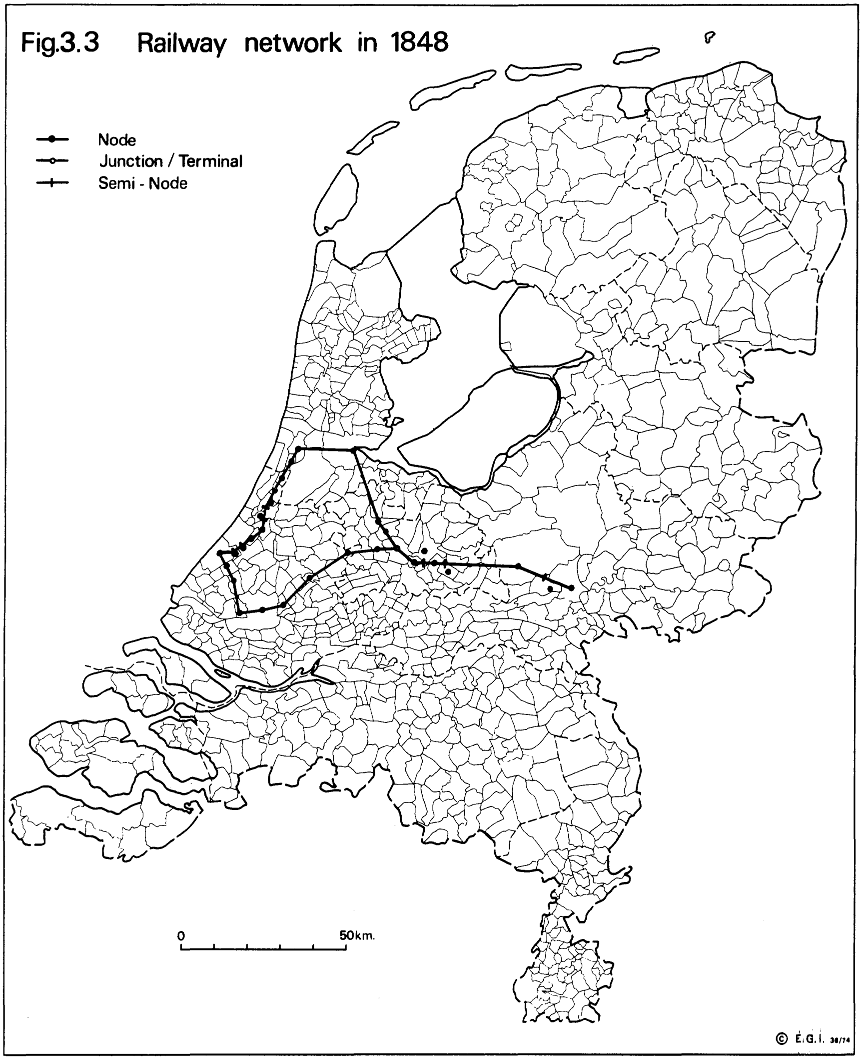
The extensions of the network constructed in the period 1850-1870, fig.3.4, connected both the emerging industrial towns in the Southern and Eastern part of the country and the agricultural North with the basic part of the network. In addition one may observe that the main orientation of these sub-networks is to the West and not to each other. The next stage in the development is the spatial integration of the network. This was the result of a deliberate government policy discussed earlier and virtually accomplished by 1915 (see fig.3.5). Although the network reached its largest physical extension by 1940 (see fig.3.6), there was no major change in the basic structure since 1915, as could be expected on the basis of the investments made in this period (see fig.3.2a). The final phase, 1970 (see fig.3.7), is already showing a retraction of the railway network in the rural fringes in the North.

Waterways

Contrasting to the expansion and spatial diffusion is the reduction and retraction of a transport network in a situation of sustained economic growth. Such a case is well illustrated by the development of the water-transport network (see fig.3.8 to fig.3.12). The structure of the network of waterways remains rather stable in the early period till 1870, though a few minor extensions can be observed.

[23.] Janelle, D.G., Transport innovation and the reinforcement of urban hierarchies, High Speed Ground Transportation Journal, 1974, Vol.8, pp.261-269.

Fig.3.3 Railway network in 1848



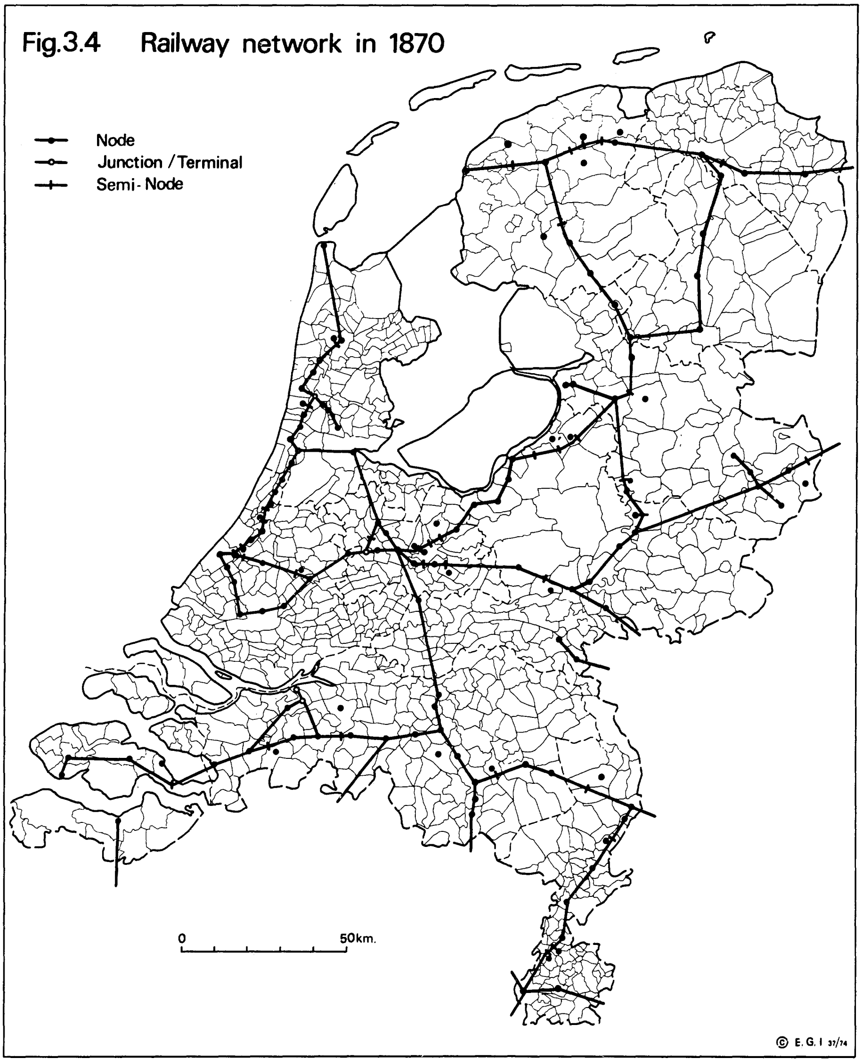


Fig.3.4 Railway network in 1870

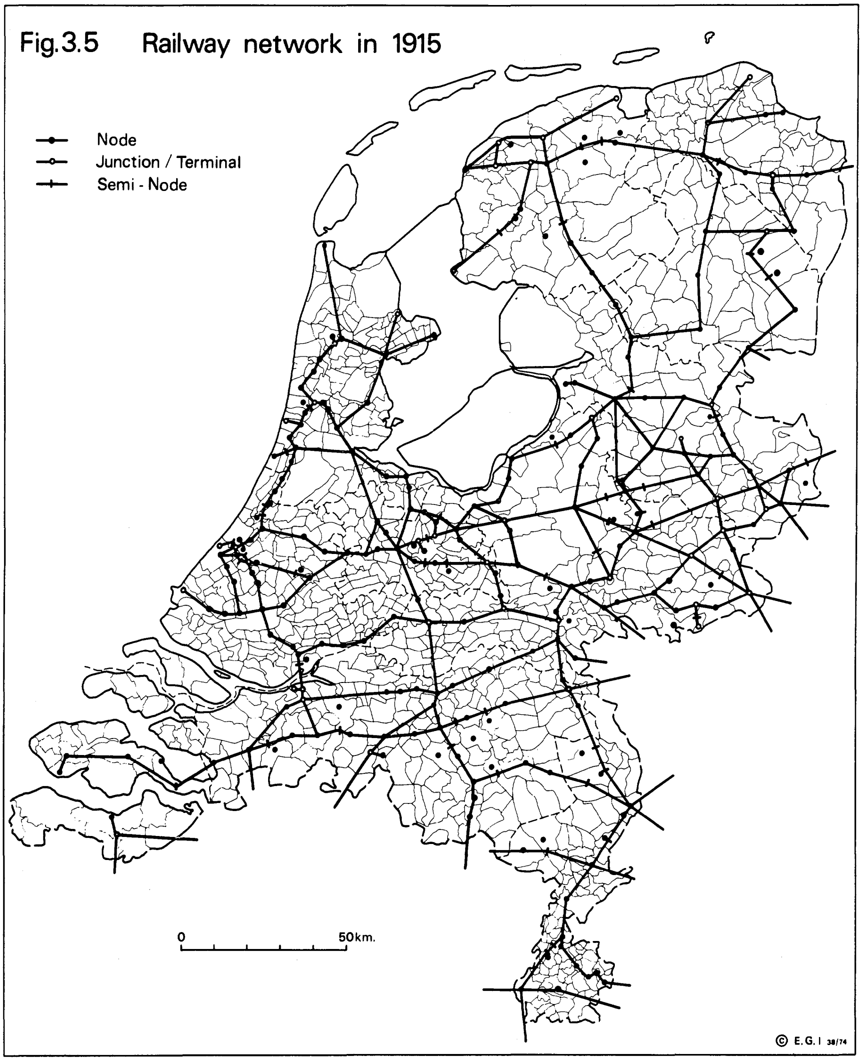
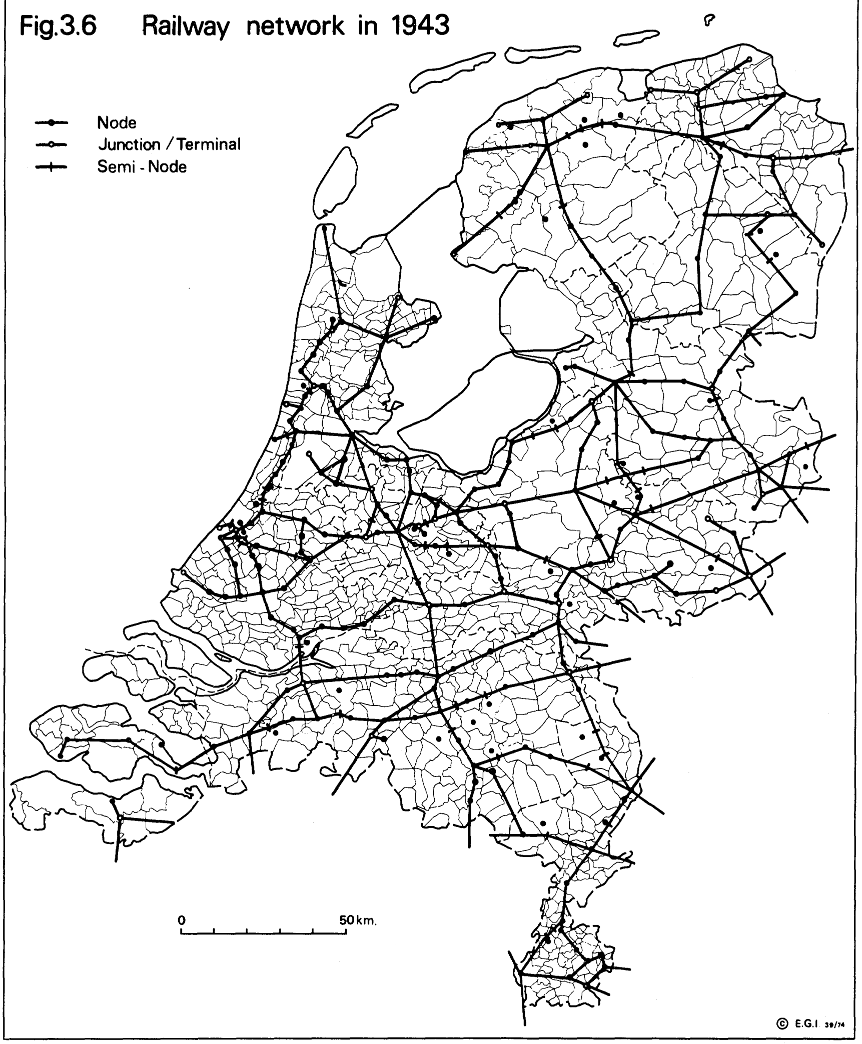


Fig.3.5 Railway network in 1915

Fig.3.6 Railway network in 1943



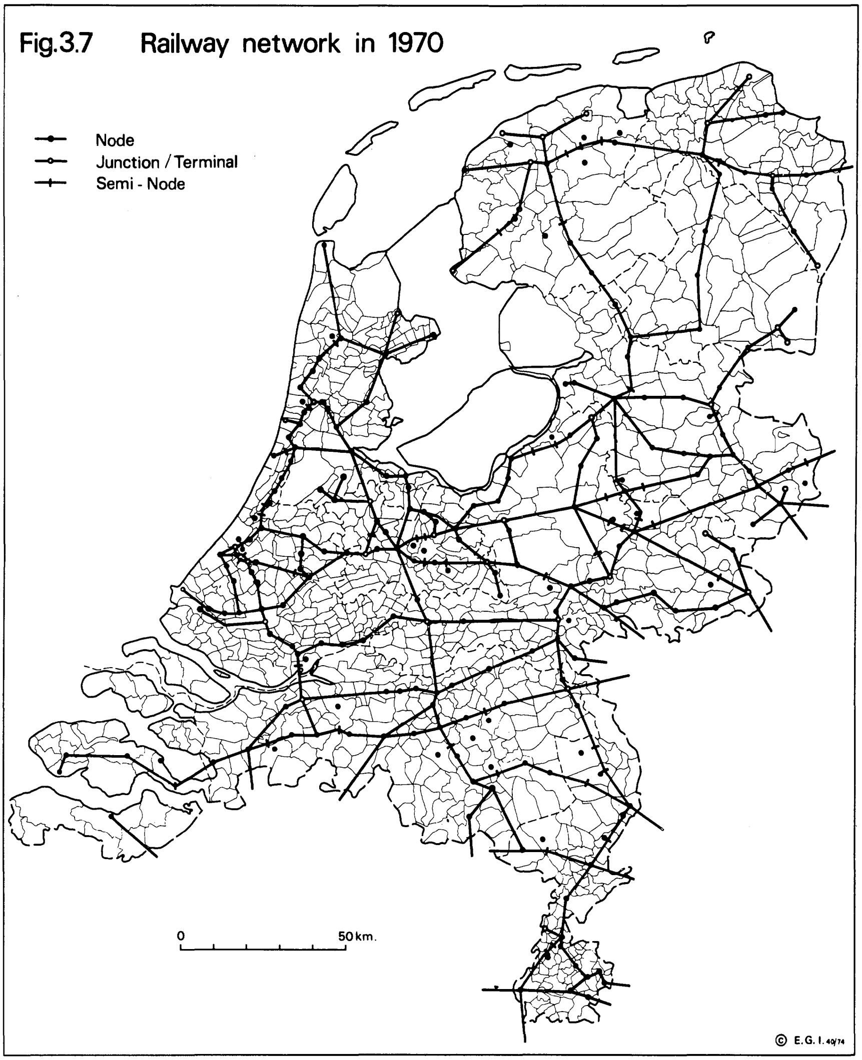


Fig.3.7 Railway network in 1970

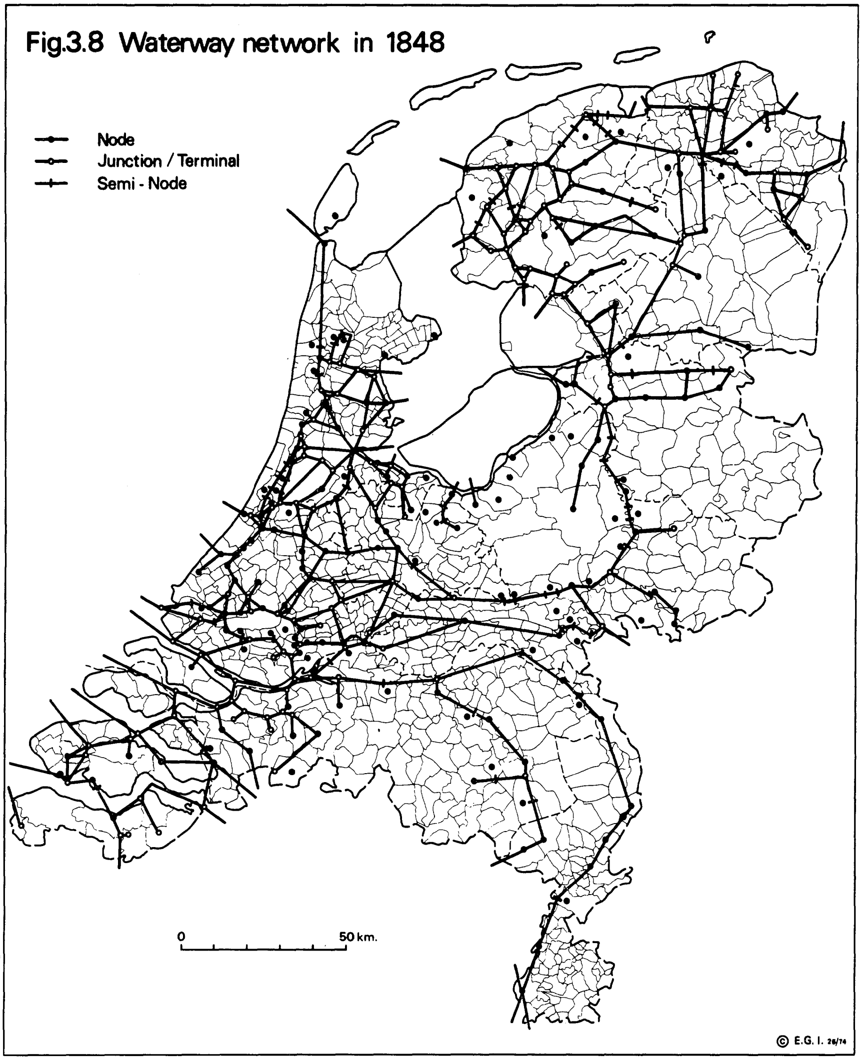


Fig.3.8 Waterway network in 1848

Fig.3.9 Waterway network in 1870

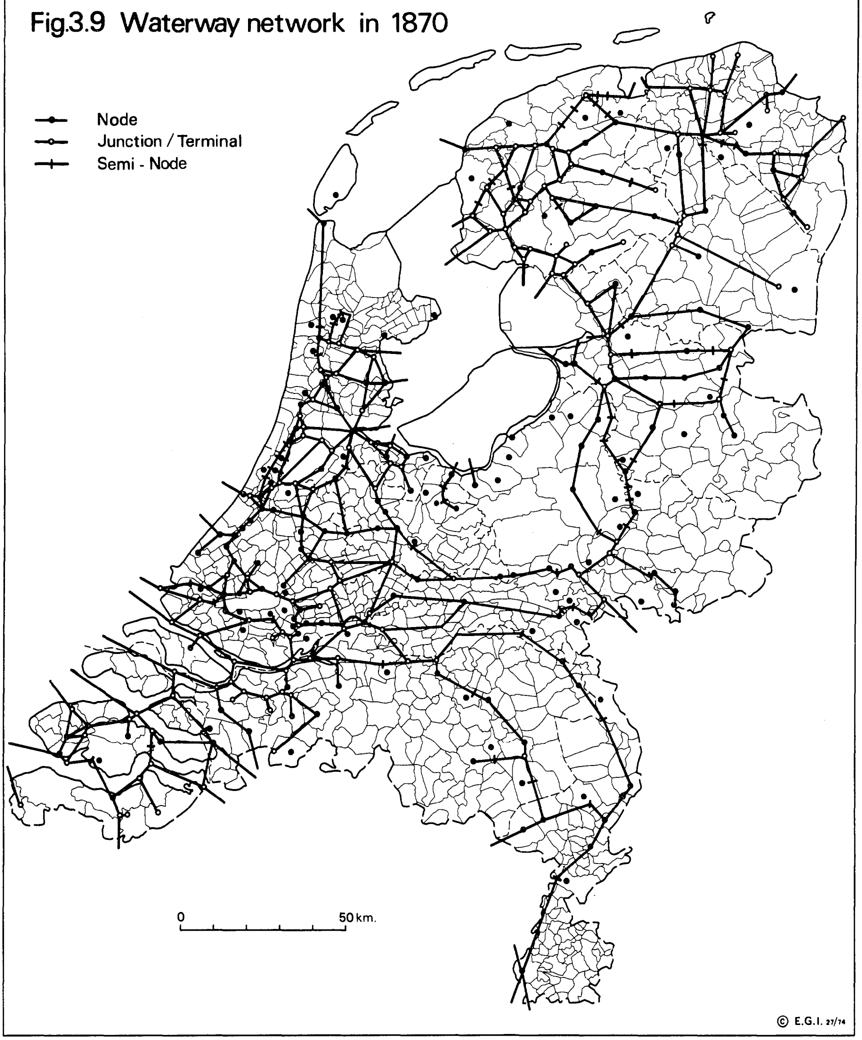


Fig. 3.10 Waterway network in 1908

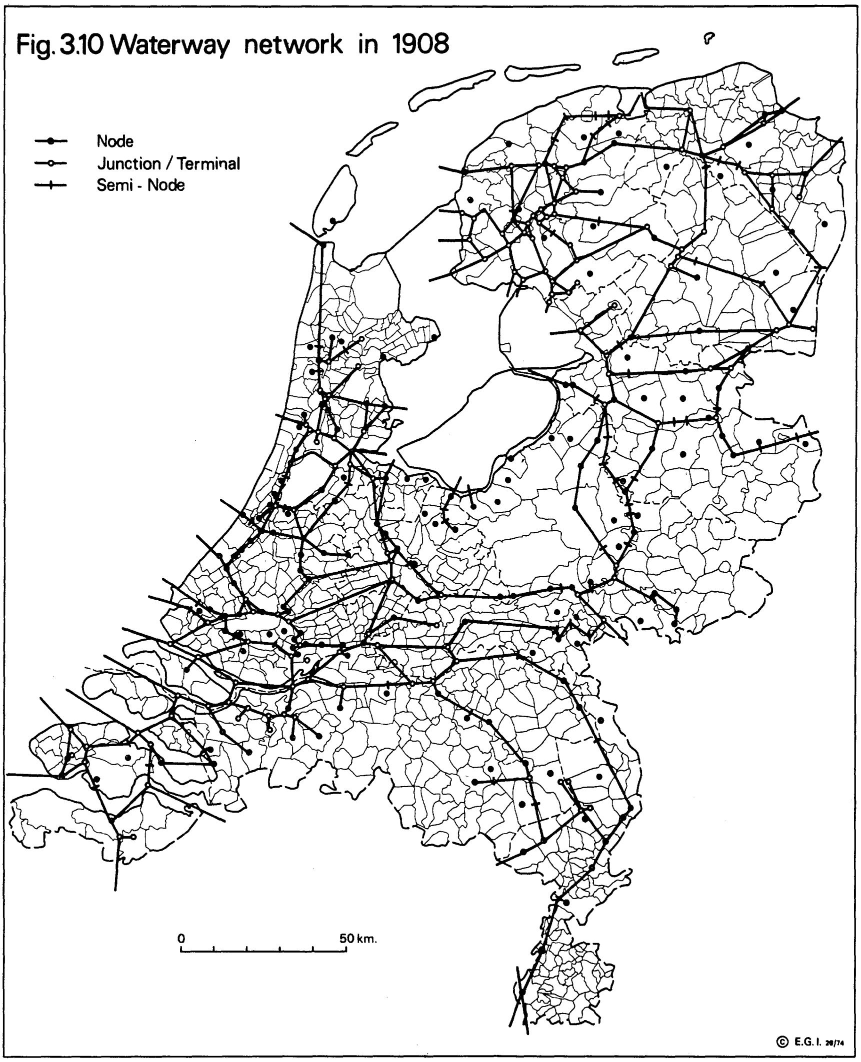


Fig.3.11 Waterway network in 1939

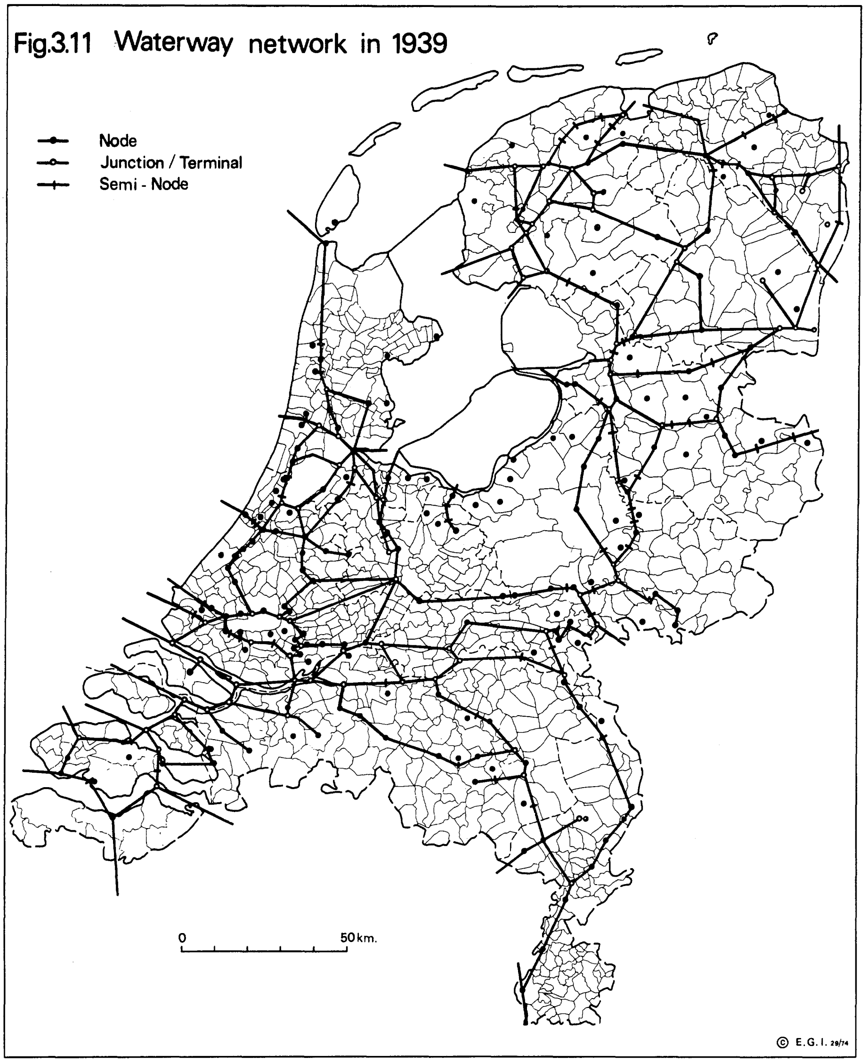
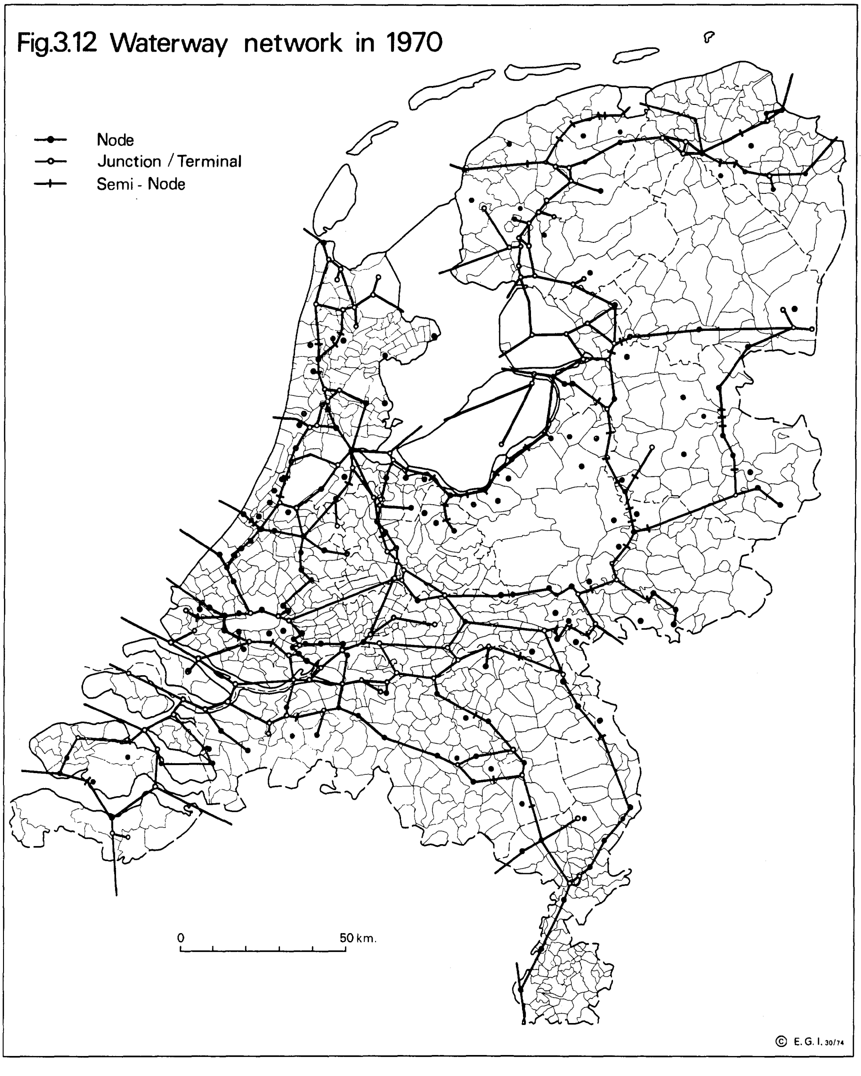


Fig.3.12 Waterway network in 1970



In essence this network is ubiquitous, offering small transport capacities in almost every location and is not requiring a great deal of capital. This network, which is nearly completely inherited from the 17th century was able to absorb the initial demand for water transportation. However, at the end of the 19th century capacity constaints were felt and this resulted in an increase in investments in water transportation over the period 1885-1910.

Investments' decisions of this kind, offering a greater capacity, require location decisions which will exclude parts of the initial transport network, as there is not enough capital available to improve the system as a whole. Every time when major investments in transport improvements are made the location decision is narrowed down to a smaller segment of the system serving fewer but larger cities and thus reducing the total length of the improved network[24.]. This process of route substitution reflects at the same time the increase in communication distance, as the economy develops and leads to bypassing smaller centres connected by smaller routes[25.]. The position of the larger centres is also reinforced by the spatial coincidence of different networks serving different modes of transport.

In the analysis of the spatial impact of such a process one has to recognize the fact that some of the routes will become obsolete and no longer be used. As a reflection of the economic aspects of the Dutch waterway system, these disused canals are not presented in fig.3.8 to fig.3.12, thus illustrating the reduction of the network over time. A minimum economic capacity for inland water transportation was assumed for each period. In the mid-1970s a minimum capacity of 600 tons was considered to provide an inadequate income for any shipper and some discussions were even suggesting 1300 tons as the marginal capacity. The Dutch Government developed a policy to stimulate shippers owning barges below 600 tons to give up this capacity. In view of this policy a minimum capacity of 600 tons in 1970 was used as a threshold value to identify navigable rivers and canals in this period. Considering all the periods threshold levels are set at 80 tons for 1850 and 1870, 250 tons in 1910 and 300 tons in 1940.

The decision for a minimum threshold level of 250 tons in 1910 is based on the capacities of special types of barges ("spitsen") developed to be used in the new canals constructed in this period in the Southern provinces. The capacities of the "spits" was between 250-400 tons while the next larger size class, 400-600 tons

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24. Lachene, R., Networks and the location of economic activities, _Papers and Proceedings of the Regional Science Association_, 1965, Vol.14, pp.193-196.

25. Haggett, P., _Locational Analysis in Human Geography_, Edward Arnold, London, 1965, p.82.

("Kempenaar"), was also developed for the modernized Southern canal system. After their introduction in this part of the country they gradually diffused to other parts of the Netherlands[26]. The impact of this increase in minimum economic capacity is readily apparent if one compares the spatial extent of the network in 1850 (fig.3.8) with that in 1940 (fig.3.11). About 60 per cent of the total network, with a length of approximately 7700 km, offered a capacity up to 150 tons. In the province of Friesland alone 60 per cent of the total network had a capacity between 80-150 tons. The ongoing reduction is further emphasized by a comparison of fig.3.11 and fig.3.12, showing the change in network structure between 1940 and 1970. Besides an overall 'thinning out' of the network the decrease is most noticeable in the Northern and Eastern part of the country. Contrasting with this development is the continuous growth and expansion in the South, especially within the province of Noord-Brabant. The urban-industrial growth of this part of the country since the beginning of the 20th century is reflected in this pattern.

Roads

A comparable series of maps has been prepared to portray the development of the road network (see fig.3.13 to fig.3.17). However, a direct parallel approach with that carried out for the river and canal system was not possible, because of the different nature of the road network. The selection of the main road system is based on two criteria, which were used in the preparation of the source maps[27]. First, the technical quality of a route is of importance, i.e. whether it is a surfaced road or not. Second, the traffic intensity on the road is used to determine the importance of the road relative to other roads. The use of these two criteria jointly will lead to a very large coverage of the national territory, when the overall traffic intensity is low and fairly evenly distributed. This is evident from an analysis of fig.3.13 to fig.3.15, which show the development of the road network from 1848 to 1907. Over this period one can note a gradual growth and expansion of the road system, with considerable growth in the Northern parts of the Netherlands. As in the situation with the railway network one can also observe the lack of integration between the Northern and Southern-most provinces. This integration will be achieved around 1910 and is shown in fig.3.15. Thus far this development is much more comparable to the growth of the railway network than to that of the river and canal system, both in type of growth and in its actual physical location.

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[26] Keuning, H.J., op.cit. 13, pp.475-476.

[27] See Appendix 1 for a list of the maps which are consulted for the preparation of the networks.

Fig.3.13 Road network in 1848

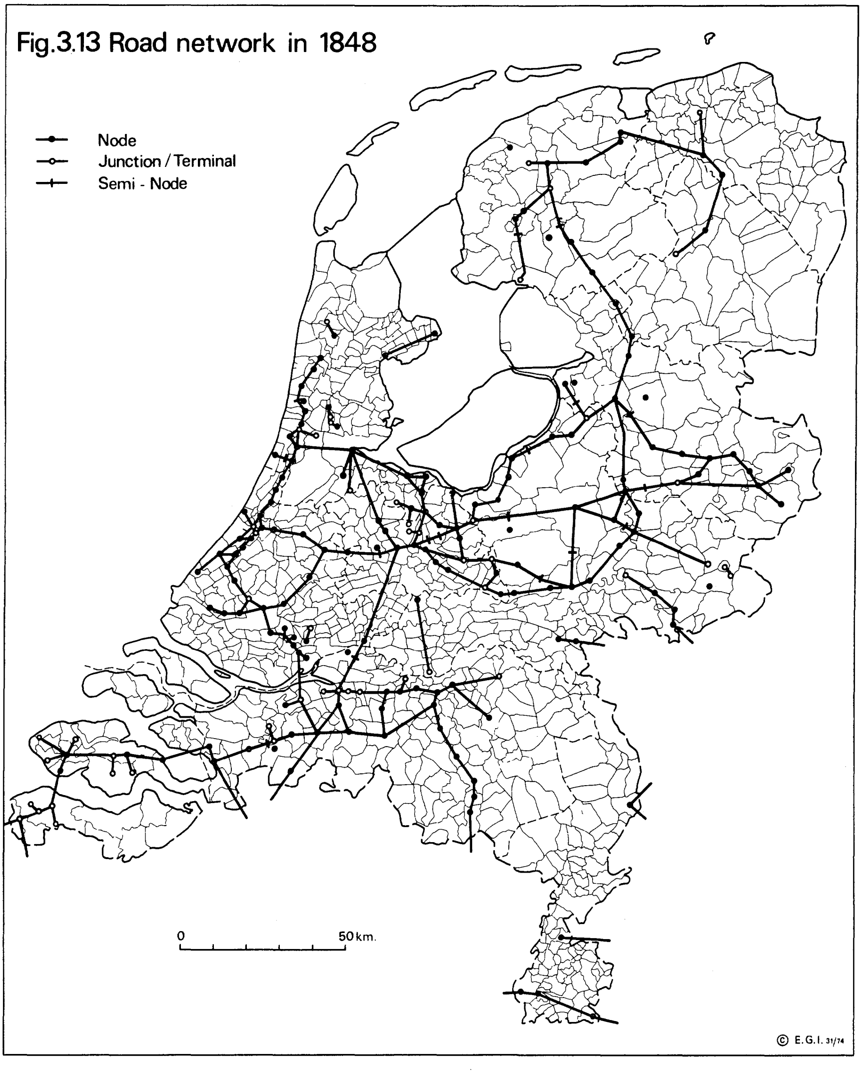

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Fig. 3.14 Road network in 1870

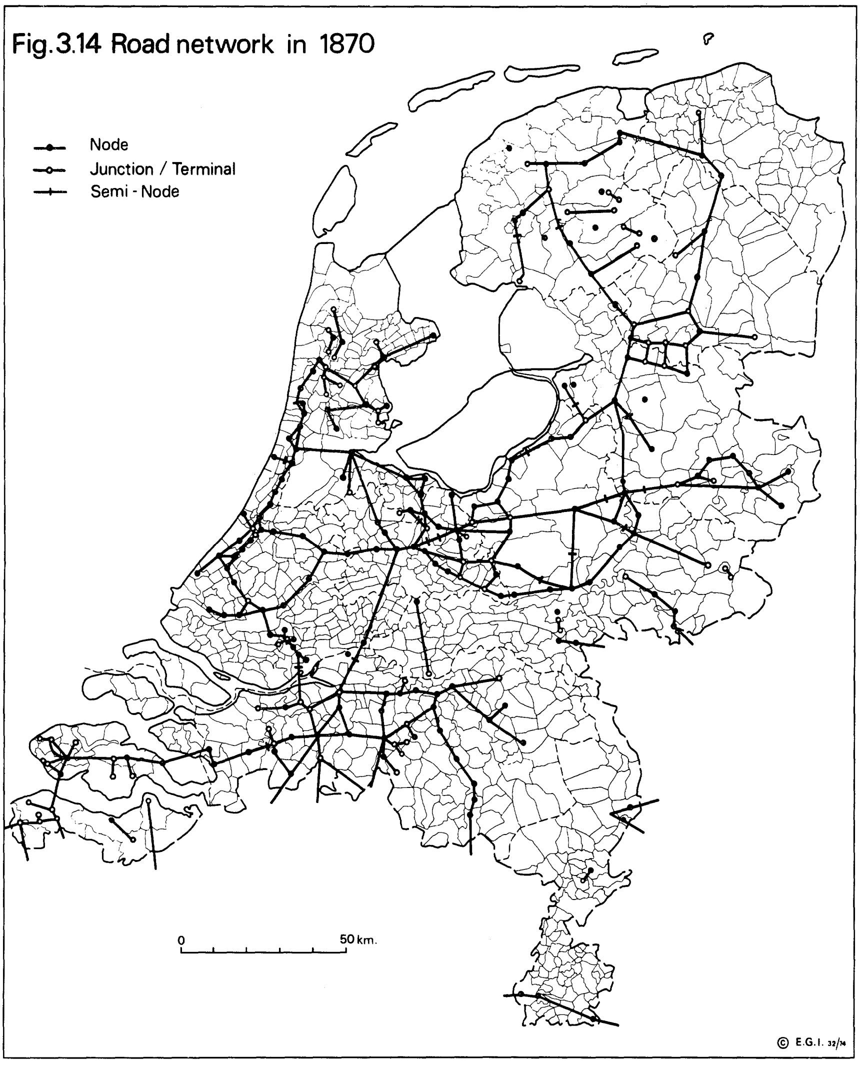


Fig. 3.15 Road network in 1907

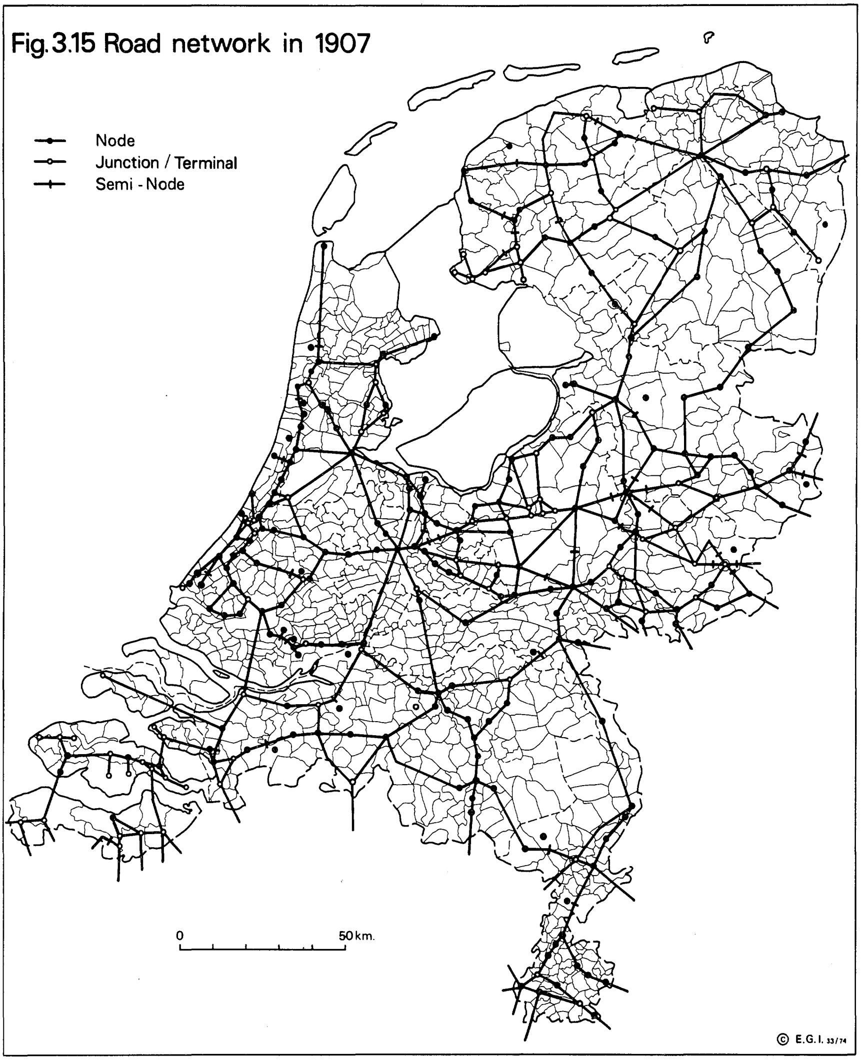


Fig.3.16 Road network in 1947

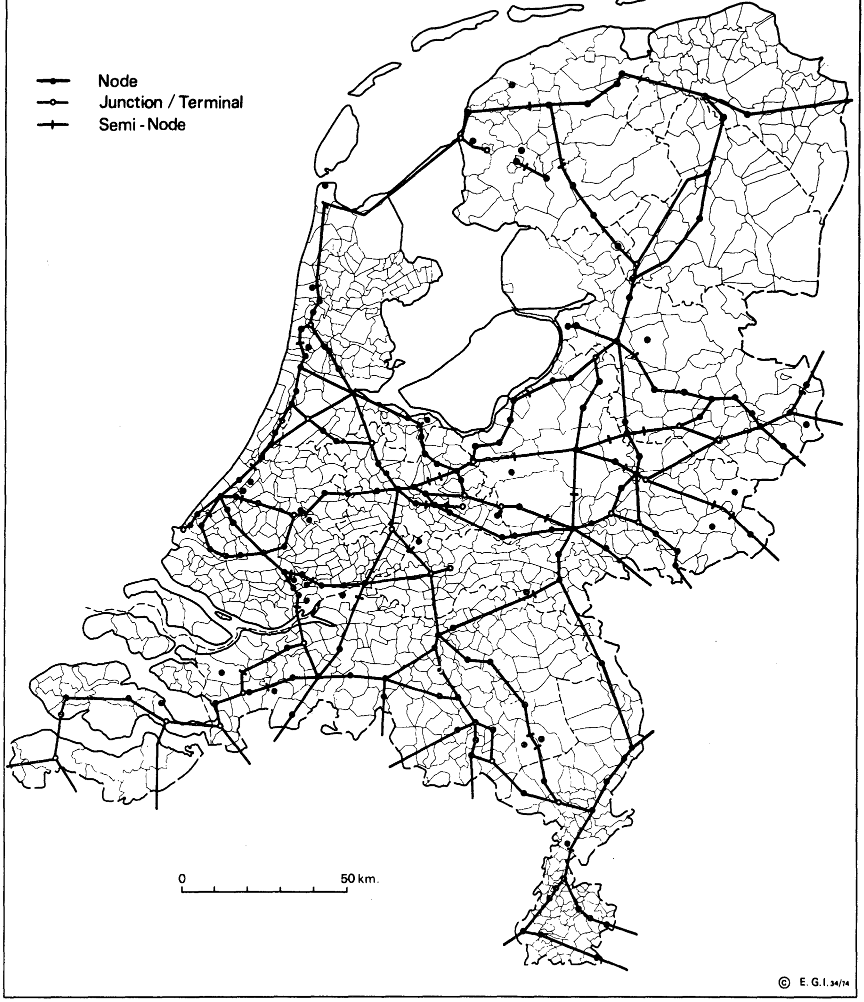
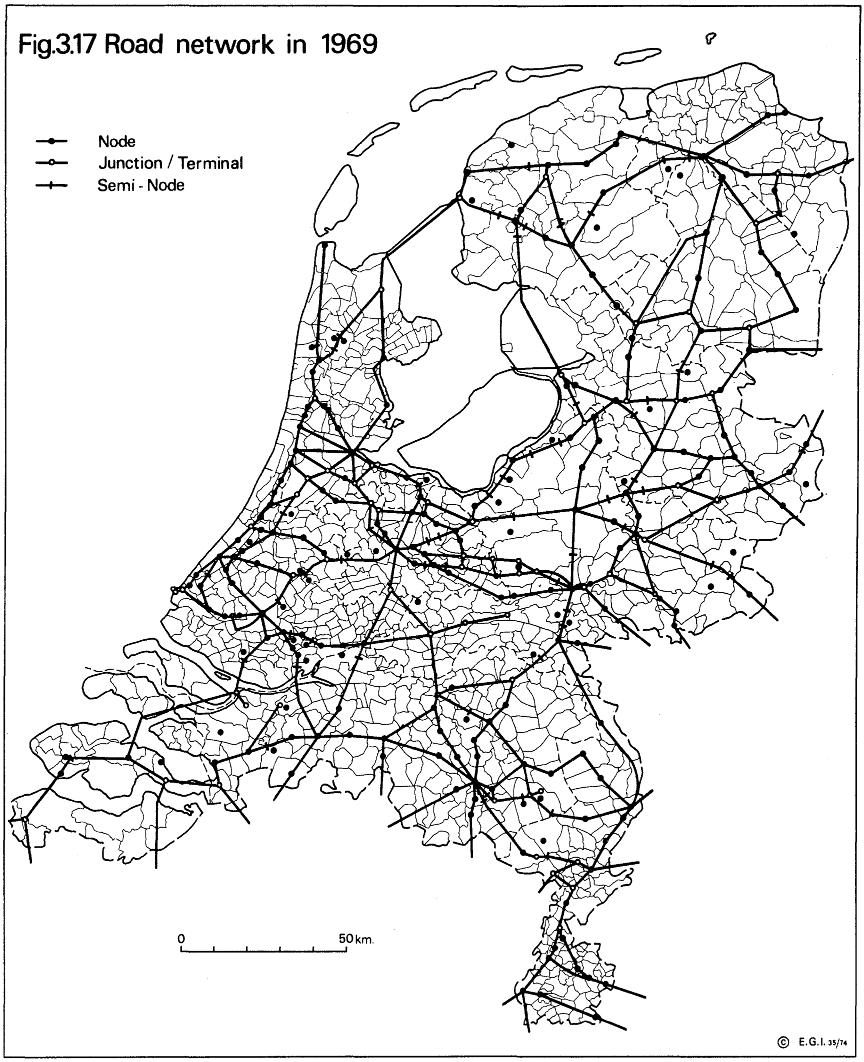


Fig.3.17 Road network in 1969



Contrasting to the development discussed above is the change between 1907 and 1947, which shows an overall reduction in the total length of the network, a thinning out, while the basic structure reached in 1910 remains the same. An explanation for this change could be the tremendous relative increase in motorvehicle transportation over this period. The total number of cars grew in this period from 2,000 in 1910, via 11,000 in 1920 and 68,000 in 1929 to 100,000 in 1939, while the number of trucks increased from 27,000 in 1928 to 48,000 in 1939 for the whole of the country[28.]. The considerable growth of this type of transportation in the two decades before the second world war is also reflected in the high relative proportion the investments in this sector have had in the second half of this period (see fig.3.2c). The total intensity of traffic, taking 1955=1,000, rose from 0·2 in 1908 and 33 in 1939 to 303 in 1970. The pattern in 1970 (fig.3.17) indicates a further growth of the network, which must be able to absorb a large proportion of some 2,000,000 cars and 280,000 trucks at times.

The discussion in this paragraph has been focused upon the spatial and visual aspects of network development. The networks constructed for this purpose will now be used as a basis for a more quantitative analytical approach of the impact of network development on the growth of urban areas. At the same time the possible differences between the various modes of transport, as indicated in the introduction of this section, will be considered in detail for the specified time periods.

3.5 Network development and urban growth

An implicit assumption in the discussion of the spatial aspects of transport network has been that the network is becoming increasingly complex as the economy develops. In an attempt to generalize from place specific elements, such as break of bulk points, Garrison[29.] tries to analyse the effect of the construction of the interstate highway system in the U.S.A. on the relative location of places. This study was one of the first studies in geography applying graph theory to analyse the problem. In an extensive development of this methodology Kansky[30.] analyses the relationship between the degree of economic development and

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28. Zeventig jaren statistiek in tijdreeksen, C.B.S., Staatsuitgevery, Den Haag, 1970, p.107.

29. Garrison, W.L., Connectivity of the Interstate Highway System, Papers and Proceedings of the Regional Science Association, 1960, Vol.6, pp.121-137.

30. Kansky, K.J., Structure of Transportation Networks, Research Paper No.84, Department of Geography, University of Chicago, 1963.

the structure of the transportation network within and between a number of countries.

On the basis of his analysis, Kansky concluded that there was a positive relationship. Haynes and Ip[31.] tried to extend Kansky's study to the intra-regional scale and tested for the Canadian province of Quebec the hypothesis that the population of an area is positively related to the structure of its transportation network. The results of their analysis did not lead to a rejection of this hypothesis. Another study in this context is one by O'Sullivan[32.] in which he analyses the relationship between transport networks, transportation economies and concentration in the Irish economy. To test his hypothesis O'Sullivan makes use of regression analysis, in which the index of accessibility of a town on the network is used as the dependent variable. One of his conclusions is that there exists a functional relationship between the level of the economic activities in a town and its accessibility on a network.

On the basis of a review of the literature, Gauthier[33.] suggests three possible types of non-spatial relationships of the role of transportation in the development process: (1) a positive effect on the development process - the expansion in directly productive activities being a direct result of providing improved transportation facilities, (2) a permissive effect on the development process, because transportation does not independently produce directly productive activities or subsequent increases in the level of economic growth, and (3) a negative effect on the development process, occurring when an over-investment in transportation reduces potential growth in directly productive activities. In this study, however, a much more limited goal will be pursued and an attempt will be made to analyse the relationship between accessibility, changes in levels of accessibility and population size and growth. The direct relationship expresses a situation of balanced growth between urban centres and increases in nodal accessibility, in which investments in one sector, for example manufacturing, stimulate investments in transportation and reverse[34.]. Unbalanced relationships over time occur when the

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31. Haynes, K.E. and P. Ip, Population economic development and the structure of transportation in the provinces of Quebec, Canada, Tijdschrift voor Economische en Sociale Geografie, 1971, Vol.52, pp.356-363.

32. O'Sullivan, P., Transport networks and the Irish economy, London School of Economics, Geographical Papers No.4, 1969.

33. Gauthier, H.L., Geography, Transportation and Regional Development, Economic Geography, 1970, Vol.46, pp.612-619. See also chapter 1, pp.9-11, for a more extensive discussion of these three types of relationships.

34. Gauthier, H.L., Transportation and the growth of the Sao Paulo economy, Journal of Regional Science, 1968, Vol.8, pp.77-94, see p.92.

effects of investments in either transportation or the urban economy are noticeable with a time lag, requiring additional investments in other sectors before an increased demand in the sector of interest occurs. Thus, the non-spatial relationships summarized by Gauthier can be analysed in a spatial context, when we examine the positive or negative effects over space, using the transportation network and urban size as a framework of reference.

A major empirical problem, involved in using graph-theoretic measures to analyse a real world transportation network, is that of defining the graph, which reflects this network best[35.]. Links or routes of a transportation network have properties like capacity, intensity and type of use, cost of construction etc. Some of these problems have already been mentioned in the discussion of the maps showing the road and canal network. An additional problem is that of defining the nodes and links of the system in a meaningful way. An important question within this context is whether to include all cities or to define only cities of a certain size class as nodes on a network. The next part of this section will be devoted to a discussion of these issues, as they are relevant for the analysis of the theoretical questions raised in the previous paragraph.

Measuring accessibility on a network

A large number of indices have been developed to measure the various structural topological aspects of transportation networks[36.]. These indices can be divided roughly into two categories[37.]: (1) network-specific measures based on gross characteristics, making use of the number of nodes, links and subgraphs, and (2) node-specific measures based on shortest-path characteristics, where the shortest path between two nodes i and j is defined as the minimum number of links between the i^{th} and j^{th} node. This set of measures can be considered to give an expression of the accessibility of node i.

The concept of accessibility, however, is related to both the relative position of a node on the network, and the degree to which two places on the same network are connected. Ingram considers this first type of accessibility to measure the integral accessibility of a node as it expresses the degree of inter-connection

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[35.] Garrison, W.L. and D.F. Marble, Factor analytic study of the connectivity of a transportation network, Papers and Proceedings of the Regional Science Association, Vol.12, 1964, pp.231-238, see esp. p.233.

[36.] Leusmann, Chr., Netze - ein Überblick über Methoden ihrer Strukturellen Erschliessung in der Geographie, Erdkunde, 1974, Vol.28, pp.55-56.

[37.] Haggett, P. and R.J. Chorley, Network Analysis in Geography, Edward Arnold, London, 1969, pp.32-34.

with all other nodes[38.]. The value of this measure varies as the network changes, while the connectivity of a node may stay the same, thus indicating the relative accessibility of a node. Relative in this context means relative to its direct or local environment and in this way accessibility is measured on a different (lower) geographical scale then when it is defined as integral accessibility.

$$\text{Thus : } A_i = \sum_{j=1}^{n} a_{ij} \quad ,$$

where A_i is the integral accessibility for node i and a_{ij} is the relative accessibility of node j from i.

When a_{ij} is some measure of distance, A_i will be at a minimum at the point of minimum travel (centre of gravity) of the network under consideration. The farther one is away from this point, the larger A_i will become. The difference between A_i and a_{ij} can be illustrated by the case where i is a node in a well-developed subsection of the network which is not close to the centre of gravity. In this case the relative accessibility of i within its regional economy may be large, while, at the same time, its integral accessibility is poor. In which case one may conclude that integral accessibility is not always a good indicator of the growth of the city at location i over time, from a regional point of view, because integral accessibility refers to the relative position of i in the total network.

In addition to this problem is the problem of comparing two or more networks with each other. This comparison can be between different networks at the same point in time or the same network at different points in time at different stages of development. The problem arises because the measures developed emphasise the morphology of the network, i.e. the pattern between nodes, and they do not incorporate information about orientation or metric distance. Thus, different networks can generate the same value for the indices which describe these networks.

There have been some attempts to improve the discriminatory power of the existing measures of network structure by suggesting new ones. Cummings et.al.[39.] make use of probability theory and analyse the different link-node combinations, which can occur between a given set of nodes. In this way it is possible to test the hypothesis whether the difference with another network, considered as a different link-node combination, has arisen as a result of chance or whether this difference is caused by systematic geographical factors. A method to compare different networks,

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[38.] Ingram, D.R., The concept of accessibility: a search for an operational form, Regional Studies, 1971, Vol.5, pp.101-107.

[39.] Cummings, L.P., B.J. Manly and H.C. Weinand, Measuring Association in Link-node problems, Geo Forum, 1973, pp.43-51.

each having a different number of nodes, is proposed by James et.al.[40]. Their measure, the so-called S-I index, provide a means of determining which theoretical discrete frequency distribution is most closely approximated by the observed frequency distribution of all possible shortest-path lengths in the network. It is possible to extend this method to examine the distribution of path lengths from any given node. Such an extension would contribute in the analysis of the integral accessibility of a node with respect to its network.

The discussion in the preceding paragraphs has made clear that it is difficult to measure accessibility in an unambiguous manner, such that it can be used in a comparative way over space and time. The simple measure, which will be employed in the analysis here, is based upon the concept of relative accessibility and in this way the regional aspects of the node are emphasized. The degree of accessibility is determined on the basis of the total number of first-order links, which are the total number of incoming or outgoing routes. As "it is evident that transportation routes crossing the delimiting boundaries of the area under study are instruments of economic and other interchange, the number or character of the routes terminating in the regions outside the areas of study is a rough measure of inter-regional interchange, or a measure of the "exogenous factor""[41].

The degree of accessibility of a node can now be determined for each transport network and the related periods, where the total accessibility of a node can be considered as the sum of the relative accessibility of node i for each transport network. The implicit assumptions which are made here are obvious, but important to mention. First, the joint effect of all transport networks together is assumed to be additive, which may not be unreasonable as a first approximation, but this excludes the possible occurrence of transportation economies as a result of the joint occurrence. Second, the relative impact on the urban economy of each transportation subsector is treated as if there exists no difference between the various modes of transportation in the way they operate, their cost structure, the kind of goods transported etc.. As a consequence of this assumption an equal weight is assigned to each transportation subsector and this may seriously affect the evaluation of the overall effect.

The total (relative) accessibility for 278 nodes for the five periods is shown in fig.3.18 and illustrates the distribution of the total number of routes

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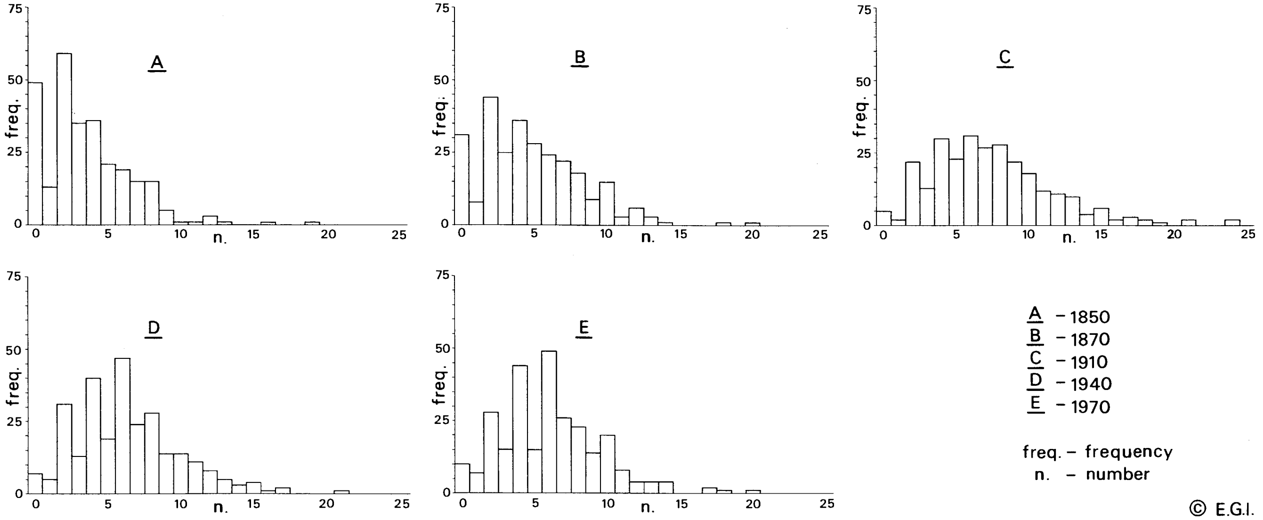
40. James, G.A., A.D. Cliff, P. Haggett, Some discrete distributions for graphs with applications to regional transport networks, Geografiska Annaler, Ser.B., 1970, pp.14-21.

41. Kansky, K.J., op.cit. 30, p.64.

Fig. 3.18 Frequency distributions of the total relative accessibility



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or overall accessibility (see table 3.1). The networks shown on the maps in fig.3.3 to fig.3.17 were used as the basis for the observations.

table 3.1 Total relative accessibility for 278 nodes

time	1850	1870	1910	1940	1970
number of routes	974	1319	2048	1748	1648

The joint effect of the three networks is a maximum overall accessibility for 1910, whereafter a gradual decline is noticeable. This decline could reflect an increasing urban concentration and specialization as the urban-industrial economy develops an idea which is also supported by the analysis of fig.3.18. The frequency distributions of the total accessibility is heavily skewed in 1850 and approaching normality towards 1910. Over this period one can observe a sharp reduction in the number of nodes having no connection at all or only to incoming or outgoing routes. Another important feature is the increase in the even number of connections, which is especially the case for the left hand side of the distributions of 1940 and 1970. This reflects both the increased accessibility of a place as a terminal point and at the same time the intermediate location of this place between two other centres, with which this place became connected. The relative larger number of occurrence of the even values emphasizes the spatial development of each transport network, as well as the overall spatial distribution of the three networks, and the value six is clearly becoming the modal value after 1940. The frequency distribution of the total accessibility thus reflects the increasing integration of all the nodes on the network, at the same time suggesting an improved efficiency in the structure of the different transportation networks because of the increasing number of even accessibility values.

Accessibility and urban size

Some of the problems associated with the analysis of urban size, which covered a long period, were discussed in chapter two. This discussion is also relevant for the analysis of the relation between the growth of an urban economy and the possibility for interregional interaction. It was indicated that population size and growth could be used as an approximation of the size and growth of the urban economy.

For the analysis of the decennial population growth from 1850 onwards till

1970 a threshold level of 5,000 inhabitants in 1970 was used. One may, however, argue that this minimum level is a rather generous indicator for the inclusion of places in the urban system. This could be especially the case for areas at or around the threshold level as one might expect that these areas can be predominantly rural or even lacking an economic base, which is sufficient to support this population. The analysis of the population growth pattern by size class showed also an overall decline in population for all the places in the 5,000 - 10,000 size class, whereas the next higher size class encompassing all municipalities of 10,000 - 30,000 inhabitants showed a continuous growth. For these reasons the minimum threshold value is increased from 5,000 to 10,000 inhabitants in 1970, thus reducing the total number of places in the analysis from 502 to 278.

The periods 1850, 1870, 1910, 1940 and 1970 will be used as reference points for the examination of the relations between investments in transport networks, which is measured by relative accessibility, and urban growth and size. This rather general hypothesis will be analysed here in more detail on the basis of five simple sub-hypotheses:

H1 : Population size and the relative accessibility of a place are positively associated.

The relationship formulated in this first hypothesis expresses the coincidence of routes and of different transport networks one can observe sometimes in the higher order places of the urban system. At the same time high levels of accessibility may also give rise to rapid urban growth. To analyse this effect the population growth over the next decade is compared with the levels of accessibility at the beginning of the period.

H2 : An increase in population size is positively associated with a high level of accessibility.

As is discussed earlier, population growth can also be induced by increasing accessibility of a place and thus follow investments in transportation which may stimulate the growth.

H3 : An increase in population size is positively associated with a previous growth in levels of accessibility.

The growth in accessibility is measured as the increase in the level between two periods, for example between 1850 and 1870, while the population growth is calculated for the period 1870-80, where 1870 is the relevant period. The reverse of this hypothesis is the following nature of transport development and such a development is thus preceded by a period of population growth. Thus, a population growth over the period 1860-1870 can be followed by a growth in levels of accessibility in the period 1870-1910.

H4 : An increase in levels of accessibility is positively associated with previous growth in population size.

The fifth hypothesis is an attempt to measure the direct association between population growth and an increase in accessibility.

H5 : An increase in population size is positively associated with an increase in levels of accessibility during the same period.

A preliminary investigation of these five hypotheses was carried out using correlation analysis. The results of this analysis are shown in table 3.2 and these indicate that most of the hypothesized relations are not significant, with the first hypothesis as an exception. Even for this case the correlation coëfficients are rather low for the three subsectors, while the performance of the relation using total accessibility is somewhat better. This result tends to support the general hypothesis, that the development of transport networks reinforces the existing spatial structure.

However, before we draw somewhat more definite conclusions about the nature of the hypothesized relations, the influence of a minimum size criterion on the results will be examined in more detail. This definition is of a crucial importance for the incorporation of a place in the analysis. The relevant question in this context is not only "at what minimum level can we consider a place to be urban", but "what is the necessary minimum size of an urban area to support growth due to investments either in transportation or in a sector of the urban economy". In order to develop some understanding about the nature of this problem, three possible definitions for a minimum threshold value are used, each reducing the number of cities or nodes in the analysis: (1) the already employed minimum level of 10,000 inhabitants, which reduces the initial total from 502, where 5,000 is the threshold, to 278 cities (municipalities), (2) the introduction of a minimum density criterion of 1,000 inhabitants per km^2, which stresses the concentration element of a city[42.] and diminishes the number from 278 to 88 cities, and (3) a higher minimum population threshold excluding all places with less than 50,000 inhabitants in 1970, leaving only 33 cities out of a total of 502. These three definitions are compared on the basis of the first hypothesis (see table 3.3), while also the effect for the three transportation subsectors is examined. The correlation coefficients expressing the association increase with the decreasing number of cities in the analysis, both for the total accessibility and for two of the three subsectors. The nature of the association with the road transport network seems to be the least affected by a

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42. Bevolking der gemeenten in Nederland per 1 januari 1970, C.B.S., Staatsuitgeverij 1971. This level is also used in a definition for urban area by the C.B.S.

table 3.2 Correlation analysis of five hypotheses

Year	Roads	Waterways	Railroads	Total accessibility
1850				
H1	0.299	0.398	0.333	0.477
H2	0.008	0.127	-0.004	0.084
1870				
H1	0.289	0.391	0.213	0.441
H2	0.073	0.148	-0.000	0.120
H3	0.004	0.044	-0.019	0.004
H4	-0.005	0.088	0.015	0.041
H5	-0.031	-0.146	0.044	-0.036
1910				
H1	0.280	0.350	0.249	0.427
H2	-0.078	-0.226	-0.028	-0.172
H3	0.029	-0.015	-0.016	-0.039
H4	0.097	0.149	0.103	0.193
H5	0.047	-0.023	-0.000	-0.041
1940				
H1	0.321	0.277	0.312	0.460
H2	-0.072	-0.237	-0.025	-0.188
H3	0.101	0.165	0.067	0.141
H4	0.047	0.158	0.047	0.060
H5	-0.061	-0.054	-0.041	-0.160
1970				
H1	0.426	0.320	0.365	0.509
H4	-0.033	0.067	0.134	0.104

table 3.3 Correlation coefficients for population size and accessibility

A per sector for 278 nodes (cities) (10,000 inh.; 1970)

Year	Roads	Waterways	Railroads	Total
1850	0.299	0.398	0.333	0.477
1870	0.289	0.391	0.213	0.441
1910	0.280	0.350	0.249	0.427
1940	0.321	0.277	0.312	0.460
1970	0.426	0.320	0.365	0.509

B per sector for 88 nodes (cities) (>1000 inh./km^2; 1970)

Year	Roads	Waterways	Railroads	Total
1850	0.345	0.520	0.377	0.554
1870	0.325	0.516	0.252	0.525
1910	0.381	0.526	0.340	0.574
1940	0.385	0.449	0.411	0.598
1970	0.485	0.481	0.483	0.662

C per sector for 33 nodes (cities) (>50,000 inh.; 1970)

Year	Roads	Waterways	Railroads	Total
1850	0.280	0.701	0.497	0.702
1870	0.252	0.692	0.119	0.618
1910	0.182	0.622	0.145	0.574
1940	0.273	0.496	0.260	0.630
1970	0.393	0.567	0.408	0.707

changing threshold.

The pattern of the coefficients in table 3.3C deviates from those in the other two tables 3.3A and 3.3B, when the values are compared over the periods. In these two cases one can note an gradual increase in the value of the coefficient, starting in 1850 to 1970. For the 33 cities, however, the value drops from a value of 0·70 in 1850 to 0·57 in 1910 and increases from here to 0·71 in 1970. The same pattern can be observed for the association of the population size with the railroad network for the three different definitions used, although the case for the 33 cities is most pronounced.

In contrast to the pattern of the railway coefficient is that of the waterway network, where the value of the coefficients increases much more rapidly than can be noted for any of the other two networks. This result suggests a considerable influence of the water-transport network in the overall relationship, especially as these is assumed to be additive. The temporal variations in the coefficients for this network, i.e. a decrease in the value from 1850 to 1970, could reflect the retraction of this network over time (see table 3.3B and 3.3C).

Finally, the changes in the nature of the relations one can observe, especially in table 3.3C, indicate a spurious association between the spatial distribution of the population and the spatial structure of the transport networks. Again, the period around 1910 seems to be of crucial importance in this respect, as was the case in the analysis of the urban distribution and growth in chapter 2, where a marked concentration of the population in a few centres could be noted. At the same time the total accessibility reaches a peak value for 1910 (see table 3.1), which could indicate a large spatial coverage (see fig.3.18C). The coincidence of these two distributions may well explain the observed pattern of the correlation coefficients.

The analysis on the basis of the three different threshold definitions has emphasized the occurrence of different levels and different types of explanation. However, it is not possible to determine on this basis which threshold level is most relevant for the analysis of a particular hypothesis. The five research hypotheses formulated in this section have only been analysed with respect to their feasibility. In the next section a more detailed examination will be made of the nature of the relationship between the levels of accessibility for each transportation subsector and population size as is formulated in the first hypothesis.

A cross-temporal analysis of transport networks

One of the findings in the previous section is, that transport investments are positively associated with the size of the urban economy (cf. hypothesis 1). It is, however, not clear what the magnitude is of this association and whether there are differences between transportation subsectors. Also the nature of the relationships within one sector may vary from one period to the next. These questions will be studied here on the basis of two regression models:

(1) $\text{Log } X_1 = b_0 + b_i X_i$, for $i = 2,3,4,5$

(2) $\text{Log } X_1 = b_0 + b_2 X_2 + b_3 X_3 + b_4 X_4$, where

X_1 = population size of town j

X_2 = accessibility on the road network for town j

X_3 = accessibility on the waterway network for town j

X_4 = accessibility on the railway network for town j

X_5 = total accessibility of town j, defined as $X_5 = \sum_{i=2}^{4} X_i$

The first model estimates, separately for each transportation subsector as well as for the total accessibility, the independent simple effect on the variable population size. The second model is a multiple regression model in which the joint independent effect of each subsector is estimated. The regression coefficients of this model thus can be interpreted as weights for the contribution of each subsector to the total accessibility of a place. In this way these estimates can be used to evaluate the earlier assumption of an equal weight for each subsector as is still applied in the definition of variable X_5.

The correct specification of the two models is of considerable importance as this can have direct consequences for the evaluation of the results. A first point of interest is the logarithmic transformation of the variable population size. The rational for this transformation was the reduction of the skewness of the data. The effect of this procedure has been evaluated on the basis of a comparison of the coefficients, which were estimated with and without a transformed dependent variable for each of the four variables over the five periods on the basis of 33 cities (j=33). The evaluation of the two sets of twenty coefficients was carried out on the basis of their respective T, R and F values. The results with respect to variable X_2 are consistently better for the non-transformed model, with the exception of the coefficient for 1970. Although the T, R and F values were higher (better), this did not lead to a statistically significance of the coefficients.

As the results did improve for the other 16 coefficients, the logarithmic transformation was preferred. This decision did not influence the specification of the second model as a multiplicative relationship between the independent variable is not realistic. Such a relationship would imply that in the absence of one transportation subsector in town j, the population of that town would drop to zero, which is not the case in a real-world situation.

The results of the simple regression model for the three threshold values are presented in table 3.4, 3.5 and 3.6. The coefficients reported in these tables have all the same interpretation, as the relevant variables are all measured in the same metric, i.e. the number of incoming or outgoing routes. From table 3.4 we can read that the increase in total accessibility has only a small effect on city size, as compared with the other variables. This is also the case for the coefficients of the water-transport network, which are in the same order of magnitude. Both the railway and road network have contributed significantly in the explanation of urban size, whereas since 1910 the magnitude of the coefficients is on about the same level. Before this date the road network seems to be of lesser importance in relation to urban size.

In the analysis of table 3.5 a number of different observations can be made, although both the total accessibility and that of the water-transport network are on about the same level with slightly higher coefficients than those in table 3.4. The largest difference can be noted for the railway network as regards the magnitude of the coefficients and their development over time. The importance of the accessibility on the railway network increases till 1940, a development which is consistent with the interpretation of the map-patterns for this subsector. The coefficients of the road network show the same pattern as in the previous analysis, although the values at 1910 and 1940 are much more pronounced. This suggests that the reduction of the network which can be observed over this period affects the smaller places more than the larger ones, as in this part of the analysis only 88 towns are under consideration, compared with the 278 in table 3.4.

In the case of the 33 cities (table 3.6) the same low overall relationship can be observed as in the other two tables 3.4 and 3.5. However, there is a difference with respect to table 3.4 when the correlation coefficients for the total accessibility are compared. In this table the highest association can be observed for 1910, while about the reverse is true for table 3.6. This contrasting temporal pattern confirms the earlier interpretation of the nature of these coefficients as regards their descriptive value of the spatial coincidence of the distribution patterns of the population and the total accessibility. This relation is also reflected in the size of the coëfficients for the railway network, which is of con-

table 3.4 Regression coefficients of model 1; number of cities is 278

Year	b_2		b_3		b_4		b_5	
1850	0.07		0.06		0.10		0.05	
T		5.29		5.44		2.65		6.99
R		0.30		0.31		0.15		0.38
F		28.06		29.62		7.02		48.97
1870	0.07		0.07		0.10		0.05	
T		5.53		5.95		5.26		8.50
R		0.32		0.34		0.30		0.46
F		30.57		35.37		27.70		72.18
1910	0.11		0.08		0.11		0.06	
T		9.15		6.81		8.12		13.13
R		0.48		0.38		0.43		0.61
F		83.73		46.43		66.03		172.28
1940	0.12		0.06		0.12		0.06	
T		8.47		4.11		9.67		12.14
R		0.45		0.24		0.50		0.58
F		71.74		16.92		93.52		147.29
1970	0.11		0.06		0.12		0.06	
T		10.38		4.62		9.68		12.14
R		0.53		0.26		0.50		0.59
F		107.77		21.30		93.85		147.28

$\alpha = 0.01$ $F_{(1,276)} = 6.70$; $T = 2.32$ * not significant at this level

$\alpha = 0.05$ $F_{(1,276)} = 3.60$; $T = 1.64$ ** not significant at this level

table 3.5 Regression coefficients of model 1; number of cities is 88

Year	b_2		b_3		b_4		b_5	
1850	0.113		0.084		0.148		0.061	
T		3.53		3.27		2.20*		4.22
R		0.36		0.33		0.23		0.41
F		12.48		10.72		4.83*		17.77
1870	0.094		0.083		0.181		0.067	
T		3.38		3.32		4.50		5.29
R		0.34		0.34		0.44		0.49
F		11.42		11.00		20.25		28.06
1910	0.182		0.119		0.221		0.089	
T		6.05		4.001		7.61		9.25
R		0.55		0.40		0.63		0.70
F		36.57		16.06		57.89		85.60
1940	0.178		0.098		0.228		0.088	
T		5.73		2.94		9.080		8.42
R		0.53		0.30		0.70		0.67
F		32.84		8.63		82.45		70.82
1970	0.133		0.104		0.195		0.085	
T		6.40		3.80		8.33		9.99
R		0.57		0.38		0.67		0.73
F		40.98		14.44		69.36		99.99

$\alpha = 0.01$ $F_{(1,86)} = 6.96$; $T = 2.32$ * not significant at this level

$\alpha = 0.05$ $F_{(1,86)} = 3.96$; $T = 1.64$ ** not significant at this level

table 3.6 Regression coefficients of model 1; number of cities is 33

Year	b_2		b_3		b_4		b_5	
1850	0.069		0.127		0.240		0.08	
T		1.37**		6.328		3.41		5.87
R		0.24		0.75		0.52		0.72
F		1.89**		40.05		11.63		34.52
1870	0.043		0.118		0.095		0.07	
T		1.17**		6.03		1.79*		5.24
R		0.20		0.73		0.31		0.68
F		1.38**		36.40		3.2 **		27.47
1910	0.031		0.11		0.08		0.06	
T		0.87**		4.71		1.48**		4.82
R		0.15		0.65		0.25		0.65
F		0.77**		22.18		2.20**		23.21
1940	0.054		0.08		0.09		0.06	
T		1.41**		2.79		1.93*		4.20
R		0.24		0.45		0.32		0.60
F		1.97**		7.8		3.7 **		17.68
1970	0.072		0.08		0.13		0.06	
T		2.62		3.52		2.76		5.67
R		0.43		0.53		0.44		0.71
F		6.87*		12.40		7.67		32.22

$\alpha = 0.01$ $F_{(1,31)} = 7.56$; $T = 2.32$ * not significant at this level

$\alpha = 0.05$ $F_{(1,31)} = 4.17$; $T = 1.64$ ** not significant at this level

siderable magnitude in 1850, thus indicating the early location of this group of cities on the railway network. The coefficients for the next three periods, 1870, 1910 and 1940, drop to near insignificance, as is the case for 1910.

In this part of the analysis the position of the railway and waterway system seems to be reversed, although these both stress the association with the larger towns in the early period. This association drops gradually over time, as the waterway system adjusts itself to changing capacity constraints and changing competition by other transportation subsectors. This can be illustrated by the growth in importance of the accessibility of a city to the road network in the last period, as the coefficients for all the previous periods have been insignificant with the exception of the period 1970.

As a preliminary conclusion one can say that in using different threshold levels, different aspects of the spatial structure are emphasized. These differences are not caused in this instance, as a result of a specific level of aggregation, but as a consequence of the different filters selected. In this respect the 33 cities can be much more associated with the top half of the Dutch urban hierarchy, while the 88 cities express much better the nature of the urban system as a whole.

The above conclusion is also supported by the examination of the relations presented in table 3.7. This table shows the joint effect of the individual transportation subsectors in a multiple regression framework. The position of the railway network shows a considerable difference with the individual analysis in table 3.4 for the 278 places. It changes from the most important contribution to insignificance (at the 0·05 level) in 1850 and is becoming gradually more important as time progresses. The water-network system which has a more important position, in relation to urban size jointly with the road network, loses its position in the second half of the period.

Contrasting to the analysis of the road network for the 278 places, the analysis of the values based on the next higher threshold (88 places) indicates only significant coefficients for the beginning (1850) and end (1970) of the period. The relative importance of the waterway network is somewhat improved for the second half of the whole time-period, indicating a closer association of the 88 cities with this network. This relation of the waterway network with the higher order centres is re-emphasized by the analysis of table 3.7 for the case of the top 33 centres in the urban hierarchy (see also table 3.6). Its relative position with respect to the other two subsectors is rather strong as these have only weak or non-significant associations.

table 3.7 Regression coefficients of model 2; for three groups of cities

	b_2	T	b_3	T	b_4	T	R	F
time/j=278								
1850	0.062	4.29	0.053	4.51	-0.006	-0.17**	0.40	17.13
1870	0.040	3.07	0.055	5.11	0.059	3.16	0.46	24.18
1910	0.068	5.19	0.062	5.75	0.061	4.04	0.60	50.45
1940	0.071	4.76	0.032	2.67	0.088	5.95	0.57	44.52
1970	0.072	6.30	0.020	1.89*	0.070	5.42	0.60	52 78
time/j=88								
1850	0.092	2.62	0.065	2.29*	-0.015	-0.20**	0.43	6.31
1870	0.034	1.16**	0.061	2.54	0.140	3.21	0.54	10.49
1910	0.060	1.84*	0.086	3.68	0.166	4.85	0.72	29.78
1940	0.065	2.18*	0.056	2.28*	0.184	6.35	0.74	33.73
1970	0.061	2.95	0.061	2.92	0.138	5.31	0.74	33.99
time/j=33								
1850	0.004	0.13**	0.109	4.89	0.102	1.63**	0.78	14.76
1870	0.015	0.60**	0.113	5.99	0.065	1.67*	0.77	14.51
1910	-0.008	-0.27**	0.109	4.79	0.087	1.69*	0.69	8.90
1940	0.020	0.49**	0.079	2.85	0.077	1.37**	0.55	4.28
1970	0.049	1.97*	0.073	3.24	0.060	1.47**	0.68	8.42

$\alpha = 0.01$ $F_{(3,29)} = 4.54$; $F_{(3,84)} = 4.04$; $F_{(3,274)} = 3.83$; $T = 2.32$

$\alpha = 0.05$ $F_{(3,29)} = 2.93$; $F_{(3,84)} = 2.72$; $F_{(3,274)} = 2.62$; $T = 1.64$

* not significant at this level

** not significant at this level

3.6 Conclusions

The analysis of the transportation system in this chapter has thrown some light on the growth and development of the Dutch urban system. It has been hypothesized that the structure of transport networks reflects aspects of the way this urban system operates and that by studying the way in which the transport networks evolved over time, the changing nature of the inter-urban relationships is also revealed.

An analysis of the temporal, non-spatial sequence in which investments in transport networks were made indicated the occurrence of four important periods. Each of these periods could be related to a specific mode of transportation and associated technological innovation, which was introduced over the whole study period. The four periods, in turn, were used as the basis for the analysis of the spatial sequence of the allocation of the investments in transportation. Here one could observe the diffusion of the railway network and the retraction of older and already existing transport routes, in a situation of changing transport technology and spatial variations in the main centres of demand for transportation.

The relationship between the urban structure and transport routes has been studied through a number of hypotheses relating urban size and growth to accessibility to the railway, road and water-transport networks. It appeared on the basis of correlation analysis that there was some association between urban size and accessibility to a transport network. The exact nature of these relationships were then studied using regression techniques and the introduction of a variable threshold, for the lower boundary definition of an urban place threw considerable light on the nature of the relations and the nature of the urban system.

In terms of a detailed analysis of a 278, 88 or 33 node city system in relation to the three modes of transportation, the earlier formulated hypothesis between urban size and accessibility is best supported for the case of the 88 urban areas. In this analysis the different influences of the railway, waterway and road system are most clearly illustrated. However, in terms of singling out a specific variable the examination of the 33 city systems appeared to be the most powerful. The pre-industrial relationship with the waterway system gradually disappears, while one may note in the first half of the period a reinforcement of the older mercantile centres by the construction of the road network. However after 1910 the picture changes as in other parts of the country new urban subsystems begin to develop, which become increasingly more integrated over time, thus lowering the influence of the older centres in this respect.

Finally, one can observe that the period around 1910 must have been a period of considerable change. This fact became already evident after the analysis of the population distribution over the period 1840-1970 in chapter 2, but this is also supported by the investment sequence in infrastructure (network) development, which reached a peak-level just before 1910. After this period the population distribution changed and became more dispersed, leading to a larger number of medium-sized centres. The internal structure of these centres will have experienced considerable change since this period, both because of the redistribution of the population and their integration in a larger urban system through the development of transport networks. The specific nature of the internal urban structure of the top half of the urban system, the 33 largest cities, will be examined in more detail in the next chapter.

4. A CROSS-TEMPORAL ANALYSIS OF THE URBAN SYSTEM

4.1 Introduction

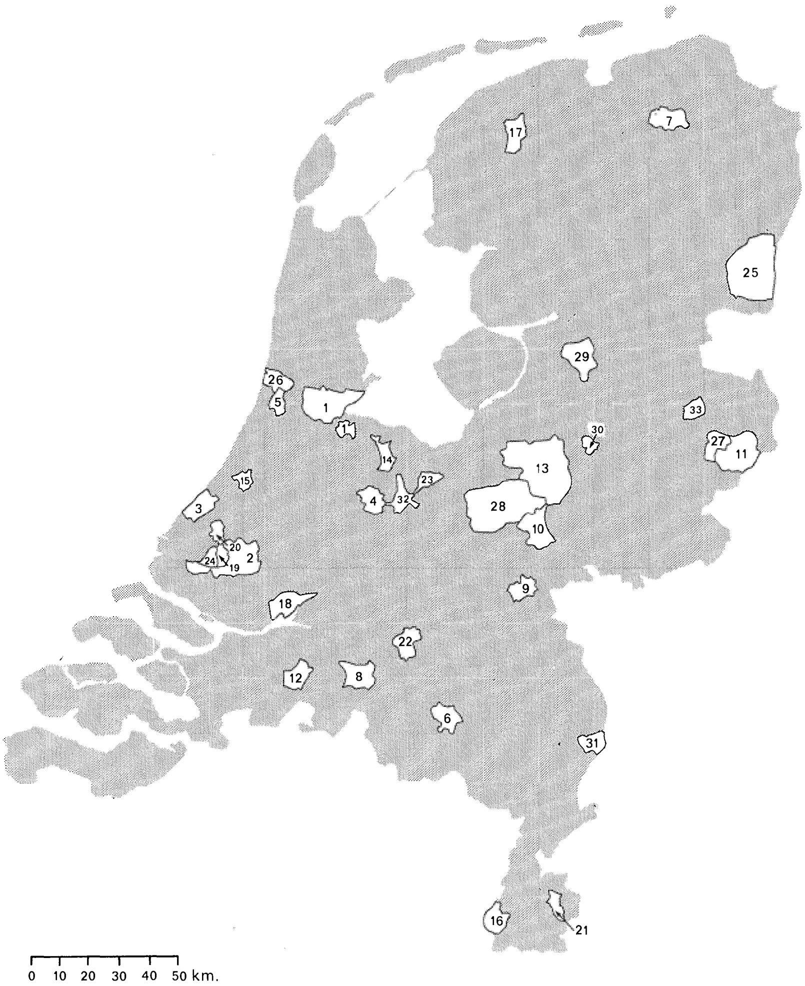
After the beginning of the 20th century the rate of growth of the economy increased considerably. This growth had a tremendous impact on the spatial organisation of the urban system. The population was becoming increasingly concentrated in the three largest urban centres till 1910. However, after this period one can observe a redistribution of the population over the city system, as a consequence of a changing spatial organizational structure. This functional reorganisation did influence different parts of the city system in different ways. It led to a reinforcement of some parts of the system and to changing spatial relationships, which are illustrated by the development of the physical infrastructure over the whole study period.

The purpose in this chapter is, to study the nature of change in the urban system as it develops from a pre-industrial to an industrial state. In this context two issues seem to be of immediate relevance. First, the study of the structural or static aspects of the system and second, the analysis of its dynamic properties. The study of the structure of an urban system involves the analysis of its global aspects as well as the nature of its nodes and their linkages. The latter aspect is already discussed in more detail in chapter three. While the overall structure of the urban system as a population system is examined in the second chapter. On the basis of these analyses it seems that an examination of the 33 top-ranking cities, in population terms, could provide a useful framework to study the questions indicated above in more detail. The relative position of the individual cities with respect to the urban system as a whole (see fig.4.1) will be one of those questions in which special attention will be given to population size and functional considerations.

As regard the dynamics of the system a number of interesting associated problems are questions related to the sensitivity of the urban system to functional change, the nature of the adaptation and reorientation of the older centres as well as of the newly emerging cities. These latter aspects are partly illustrated by the shifts in the relative position of the centres in the urban network.

Finally, the problem of the geographical scale of the analysis is apparent as one set of questions is focussed on the overall behaviour of the city system and the other group of questions deal with the intermediate and micro level aspects. Starting from the macro level, which is already discussed earlier, the analysis in this chapter will be focussed mainly on the intermediate and individual scale.

Fig. 4.1 The location of 33 municipalities with population above 50,000 inhabitants (1/1/60).



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4.2 Changes in population distribution

The growth of the population system in the past 140 years has shown a rather stable development, in which two major processes occurred (see fig.2.1 and table 2.1). First, an increasing number of larger cities in the period 1870-1910. Second, the growing concentration of the population in absolute number in the top of the urban hierarchy. These observations warrant a more detailed analysis of the nature and growth of the larger centres.

An examination of table 4.1 reveals that in the process of urbanization, which is evident from the proportion of the population in cities larger than 50,000, the period 1880-1920 is of special importance. The population growth rate is faster for this group of cities than for the growth rate of the population as a whole, as between 1840 and 1970 the relative number increases from 15·41 per cent to 43·26 per cent. The number of cities in this group doubles from 1880 to 1890 indicating already the occurrence of a considerable growth before this period, while it also doubled over the period 1930-1970. In the latter period, however, this increase in number is much closer associated with the overall growth rate of the total population, as can be seen from the proportional representation in this period, which ranges between 39·69 per cent in 1930 and 45·10 per cent in 1960.

The position of the smaller centres in the group of cities over 50,000 becomes also clear when the average proportion of the population per city is taken into consideration. Again, the period after 1920 shows a growing number of cities which have an average population just above 50,000 and their number is steadily growing. This development is in sharp contrast with the early periods in the analysis where one may note the growing importance in population terms of the four main cities till 1880.

Thus, in general, we may observe that the increasing concentration of the population in the Netherlands has led to an increase in the size and number of cities. Some modifications in this statement have already been made on the basis of the above discussion. A closer examination of the role played by the individual cities in the population system could "reflect the changing shares of the total urban economic activity obtained by these cities at various decades"[1].

A first step towards such an analysis is the study of the rank-size characteristics of the cities in the system (see table 4.2). The number of cities in

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[1] Madden, C.H., On some indications of stability in the growth of cities in the United States, Economic Development and Cultural Change, 1956, p.242.

table 4.1 Population distribution in cities over 50,000, 1840-1970

Year	Total population[1]	Per cent in cities (>50,000)	Number of cities	Average proportion per city
1840	2,860,559	15•41	4	3•85
1850	3,056,879	15•56	4	3•89
1860	3,390,128	16•06	4	4•01
1870	3,579,529	16•46	4	4•11
1880	4,012,693	18•26	4	4•57
1890	4,511,415	25•79	8	3•22
1900	5,104,137	28•29	8	3•53
1910	5,857,949	32•21	10	3•22
1920	6,831,231	37•31	16	2•33
1930	7,832,175	39•69	20	1•98
1940	8,833,977	41•48	22	1•88
1950	10,026,773	42•01	25	1•68
1960	11,417,254	45•10	34	1•32
1970	12,957,621	43•26	39	1•11

1) this is the population of the country as a whole

table 4.2 Rank of cities over 50,000 in 1960, at each decade 1840-1970

City		1840	1850	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	Average Rank	Standard Deviation	Maximum Range of Ranks
1. Amsterdam	(1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.00	0
2. Rotterdam	(2)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0.00	0
3. Den Haag	(3)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0.00	0
4. Utrecht	(4)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0.00	0
5. Haarlem	(5)	9	9	9	7	8	6	6	5	5	5	5	5	5	6	6.43	1.65	4
6. Eindhoven	(6)	25	30	34	31	24	24	25	23	7	7	7	7	6	5	18.21	10.96	29
7. Groningen	(7)	6	6	6	6	6	5	5	6	6	6	6	6	7	7	6	0.55	2
8. Tilburg	(8)	20	21	21	17	12	12	13	11	12	11	8	8	8	8	13.00	4.84	13
9. Nijmegen	(9)	13	14	16	16	17	14	9	9	9	8	9	9	9	9	11.50	3.30	9
10. Arnhem	(10)	16	16	10	8	7	8	7	7	8	9	10	11	10	11	9.86	2.96	8
11. Enschede	(11)	29	24	26	23	26	20	17	16	11	13	11	10	11	10	17.64	6.89	19
12. Breda	(12)	10	10	14	15	15	13	12	14	15	12	13	13	12	13	12.93	1.64	5
13. Apeldoorn	(13)	41	36	33	32	27	23	21	19	17	16	15	15	13	12	22.86	9.38	29
14. Hilversum	(14)	92	93	94	89	70	47	29	22	23	18	14	14	14	15	45.29	34.26	80
15. Leiden	(15)	5	5	5	5	5	7	8	8	10	10	12	12	15	14	8.64	3.56	10
16. Maastricht	(16)	7	8	7	9	10	10	11	12	14	15	17	17	16	16	12.07	3.71	10
17. Dordrecht	(17)	12	12	11	11	11	11	10	13	13	17	18	18	17	17	13.67	3.03	7
18. Leeuwarden	(18)	8	7	8	10	9	9	14	15	16	14	16	16	18	18	12.71	4.01	11
19. Schiedam	(19)	21	20	18	18	18	18	19	21	20	19	19	19	19	20	19.21	1.05	3
20. Delft	(20)	15	15	15	14	13	15	15	18	18	20	20	20	20	19	16.93	2.59	5
21. Heerlen	(21)	117	125	121	131	129	149	132	70	25	22	21	21	21	26	79.29	53.62	128
22. 's-Hertogenbosch	(22)	11	13	12	13	16	17	18	20	22	23	24	23	22	21	18.21	4.56	13
23. Amersfoort	(23)	22	23	27	28	32	32	31	29	26	26	23	22	23	24	26.29	3.65	10
24. Vlaardingen	(24)	47	48	50	51	54	41	35	32	35	34	32	27	24	23	38.07	10.40	31
25. Emmen	(25)	298	271	195	105	52	37	30	26	21	24	25	24	25	22	81.86	96.55	277
26. Zwolle	(29)	14	11	13	12	14	16	16	17	19	21	22	25	26	25	17.93	5.11	15
27. Velsen	(26)	317	318	318	226	114	107	66	39	31	25	26	28	27	30	119.00	120.98	292
28. Hengelo	(27)	113	121	124	82	87	59	41	34	34	29	27	26	28	28	59.50	38.03	98
29. Deventer	(30)	19	18	19	20	19	19	20	25	24	28	28	29	29	31	23.43	4.77	11
30. Venlo	(31)	28	32	38	42	39	35	32	31	29	31	29	31	30	33	32.86	4.17	14
31. Helmond	(*)	52	49	48	48	49	46	46	41	38	32	35	30	31	37	41.57	7.62	20
32. Ede	(28)	49	47	46	47	50	50	48	43	41	37	36	36	32	27	42.07	7.35	18
33. Zeist	(32)	212	176	144	116	123	109	81	63	54	42	38	34	33	36	90.07	58.00	179
34. Almelo	(33)	72	71	66	45	42	42	37	36	36	33	34	35	34	35	44.14	14.32	39

( ) relative position in 1960, when no population adjustments are made on the basis of the 1970 boundary definitions, (*) cities marked with an asterix consequently disappear. See also fig.4.1 for the location of the cities, where the number displayed, between brackets corresponds with the names listed in this table.

the study is determined by the size characteristics of the cities in 1960. The resulting centres are the same as those examined in the study of the development of infrastructure, as both are defined in the way discussed in chapter two.

The nature of change in rank is described by the average rank, the standard deviation and the maximum range of the shift over the period. Although these three indices are closely related, each emphasizes another aspect of the position each individual city occupies in the array of all cities above 5,000 inhabitants. The average rank indicates the relative amount of change in the position of a city, also in relation to the length of the period. The top four cities, for example, have occupied the same position in the urban hierarchy over the past 140 years. The next most stable cities exhibiting a maximum range in rank of five or less positions can be found at different positions in the next fifteen places. The large degree of stability amongst these cities is also reflected by their standard deviations, which are all small; the standard deviation here can be interpreted as an index of consistency of a city's position in the total rank-order.

When all the cities are grouped on the basis of rank-order stability, five groups emerge (see table 4.3). The third group, which is also the largest group, contains twelve cities and with the exception of Tilburg, Nijmegen and Arnhem, having rank 8, 9 and 10, all these cities have dropped in relative position. Leeuwarden's rank, for example, dropped consistently from 8 in 1840 to 18 in 1970. Deventer's position changed from 19 to 29. The most interesting point is, in fact, that the cities in this group occupied all an important position in the pre-industrial period of the Netherlands. In a sense they are overtaken by two faster growing groups of cities.

The cities in both group IV and group V have experienced rapid growth as a consequence of the industrialization, which is especially the case for the cities in the last group. Zeist is an interesting exception in this group as it reflects the early suburbanization which occurred East of Utrecht in the period 1890-1930.

This preliminary investigation thus reveals a number of cities which can be grouped on the basis of their rank-size characteristics and these groups can be interpreted in terms of some functional aspects of the cities belonging to these groups. As such, the analysis tends to support Madden's assertion in this respect, which is mentioned above. It is, however, impossible because of data limitations to carry out a functional analysis of the 33 cities over the 140 year period.

The only viable alternative is the study of the structure and change after 1910. In such an analysis we may be able to witness some of the changes from an urban-industrial to a service economy. Although the major changes from a predominantly rural-commercial economy to an urban-industrial have already occurred in the pretable 4.3 Grouping of cities on the basis of changes in rank

Amsterdam	(1)		Arnhem	(10)	
Rotterdam	(2)	group I	Nijmegen	(9)	
Den Haag	(3)	(0-0)	Leiden	(15)	
Utrecht	(4)		Maastricht	(16)	
			Dordrecht	(17)	
			Leeuwarden	(18)	group III
Groningen	(7)		's-Hertogenbosch	(22)	(5-15)
Haarlem	(5)	group II	Amersfoort	(23)	
Breda	(10)	(0-5)	Zwolle	(26)	
Schiedam	(19)		Deventer	(29)	
Delft	(20)		Venlo	(30)	
			Tilburg	(8)	
Helmond	(31)				
Ede	(32)		Hilversum	(14)	
Almelo	(34)	group IV	Heerlen	(21)	
Apeldoorn	(13)	(15-40)	Emmen	(25)	group V
Enschede	(11)		Velsen	(27)	(80-300)
Eindhoven	(6)		Zeist	(33)	
Vlaardingen	(24)		Hengelo	(28)	

The number between brackets refers to the rank of each city in 1960. The maximum change in rank-order for each city within a group of cities is given in brackets below the group number. Thus, the maximum change in rank-order in group II, for example, is between zero and five.

vious period. The changes in the economic structure of the 33 cities are illustrated in fig.4.2, with respect to employment in services, industry and agriculture, which is represented through the solid line in this figure[2]. The closer a city is located to this line, the lower its proportion of the population employed in agriculture. Thus, Emmen (25), for example, shows a considerable decline of its employment in agriculture against an increase in industrial workers. Contrasting with this case is the development of Heerlen (21), in which the proportion of the population active in services increases at a much faster rate than those in industry: A parallel replacement along the solid line, which is in all cases upwards, indicates a move towards a service oriented urban economy. Some cities have experienced considerable change in this respect, like the city of Eindhoven (6), which is predominantly an industrial town in 1930 with 79 per cent of the population employed in industry, in comparison with 'only' 59 per cent in 1960, or The Hague (3) at the other extreme end of the spectrum going from about 56 per cent active in the service sector in 1930 to 71 per cent in 1960.

On the basis of these three broad categories of employment one can observe indications of the changing functional characteristics in the top of the urban hierarchy. The analysis of these changes, however, call for a more formal approach than presented thus far in this section, to arrive at a better understanding of the nature of the change and how this may affect the organizational structure of the urban system.

4.3 Functional classification

In 1965 Smith[3] discussed in a review article the method and purpose in functional town classification. He points out that there are basically two different approaches to the classification of towns, threshold analysis and cluster analysis.

In threshold analysis cities are classified according certain threshold values, which can be determined either on the basis of (1) the occupational structure of well-defined types of cities, or (2) arithmetic means or some other statistically defined quantity, or (3) arbitrary majority quantities, which are often, but not always, defined as 50 per cent[4]. In the past this approach has also been used in the

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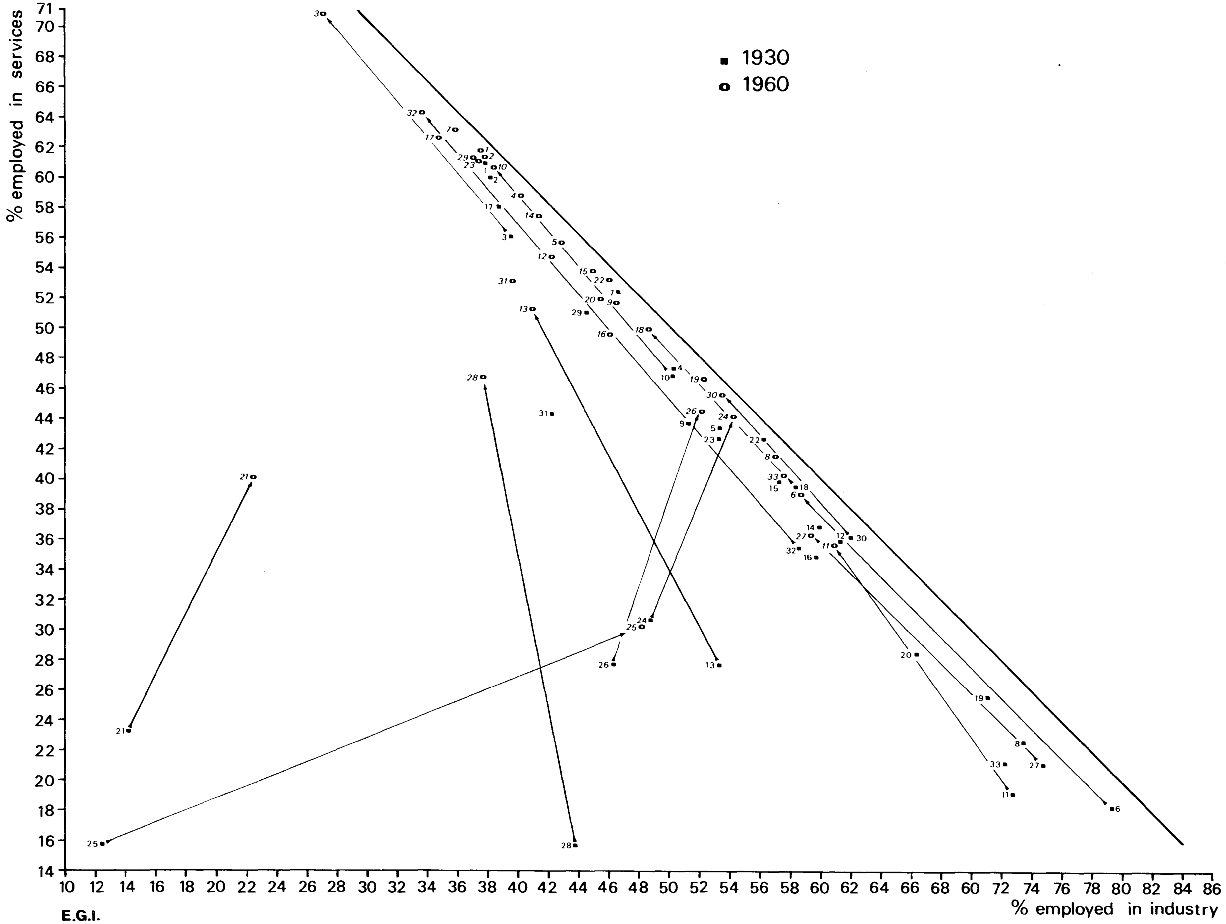
[2] The numbers in fig.4.2 are in accord with fig.4.1 and will be used in this way in the rest of this chapter.

[3] Smith, R.H.T., Method and purpose in functional town classification, Annals of the Association of American Geographers, 1965, Vol.55, pp.539-548.

[4] Smith, R.H.T., op.cit. 3, p.541.

Fig. 4.2 The changing structure of economic activities in urban areas (1930 - 1960).



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classification of towns[5.] and municipalities[6.] in the Netherlands. A major weakness of this procedure is, according to Smith, that the functional similarities between cities are ignored, which can be solved by cluster analysis.

In using cluster analysis, the procedures followed are developed to maximize the functional similarity within a group of towns and to minimize this similarity between groups of towns. As the technical possibilities for such procedures increased in the 1960s, this approach became increasingly popular amongst research workers, leading to the incorporation of a large number of variables in the classification procedure. Moser and Scott[7.] examined already in 1961 the interrelationships between 57 variables for 157 British towns, while Hadden and Borgatta[8.], for example, studied the characteristics of 65 socio-economic variables measured upon 644 cities in the United States.

A large number of studies in this period served only a pedagogic purpose, but on the basis of these studies gradually a generally accepted methodology emerged[9.]. Factor analysis or principal component analysis was the technique most commonly used to study functional differences between cities[10.] or, at a lower geographical scale, between parts of the city[11.]. A major problem in this approach is the selection of the variables and the identification of the clusters of variables and cities derived on this basis.

Although the ultimate choice of the number and the nature of the variables is determined by the objectives of the study and the available data base, it is possible to make some general statements in this respect. First, the total set of variables can be divided into two categories of unequal size of which the smallest subset contains the differentiating characteristics and the largest subset the

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5. Steigenga, W., A comparative analysis and a classification of Netherlands towns, Tijdschrift voor Economische en Sociale Geografie, 1955, Vol.46, pp.105-119.

6. Typologie van de Nederlandse gemeenten naar urbanisatie graad in 1960, C.B.S., 's-Gravenhage, 1964.

7. Moser, C.A. and W. Scott, British towns: A statistical study of their social and economic differences, Oliver and Boyd, London, 1961.

8. Hadden, J.K. and E.F. Borgatta, American Cities: Their social characteristics, Chicago, 1965.

9. Berry, B.J.L. and K.B. Smith (eds.), City Classification handbook: Methods and applications, J.Wiley, New York, 1972.

10. Berry, B.J.L. (ed.), Comparative factorial ecology, in Economic Geography, 1971, Vol.47, No.2 (supplement), pp.207-367. See also for an extensive bibliography, pp.356-367.

11. Timms, D., The urban mosaic, towards a theory of residential differentiation, Cambridge University Press, 1971.

accessory characteristics. This is explained by the fact that not every variable has the same discriminating power and, as Bunge[12.] observed, a good differentiating characteristic has a large number of accessory characteristics, which are highly correlated with it. As in factor analysis the set of differentiating characteristics is determined in an indirect way, on the basis of the analysis of the intercorrelations of the accessory characteristics, the selection of subsets of variables become important.

Ideally, given a priori knowledge on the nature and number of the differentiating characteristics, there should be as many subsets of variables as differentiating characteristics. Social area analysis in its restricted sense may serve as an example in this case, where on the basis of theoretical considerations three constructs were thought to describe the way in which the urban populations are differentiated[13.]. These three characteristics are: (1) economic status or social rank, (2) family status (age structure) or urbanization, and (3) ethnic status or segregation and together they provide the framework for the selection of the variables. In the extensions of social area analysis to urban ecological analysis, the direct link with a theoretical foundation disappeared and consequently the selection of the variables and factor identification, as differentiating characteristics, became more difficult.

The third comment in this respect deals with the composition of the various subsets. In factorial ecology, like in other factor analytic studies, the importance of a factor is determined by its contribution to the total variation, i.e. on the number of accessory characteristics and their amount of intercorrelation as measured through the factor loadings. Thus, the distribution of the number of accessory characteristics over the various subsets can influence the weight allocated to a factor. This consequence should be borne in mind, as for some characteristics more statistical information is available than for other equally important categories which then, as a consequence of an over-representation of some group of variables in a subset, can disappear in a subsequent phase of the analysis. This effect may be best illustrated on the basic model in factor analysis[14.]:

[12.] Bunge, W., Theoretical Geography, Lund Series in Geography, Ser.C., No.1, 2nd edition, Gleerup, Lund, 1966, p.18.

[13.] See for a concise discussion of social area analysis, Rees, P.H., Concepts of social space: towards an urban social geography, chapter 10, in Geographic Perspectives on urban systems, B.J.L. Berry and F.E. Horton, eds., Prentice Hall, Englewood Cliffs, New Jersey, 1970, pp.306-394.

[14.] Lawley, D.N. and A.E. Maxwell, Factor analysis as a statistical method, Butterworths, London, 1963, p.3.

$$x_i = \sum_{r=1}^{k} l_{ir} f_r + e_i \qquad (i = 1, 2, \ldots\ldots\ldots, p) \quad ,$$

where f_r is the r^{th} common factor, k is specified and e_i is a residual representing sources of variation affecting only x_i. The coëfficient l_{ir} is usually termed the loading of the i^{th} variable on the r^{th} factor. The p observed variables x_i can thus be considered as redistributed over the factors f_r according to the weights l_{ir}. The factors f_r can be viewed as the differentiating characteristics and the case discussed above can now be described by the situation in which most l_{ir}'s have a significant contribution to one f_r and contrasting to this some f_r's disappear because most l_{ir}'s are close to zero for these f_r's. The problem then arises when the empirically derived number of factors r' is smaller than the theoretically expected number r, because of misspecification of the initial set of variables.

In the subsequent analysis in this chapter factor analysis (principal axis solution) will be used as a method for classifying the 33 cities under study, according to their functional characteristics[15.]. The objective of this classification is to provide a basis for the analysis of the change in the organizational structure of the urban system over time. The problems associated with an analysis of urban structures over time will be discussed briefly in the following section.

4.4 Temporal variations and stability

The functional classification of cities over time requires the construction and analysis of a three-dimensional matrix. Each dimension can be associated with a specific category; the observational units which are in this case the range of cities is one dimension, while the set of variables measured upon these cities is part of the second dimension and the number of periods considered is portrayed through the third dimension. The analysis of such a three-dimensional matrix can be viewed as a special case of the more general multi-dimensional problem, which is discussed by Horst[16.]. He proposes a reduction of the multi-dimensional matrix into a series of two-dimensional matrices, which can be factor analyzed in the total manner. Thus, for the three-dimensional case, one category is represented along the rows, while

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15. This method will be also employed in a revision of the classification of the Dutch municipalities to their degree of urbanization (see, op.cit. 6). Herziening typologie van Nederlandse gemeenten, Census monografie, SISWO, Amsterdam, 1976.

16. Horst, P., Factor analysis of data matrices, Holt, Rinehart and Winston, Inc., New York, 1965, see pp.315-332.

the other two are collapsed into the columns of this two-dimensional matrix. As such a process can be carried out three times, once for every category, the resulting two-dimensional matrices are given by the three possible combinations {1,(2,3)}, {2,(1,3)} and {3,(1,2)}, where 1, 2 and 3 stand for the dimensions[17.].

An interesting extension of this method for the case of three-dimensional analysis is suggested by Tucker[18.]. This involves the computation of a core matrix which links together the three two-mode factor loading matrices, calculated in the manner discussed above. This core matrix is then used to derive the three-dimensional matrix of factor scores. The first application of this model in geography was by Cant[19.] in a study of the changes in the location pattern in manufacturing in New Zealand. His conclusion was that the initial stages of the study, the factor analysis of the three separate modes, was more successful than the analysis of the core matrix. As "the complex patterns of the original data" are not reduced to a set of clear, simple relationships "and the illumination tends to proceed from the data to the results"[20.]. A considerable problem in the interpretation of the results obtained through the core matrix is, that it is not possible to standardise the data for both modes simultaneously.

A simpler and more direct approach, as an alternative to the above procedures, is to restrict oneself to a number of cross-sectional analyses, as many as there are periods, and cross-temporal analyses. As in most applied studies the range of time periods under consideration is usually rather short compared to the number of variables, or the number of variables is rather limited compared to the length of the whole study period[21.], this restriction will create in most cases no problems. In the present study there are only three cross-sections available which is, of course, too small a number for a meaningful cross-temporal factor analysis.

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17. See for a brief review of the various applications of these methods in geography, Chojnicki, Z., and T. Czyz, Some problems in the application of factor analysis in geography, Geographical Analysis, 1976, Vol.8, pp.416-428.

18. Tucker, L.R., Implications of factor analysis of three-way matrices for measurement of change, in Problems in measuring change, C.W. Harris, ed., Madison, Wisconsin, 1963, pp.122-137.

19. Cant, R.G., Changes in the location of manufacturing in New Zealand, 1957-1968: an application of three mode factor analysis, New Zealand Geographer, 1971, pp.38-55.

20. Cant, R.G., op.cit. 19, p.52.

21. Jeffrey, D., E. Cassetti and L.J. King, Economic fluctuations in a multi-regional setting: a bi-factor analytic approach, Journal of Regional Science, 1969, pp.397-404.

Thus, the emphasis will be on the inter-temporal comparison of three factor analyses based on cross-sectional data.

If we use the factor analysis model as a tool for studying change, then we have to recognize a number of possible sources of variation which can only be studied in a fruitful manner if there is a sufficient control on the technical sources of variation. Janson[22.] stated that before substantive invariances or changes can be revealed through factor analysis and not only for this method, the following elements should be kept invariant: (1) the number and selection of theoretical variables, (2) the operational definition of variables, (3) the definition of the study area, (4) the (areal) units of observation, and (5) the specific factorial model used and the number of dimensions. As these conditions are satisfied in this study, two possible sources variation remain: (1) the factor structure is stable and it is possible to observe a change in the factor scores, and (2) the factor scores are stable and one may observe a change in the factor structure.

The basic assumption in the first case is that any selective process of change operates directly on the factors and only indirectly on the variables themselves[23.]. The observed pattern of change is a change in the spatial configuration of the variables that produces the factor scores[24.]. These changes can be caused by a random element or by changes in the spatial structure of the regions under study. Jaumotte and Paelinck[25.] examined the changes in the economic structure of the Belgian provinces on the basis of the variation in factor scores from one period to the next, using shift and share analysis. Thus, given factor stability, the clustering of regions, or cities in urban dimension space, on the basis of factor scores may exhibit changes from one period to the next. Three of the four questions raised by King in this context are all based on the stability of urban dimension and the related variation in the scores of the individual cities[26.]. His fourth point is that

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[22.] Janson, C.G., Some problems of ecological factor analysis, in Quantitative Ecological Analysis in the Social Sciences, M. Dogan and S.Rokkan, eds., M.I.T. Press, Cambridge, Massachusetts, 1969, pp.301-343.

[23.] Lawley, D.N. and A.E. Maxwell, op.cit. 14, pp.92-97.

[24.] Haynes, K.E., Spatial change in urban structure: alternative approaches to ecological dynamics, Economic Geography, 1971, Vol.47, pp.324-335, see especially in this context pp.326-327.

[25.] Jaumotte, Ch. and J.H.P. Paelinck, The differential economic structure of the Belgian provinces: a time varying factor analysis, Regional and Urban Economics, 1971, Vol.1, pp.41-75.

[26.] King, L.J., Cross-sectional analysis of Canadian urban dimensions: 1951 and 1961, Canadian Geographer, 1966, Vol.4, pp.205-224, see p.207 and p.208 for these four questions.

the basic form of a dimension may remain comparatively stable but the loadings of different variables on this dimension may vary from one time to another. Such a variation can be caused by a weak relation of the variable with the dimension, as a differentiating characteristic and variations in factor loading are consequently due to change. A systematic but gradual change in the accessory characteristics, however, can be an indication of structural change which is reflected by the second source of variation.

Megee was also confronted by the same problem of variations in factor structures and factor scores when she observed[27.] that "key growth factors change over a period of time, thus making it impossible to compare the changes in development and growth of a state or entity on the same factor. When the same variables are used from one time period to the next, the underlying factors will normally be different. Thus it is difficult to show changes or relative stability of regions on the same factors over a period of time, using this particular method of factor analyzing the data". However, the method employed in Megee's study is unconstrained in the sense that no distributional assumptions are incorporated with respect to the occurrence of a random element, neither as regards the factor structure nor the factor scores. At the same time it has been allowed that substantive differences occur simultaneously in both the factor pattern and the factor score matrix[28.]. Thus, the isolation of spatial change or compositional change then becomes a very difficult matter.

However, the problem observed by Megee is a very real one in applied analysis and also noted by psychologists like Thurstone, especially for the case of principal axis factor solutions, which are most commonly used in geography. To reduce the variation in results Thurstone proposed a rotation to simple structure to arrive at factorial invariance or stable dimensions in replication[29.]. The invariance of the results, given the same conditions, is a desirable goal in a scientific methodology and as Horst argues, the second objective of factor analysis is, to find a particular method of analysis and reduction of the dimensions which will yield rather stable results. Thus, when the replication conditions are satisfied, the observed change can be interpreted in terms of spatial or compositional change.

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27. Megee, M., Economic factors and economic regionalization in the United States, Geografiska Annaler, 1965, Vol.47, pp.125-137, see p.136 and p.137.

28. Megee, M., op.cit. 17, see p.128.

29. See Horst, P., op.cit. 16, pp.19-20.

In a recent study Rompuy and Tejano[30] attempt to link these two sources of change in a formal, autoregressive, structure. They assume that the second period observations can be linearly explained by the first period observations up to a residual term, which basically is the assumption that there is no spatial change. The residual terms can, when transformed, be explained by the usual linear factor model and the observed spatial variations are thus directly associated to structural change. A major problem in this approach, according to the authors, is the identification and interpretation of the patterns of change which are incorporated in the factors from the factor analysis. Although they interpreted the first factor, the second remaining factor is, as yet, unexplained.

On the basis of the above discussion the procedure in this chapter will consist of two stages. First, the functional structure of the top 33 cities of the urban system will be described using factor analysis and the factor patterns studied with respect to structural change. Second, on the basis of this first step a grouping of the cities will be performed using the factor scores and after the identification of the clusters these will be examined as to their degree of temporal stability.

4.5 Structural analysis

In a study of interurban comparison four aspects seem to be relevant to describe effectively some main features of the urban structure, where each of these aspects should characterize a different element[31]. First, the demographic structure of the city which is measured by variable 2, 3 and 4 (see table 4.4). Second, a cultural aspect is of importance as this may give rise to a higher degree of regional or local homogeneity. In some countries such differences are caused by variations in ethnicity. In the Netherlands it is felt that this role has been fulfilled up to the recent past by differences in religion; variables 5, 6 and 7. This lack of homogeneity is also reflected by a wealth of parallel social organizations each pursuing the same goal and their only difference is the different religious background of their membership. Thus, cities being located in a region which is dominated by a specific religious group may have more contacts and linkage amongst themselves than can be expected from their position in the urban hierarchy.

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[30] Van Rompuy, P. and A. Tejano, Intertemporal factor analysis applied to Belgian standards of living indicators, Regional Science Research Paper No.5, Centrum voor Economische Studies van de Katholieke Universiteit te Leuven, Leuven, 1975, see pp.6-7.

[31] Janson, C.G., A preliminary report on Swedish urban structure, Economic Geography, 1971, Vol.47, pp.249-257.

table 4.4 Factor loadings for 33 cities over 50,000; 1930-1960

variables*	dimensions 1930				dimensions 1947				dimensions 1960			
	1	2	3	4	1	2	3	4	1	2	3	4
1 population density per ha	.70	.03	-.22	.17	.60	.39	.09	.04	.64	-.47	.07	-.31
2 % of the population, 0-15 year	-.85	-.32	-.29	.18	-.90	-.01	-.23	-.14	-.83	.25	-.23	-.10
3 % of the population, 65 year and above	.77	-.23	.12	-.20	.72	-.28	-.01	-.39	.89	.14	-.00	.26
4 % women, 15-39 year	.46	.74	.07	-.17	-.28	.70	-.30	.16	-.72	-.30	-.16	-.15
5 % roman catholic	-.38	.70	-.55	-.09	-.60	.74	-.02	-.15	-.70	-.66	-.21	.02
6 % dutch reformed	.16	-.72	.60	.04	.32	-.87	-.08	-.16	.43	.84	.08	.04
7 % reformed	.21	-.80	.38	.24	.31	-.81	-.22	.26	.44	.80	-.05	.07
8 average number of persons per household	-.93	.04	-.19	.10	-.93	.09	-.17	.01	-.94	.21	-.23	-.07
9 average number of persons per dwelling unit	-.84	.21	-.28	-.03	-.87	.24	-.20	-.15	-.81	-.06	-.37	.22
10 finished number of new dwelling units	.01	.56	.30	.55	-.50	-.18	-.13	.52	-.26	.15	-.31	.79
11 % employed in agricultural activities	-.66	-.61	-.24	.05	-.44	-.70	-.35	-.10	-.32	.72	-.33	-.11
12 % employed in manufacturing industries	-.02	.68	.65	-.06	-.10	.06	.93	.09	-.47	.12	.79	-.06
13 % employed in textile industry	-.32	.24	.52	-.65	-.35	-.24	.51	-.53	-.35	.18	.51	-.13
14 % employed in metal industry	-.10	.48	.39	.68	.01	.14	.68	.58	-.18	-.16	.69	.28
15 % employed in building and construction	.61	.09	.04	.06	.28	.01	-.20	-.08	.04	.42	-.42	-.55
16 % employed in tertiary activities	.87	-.01	-.44	.01	.74	.44	-.36	-.07	.74	-.29	-.47	.16
17 % employed in transportation	.68	-.06	-.47	.11	.65	.36	-.27	.40	.61	-.23	-.05	-.04
18 % employed in banking and insurances	.77	.05	-.36	.27	.75	.49	-.08	-.10	.70	-.50	-.21	-.09
eigenvalues	6.53	3.81	2.60	1.42	6.21	3.90	2.24	1.41	6.75	3.33	2.31	1.33
% of total variance, cumulative	36.25	57.44	71.90	79.80	34.52	56.18	68.62	76.45	37.51	56.03	68.88	76.26

* Sources : *Statistisch Steden Boek*, cijfers omtrent de Nederlandse Gemeenten met 50.000 en meer inwoners,1960-65, Amsterdam,1966.
Statistisch Steden Boek, cijfers omtrent de Nederlandse Gemeenten met 50.000 en meer inwoners,1955-60, Amsterdam,1961.
Population Census, 1947, Utrecht, De Haan, 1954.
Population Census, 1930, 's-Gravenhage, 1932, 1933, 1934.

Third, the density of the urban population and their housing situation are both aspects characterizing the physical-morphological organization of urban space as a place to live and this is reflected through variables 1, 8, 9 and 10. Fourth, the employment structure is of considerable importance in the analysis of change in functional structure and this is reflected in the choice of the variables and their number, eight out of a total of eighteen. First of all the three main sectors, agriculture, manufacturing and the service sector, are incorporated, variable 11, 12 and 16, while both the secondary sectors are further represented by some important subcategories, respectively variable 13, 14, 15 and 17 and 18.

Unfortunately, it has not been possible to incorporate also 1910 in the analysis, as the largest part of the available information is only of a demographic nature and the employment categories are defined on a completely different basis. To arrive at a comparable set of variables for the three periods under consideration, 1930, 1947 and 1960, the most recent period is used as a basis. As for this period more information is available than for earlier periods, a separate factor analysis has been carried for a larger set of variables which were all selected on the basis of the four aspects mentioned above. The purpose of this analysis was to study the effects of the reduction of the data set, from an initial size of 37 variables, to a smaller set, because not only the total available amount of information decreases, but it is also variable over time. The reduction of the 1960 data set, through a deletion of variables, to a set of 18 variables did, however, not give rise to a fundamental change in factor structure. However, considerable changes did occur when going below this level. Thus, it can be argued that the 18 variable set holds the main accessory characteristics which define the four aspects of the urban structure for the three periods under consideration.

To ensure comparability also the spatial basis is kept constant over the whole study period, using the 1960 boundary definitions in the way discussed in chapter 2. As also the same type of factor analysis, principal component method, will be used, the conditions for comparability are satisfied and it should be possible to study the changes in urban structure over time in a meaningful way. The first results of the analysis are reported in table 4.4, by the factor loadings for the three periods; see Appendix 2 for the three matrices showing the simple correlation between the 18 selected variables. The four factors derived for each period give the unrotated or principal component solution and no rotation to simple structure has been applied, as this would not have improved the identification of the components[32]. No

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[32] In the rest of this discussion the terminology of factor analysis will be used, although the differences between factor analysis and principal component analysis are realized.

cut-off point has been used in this analysis as the purpose was the extraction of four factors; the same number for each period. Although an eigenvalue cut-off point of one corresponds to the 1930 solution, both for 1947 and 1960 an additional factor would have been extracted in such a case. The first four factors account for about 80 per cent in 1930 and 76 per cent in 1947 and 1960 of the total variance of the 18 standardized variables. The four main aspects of the urban structure are reflected in these factors by a number of different combinations which indicate their interrelationships.

Dimension 1 : familism and higher order urban activities

On the first factor there are two clusters of variables, one with high positive loadings and one with high negative loadings. The cluster with the positive loadings can be associated with tertiary activities, transportation and banking and insurances (variables 16, 17 and 18). These activities are spatially coincident with high population densities (1) and a large proportion of the population which is older than 65 years (3). Cities with a high positive score on this dimension are thus characterized by these variables. Cities with a high negative score on this dimension can be associated with the cluster of negative loadings. Here we can note a much younger population structure (2) concomitant with a larger average size of the household (8) and more persons per dwelling unit (9). This demographic characteristic is inversely related to the population density per ha. (1), suggesting lower overall densities in the cities which is also reflected by a weak positive association with the agricultural activities (11) in this cluster.

Dimension 2 : cultural-religious and primary activities

The second factor accounts for about 22 per cent of the total variance. Also on this factor there is a cluster of positive and negative loadings. The cities with a relative high proportion of protestants within their boundaries (variables 6 and 7) have also a relative larger number of persons active in agriculture (11). This latter fact may be caused by the larger total area of the city which is incorporated in the analysis. Such overbounded cities are generally more predominant in the Middle and Northern part of the country.

As was expected by the selection of the variables, the predominantly high proportion of Roman Catholics (5) have high opposite positive loadings on this factor. Consequently, cities with a high positive score can be associated with this variable, but also with a relatively high proportion of the female population in the active age group (4). This religious dichotomy has strong regional associations in the Netherlands, but, as will become evident from the subsequent analysis, these differences are not so dominant that they have an overriding influence on the final grouping of cities.

Dimension 3 : manufacturing and services

This factor very strongly reflects the industrial component of the urban system by its cluster of positive loadings. These loadings reflect the employment opportunities in manufacturing industries (12) and more specifically also in metal and textile industry (13, 14). The cluster of negative loadings can be associated with tertiary activities (16, 17 and 18), which have a lower weight than the secondary employment opportunities on this factor. These loadings have also a lower numerical value than those on the first factor, thus they represent only a modest importance of the tertiary activities in cities which have a high negative score on this factor.

Dimension 4 : physical expansion

Factor four is the last factor of the set and consequently it has the smallest number of variables associated with it. The amount of variation explained by this factor is only 8 per cent of the total variance. The variable which is most closely connected with this factor gives the number of new finished dwelling units (10) and can be considered as an indication of the physical expansion of the built-up area of a city. Most closely associated with this variable is variable (14), expressing the employment in the metal industry, which is also a growth industry as opposed to the textile industry (13) which is inversely related with this factor. The association of these two employment subsectors with this factor weakens, however, over time as will be discussed below, but the loading of variable (10) is the only loading which maintains numerically a position of certain importance. Obviously, this fourth factor is the weakest of the set.

Stability of the urban dimensions

The question one can immediately raise at this stage of the analysis is whether the interpretation of the four dimensions is consistent over time. This question thus refers to the variability of the loadings of the 18 variables between 1930, 1947 and 1960. The inter-temporal correlations between the four dimensions can be interpreted as a measure of correspondence from one time period to the next (see table 4.5).

The stability of the urban dimensions can be best observed between 1947 and 1960. The next most stable period is 1930-1947, although one can note that the degree of correspondence between dimensions varies considerably for this period, table 4.5 Inter-temporal correlations between urban dimensions

A		1947			
		1	2	3	4
1930	1	0.93	0.20	-0.07	0.12
	2	-0.27	0.73	0.44	0.23
	3	0.09	-0.54	0.64	-0.06
	4	0.07	-0.02	-0.05	0.79

B		1960			
		1	2	3	4
1930	1	0.83	-0.26	-0.02	-0.11
	2	-0.44	-0.68	0.25	0.15
	3	0.02	0.53	0.74	-0.07
	4	0.11	0.01	-0.07	0.39

C		1960			
		1	2	3	4
1947	1	0.96	-0.12	0.09	-0.14
	2	-0.16	-0.94	-0.12	-0.14
	3	-0.12	-0.10	0.93	0.04
	4	0.00	-0.09	0.12	0.38

compared with the other period in which the correlation coefficients are larger than .90 for the first three dimensions (see table 4.5A and C). The largest difference amongst the factors is between 1930 and 1960 and on the basis of these differences it appears that the change between 1930 and 1947, if there is any, is of the most importance. This conclusion is also supported by the intercorrelations of the third factor in 1930 with the second factor in 1947 and the second factor in 1930 with the third in 1947; -0.54 and 0.44 respectively, see table 4.5A. These intercorrelations, which are absent in 1947-60, indicate changing relationships amongst the second and third dimensions in 1930 and 1947 and to a lesser degree also between the first and the second dimension. The situation is completely different for the fourth dimension which has its largest correspondence between 1930 and 1947 and not for the next period 1947-60, for which there is only a correlation coefficient as low as .38. From this perspective one may conclude that this dimension occupies a different position in the urban dimension space and that its behaviour over time with respect to the three other urban dimensions indicates a lack of association with them.

Although one may think that the interpretation of the four urban dimensions is no longer consistent for the three periods together, this is not the case. The interpretation is based on the numerical values of the loadings on the factors and the square of this value represents the amount of variation contributed by this particular variable to the factor. In the case of the first dimension the eight relevant variables account for about 79 per cent of the variation in this factor for 1930 and 1947 and 72 per cent in 1960. Also for the second and third dimension one can observe that the amount of variation contributed by the substantive variables is of roughly the same numerical order of magnitude. Again the fourth dimension is a different case, as it changes from a contribution of 83 per cent in 1930 to 54 per cent in 1960 and thus reflects a considerable degree of instability. This dimension expresses most strongly the general pattern of a decreasing coincidence from 1930 to 1960. The nature of the change can not be best observed on the level of the dimension but is more pronounced in the composition of the underlying variables.

Thus, one can state as a preliminary conclusion that the overall nature of the first three dimensions remains stable but there is a gradual change in their internal composition which is most salient for the period 1930-1947. This pattern of change in the urban structure is portrayed in fig.4.3 and 4.4. The largest amount of change in the first dimension is caused by the variables which have a near insignificant contribution to the first factor for two out of three periods, like variables (4, 5, 6 and 7). This is especially the case for the female population in the active age group (4) which shifts from factor two to the negative cluster in the first dimension and thus strengthens the population household-size aspects of this dimension. Besides the constant decreasing importance of agricultural activities, there is a negative shift to be noted for the employment in metal industries, indicating the growing association of this employment category with the cities which have a negative score on this dimension.

The amount of variation is larger in the second dimension, as could be expected on the basis of a lower inter-temporal correlation compared with the first and the third dimension. The year 1930 especially occupies a different position in this dimension for variable (10, 12, 13 and 14). This first variable is rather unstable for the whole period of the analysis as it not only expresses physical growth on the fourth dimension but is also represented at different dimensions in different periods. The decrease of the importance of the employment variables in manufacturing, metal and textile industries in this dimension is caused by the growing concentration of these activities in some centres. This growing specialization is also reflected in the structure of the third dimension (see fig.4.4).

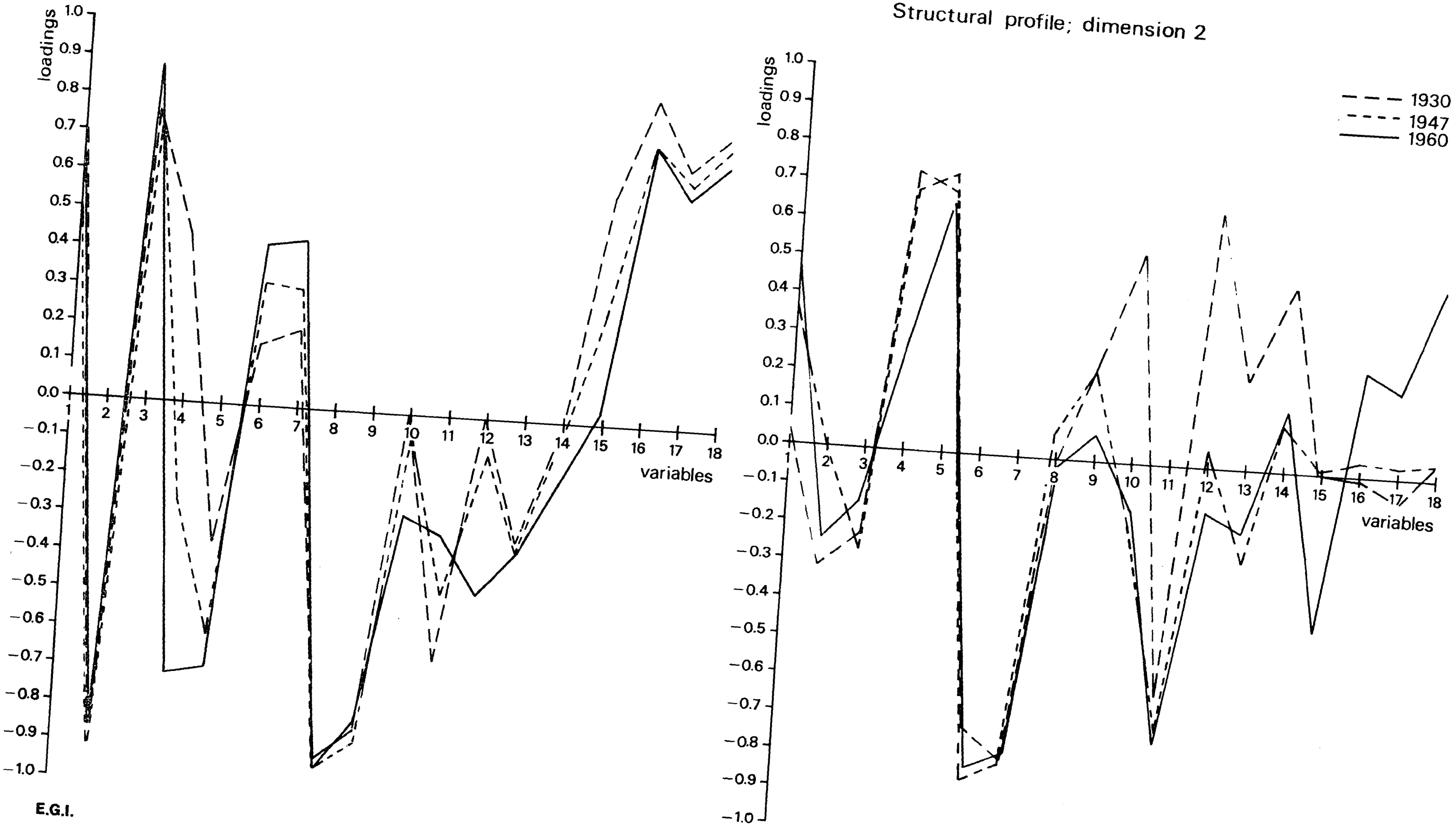
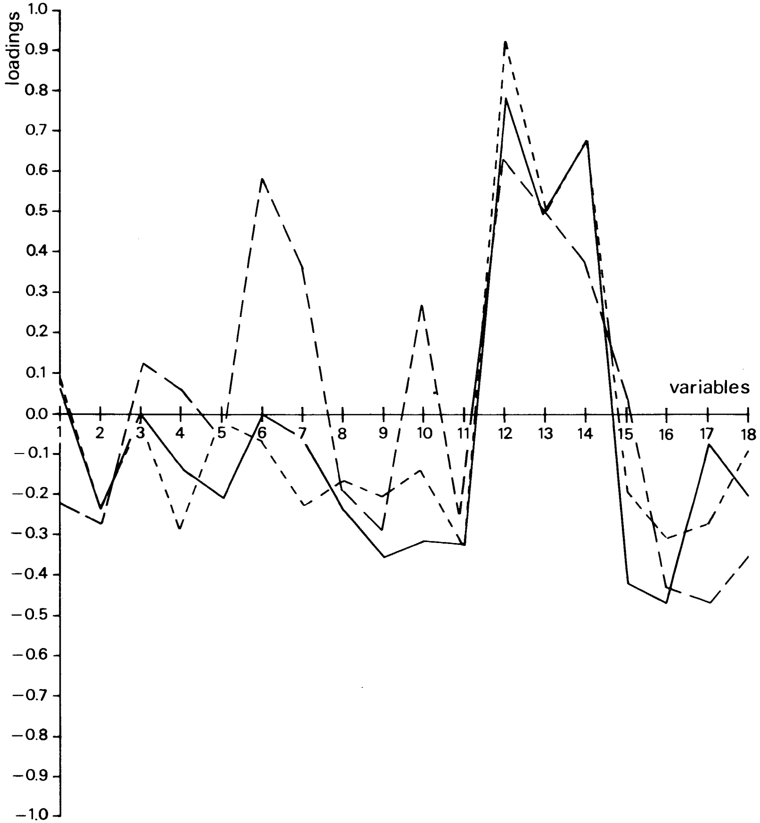


Fig. 4.3 Structural profile; dimension 1

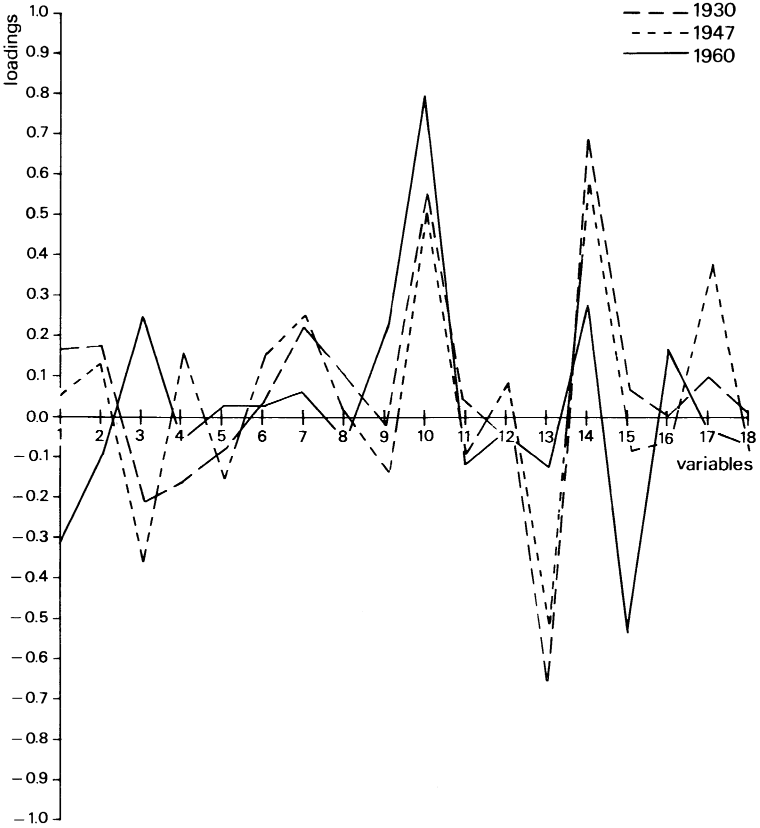
Structural profile; dimension 2

E.G.I.

Fig.4.4 Structural profile; dimension 3



Structural profile; dimension 4



E.G.I.

On the basis of a close examination of the structure of the urban dimensions one may conclude that their basic pattern is reinforced over time, with the exception of the fourth dimension. The earlier observed relations amongst the second and third dimension in 1930 and 1947 can be explained by the increasing concentration of manufacturing activities in some urban centres. The ecological association of the proportion of the urban population which belong to the Roman Catholic religion weakens over time and consequently looses its strong regional association since 1930. This development is not so much the case for the protestant group which is getting, as a result, a slightly more dominant position on the second urban dimension over time[33.].

4.6 Urban profiles and grouping analysis

The four urban dimensions characterize the structure of the top of the urban hierarchy, but not of the individual city. Each city will have its own particular combination of these dimensions, which reflects best the internal structure of that city. The results of such a process of evaluation are given by the scores of a city on the four dimensions. Each set of scores thus can be considered as the generalized profile of a city, which can be interpreted on the basis of these dimensions. To ease the interpretation and comparability between the scores for each dimension, the scores are standardized with respect to a common origin with a mean equal to zero and a standard deviation to one.

Using these generalized profiles, it is possible to group the cities into a number of groups on the basis of the similarity between members. The particular algorithm used here is Ward's procedure for hierarchical grouping[34.]. This procedure is a step-wise procedure (see fig.4.5), which creates at each step a group with the maximum internal homogeneity. It will be obvious that each next step will create a group of a lower internal homogeneity, as in the final step all cities are in one group (see also fig.4.6). At this step the highest level of generalization has been reached, but at the same time the lowest possible similarity between group members or homogeneity of the group. Evidently, the problem in such a procedure is to determine that level where one has a small number of groups with an acceptable amount of

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33. These compositional changes probably influenced the change in signs of the loading of the second factor for 1960, but do not fundamentally change the relationships between the variables and this dimension. For this reason are the 1960 loadings portrayed with an inverse sign in fig.4.4.

34. Ward, J.H., Hierarchical grouping to optimize an objective function, Journal of the American Statistical Association, 1963, Vol.58, pp.236-244.

Fig. 4.5 Grouping of 33 cities in: 1930, 1947, 1960

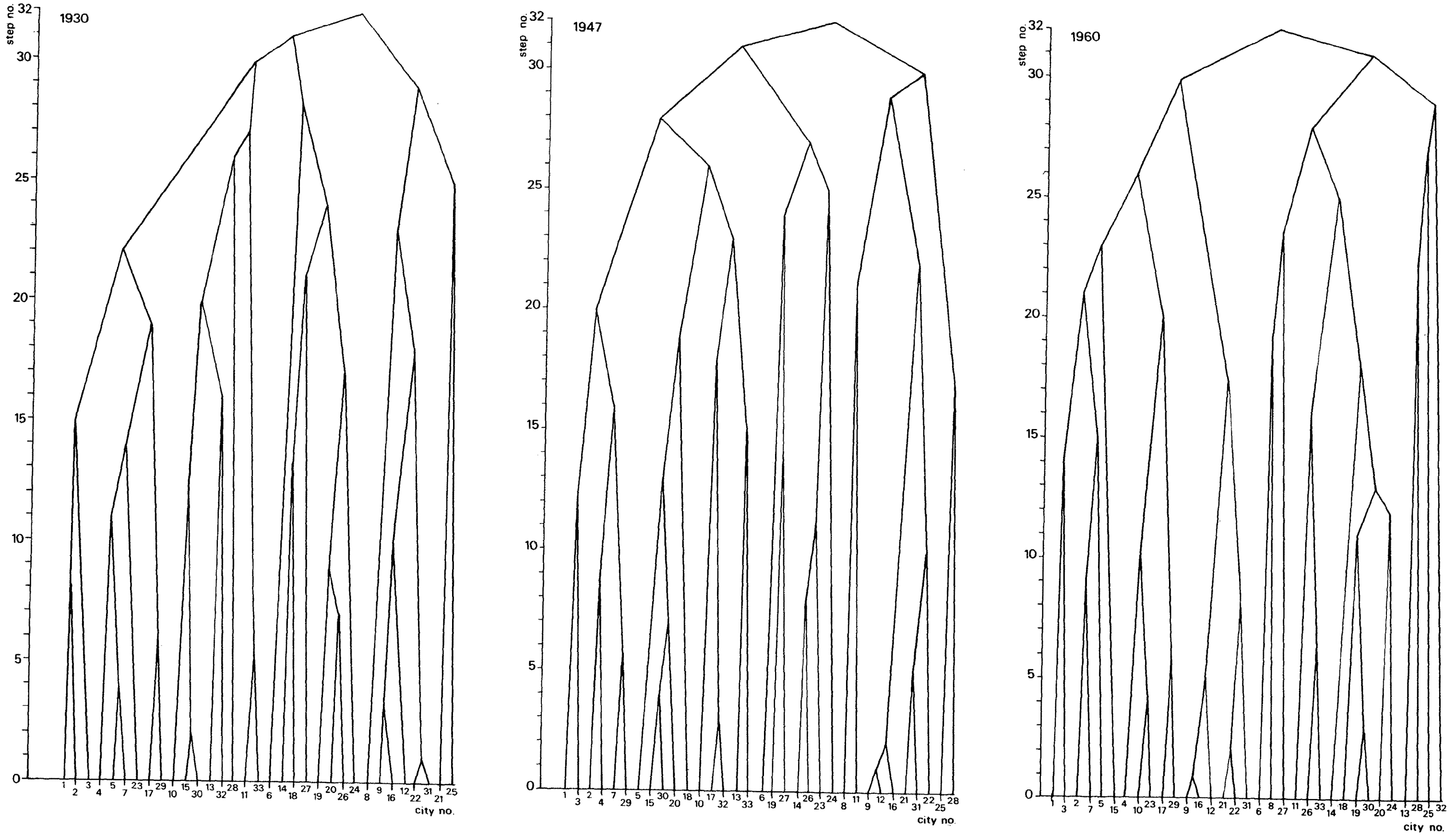
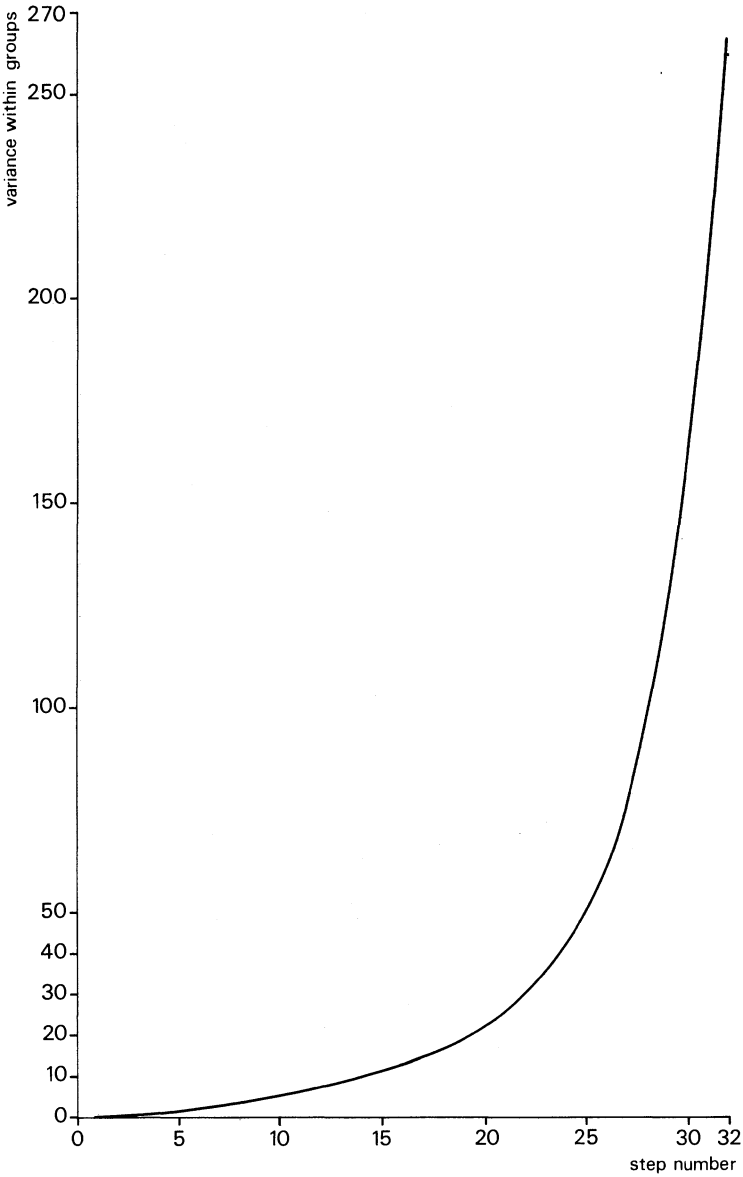


Fig. 4.6 Step-wise increase of total variance within groups.



heterogeneity within each group[35].

In the present case the number of groups is unknown, as there is no information available about the specific functional differentiation of the cities in the Dutch urban hierarchy. Besides, there is no reason to assume why this functional differentiation should produce a specific number of urban groupings in one period and another or the same number in the next period. Thus the emphasis will be on the internal homogeneity of the groups and not so much on their number in a specific period.

In this particular grouping procedure there are two types of events which have a different impact on the intra-group homogeneity. First, there is the case when one city joins a group or cluster of cities and especially in the beginning of the process the decrease in homogeneity will not be large. Second, two groups of cities join and make a new group. This will be the case in the later stages of the grouping process and a considerable increase in heterogeneity will be the consequence, which can be observed by a sharp increase of the within-group variance (see fig.4.6), which is used as a measure for homogeneity. These two events thus characterize two different stages in the grouping process. From the viewpoint of having a small amount of variation within a group, a cut-off point in the procedure should be selected where all individual cities have joined a group and total level of variation within the group is small.

On the basis of the above arguments the cut-off points for the three periods 1930, 1947 and 1960 have been determined at step 26, 25 and 26 respectively. At this stage in the grouping process the total amount of detail, contained in the various groups, is between 75 and 80 per cent. This implies that the groups are fairly homogeneous as only 20 to 25 per cent of the total possible variation is represented by these groups. The derived groupings are by no means perfect, as it was inevitable to incorporate both in 1930 and 1960 some groups of only one city which have not joined earlier, because they are completely different from the rest. As was expected, the number of groups varies considerably between periods. There are six groups in 1930, eight in 1947 against five in 1960 (see table 4.6, 4.7 and 4.8). Each of these groups, in a specific period, is characterized by its particular urban profile by which it can be identified.

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35. The nature of this problem is the same as in statistical test procedures where one wishes to maximize at the same time both the level of confidence and the power of the test. In such cases there is a generally accepted level of confidence which is established in practice.

table 4.6 Grouping of cities in 1930 on the basis of factor scores;
d = 76,98%

	Cities	Urban Dimensions				Group	Step	no.(26)
		1	2	3	4			
1	Amsterdam	1.734	-0.114	-1.212	-0.069	I	22	
2	Rotterdam	1.068	-0.447	-1.013	0.334			
3	's-Gravenhage	1.991	-0.035	-0.482	0.496			
4	Utrecht	0.842	0.141	-0.234	0.770			
5	Haarlem	0.981	0.137	0.006	-0.013			
7	Groningen	1.000	-0.420	0.029	0.011			
23	Amersfoort	0.203	-0.265	-0.258	0.058			
18	Leeuwarden	1.204	-0.992	-0.423	-0.352			
29	Zwolle	0.696	-0.911	-0.170	-0.045			
	group average	1.080	-0.323	-0.417	-0.130			
10	Arnhem	0.568	0.175	-0.112	-0.974	II	26	
15	Leiden	0.547	-0.317	0.396	-0.793			
30	Deventer	0.461	-0.044	0.803	-0.620			
13	Apeldoorn	-0.200	-1.126	0.811	-0.570			
32	Zeist	0.765	-0.399	1.084	0.019			
28	Ede	-1.293	-1.870	1.085	-0.875			
	group average	0.141	-0.597	0.858	-0.636			
11	Enschede	-0.826	0.485	1.747	-2.394	III	5	
33	Almelo	-0.447	0.391	1.493	-2.027			
	group average	-0.637	0.438	1.620	-2.211			
6	Eindhoven	-1.606	2.178	0.481	2.514			
14	Hilversum	0.365	0.757	1.166	1.276	IV	24	
17	Dordrecht	0.827	-0.014	0.728	1.401			
27	Hengelo	-0.668	1.279	1.610	1.143			
19	Schiedam	-0.423	0.066	0.809	1.335			
20	Delft	-0.170	-0.092	0.550	0.628			
26	Velsen	-0.617	-0.493	0.212	0.949			
24	Vlaardingen	-0.224	-1.339	0.447	0.922			
	group average	-0.130	0.406	0.789	1.093			
8	Tilburg	-1.249	1.554	-0.058	-1.340	V	23	
9	Nijmegen	0.127	0.724	-1.121	-0.562			
16	Maastricht	-0.270	1.066	-1.228	-0.731			
12	Breda	0.031	1.350	-0.491	-0.649			
22	's-Hertogenbosch	-0.493	0.918	-1.529	-0.365			
31	Venlo	-0.592	0.996	-1.924	-0.435			
	group average	-0.408	1.101	-1.059	-0.680			
21	Heerlen	-1.942	-0.412	-2.213	0.185	VI	25	
25	Emmen	-2.393	-2.898	-0.987	0.670			
	group average	-2.168	-1.655	-1.600	0.428			

table 4.7 Grouping of cities in 1947 on the basis of factor scores;
d = 78,77%

	Cities	Urban Dimensions				Group	Step no.(25)
		1	2	3	4		
1	Amsterdam	1.732	1.093	0.144	-0.221	I	20
3	's-Gravenhage	1.546	0.719	-0.791	-0.338		
2	Rotterdam	1.342	0.246	-0.278	1.038		
4	Utrecht	0.835	0.609	-0.272	0.432		
7	Groningen	1.083	0.074	-0.683	0.101		
29	Zwolle	0.778	-0.240	-1.228	0.254		
	group average	1.219	0.417	-0.518	0.211		
5	Haarlem	1.119	0.319	0.619	-0.838	II	19
15	Leiden	0.446	0.032	0.400	-0.367		
30	Deventer	0.651	-0.307	0.707	-0.746		
20	Delft	0.191	-0.363	0.879	-0.165		
17	Dordrecht	1.409	-0.157	1.031	0.430		
	group average	0.763	-0.095	0.727	-0.337		
10	Arnhem	0.555	0.371	-0.524	-1.041	III	23
18	Leeuwarden	1.061	-0.686	-0.930	-0.735		
32	Zeist	0.856	-0.826	-0.559	-0.548		
13	Apeldoorn	0.038	-1.530	-0.300	-0.737		
33	Almelo	-0.501	-0.898	0.792	-1.026		
	group average	0.402	-0.714	-0.304	-0.817		
6	Eindhoven	-1.804	1.171	1.207	1.366	IV	24
19	Schiedam	0.173	0.029	1.491	1.034		
27	Hengelo	-0.551	-0.386	2.407	1.356		
	group average	-0.727	0.271	1.702	1.252		
14	Hilversum	0.150	-0.141	0.186	0.753	V	25
26	Velsen	-0.240	-0.357	0.069	1.494		
23	Amersfoort	0.072	0.229	-0.596	0.993		
24	Vlaardingen	-0.183	-1.165	0.212	2.986		
	group average	-0.050	-0.478	-0.032	1.534		
8	Tilburg	-1.505	0.856	1.544	-1.861	VI	21
11	Enschede	-0.741	-1.087	1.954	-1.911		
	group average	-1.123	-0.116	1.749	1.886		
9	Nijmegen	-0.460	1.004	-0.456	-0.552	VII	22
12	Breda	-0.731	0.796	-0.367	-0.692		
16	Maastricht	-0.739	1.230	-0.354	-0.776		
21	Heerlen	-1.557	1.279	-1.503	0.469		
31	Venlo	-1.286	1.197	-0.905	0.310		
22	's-Hertogenbosch	-0.928	1.684	-0.941	-0.077		
	group average	-0.713	1.198	-0.754	-0.220		
25	Emmen	-1.804	-1.915	-1.844	-0.115	VIII	17
28	Ede	-1.007	-2.879	-1.112	-0.261		
	group average	-1.406	-2.397	-1.478	-0.188		

table 4.8 Grouping of cities in 1960 on the basis of factor scores; d = 79,61%

	Cities	Urban Dimensions				Group	Step no.(26)
		1	2	3	4		
1	Amsterdam	1.819	-1.477	0.202	-0.436	I	26
3	's-Gravenhage	1.922	-0.955	-0.750	-0.510		
2	Rotterdam	1.534	-0.320	-0.072	-0.452		
7	Groningen	1.272	0.006	-0.480	-0.027		
5	Haarlem	1.085	-0.592	0.232	-0.887		
15	Leiden	0.712	0.041	0.606	-1.814		
4	Utrecht	0.492	-0.519	-0.357	-0.256		
10	Arnhem	0.267	-0.243	-0.721	-0.456		
23	Amersfoort	0.291	0.175	-0.619	-0.462		
29	Zwolle	0.680	0.504	-0.651	-0.186		
18	Leeuwarden	1.072	0.591	-0.634	0.123		
	group average	1.013	-0.254	-0.295	-0.408		
9	Nijmegen	-0.838	-0.920	-0.608	-0.161	II	17
16	Maastricht	-0.793	-1.123	-0.833	-0.009		
12	Breda	-0.809	-0.870	-1.031	0.168		
21	Heerlen	-1.166	-1.215	-1.269	-0.066		
22	's-Hertogenbosch	-1.339	-1.121	-1.081	0.194		
31	Venlo	-1.533	-1.053	-1.336	0.557		
	group average	-1.080	-1.050	-1.026	0.114		
6	Eindhoven	-1.608	-0.987	1.345	0.705	III	24
8	Tilburg	-1.778	-0.858	0.615	-0.418		
27	Hengelo	-0.696	-0.035	2.400	1.597		
	group average	-1.361	-0.627	1.453	0.628		
11	Enschede	-0.730	1.009	1.781	-0.240	IV	25
26	Velsen	-0.223	0.241	1.008	-0.650		
33	Almelo	-0.601	0.788	1.175	-0.744		
14	Hilversum	0.561	-0.077	0.351	0.897		
17	Dordrecht	0.752	0.296	0.945	0.211		
19	Schiedam	0.225	-0.156	1.176	0.172		
30	Deventer	0.235	0.199	1.286	0.233		
20	Delft	0.128	0.134	0.426	0.012		
24	Vlaardingen	0.139	0.694	0.889	0.546		
	group average	0.054	0.348	1.004	0.049		
13	Apeldoorn	0.047	1.489	-0.365	0.515	V	22
28	Ede	-0.606	2.875	-1.492	0.486		
	group average	-0.280	2.182	-0.929	0.501		
25	Emmen	-1.294	2.509	-1.003	-2.461		
32	Zeist	0.779	0.970	-1.135	3.902		

Grouping of cities in 1930

The six groups of cities in 1930 (see table 4.6) can be given an interpretation using their group average. The scores for each city on the four dimensions have been standardized for every dimension. This make the overall mean equal to zero, but this is not necessarily the case for the individual group mean. A group mean of zero can be interpreted in two ways. If the dimension is identified by one cluster then this zero mean represents the average of that cluster. In most cases here the dimensions are bifocal which implies for a zero mean that both the cluster of positive and negative variables on a dimension are in balance. Consequently a positive mean score can be interpreted as a dominance of the cluster of variables having positive loadings on this dimension because these variables outweigh the negative cluster numerically.

The cities in the first group can be associated with higher order urban activities, especially tertiary activities, banking and insurances. This structure is weakly reinforced by the mean value (-0.417) of the third dimension. These cities, which are the main centres of the Dutch urban system in this period, are also characterized by high population densities and an older resident population.

Contrasting to this group of cities is the second group with a mean of about zero for the first dimension. This group has a demographically much younger population and a population, which is actively employed in manufacturing and in the metal and textile industry. The importance of these two categories of employment in some cities is reflected by the mean value of the third and fourth dimension of the third group. However, their degree of local and regional concentration is outweighed by the city of Eindhoven, which maintains a separate position from the rest, as a one-member group. This unique position is emphasized by the fact that this city occupies three extreme positions on the four dimensions. Together these values indicate the existence of a predominantly young population, both in the age group below 15 years and in the active age group between 15-40 years. The high positive score on the fourth dimension indicates that the metal industry is the biggest employer within a dominating manufacturing sector.

The cities in the fourth group show a more balanced structure of the urban economy, although one may also observe in this case the importance of the secondary sector in these cities for the 1930s. As is also the case for Eindhoven, the cities in this group have not only a strong component in the metal industry but they experience considerable physical expansion as well. The latter growth element is also reflected by the high positive mean score on the fourth dimension.

The cities in the last two groups are in a way more different from the previous four groups than can be expected on their group membership alone. This difference can be seen in fig.4.5 where these two groups of cities join the rest of the city system at the last stage in the grouping process. An examination of the mean scores for group V indicates that this is the only group of cities which have large negative scores on the third dimension and large positive scores on the second dimension. These cities are all located in the Southern Roman Catholic part of the country and have a predominantly large economic active population, which finds employment in the manufacturing and textile industry. Besides these activities the employment opportunities in the service sector seem also to be of some importance and these six cities are all regional centres of second order importance.

Finally, both Heerlen and Emmen are extreme places in some respect. Both can be characterized by a young demographic structure and a large family/household size. The proportion of the population active in primary activities is considerable, albeit agriculture in the case of Emmen and mining for Heerlen. The importance of these places as second order service centres can be derived from their negative scores on the third dimension, which is largest for Heerlen.

Grouping of cities in 1947

The number of different groupings have increased from six to eight groups since 1930 and this suggests an increasing functional specialization. At the same time the number of cities per group decreased. The pattern of change will be examined later; at present the specific structure of each group is of interest.

The first group contains six cities which are in the top of the urban hierarchy both from a functional and from a population-size point of view, with the exception of Zwolle which is 29th ranking. Again the very strong service component, expressed by the first dimension, is reinforced by the second and third dimension. This feature, together with high population densities, seems to be a dominant element in the total urban structure of these cities.

The second group of cities has a lesser emphasis on the service activities which are, however, still above average. This is, however, compensated by a sizeable industrial manufacturing sector in which both the metal and, to a lesser degree, the textile industry are of importance. This last group of activities is below average in the third group of cities which have in contrast a relatively high proportion of the population active in agricultural activities. The relative large areal size of these cities and their location in the Middle and Northern part of the country, which is spatially correlated with predominantly protestant population groups, may explain the nature of this group.

The three cities in the fourth group, Eindhoven, Schiedam and Hengelo, can be considered as the main industrial cities in the Netherlands in 1947 which all have a strong emphasis on the metal industry and experience rapid physical expansion. This structure is complemented by a relative young demographic composition and a large household size which is associated with high densities per dwelling unit. This part of the urban structure is dominant in the sixth group for the cities Tilburg and Enschede. Contrasting with the three cities in the fourth group, the employment in the textile industry is a very characteristic element in the urban structure for these two cities.

The cities Hilversum, Velsen, Amersfoort and Vlaardingen, group V, display a much more average composition, with the exception of a strong emphasis on employment opportunities in the metal industry. The second order regional centres in the Southern part of the Netherlands have a young demographic structure in combination with a large household size, indicating a large economically dependent population. Furthermore, they display no special type of industrial employment structure. The last group, Emmen and Ede, show much resemblance to the previous group of six cities, but their main difference is a stronger emphasis on the demographic structure component and the contrast between the regionally dominant catholic religion in the South and the protestant religion.

In comparison to the earlier period, 1930, the grouping of cities in 1947 seems much more sensitive to single factors and less to a combination of factors. An important role is played by the population boom directly after the war, 1946, which seems to have hit some cities much more than others, causing in the cities hit a young urban population structure. A second element of importance is contributed by the physical expansion of the cities, sometimes in combination with the metal industry as growth sector in the urban economy. Alternatively, the manufacturing industry as a whole, sometimes in combination with the metal industry sometimes with the textile industry, did provide a basis for various groupings of cities.

Grouping of cities in 1960

The grouping of cities in this period indicates a convergence of the diverse urban pattern in 1947 to larger more homogeneous groups of cities. This is reflected by the smaller number of groups, five for this period, with the exception of Emmen and Zeist, which are one-member groups and as such occupy a special position. Whether this convergence into larger groups also implies a replication of the 1930 spatial structure is a question which can only be answered after the interpretation of the five groups.

The first group, which contains the top of the urban hierarchy, Amsterdam, The Hague, Rotterdam and Groningen, is much larger than in 1947. This could suggest a widening of the top of the hierarchy with more integration in the structure of the urban system as a whole. The pattern of the average scores for this group emphasizes its service employment element while the remainder of the scores are close to the overall average on the urban dimension for the 33 cities together.

The second order service centres in group II which are located in the South of the country are still dominated by a young demographic structure in combination with large household sizes and high densities per dwelling unit. Complementary to this group are the cities Eindhoven, Tilburg and Hengelo which have a still dominant manufacturing sector in which both the textile and metal industry play an important role.

The fourth group consists of nine cities which are on average close to the structure of the total group of 33 cities, with the exception of a positive high score on the third dimension. This score emphasizes the dominant position of the industrial component in the urban structure of the cities in this group. Apeldoorn and Ede, the largest cities in the Netherlands as far as areal extent is concerned, show up in the last group with a relative large proportion of their population active in agriculture within their city boundaries. These cities are at the same time located in a predominantly protestant area which reinforces their score on the second dimension.

Temporal stability in group membership

A main feature of the analysis of the urban system presented thus far is that it is a relative analysis. The classification of the cities vis à vis each other is carried out against the average urban structure made up by the 33 cities. The groupings of cities in 1930, 1947 and 1960 are relative to this basis. A stable group or group core consists of those cities which belong to the same group over the whole period. On the basis of this definition of stability three group cores emerge (see table 4.9).

What is the nature of this stability? As we have shown in the previous section the four urban dimensions are fairly stable over time, with the most stable pattern for the 1947-1960 period. Any change in this structure can only be a proportional change with respect to all contributing variables. The nature of change in group membership is thus to a large extent caused by the internal processes at work for each individual city and these determine its relative functional position in the urban system.

The cities in the three stable group cores thus reflect the functional stability of this part of the urban system. For these cities there was little need table 4.9 Changes in group membership 1930 - 1960

	Group core in 1930/47/60	temporary group members in					
			1930		1947		1960
1	1 Amsterdam		23 Amersfoort				23 Amersfoort
	2 Rotterdam		18 Leeuwarden				18 Leeuwarden
	3 's-Gravenhage		5 Haarlem				5 Haarlem
	4 Utrecht						15 Leiden
	7 Groningen						10 Arnhem
	29 Zwolle						
2	9 Nijmegen		8 Tilburg		21 Heerlen		21 Heerlen
	16 Maastricht						
	12 Breda						
	22 's-Hertogenbosch						
	31 Venlo						
3	14 Hilversum		18 Dordrecht		23 Amersfoort		11 Enschede
	24 Vlaardingen		19 Schiedam				18 Dordrecht
	26 Velsen		20 Delft				19 Schiedam
			27 Hengelo				20 Delft
							30 Deventer
							33 Almelo
		II	10 Arnhem	III	10 Arnhem	III	6 Eindhoven
			15 Leiden		18 Leeuwarden		8 Tilburg
			30 Deventer		32 Zeist		27 Hengelo
			13 Apeldoorn		13 Apeldoorn	V	13 Apeldoorn
			32 Zeist		33 Almelo		28 Ede
			28 Ede				
		III	11 Enschede	II	5 Haarlem		25 Emmen
			33 Almelo		15 Leiden		
					30 Deventer		32 Zeist
					20 Delft		
					17 Dordrecht		
		VI	21 Heerlen	VI	8 Tilburg		
			25 Emmen		11 Enschede		
			6 Eindhoven				
				IV	6 Eindhoven		
					19 Schiedam		
					27 Hengelo		
				VIII	25 Emmen		
					28 Ede		

of a functional spatial reorganisation, while the other cities had to adjust themselves organizationally to changing external links. The first group of cities contains the higher order centres with a strong emphasis on employment in service activities. At the same time these cities are characterized by high population densities and an older demographic composition. This is in contrast to the cities in the second group which have a rather large proportion of the population in the age-group (0-15 year) in combination with larger household sizes. The importance of the tertiary activities in these cities is also very noticeable and when their absolute size is taken into account, they can be classified as second order regional service centres.

The three cities in the third group have a much stronger association with the manufacturing industry than those in the other two groups. The unstability of the fourth dimension from 1947 to 1960 is illustrated here by the shift of the highest score from the fourth to the third dimension in this period. The third dimension has had throughout the period a strong association with the secondary activities which did become more pronounced as the loadings of the relevant variables were getting a unique association with this dimension. Not only these three cities, but larger and different groups of cities were having similar orientations in different periods.

An interesting observation in this context is that group membership in 1930 is much more comparable to group membership in 1960 than in 1947. This is not only the case for the industrial towns in the third group, but also for the higher order urban centres in the first group, like Amersfoort, Leeuwarden and Haarlem. The different positions the cities occupy in the 1947 functional space are very noticeable, especially in light of the close correspondence of the overall urban structure between 1947 and 1960. This suggests the occurrence of a time lag in the readjustment of the internal structure of the cities which are members of the same group in 1930 and 1960 and not in 1947. It may be considered as a lag, as the largest difference between urban dimensions can be observed between 1930 and 1947 and not between 1947 and 1960. This kind of spatial and functional adjustments to changes in the overall structure may also occur in the opposite way. There are, however, no such cases in the groups of cities under study.

Another interpretation is that the observed deviations with the 1947 grouping structure can be explained by temporal variations in the internal dynamics of the individual cities within a generally stable urban structure. In such a case there is no time lag between the aggregate and individual structure but it is an aspect of the dynamic development of the urban system, as a stable structure, over time. It is impossible on the basis of the three points in time studied here, to decide which of the two explanations is most likely. To some extent this is not a real issue as the second point is more of a technical nature and can be compared with the idea of the random variations which have a zero sum around a given value. Digressing from a technical observation, the first explanation given can be considered as a functional interpretation of the observed events.

Temporal variations of a completely different nature are displayed by the groups which have no stable group core in 1930, 1947 and 1960: each of those groups has a different structure in each period. The cities in these groups must have experienced a continuous change and readjustment in their internal structure. This whole process of change in a relatively stable urban structure requires, at the same time, a continuous readjustment of the external relations of a city with the other cities in the urban system. The changing nature of the external linkage will be felt to a lesser degree in cities in the stable part of the system as only some of their relations will have to change. The cities which do not belong to the stable core sometimes group together and sometimes they do not. The first kind of occurrence can be considered as a chance occurrence and not as a result of any systematic process. The main reason for these cities being together once in one group is that they have a comparable structure at only one point in time. In this respect these cities are not so much different from the cities which are not a member of any group, except their own one-member group. Such cities, like Eindhoven, Emmen or Zeist have an internal structure which is very unlike that of any other centre and their growth path do not converge upon a common structure, not even accidently.

4.7 Conclusions

The fundamental research question in this chapter was focussed on the development of the urban system from a pre-industrial to an industrial state. The best starting point for such an analysis is before or around 1910. This choice of this position in time can be argued on the basis of the analysis of the urban system as a population system and the level of investments in infrastructure. However, as comparability over time is a very important criterion, the state of the urban system in 1930 has been used as the basis of reference for the analysis. At this time there had been already considerable changes in the structure and we may be able to study the second part of the industrialization phase till 1960. This task has been performed on the 33 largest cities of the system, each having a population of at least 50,000 inhabitants in 1960. As these cities contain about 45 per cent of the total population of the Netherlands, their functional pattern and changes in their structure are fundamental for the rest of the urban system.

The 33 cities did, of course, not occupy the same relative position in the urban hierarchy and an analysis of the change in this position gave rise to a classification of the cities into five groups. A comparison of the cities in these five groups with the functional groupings of cities made at a further stage of the analysis, indicates that there is a considerable functional heterogeneity amongst the cities in these groups. The functional structure of this part of the urban system is studied with the use of factor analyses and grouping analyses. These two types of analyses provided the basis for the study of the structure of the urban system and for an examination of the relative position of the urban centres within this functionally defined system.

The factor analysis was performed on the same 18 variables for 1930, 1947 and 1960. These variables measured 4 different related aspects of the internal urban structure: the demographic structure, a cultural-regional aspect, some physical and density features of the intra-urban space and the socio-economic structure, which got a heavy emphasis by its representation in 8 variables. Four urban dimensions were extracted and these represented the selected aspect in various combinations of bipolar factors. Although there have been changes in the relative importance of some variables, this has not led to fundamental changes in the structure of the urban system as a whole. The largest amount of change was caused by the growing importance of secondary activities, which shifted somewhat from the second to the third factor in the period 1930-1947. A decreasing regional concentration could be noted for the cultural-religious aspect, but this was not strong enough to be expressed by different urban dimensions for 1947-1960. Especially the latter period showed a very stable pattern for the three most important dimensions. Thus, while recognizing the influence of these disturbing elements it can be concluded that the urban dimension space was relatively stable for the period 1930-1960.

The above conclusion has been the basis for the grouping analysis and the subsequent interpretation of the groups using the average group score on the urban dimensions. The interpretation was based on the identification of dominant scores, working from the assumption that each city in the analysis was equipped with a minimum number of necessary urban functions. Every period was characterized by a different number of groups which sometimes contained different combinations of cities as well. As far as stable group membership is concerned, the 1930 groupings are much more like the 1960 ones than those for 1947. Especially this latter period showed a large number of groups, each of them with slightly changing emphasis in combinations of urban dimensions. Nevertheless, three stable group cores can be identified and these are associated with: (1) the top of the urban hierarchy which shows a remarkable stability over time in the previous studies, but displays here a considerable temporal homogeneity in their functional structure as well, (2) a group demographically dynamic urban centres of second order importance in the urban hierarchy, and (3) a small group of predominantly industrial cities. The first and the second group contains all cities which were already of some importance in the pre-industrial period and their continuing presence and importance suggests an early adaptation in a changing economic environment. In contrast to this is the increased specialization in the industrialization phase, which has led to the development of the cities in the third group as manufacturing centres.

Finally, the cities have to be mentioned which do not belong to a specific group for more than one period. These cities do represent in a way the two most extreme positions a city can occupy in the range of possibilities. Either these cities express the most dynamic aspects of the urban system by a continuing rate of change which does not lead to a convergence, or these cities represent the opposite, a lack of dynamism in their structure; it is the outside world that rushes around them and they regress to another level in the urban hierarchy. Another explanation which has been proposed in this context is that these cities are fluctuating around their respective levels in the urban hierarchy and that the period of observation discussed here, is too short to observe this process. Such a hierarchy is, of course, not a rigid step-wise structure but a more continuous structure in which the various levels are represented by clusters of cities. In this study there has been made no attempt to develop this concept further, consequently the clusters discussed can be given only a functional interpretation and hardly any meaningful hierarchical relevance.

5. THE DIFFUSION OF T.V. OWNERSHIP IN THE URBAN SYSTEM, 1957-1967

5.1 Introduction

The focuss in this chapter is on the way the urban system influences the spatial organisation of a society. The position of the major nodes in this system, their evolution and functional characteristics have been the topic of discussion in the foregoing chapters. These nodes, the urban centres, interact in many ways with each other. The various interaction patterns, however, exhibit a specific spatial structure, which reflects the general characteristics of the linkage structure of the urban system. The nature of this linkage structure will be explored here using the diffusion of T.V. ownership in the urban system as an analytical tool. The results of such an analysis will be of particular relevance for the present study, when the principles which are satisfactory for the analysis of spatial diffusion processes can be generalized to any type of movement in geographic space. On the basis of the literature examined by Brown and Moore, they conclude that this is at least partly the case[1.].

There are six basic elements which are common to all spatial diffusion studies[2.]: (1) an area or environment, (2) a temporal dimension, (3) an item being diffused, (4) places in which the item is located in time t, (5) places in which the item is located for the first time in time t+1, and (6) paths of movement or relationship between origin places (4) and destination places (5). The last four elements determine the formal structure of the analysis and can be represented by a directed graph in a spatial-temporal framework (the first two elements).

The basic elements of an urban system are the cities or nodes, the areas around them and the linkages between the nodes. To understand fully the way in which the diffusion operates in such a system, one has to know: (1) the frequency with which the items being diffused - or information about these items - are transmitted, (2) the characteristics of the receiving node, as some nodes may receive the items earlier than others which can indicate their resistance to adopt the item, and (3) the nature of the linkages with respect to the origin node, as biases in these linkages can affect the time elapsed between introduction and adoption. Usually one knows very little about the frequency with which information about an innovation is transmitted.

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1. Brown, L.A. and E.G. Moore, Diffusion research: a perspective, in Progress in Geography, C. Board, R.J. Chorley, P. Haggett, D.R. Stoddard, eds., Vol.1, Edward Arnold, London, 1969, pp.119-157; see p.146.

2. Brown, L.A., Diffusion processes and location, Regional Science Research Institute, Bibliography Series No.4, 1968, pp.9-25.

The most common assumption is a constant level for each unit which has adopted the innovation for the whole time-period. It is of importance in this context to differentiate between personal contacts and impersonal contacts via mass-media. The role of these two sources of information is not uniform over the period. Rogers, for example, notes that impersonal contacts play a more important role in the early phases of the diffusion process, while personal sources of information become more important in the later stages[3.]. It is even doubtful whether the intensity of personal contact flows remains the same over time, for, as Brown observed in his study of the diffusion of T.V. licenses in Southern Sweden, the enthusiasm of late adopters about the innovation is generally less than that of those who adopted earlier[4.].

Thus, the analysis presented here will focuss upon the nature of the linkages in the urban system and the way in which the characteristics of the nodes in the system influence the flow structure. The influence of the characteristics of the urban centres will be operative in two ways. First, it will be expressed as a general feature, non-specific as far as the item being diffused is concerned, but specific for the structural relationships of the linkages in the urban system. Second, it will be specific to the item being diffused, because some of its properties may be easier accepted in some places than in others. The joint outcome of these two features of the diffusion process will be examined by the analysis of the map patterns in section 5.4. The conceptual framework for this discussion is provided below in section 5.2 and 5.3, where both the formal and functional aspects of the diffusion process are discussed[5.]. The former can be associated with a size or hierarchical effect, a neighborhood or wave effect (section 5.3) and a temporal effect (section 5.2), which all represent the general features of the innovation process. The latter focusses on the substantive processes by which an innovation spreads from one place to another.

The homogeneity assumption which is at the basis of the above analysis will be relaxed in section 5.5 by the incorporation of the spatio-temporal variations in regional structure. This will enable us to study the differences in acceptance ratios of the innovation caused by these variations, which can be partly associated with the

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[3.] Rogers, E.M., Diffusion of Innovations, New York, Free Press, 1962, pp.171-187.

[4.] Brown, L.A., Diffusion dynamics, Lund Studies in Geography, Ser.B., Human geography, No.29, Gleerup, Lund, 1968, pp.54-60.

[5.] Brown, L.A. and K.R. Cox, Empirical Regularities in the diffusion of Innovation, Annals of the Association of American Geographers, 1971, Vol.61, pp.551-559.
Ray, D.M. et.al., Functional prerequisites, spatial diffusion and allometric growth, Economic Geography, 1974, Vol.50, pp.341-351.

item specific characteristics. A number of hypotheses will be formulated in this context and examined using regression analysis, while at the same time and in combination with this analysis some formal hypotheses will be studied regarding the functional structure of the urban system.

5.2 Diffusion as a temporal process

The growth of the number of adopters of an innovation over time can be represented by a S-shaped curve. Casetti has shown that the logistic curve follows directly from a number of assumptions that are fundamental for the diffusion processes studied by Hägerstrand[6.]. Adoption is considered to be a result of constant transmission of information by the persons who have already adopted this innovation. It is recognized that potential adopters can have different levels of resistance to the innovation. Ultimately the resistance is overcome by a sufficiently large repetition of the same information. Thus, the users who have adopted the innovation earlier have a lower degree of resistance than those who adopted the innovation later. The average resistance of the remaining potential adopters increases in this case more rapidly than the proportion of adopters. According to this view the population can be divided into four groups, each representing a specific section of the S-shaped curve, i.e. innovaters or early adopters, early majority, late majority and laggards[7.].

An important element in this discussion is that the total potential population of adopters is turned into adopters in the final instance. In a study of the diffusion of five innovations in Chili, Pedersen observed that none of these processes reached the point of inflexion in the S-curve within the study period[8.]. To explain this phenomenon Pedersen introduced the idea of a threshold level which causes the early termination of the diffusion process. Such a threshold can be the minimum number of people necessary for the adoption of an innovation or the minimum income level. Under unchanging circumstances a threshold can act as an impermeable barrier, irrespective of the available amount of information about the innovation.

The logistic curve can thus be used as a device to describe and analyse the diffusion process both for one area and for a number of sub-areas. A very interesting study in this respect is Griliches' analysis of the diffusion of hybrid corn

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[6.] Casetti, E., Why do diffusion processes conform to logistic trends?, Geographical Analysis, 1969, Vol.1, pp.101-106.
Hägerstrand, T., Innovation diffusion as a spatial process, translated from Swedish by A. Pred, University of Chicago Press., 1967.

[7.] Rogers, E.M. op.cit. 3.

[8.] Pedersen, P.O., Innovation diffusion within and between national urban systems, Geographical Analysis, 1970, Vol.2, pp.203-254.

in the 'Corn Belt' in the United States[9]. Each sub-area was characterized by its logistic and these were compared on the basis of their three main features, i.e. the date of origin of the development, the slope of the curve and its ceiling. Regional variations in the date of origin could be identified with supply factors, variations in ceilings with demand factors. In most studies of the diffusion of innovations by geographers, there is an orientation towards the demand side of the problem, while usually the supply side is ignored. The studies by Brown et.al.[10] are a notable exception to these other cases where supply is thought to be uniformly available in unlimited quantities, at every point in space. The restrictions on this assumption and their spatial consequences will be discussed in the next section.

The graph describing the growth of T.V. ownership in the Netherlands is very unlike a logistic curve (see fig.5.1). Even when we disregard temporally for the lack of information in the early period 1951-1956, the next period 1957-1967 is not reflecting the features of the generally postulated shape. A comparison with the growth rate of radio-ownership indicates that roughly the same type of growth pattern existed for both the radio and television till 1960, whereafter the growth of the radio started leveling off, if a correction is made for a change in registration and licencing in 1961. Thus there is some indication of a ceiling or a saturation level for the number of radio sets but not for television sets in the study period. The empirical determination of a saturation level appears to be a major problem in this type of analysis.

Bain estimated this level for a number of regions in the United Kingdom[11]. He assumed that the actual growth path of T.V. ownership could be represented by the segments of a family of logistic curves. The results were discouraging in the sense that rising incomes and declining prices seemed to slow down the growth process described by his model, instead of reflecting an increased rate of growth, as could be observed empirically. Thus there could be some doubt about the validity of the logistic growth model in the case of T.V. ownership. This point was taken up by Bonus in a

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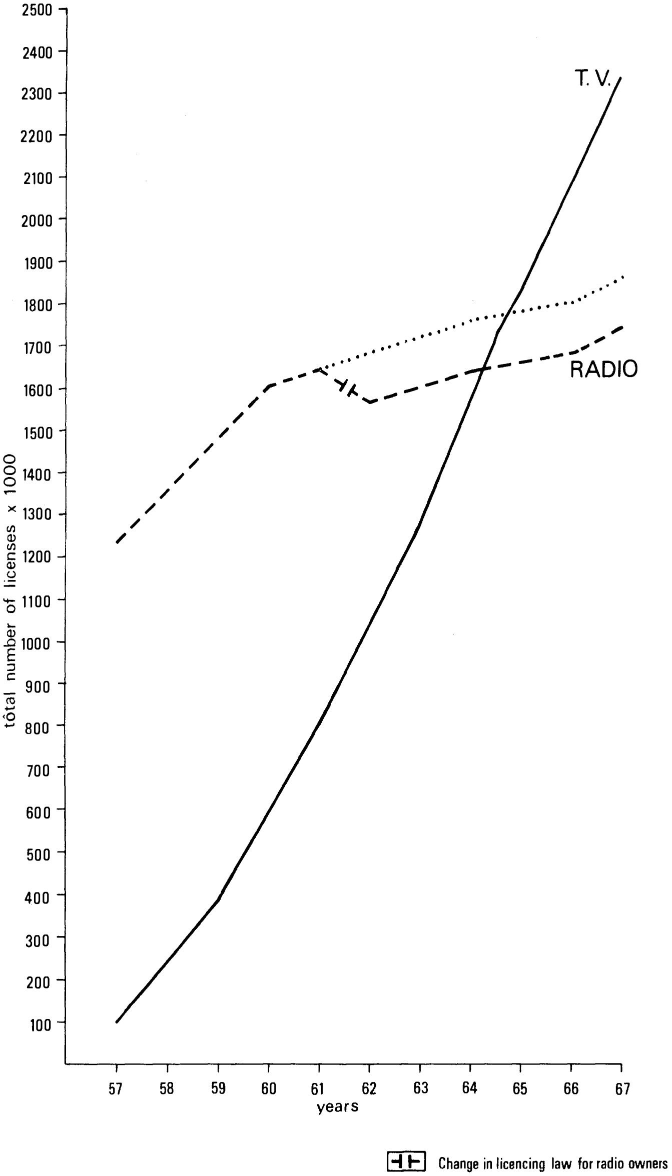
[9] Griliches, Zvi, Hybrid Corn: an exploration in the economics of technological change, Econometrica, 1957, Vol.25, pp.501-523.

[10] Brown, L.A. and K.R. Cox, op.cit. 5.
Brown, L.A. et.al., The diffusion of cable television in Ohio: a case study of diffusion agency location patterns and processes of the polynuclear type, Economic Geography, 1974, Vol.50, pp.285-299.
Brown, L.A., The market and infrastructure context of adoption: a spatial perspective on the diffusion of innovation, Economic Geography, 1975, Vol.51, pp. 185-217.

[11] Bain, A.D., The growth of television ownership in the United Kingdom, International Economic Review, 1962, Vol.3, pp.145-167.

Fig.5.1 Number of radio and t.v. licenses 1957-1967



study of the growth of T.V. ownership, as well as car ownership, in Western Germany[12]. He showed in these analyses that a logistic growth curve, which is positively skew, is consistent with the observed facts. The positive skewness can be explained as the effect of rising incomes and declining prices. Rising incomes will raise the saturation level as more people can afford to buy and this will cause a prolonged continuous high growth rate. Eventually there will exist an income level beyond which rising incomes will no longer stimulate the demand for television sets and the rate of growth will be retarded[13]. The effect of declining prices on the rate of growth is of the same order as the influence of rising incomes and both factors will reinforce each other, causing a steeper growth path and a higher saturation level. Thus the growth path shown in fig.5.1 is not necessarily incompatible with a logistic growth curve, but merely shows the intermediate stages of a process which is not yet completed in 1967.

5.3 Diffusion as a spatial process

In the period 1957-1967 we have observed a rapid growth of T.V. ownership. The frequency distribution of the acceptance rate for a number of successive one-year periods indicates differences in acceptance patterns over time (see fig.5.2). In the case where individual differences have disappeared at the aggregate municipal level, the observed acceptance ratio, i.e. the number of television sets per capita, will be the same for each municipality. The associated graphs then would consist of a series of vertical bars of the same length throughout the whole period. The change we can observe from heavily skewed distributions in the early period 1957-1960 to 'normal' type of distributions in the later years points to a regional variation in acceptance patterns. This implies that the differences in income and prices which were relevant in the understanding of the individual case, as discussed in the previous section, can also play a role in the explanation of the aggregate situation. Thus, differences in resistance levels based on differences in social behaviour and economic conditions can be of importance in the understanding of the spatial pattern of acceptances.

A close examination of the shape of the successive graphs after 1960 in fig.5.2 reveals a number of structural similarities between the graphs. The right-

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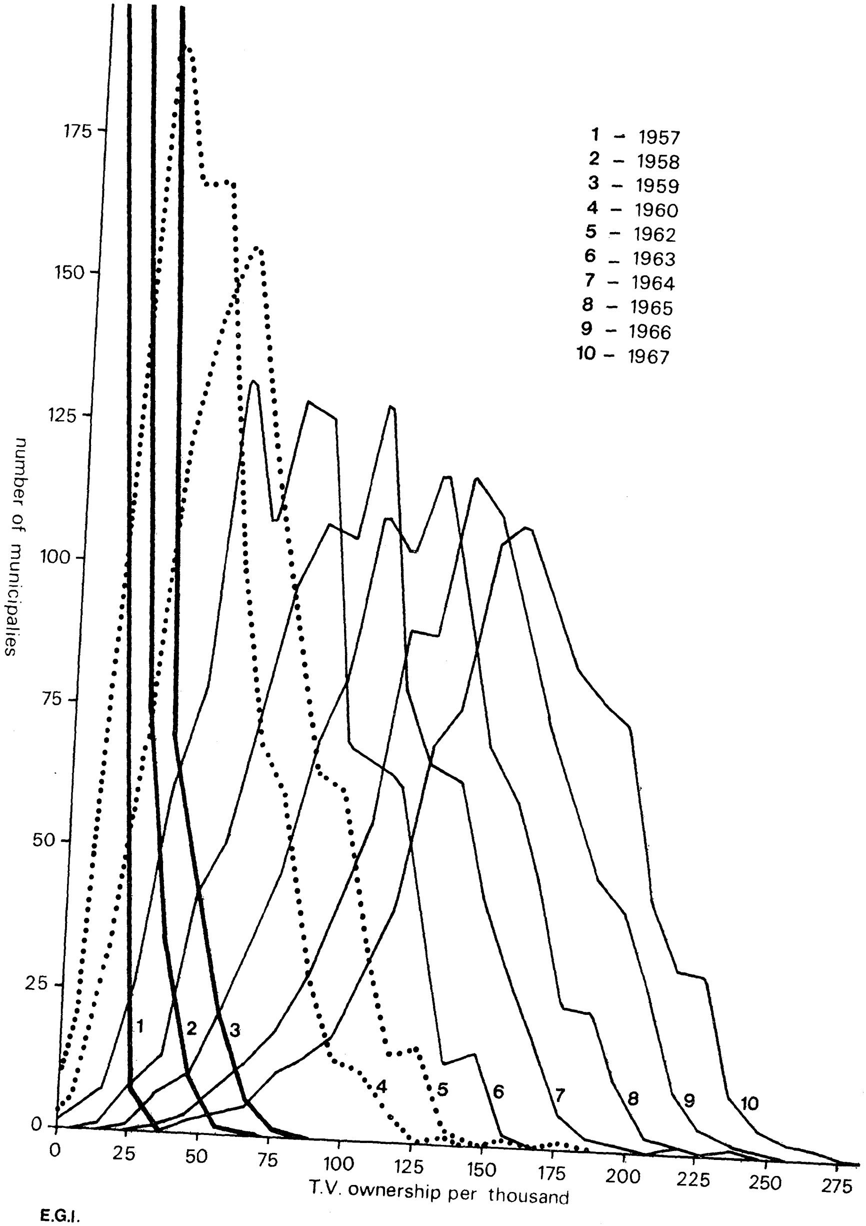
[12] Bonus, H., Die Ausbreitung des Fernsehens in der Bundesrepublik Deutschland, Zeitschrift für die Gesamte Staatswissenschaft, 1967, Band 123, pp.322-338. Bonus, H. and H.von Schweinitz, Automobile und Motorisierung in der Bundesrepublik, Zeitschrift für die Gesamte Staatswissenschaft, 1968, Band 124, pp. 541-568.

[13] Bonus, H., op.cit. 12, pp.328-332.

THE DIFFUSION OF T.V. OWNERSHIP IN THE URBAN SYSTEM

Fig. 5.2 T.V. ownership per municipality



E.G.I.

Fig 5.3 T.V. ownership per capita (x1000) 1961

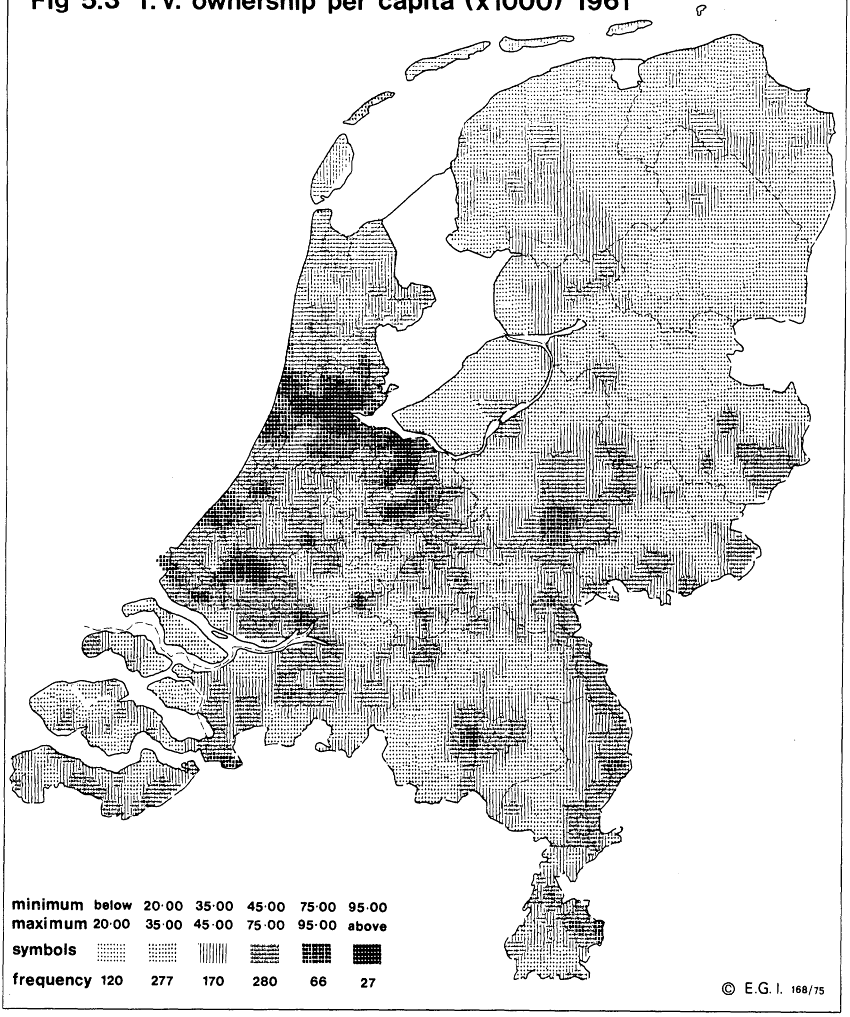
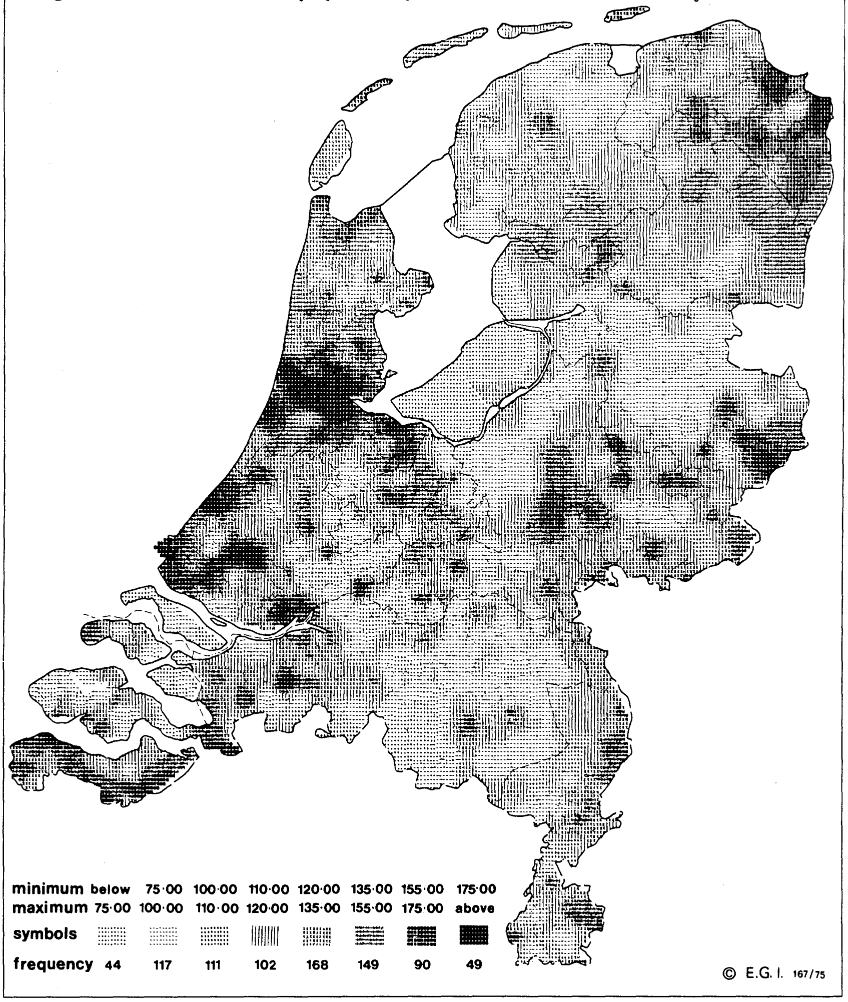


Fig 5.4 T.V. ownership per capita (x1000) 1965



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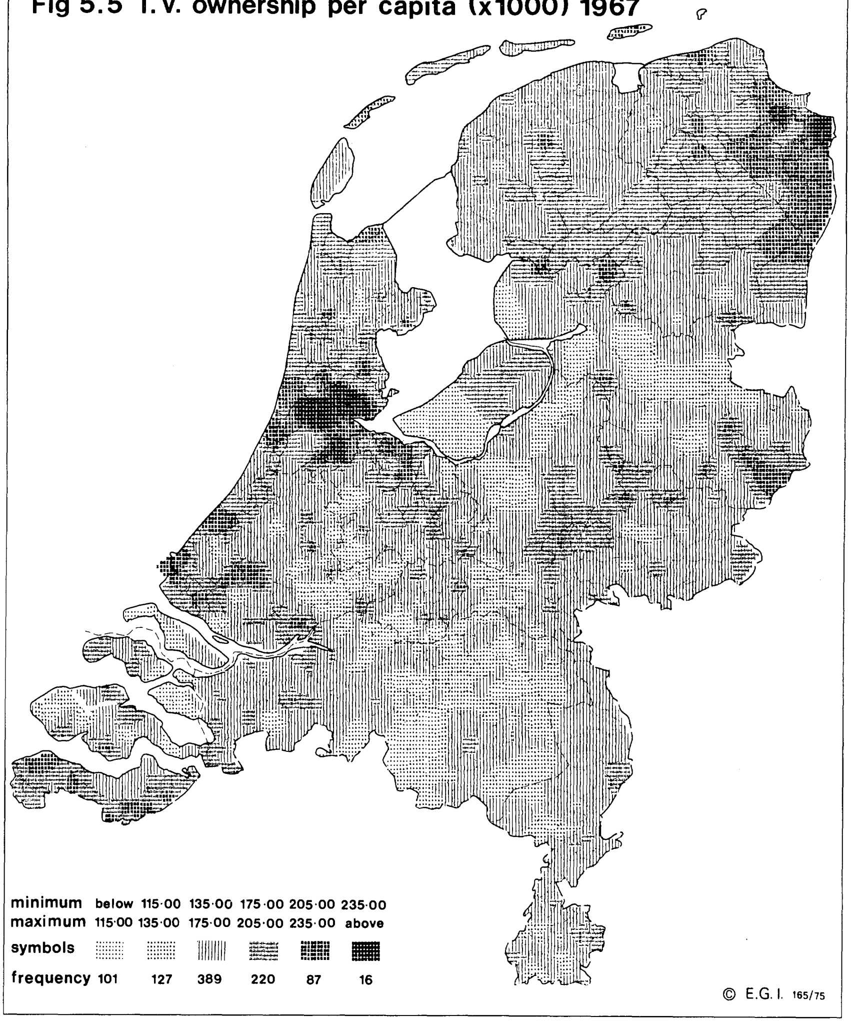

Fig 5.5 T.V. ownership per capita (x1000) 1967

minimum	below	115·00	135·00	175·00	205·00	235·00
maximum	115·00	135·00	175·00	205·00	235·00	above
symbols	░	▒	▥	▤	▦	■
frequency	101	127	389	220	87	16

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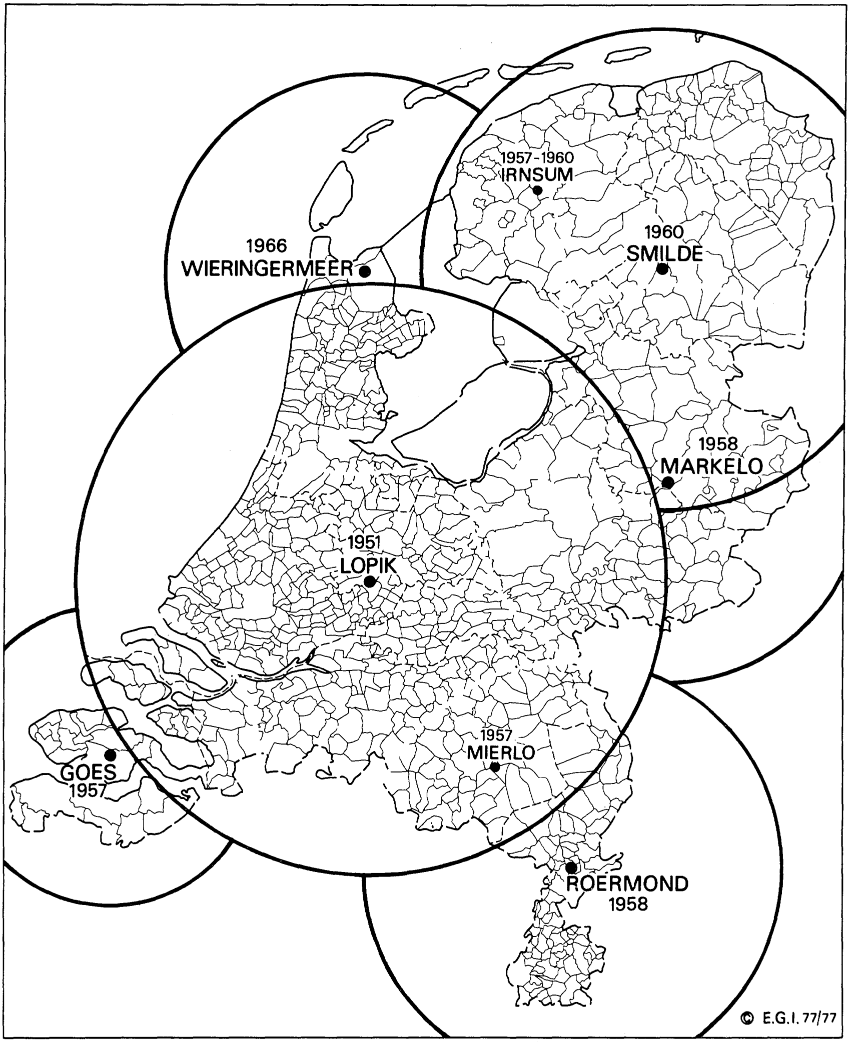
Fig. 5.6 The distribution of T.V. transmitters, the area covered by each transmitter and the date of first transmission for each.



hand leg of each distribution shows the existence of two 'shoulders' at a different height. These shoulders are a recurrent phenomenon in every distribution. The shape features of the left side of the distributions are less pronounced but the bi-modal distribution in 1963 is the most characteristic feature. The question here is, what is the nature of the spatial pattern associated with these irregularities and is this pattern persistent over the period? If the latter is true, then we might be able to deduce some empirical regularities from the spatial representation of these statistical features (see fig.5.3 to fig.5.5)[14].

The two shoulders on the right-hand side of the 1961 distribution can be associated with the main urban centres and the suburban areas in their immediate surroundings. As this is also the case for 1965 and 1967, albeit on higher absolute levels of frequency, the spread seems to have an urban origin and diffuses from there outward. The pattern for 1965 indicates a remarkable growth in the North and East of the country. It is remarkable because the growth which occurred here after 1963 must have been very fast in the period till 1965 to obtain the same high level as could be observed in the urban areas in the Western and Southern part of the Netherlands. Moreover as the suburban areas, which were in the same size class, have not experienced the same rapid increase. A change and improvement of receptive conditions might be brought forward as a hypothesis to explain this pattern. However, since 1960 the conditions for receiving television programs of a good quality are everywhere the same (see fig.5.6). The first programs were broadcasted since October 2nd 1951 in the Western provinces and already since 7th May 1957 the whole of the North was covered. This improvement of reception conditions in the 1960s can hardly explain the sudden growth in the North since 1963. The pattern for 1967 reflects a leveling off of the growth in the early centres with a continued growth in the surrounding areas. Both for the North and the main conurbations in the West the growth has been still considerable and this keeps these areas in a leading position.

Hierarchical diffusion

The observation that early adoption can be associated with the larger urban centres is a result which is in agreement with the literature on innovation diffusion. Bowers noted this phenomenon in his study of the diffusion of radio amateurs[15]. In

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[14] The class intervals for these four maps have been selected, to display the main aspects of the frequency distributions, as discussed. The map for 1963 has been omitted from the series because of its close similarity to the 1961-pattern.

[15] Bowers, R.V., The direction of intra-societal diffusion, American Sociological Review, 1937, pp.826-836.

addition to the correspondence between city size and degree of acceptance, he also found that the diffusion proceeds from the larger cities to their tribitary smaller cities. In addition to this localized process Hägerstrand observed in his study of the diffusion of motorcars in Southern Sweden that besides this local pattern there are also short circuits in the sequence of the diffusion paths, which connect at the same time the more important places at a greater distance[16.]. In a later study on the diffusion of rotary clubs in Western Europe he notes that "the point of introduction in a new country is its primate city, sometimes some other metropolis. Then the centres next in rank follow. Soon, however, this order is broken up and replaced by one where the neighborhood effect dominates over the pure size succession"[17.].

It remains an unanswered question whether this process is also at work in the present case. What we do observe is a high concentration in the main urban areas and a lower level in the acceptance ratio in their immediate surroundings. This could be caused by a hierarchical diffusion process using the linkage structure in the urban system. This linkage structure may reflect the existing social structure and communication linkages and is of importance not only in rural areas[18.] but also within and between urban centres[19.]. The repeated use of the same communication structure tends to reinforce the existing structure.

The main theoretical feature in the discussion of spatial diffusion processes thus far is that they can be described by three kind of processes: (1) the information about a message, sometimes an innovation, has a consistent relationship over time. The related acceptance pattern of the message can be described by a logistic curve, (2) diffusion process is related with the functional organisation of an area and accordingly it tends to filter down the urban hierarchy, (3) diffusion processes are influenced by the physical nature of geographic space and they display localized spread, i.e. a neighborhood effect. Hudson raised the question

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16. Hägerstrand, T., The propagation of innovation waves, Lund Studies in Geography, Ser.B., Human geography, No.4, 1952.

17. Hägerstrand, T., Aspects of the spatial structure of social communication and the diffusion of information, Papers and Proceedings of the Regional Science Association, 1966, Vol.15, pp.27-42.

18. Johansen, H.E., Diffusion of strip cropping in southwestern Wisconsin, Annals of the Association of American Geographers, 1971, Vol.61, pp.671-683.

19. Johnsson, B., Utilizing telegrams for describing contact patterns and spatial interactions, Geografiska Annaler, Ser.B., 1968, pp.48-51.
Clark, D., Communications and the Urban Future: A study of trunk telephone call patterns in Wales, Regional Studies, 1973, Vol.7, pp.315-321.

whether these processes could occur in isolation or in some logical combination[20]. He showed that the telling mechanism, the first process, which is of a non-spatial nature assumes a random mixing of knowers and non-knowers. This leads to a conflict with the functional spatial aspects of the diffusion process which assumes a concentration in specific areas. It appears that the logistic curve which is the outcome of the non-spatial process can neither be described as the result of the neighborhood effect, nor as the result of the hierarchical effect. Only the combination of these two spatial-functional processes can produce a logistic curve as the temporal outcome[21]. Thus we may conclude that in the presence of a S-shaped growth path and an observed neighborhood effect, a hierarchical process should also be at work. If this conclusion is correct then the centres which display high acceptance ratios and act as innovation centres are functionally related. These centres are mainly located in the Western and Southern part of the Netherlands. As the diffusion process is operating at a much slower rate in the North, in the presence of large cities like Groningen and Leeuwarden, this may indicate a weak functional relationship with the other centres in the urban system. Thus, urban size can act as a sufficient condition but not as a necessary condition in a diffusion process.

A second point we have to consider here is that the study of the diffusion of television sets is not one single process, but there are at least two different but related processes operative. The case under examination here is a study of household innovation, viz. the diffusion of television sets, while its associated innovation is the entrepreneurial innovation. This involves the spread of the diffusion agencies, i.e. the wholesalers and retailers. The latter spread is closely associated with the market perception of the propagator, manufacturer, as one of his goals will be the efficient organisation of a network of agents to supply and service the market[22]. Given the present scale of production the location, diffusion policy, will be to view this as a multiple facility location problem[23]. Thus the diffusion will not be from a single source but of the polynuclear type and a critical element here again is the existence of information linkages between urban places. The role of the already existing infrastructure gets a central

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20. Hudson, J.C., Diffusion in a Central Place System, Geographical Analysis, 1969, Vol.1, pp.45-59.

21. See for an elaboration of this point, Hudson, J.C., Geographical Diffusion Theory, Studies in Geography no.19, Northwestern University, Illinois, 1972.

22. See also Klonglan, G.E. et.al., Conceptualizing and measuring the diffusion of innovations, Sociologica Ruralis, 1971, Vol.11, pp.36-48, for a discussion of the location of change agents for the acceptance of the idea of fall-out shelters.

23. Brown, L.A. et.al., op.cit. 10.

position in such an analysis. In the conceptualization of this problem Brown recognizes that there are three different positions for the infrastructure in the diffusion process: (1) infrastructure constrained diffusion where utilization costs vary continuously with distance, or (2) where utilization costs vary stepwise with distance, and (3) infrastructure independent diffusion. The associated problem for the propagator-manufacturer for the first two cases is, whether he carries out his own infrastructure development or makes use of the already existing infrastructure, i.e. radio retail outlets can be used for the distribution of television sets as well, but this is dependent upon the degree of control he has on such a network. Given an incomplete control over the existing infrastructure, the willingness to accept the innovation and act as a diffusion agent in the case of an entrepreneurial innovation can follow the same process and have the same spatial outcome as in the case of a household innovation. Thus these two processes as they are complementary and interacting, do reinforce their respective spatial outcomes. However, the lack of growth or a low growth rate in the number of diffusion agents will have a considerable retardation in the growth of the number of household acceptors as a consequence. This phenomenon might be the explanation for the low growth rate in the large cities in the Northern and Eastern part of the country, whether or not in combination with weak linkages to the rest of the urban system.

Innovation waves

In his analysis of the diffusion of an innovation from a single innovation centre over time, Hägerstrand discussed three different profiles of change[24]. Each of these profiles represents a particular growth rate of this centre and its surrounding area: (1) the rate of growth is largest in the (innovation) centre and diminishes outward, (2) the rate of growth is smallest in the centre and grows outward, and (3) the rate of growth is equal in the centre and in its surroundings. He associates these three patterns of change with three stages in the diffusion process, i.e. a primary stage, a diffusion stage and a condensing stage. If we imagine these three stages "... passing in succession as on motion pictures, ..., we will obtain some idea of the way the innovation wave propagates within a population"[25]. Morrill elaborated upon this idea in a number of ways and he showed the parallel development

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24. Hägerstrand, T., op.cit. 16, pp.13-17.

25. Hägerstrand, T., op.cit. 16, p.17.

of the diffusion wave in space and in time[26]. The graphs in fig.5.2 might be considered in this respect as another example of the development of an innovation wave over time. The different shapes of these curves can be compared with the different frequency distributions representing migration distances[27]. Each distribution represents a different reaction to the same socio-economic environment in the case of migration and this is also valid for a spatial diffusion process. The wave of diffusion is now described as the crest of the normal distribution, i.e. the acceptance curve, moving outward from the centre of origin. In a situation of increasing incomes and declining prices the saturation level increases constantly. In terms of the wave phenomenon this means that instead of one wave, we are dealing with a series of waves, each having a higher crest than the previous wave. These waves are dampened by two geographic factors[28]. First, the diffusion waves encounter barriers of higher resistance, which slow down the spread, while it may reach farther in easily accessible regions. Second, the diffusion waves usually have multiple origins as sources and when they meet they have a dampening effect upon each other, but locally they reinforce the acceptance pattern and higher acceptance ratios can be observed.

A spatial representation of the nature of this wave phenomenon is given in fig.5.7, which is related with fig.5.8 to fig.5.18. These latter figures display the total diffusion process and will be discussed later. In fig.5.7 the passage of the diffusion front is represented by the 5-10 per cent saturation level. This level was first reached by one city, Zandvoort, in 1958. Each contour line on the map represents the innovation frontier at successive one-year periods leaving untouched only two municipalities in 1967 as the most resistant cores. If we disregard the effect of unequal areal size of the individual municipalities, then we can easily see the path followed by the diffusion process. The steeper the gradients are, the stronger the local resistance, while flatter gradients indicate a faster acceptance ratio.

The main innovation centres are the Haarlem-Amsterdam conurbation, including Zandvoort, Utrecht and the associated urban areas of Hilversum, Naarden-Bussum and Zeist in the Northern part of Randstad. While The Hague, Rotterdam, Gouda and Dordrecht have this function in the Southern section. Outside this region only Eind-

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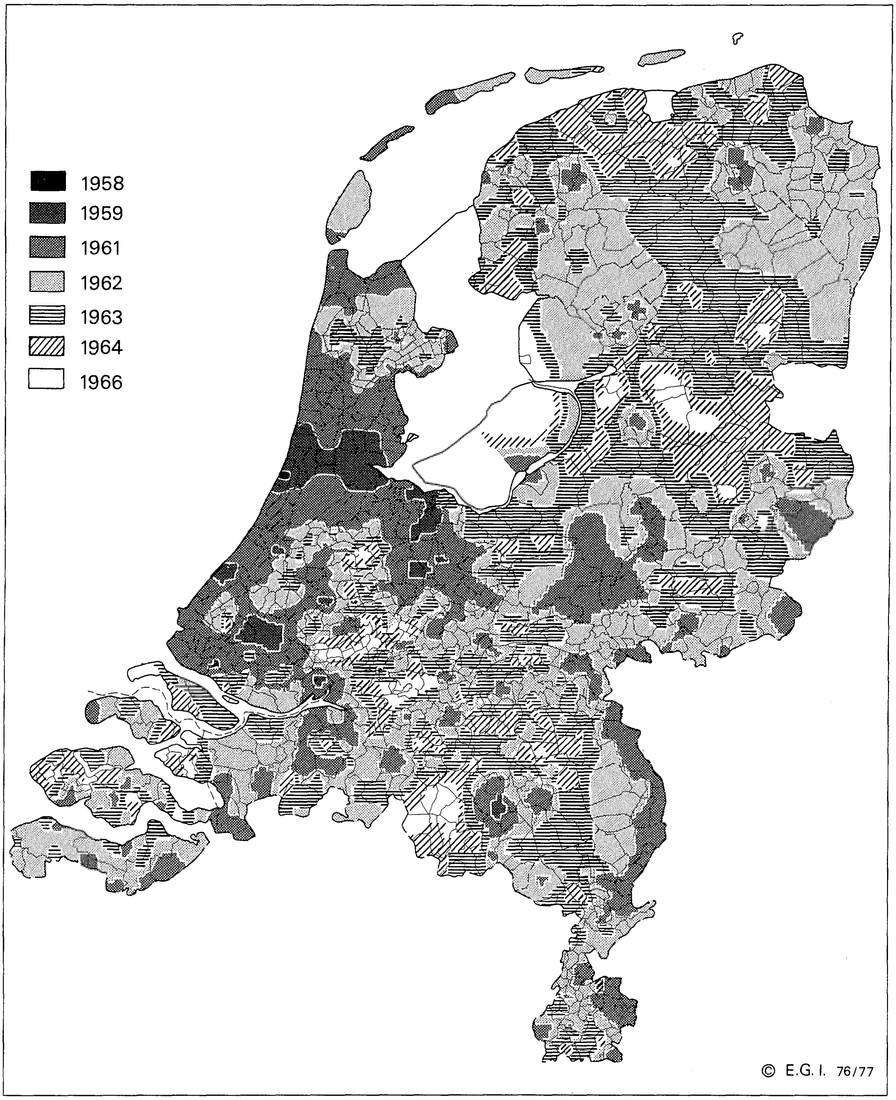
[26] Morrill, R.L., Waves of spatial diffusion, Journal of Regional Science, 1968, Vol.8, pp.1-18.
Kariel, H.G. and M.J. Vaselenak, Waves of spatial diffusion reconsidered, Journal of Regional Science, 1973, Vol.13, pp.291-296.

[27] Morrill, R.L., The distribution of migration distances, Papers and Proceedings of the Regional Science Association, 1963, Vol.11, pp.75-84.

[28] Morrill, R.L., The shape of diffusion in space and time, Economic Geography, 1970, Vol.46, pp.259-268.

Fig. 5.7 The spread of the innovation wave 1958-'66 (acceptance ratio 49-100‰)



hoven and Helmond in the province of Noord-Brabant fulfil this function. These two cities are early adopters in a lagging region, especially the gradient West of Eindhoven is particularly steep. The gradient in the Western part of the Netherlands is rather flat covering a large area in the next periods and leaving a few islands of resistance behind. This is both the case for the Southwestern part of the province of South-Holland and for its border area with the province of Utrecht (the Green Heart!). The case for the city of Gorinchem East of Dordrecht is illustrative for the operation of the hierarchical diffusion process. Dordrecht and Gorinchem belong both to the group of early adopters and are located relatively close to each other. They are, however, physically separated by a large number of areas resisting the adoption of television sets at this level.

Another interesting phenomenon is the spatial distribution of the areas of resistance over the country. The circle line in fig.5.6 indicates radius of the sender in Lopik which started transmissions in 1951. Ten years later (9-5-1961) a new and more powerful installation replaced the older one and this had an even larger radius. Thus the areas of resistance within this radius cannot be explained on the basis of a lack of receptive facilities. This argument is also applicable to areas in the Northern and Eastern part of the country. Here we can observe a considerable time lag in the diffusion from the main adoption centres into the surrounding area. The operation of the diffusion wave is more obvious here than in other parts of the country because of the spatial distribution of the towns, which is less dense here. The lower densities in the North and East cause lesser interference of the diffusion waves than in the Western province. However one can observe clear spatial biases in the diffusion pattern influencing the circular shape into specific directions, while this bias is not caused by the municipal administrative divisions.

5.4 The growth of T.V. ownership, 1957-1967

The study of a division process is like the study of a system of which the inputs and outputs are known, but nothing about the transfer mechanisms which are operative in space and time[29]. The discussion in the foregoing section was focussed upon a number of theoretical considerations about the operation of the system and on this basis a transfer mechanism and the conditions for its operation can be studied. In this section the spatial nature of the diffusion process will be explored further, using the formal aspects of the process as a basis for explanation.

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29. See, Tinline, R., Linear operators in diffusion research, in Regional Forecasting, M. Chisholm, A.E. Frey and P. Haggett, eds., Butterworths, London, 1971, pp.71-93.

THE DIFFUSION OF T.V. OWNERSHIP IN THE URBAN SYSTEM

The diffusion pattern displayed in fig.5.7 indicated the passage of the innovation front over space, but it does not tell us anything about what happened before or after this event at a particular location. Does the rate of growth retard in the innovation centres, as is suggested by the theory or do these centres experience a continuous growth as is evident from the patterns shown in fig.5.3 to fig.5.5? Are the centres which accept the innovation later also characterized by a more rapid growth rate indicating a large amount of delayed demand? A preliminary answer to these questions can be obtained by analyzing the total diffusion process, which is presented in fig.5.8 to fig.5.18, showing the growth of T.V. ownership over time for every location. This growth process can be described graphically by a logistic. Such a curve can be best mapped on the basis of geometric class intervals, as for every year the cumulative purchases of the previous period are considered[30]. This procedure allows every region to have its own logistic and spatial differences in growth behaviour can thus be studied.

The changes over time in the frequency distributions representing the acceptance ratio per municipality (see fig.5.2) points towards the occurrence of three stages in the diffusion process. These stages can be associated with those identified by Hägerstrand: (1) an innovation stage (1957-1961), (2) a diffusion stage (1961-1964), and (3) a consolidation stage (1964-1967). A saturation stage seems already to emerge in 1967 as there are already 116 municipalities with adoption rates above 20 per cent, of which there are only 7 between 25 and 30 per cent and one with a rate of 40 per cent. If we assume that the average household consists of four to five members, the saturation level for a one-television-household lies on average between 20 to 25 per cent.

The growth process in the first period (1957-1961) shows the emergence of the urban centres as innovation centres which continue to grow. Notwithstanding the high overall rate of growth for every region the urban growth rates are higher. A comparison with fig.1.3 indicates that areas having slower acceptance rates have a dominant agricultural sector. An interesting anomaly in this respect is the Northeastern fringe of the province of Limburg bordering Western Germany. Here we can observe high acceptance ratios outside the main urban areas. A tentative explanation for this phenomenon could be the early exposure to good quality West-German television stations. The weakness of such an explanation is that this does not seem to

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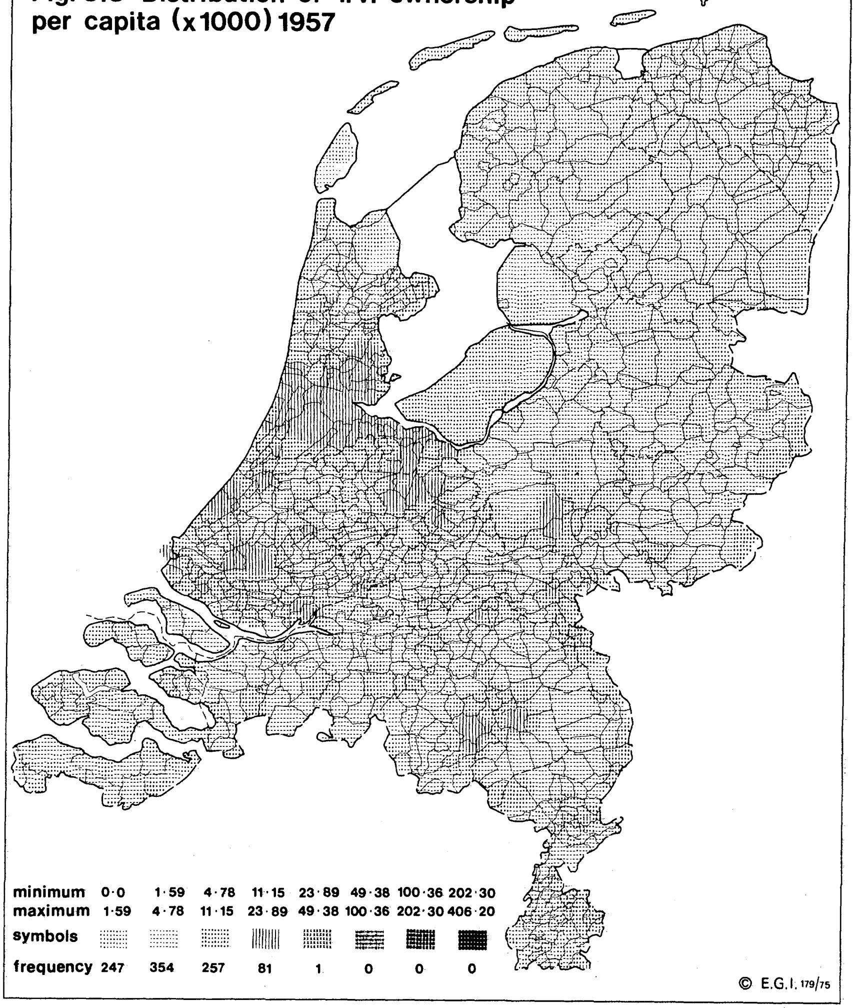
[30] Adjustments have been made for the population changes over the 1957-67 period, due to boundary corrections and annexations following the procedures outlined in chapter 2. Thus 940 municipalities are considered on the basis of the 1967 administrative definitions.

Fig. 5.8 Distribution of T.V. ownership per capita (x1000) 1957



minimum	0·0	1·59	4·78	11·15	23·89	49·38	100·36	202·30
maximum	1·59	4·78	11·15	23·89	49·38	100·36	202·30	406·20
symbols	░	░	░	▥	▦	▤	▩	■
frequency	247	354	257	81	1	0	0	0

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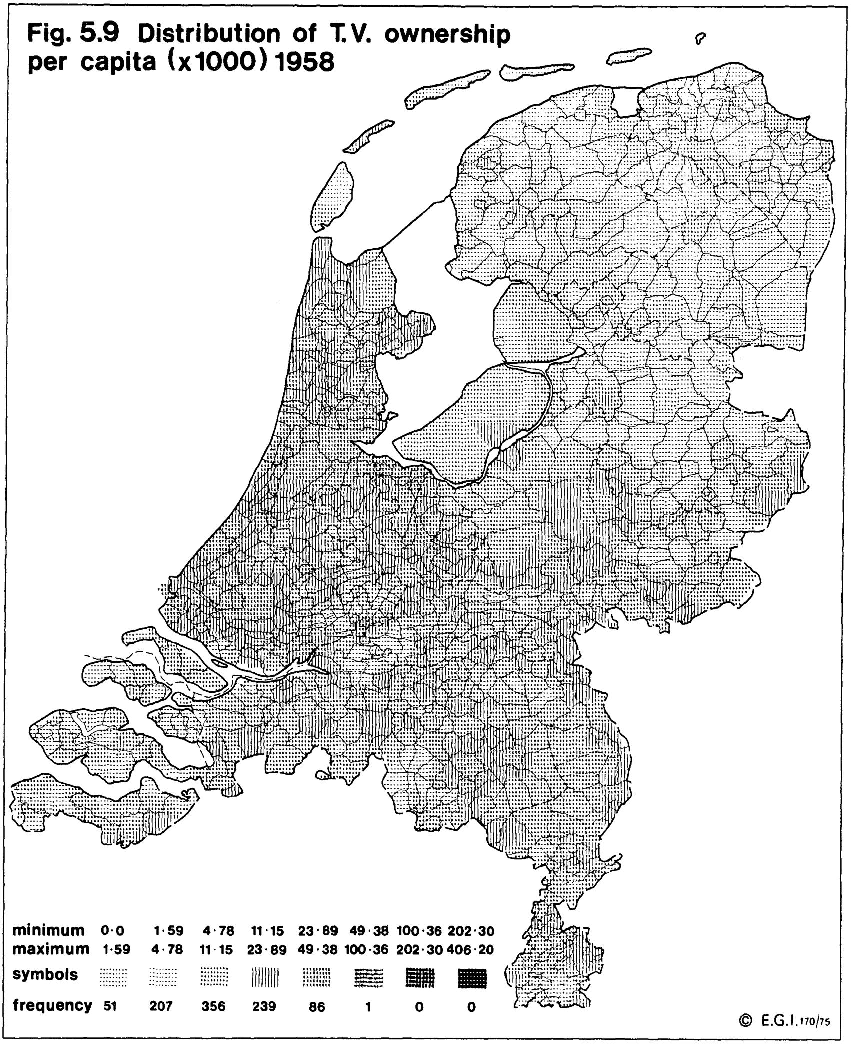
Fig. 5.9 Distribution of T.V. ownership per capita (x1000) 1958



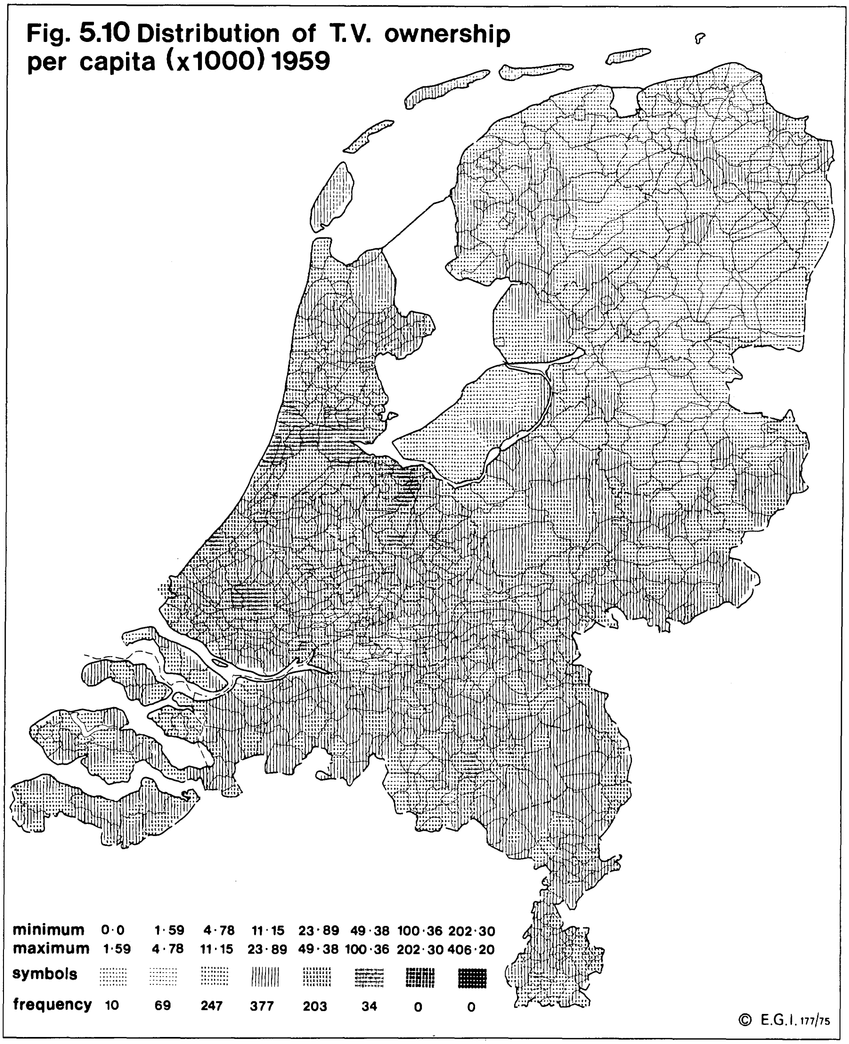


Fig. 5.10 Distribution of T.V. ownership per capita (x1000) 1959

minimum	0·0	1·59	4·78	11·15	23·89	49·38	100·36	202·30
maximum	1·59	4·78	11·15	23·89	49·38	100·36	202·30	406·20
symbols	░	░	░	▥	▦	▤	▩	■
frequency	10	69	247	377	203	34	0	0

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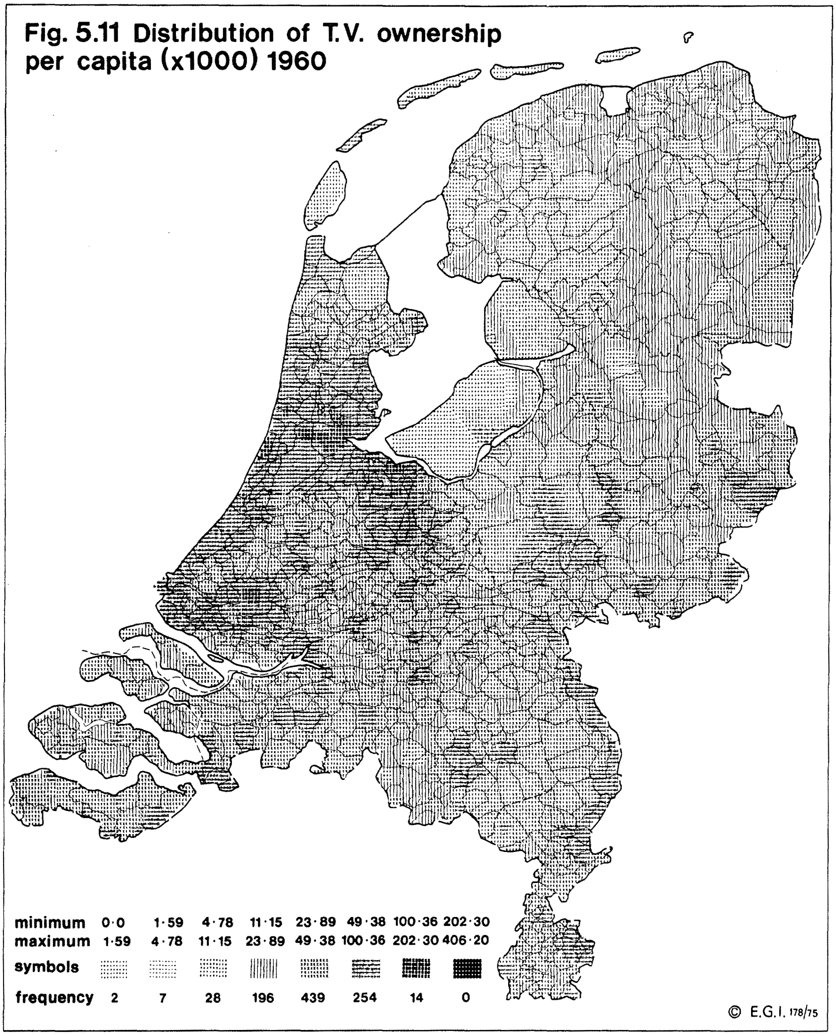
Fig. 5.11 Distribution of T.V. ownership per capita (x1000) 1960



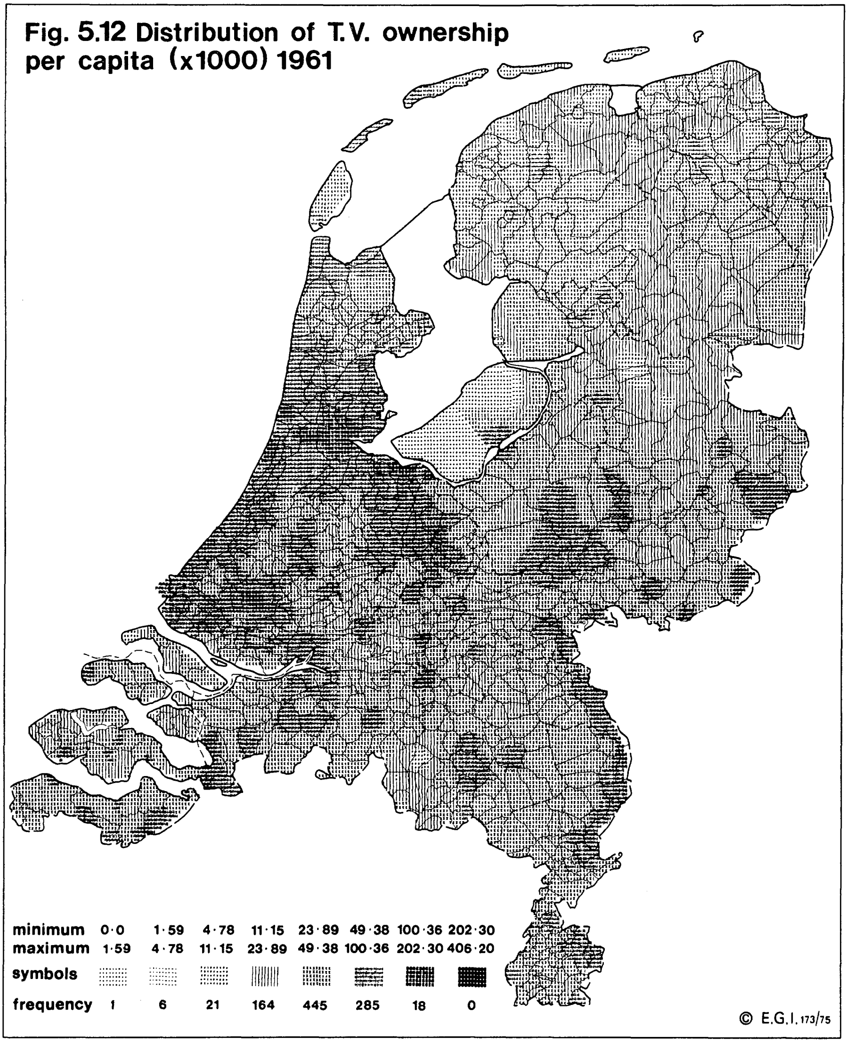
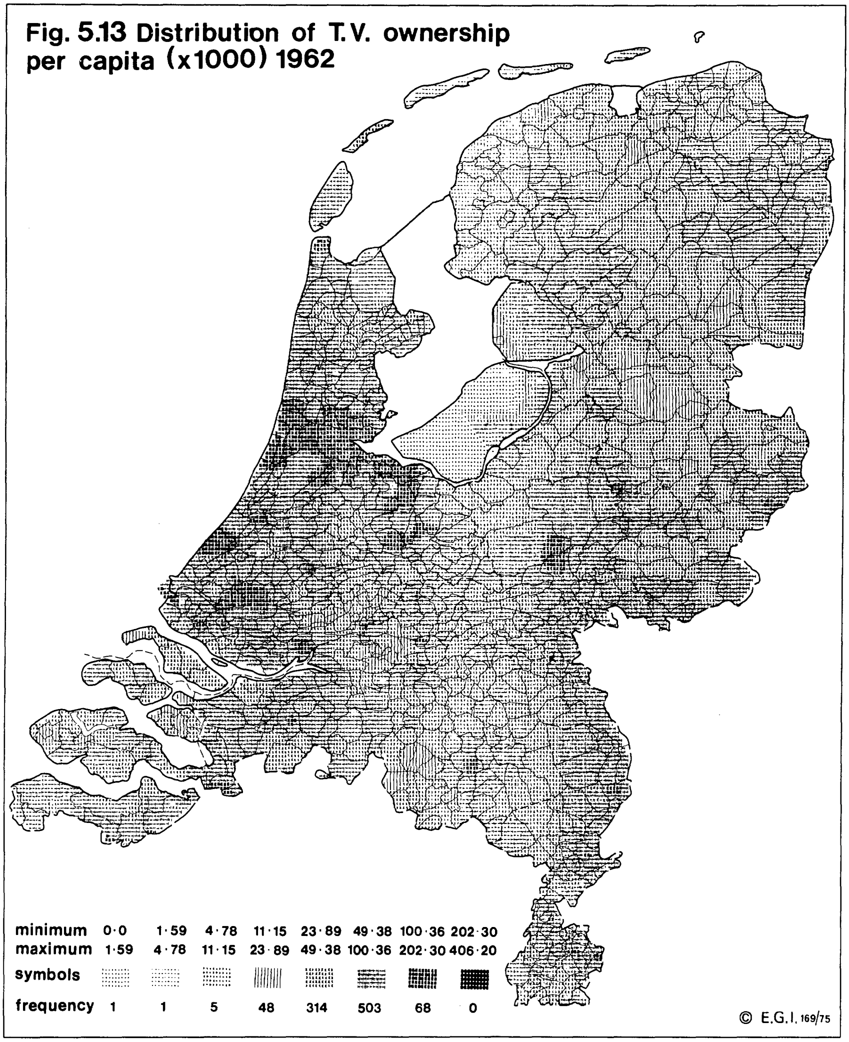


Fig. 5.12 Distribution of T.V. ownership per capita (x1000) 1961

Fig. 5.13 Distribution of T.V. ownership per capita (x1000) 1962



minimum	0·0	1·59	4·78	11·15	23·89	49·38	100·36	202·30
maximum	1·59	4·78	11·15	23·89	49·38	100·36	202·30	406·20
symbols	░	░	░	▥	▒	▤	▦	■
frequency	1	1	5	48	314	503	68	0

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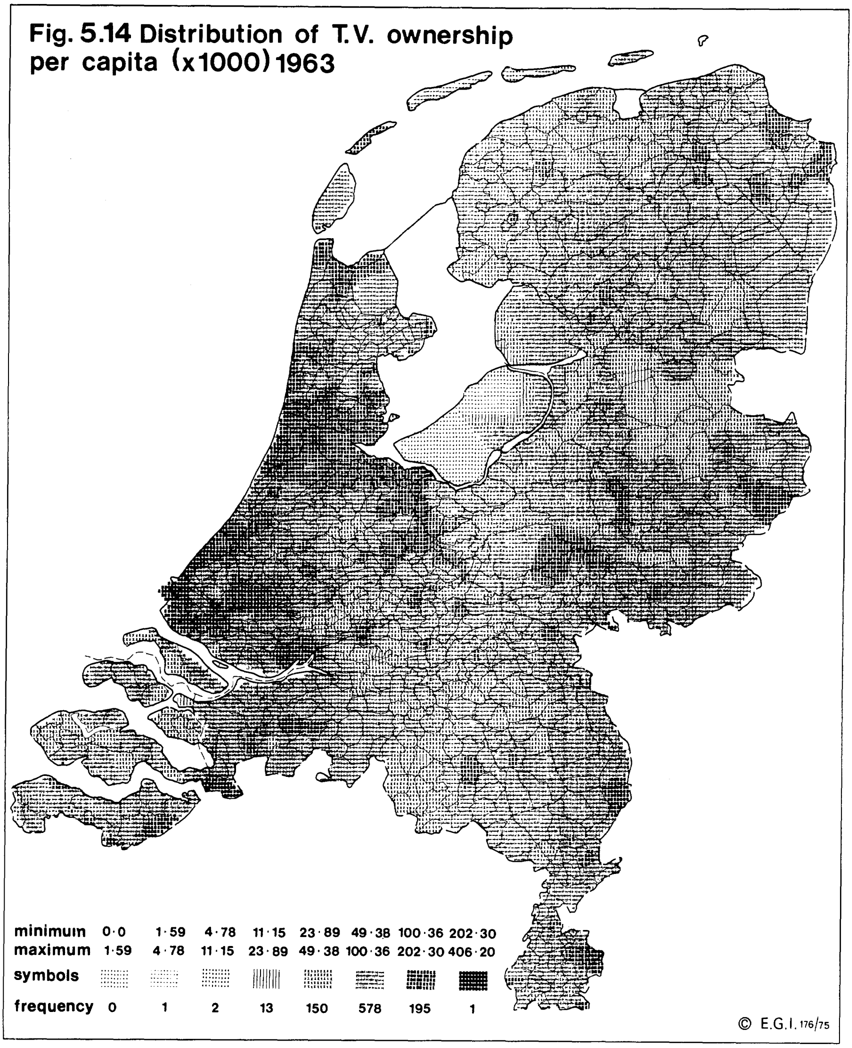

Fig. 5.14 Distribution of T.V. ownership per capita (x1000) 1963

minimum	0·0	1·59	4·78	11·15	23·89	49·38	100·36	202·30
maximum	1·59	4·78	11·15	23·89	49·38	100·36	202·30	406·20
symbols	░	░	▒	▥	▒	▤	▦	■
frequency	0	1	2	13	150	578	195	1

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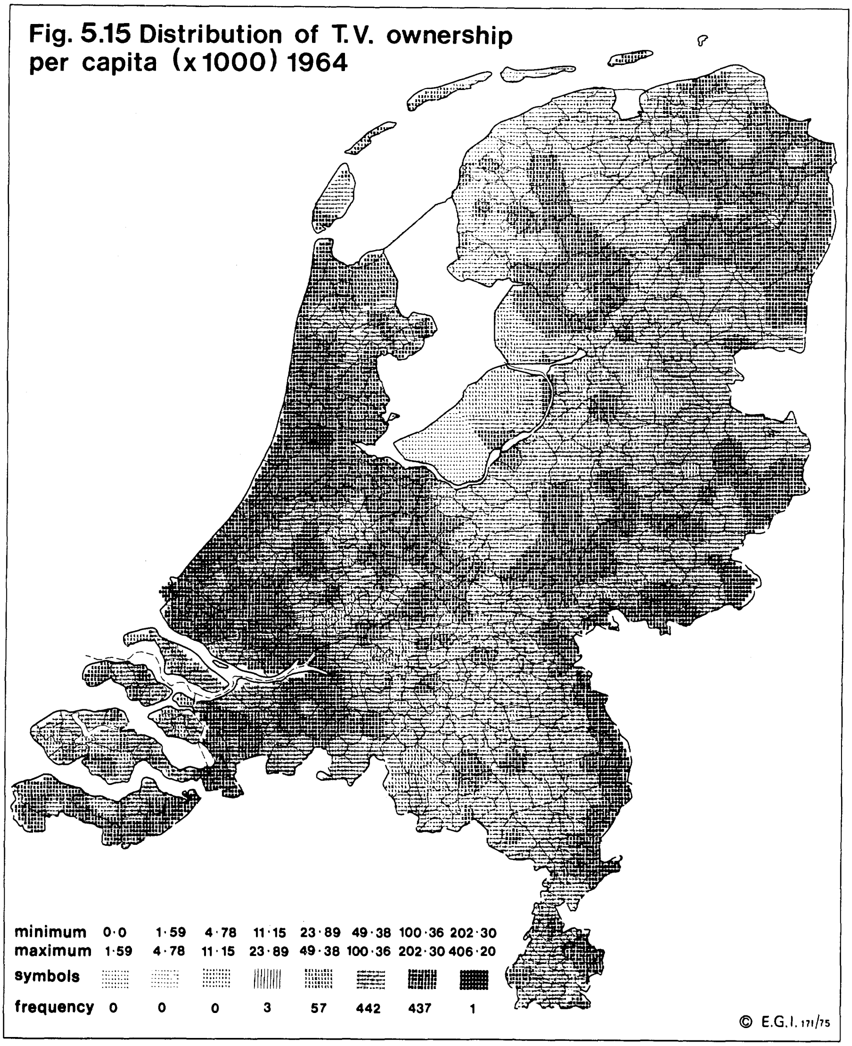
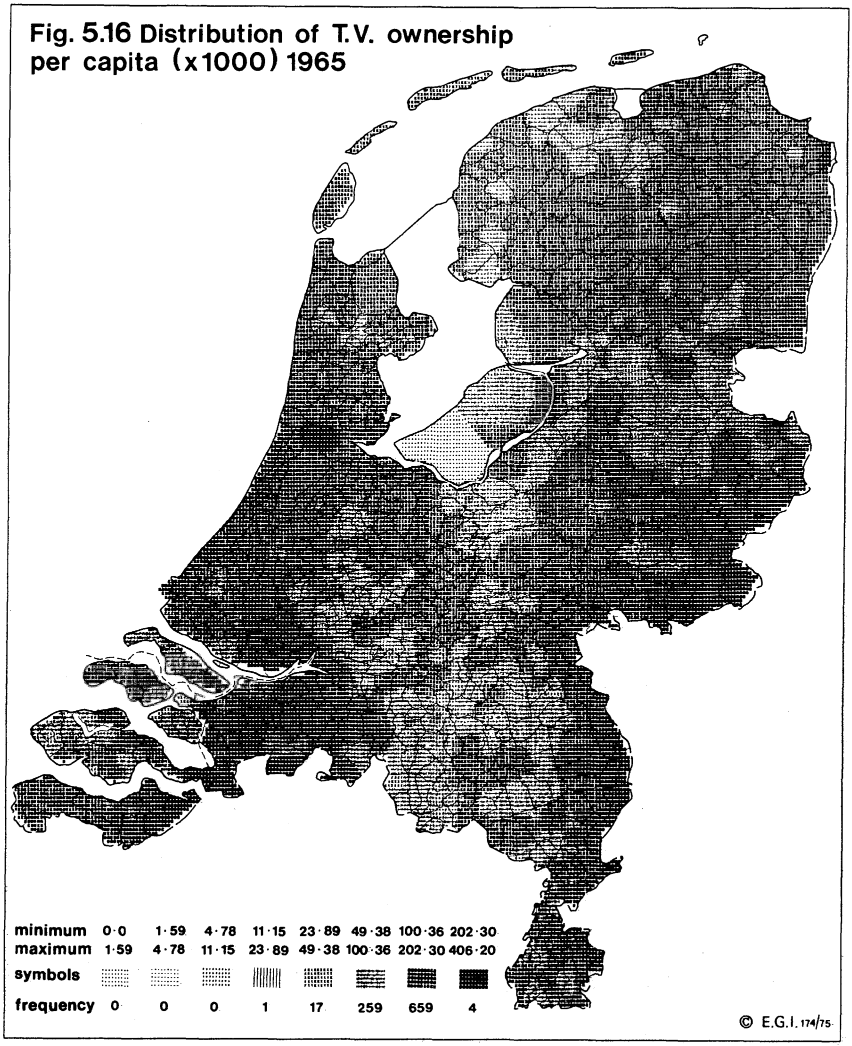


Fig. 5.15 Distribution of T.V. ownership per capita (x1000) 1964

Fig. 5.16 Distribution of T.V. ownership per capita (x1000) 1965



minimum	0·0	1·59	4·78	11·15	23·89	49·38	100·36	202·30
maximum	1·59	4·78	11·15	23·89	49·38	100·36	202·30	406·20
symbols	░	░	▒	▥	▦	▤	▩	■
frequency	0	0	0	1	17	259	659	4

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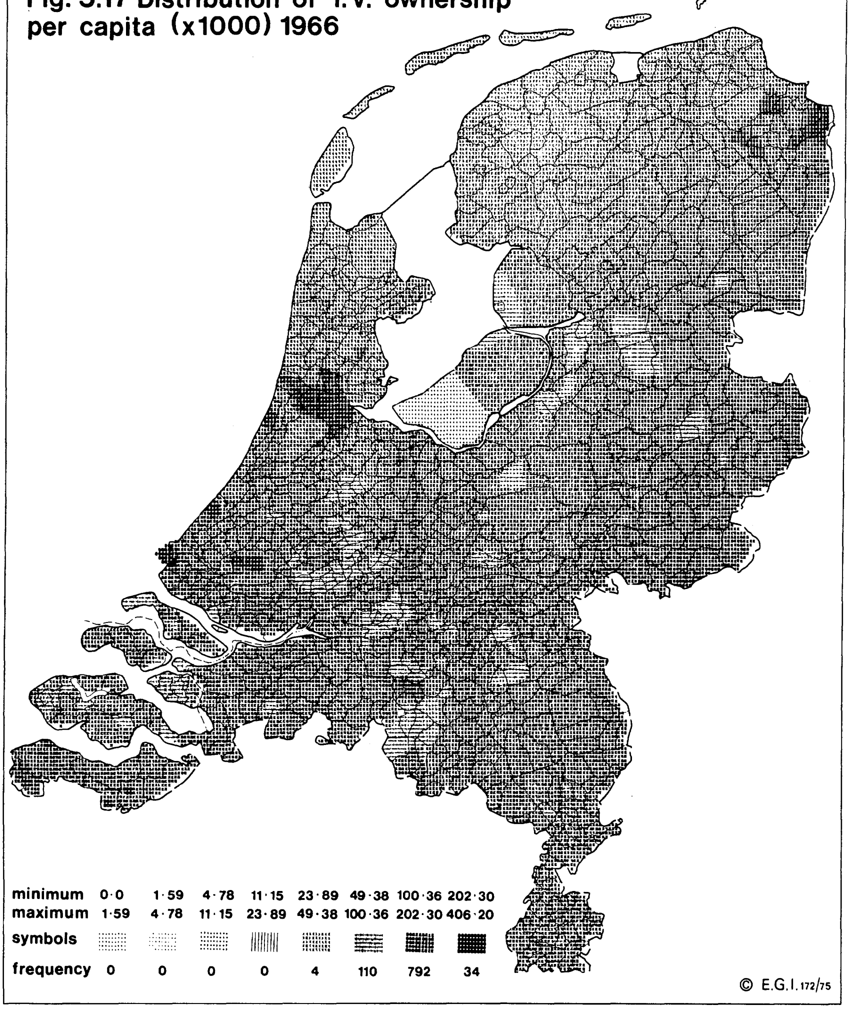

Fig. 5.17 Distribution of T.V. ownership per capita (x1000) 1966

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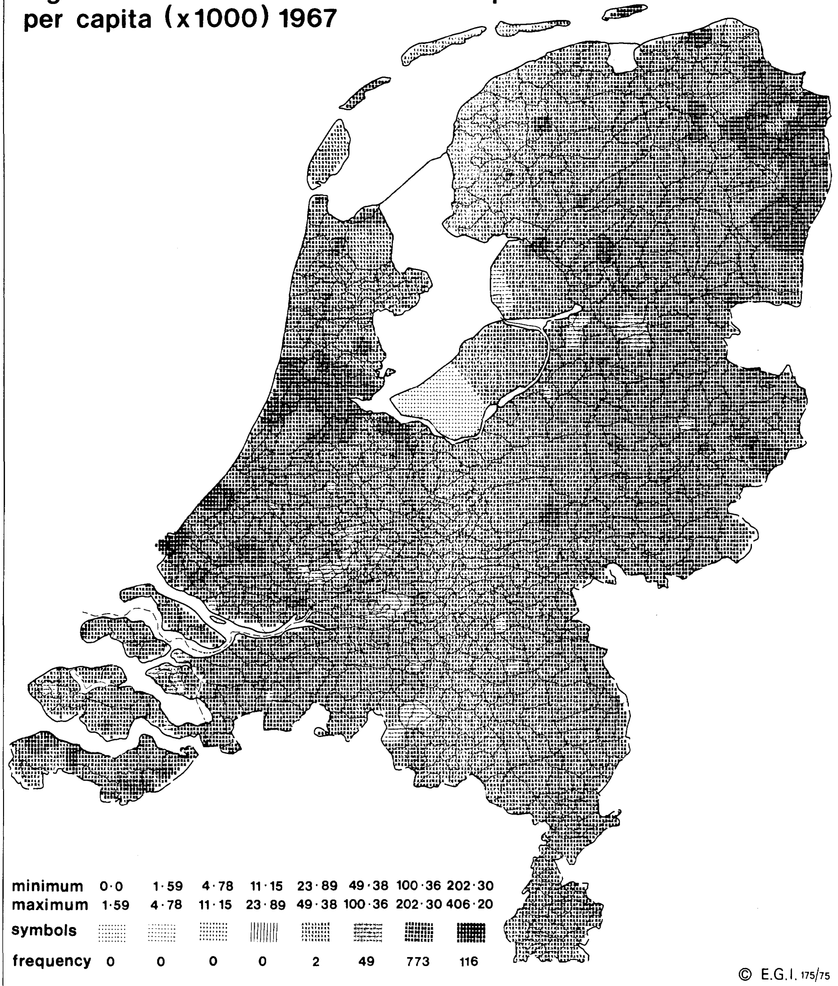
Fig. 5.18 Distribution of T.V. ownership per capita (x1000) 1967



apply to the rest of the border area, while we may assume that the familiarity with the German language is rather constant along the border.

The development in the second period (1961-1964) is particularly interesting as the differences between the main cities and their surroundings disappear and they become members of the same group. If we use the hypothesis of the importance of social contacts as an explanation for the high acceptance ratios in both areas, this may well explain the integration of urban and suburban areas at this stage. Another interesting aspect of this second period is the nearly two-fold division of the country in 1964 in areas (442) with an acceptance rate of 5-10 per cent and those (437) with a rate between 10-20 per cent. The areas in the latter group clearly represent the urbanized areas in the Netherlands. There are, however, a few exceptions to this general pattern and these are the border areas in the province of Zeeland (Zeeuws-Vlaanderen) and Groningen, which have higher than average rates compared with their surroundings. For the West-Brabant, Zeeuws-Vlaanderen areas it can be argued that they belong to the commuting shed of the Rotterdam-Dordrecht industrial region and thus may react in the same way to the innovation as their immediate surroundings. This leaves, however, unexplained the extensive growth in the Eastern part of the two Northern provinces, Groningen and Drente. More detailed research is necessary in those areas to give an adequate answer to the specific deviations observed, which probably can be explained on the basis of local characteristics.

In the last period (1964-1967) there is a filling in of the rural areas. This process is not a gradual process as in some areas the rate of growth is much faster, for example in the province of Friesland, Groningen and Drente, than in other parts of the country, viz. Eastern Brabant, the central part of the West and large parts of the provinces of Gelderland and Overijssel. As the filling in continues in 1966 new growth centres emerge on the map with acceptance ratios between 20 and 40 per cent. This pattern seems a repetition of the beginning of the process in 1957 and 1958, albeit on a higher overall level. The largest centres are again the Zandvoort-Amsterdam region and the urban areas of The Hague and Rotterdam. This continued growth can be explained by the increase in income and lower prices for T.V. sets which, as is discussed earlier, has the effect of raising the saturation level.

Finally, we can note that in 1967 most of the resistance towards television has been overcome as there are already 899 out of 940 municipalities which have an adoption rate of at least 10 per cent. Thus it can be expected that, given this development, it will be a matter of time before the last municipality reaches this level. In any case the lack of adoption in earlier periods cannot be explained using economic arguments only, as we have observed that the television sets are acquired anyhow in a later period. Although the income level can be of importance, also social factors will influence the nature of the process. This can be illustrated by the spatial association of the distribution of orthodox religious groups and the distribution of areas with low acceptance rates, which also express high resistance rates. Such a phenomenon can be caused by the lack of external contacts of the group or region or by the social structure of the group itself. Conversely, a large number of contacts may be required before the innovation is adopted, because of the degree of social control exerted by members of the group within the area. The specific social structure thus may create a barrier which will increase the necessary number of contacts with a region, before adoption occurs.

In concluding this section we can state that the analysis of the diffusion process as shown on the maps supports the hypothesis that the process follows an urban path and is polynuclear in character. Whether this latter is the consequence of a deliberate marketing strategy or is caused by the late beginning of the analysis remains unclear, viz. the first official records are from 1957 while transmission started already in 1951. However, these two patterns will reinforce each other, as in most cases household adoption will follow entrepreneurial adoption. This path follows in general the lines of the existing infrastructure (see chapter 3).

In the diffusion stage a two-fold division of the country in urbanized and rural areas is emphasized[31.]. These contrasts indicate the influence of socio-economic differences, which can act as barriers with a different degree of resistance over space. The resistance level of these barriers seem to diminish as time proceeds and this effect disappears gradually in the consolidation stage. Törnqvist suggests in his study of the diffusion of T.V. ownership in Sweden, that the observed differences between densely (urban) and thinly (rural) populated areas is not only caused by a difference in income structure, but also in age composition and number of children per household[32.]. In the next section the homogeneity assumptions which have been made in the theoretical section will be relaxed to study the way in which barriers influence the level of T.V. ownership in a region. These barriers are represented by the regional variations in the socio-economic structure of the country.

[31.] Loboda, J., The diffusion of television in Poland, <u>Economic Geography</u>, 1974, Vol. 50, pp.70-82.

[32.] Törnqvist, G., T.V. ägandets utvecklinge i Sverige, 1956-65, Uppsala, 1967, see pp.212-224 for English summary.

5.5 Regional variations in socio-economic characteristics and acceptance patterns

The hypotheses

The theoretical basis for the explanation of the diffusion process in space and time (see section 5.2 and 5.3) rest upon the assumption that there is a homogeneity in space and time for the total length of the study period. Starting from the urban network as the main factor which structured the diffusion process, it appeared, however, necessary to relax the assumption about the level of income and prices for the period to explain the observed growth. Regional variations in income per capita, as well as regional variations in the growth of this income, determine amongst other factors the final saturation level. The level of income also played a role in the date of the first purchase. Törnqvist found that households which bought a television set at the beginning of the study period had a mean income that was above the average income level in the area. Those who bought television sets at the end of the period had an income considerably below that level[33]. In addition to this feature, Dernburg noted that there will exist an income level beyond which rising incomes will no longer stimulate the demand for television sets[34]. If we reformulate these results in a hypothesis for the regional situation, as there is no information available on the household level, the research hypotheses then become:

H1 : The growth of the number of television sets in a region is positively associated with the average income in the region.

H2 : The larger the difference is between the average income and the median income in a region the smaller will be the growth of T.V. ownership.

H3 : The relationship between average income and the growth of T.V. ownership will decrease over time.

The second hypothesis takes care of the aggregation bias from the household to the regional level. The assertion is that households with higher incomes tend to buy earlier. In the regional case a high average regional income can be caused by a small group of high incomes. This group can never buy a large number of T.V. sets. The difference between the arithmetic mean and the median is an indication of the skewness of the intra-regional income distribution. When this difference is large, then the effect will be a relatively small number of purchases in the case where, at the same time, the mean is high.

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[33] Törnqvist, G., op.cit. 32, p.223.

[34] Dernburg, F., Consumer response to innovation: Television, Studies in Household Economic Behaviour, Yale Studies in Economics, Vol.9, Yale University Press, 1958.

Another important assumption is that there exists a stationary non-mobile population. Even for a reasonable short period, as the present one, in terms of an innovation diffusion process, this assumption is untenable. In the stationary situation the demographic process will have the effect not only of lowering the number of television sets per thousand in every region which enjoys a positive natural increase, but also lowering the income per capita at the same time. More important, however, is the effect of migration. First, a high level of migration indicates a large amount of external contact. The degree of external social contact is of importance in the decision to migrate or to accept an innovation. A high level of migration as an index of social contact can have a positive effect on the purchase of television sets. This type of contact is only one aspect of the multi-functional contact flows operating in an urban system. This leads to the following hypothesis:

H4 : The larger the in- and outmigration rate the faster the growth of T.V. ownership in a region.

Second, the occurrence of migration does not only reflect a certain amount of outside contact, but migrants can be T.V. owners at the same time. In this case the act of migration also implies a physical relocation of T.V. sets. This type of relocation diffusion can be of importance as on average 5 per cent of the population migrate every year between economic geographic regions in the Netherlands[35.]. If we assume that there are as many T.V. owners amongst the outmigrants as between the immigrants then it is possible to formulate the following hypothesis:

H5 : The growth of T.V. ownership is positively associated with those regions which experience a high population growth because of migration.

The importance of these two hypotheses based on migration is reinforced by the conclusions of both Dernburg and Törnqvist that T.V. densities increased more rapidly with persons in younger age groups than among those with persons in older age groups. As migration is usually observed amongst people in the younger age groups, the number of T.V. sets owned by migrants will be larger than the average number of television sets in a region. In addition to this, Törnqvist observed that early T.V. buyers were younger households which had more children than the late-buying households. These conclusions lead to the following two hypotheses:

H6 : The growth of T.V. ownership is positively associated with the average size of a household in a region.

H7 : The growth of T.V. ownership is positively associated with a young age composition in a region.

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35. This is the level at which the hypotheses will be tested.

THE DIFFUSION OF T.V. OWNERSHIP IN THE URBAN SYSTEM

In the discussion of the spatial aspects of diffusion it has been suggested that there was a sharp contrast between urban and rural acceptance patterns. However, these changing patterns can be caused by the selected class intervals and be an artefact of the mapping procedure which does not reflect the operation of a real spatial process. Thus it seems appropriate to introduce a separate test. The observed contrasts seem gradually to disappear over time. The difference between urban and rural areas can be expressed as differences in population densities and this can be formulated in:

H8 : The growth of T.V. ownership is positively associated with the population density in a region.

H9 : The relationship between the growth of T.V. ownership and population density decreases over time.

Finally, the last hypothesis, H10, is based on a suggestion by Dernburg, who tested the relationship between the growth of T.V. ownership and the level of education. In his study there was a positive relationship with an average education of 11 years and this relation became weaker for people with higher and lower education. The influence of higher education will be studied and it is proposed that there is a positive relationship.

H10 : The growth of T.V. ownership is positively associated with those regions which have a high proportion of people with a completed secondary education (about 11 years).

The data and models

The test of the hypotheses is confined by the availability of the necessary data at an appropriate regional level for the time period under study. Ideally in this case would be a time-series running from 1957 to 1967 at the municipal level. Income data to test the hypotheses H1 to H3 are only available at the level of economic geographic regions for 1958, 1960, 1963 and 1965. The municipalities are the building blocks for these regions, thus it is possible to aggregate the data on television ownership to this level. An additional problem is that the regional subdivision in economic geographic regions changed from 78 regions in 1958 to 128, or 129, when the Zuidelijke IJsselmeer Polders are included, in 1960. The basic regional pattern did not change fundamentally because of this change, as most of the additional 50 regions in 1960 are subdivisions of the 78 regions of 1958. Thus the 1958 regional division is roughly present, albeit in more detail, in the 1960 regional division and this does not create a major obstacle for the analysis.

The data for the television ownership was obtained from unpublished statistics of the Post, Telegraph and Telephone company, the licence fee administration, at a submunicipal level. The compilation of the statistics occurred at irregular intervals per year. With the exception of 1960, a data set could be created which had January 1st of each year as a reference point. As the only information available for 1960 was November 1st 1960, an artificial series has been made for January 1st by direct linear interpolation between the 1st of January 1959 and 1961. This interpolation procedure seems plausible because of the near linear growth pattern over this interval in the diffusion stage. A check on 25 municipalities belonging to different growth classes supported the procedure.

The variables which are used in the analysis are listed in table 5.1. Most of these variables are constructs from the official data before they enter the analysis. Variable X_4 is calibrated on the basis of the computation of the median income in every region. The official statistics report the internal income distribution of a region by a number of income groups and frequencies per group. The number of groups vary per period. The median of this frequency distribution is then derived following the procedures outlined by Blalock[36.]. The migration communication index (X_7) is computed as the sum of the in- and outmigration in a region relative to its population. The same procedure is followed in the calculation of the relative growth of T.V. ownership (X_2), where variable X_1 is divided by the regional population times one thousand. Finally, the information contained by variable X_5, X_9 and X_{10} is only available for the census year 1960, thus the hypotheses which are based on these variables can only be tested for this year.

The hypotheses all specify simple direct relationships. The postulated relations are tested on the basis of linear regression models, as there is no reason to assume a more complex relationship. The formal structure of the hypotheses is given in table 5.2 and they all represent a specific aspect of the innovation diffusion process. The income assumption reflects the economic threshold, while the household assumption indicates the degree of social resistance to adopt a television set. The latter hypothesis can only be tested for 1960, because this type of data is only collected for the population census. The communication and urbanization hypotheses both stress the spatial characteristics of the diffusion phenomenon in an urban system. The temporal aspect of these hypotheses, as formulated in H3 and H4, can only be tested in a non-formal sense by an inter-temporal comparison of the cross-sectional data. The integration of the partial hypotheses into one complex structure explaining the process of the diffusion of television sets is beyond the purpose of this analysis. The main goal is to analyse the way in which the urban

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[36] Blalock, H.M., <u>Social Statistics</u>, McGraw Hill, New York, 1960.

table 5.1 Variables for the testing of the hypotheses

Variable	Name
X_1	Absolute annual growth in T.V. ownership between t and t+1 (1
X_2	Relative rate of growth in T.V. ownership between t and t+1 (1
X_3	Average income per taxpayer (2
X_4	Difference between the average and median income (2
X_5	Average number of persons per household (4
X_6	Population growth due to migration (3
X_7	Migration communication index (3
X_8	Population density (5
X_9	Percentage of the population with at least secondary education (V.H.M.O.) (4
X_{10}	Percentage of the population in the age group 0-19 year (4

Sources :

1. Unpublished statistics of the Post, Telegraph and Telephone Company, 's-Gravenhage.
2. Inkomens Verdeling, 1958, 1960, 1963, 1965, Regionale gegevens, C.B.S., 's-Gravenhage.
3. Statistiek van de Binnenlandse migratie, 1958, 1960, 1963, 1965, C.B.S., 's-Gravenhage.
4. Volkstelling 31 mei 1960, C.B.S., 's-Gravenhage, 1964.
5. De Bevolking van Nederland per gemeente, per 1 januari 1958, 1960, 1963, 1965, C.B.S., 's-Gravenhage.

table 5.2 The formal structure of the hypotheses

Income assumption

H1 : $X_1 = b_0 + b_3X_3$

$X_2 = b_0 + b_3X_3$

H2 : $X_1 = b_0 + b_3X_3 + b_4X_4$

$X_2 = b_0 + b_3X_3 + b_4X_4$

Communication assumption

H_4 : $X_2 = b_0 + b_7X_7$

H_5 : $X_2 = b_0 + b_6X_6$

Urbanization assumption

H8 : $X_1 = b_0 + b_8X_8$

$X_2 = b_0 + b_8X_8$

Household characteristics assumption

H6 : $X_1 = b_0 + b_5X_5$

H_7 : $X_1 = b_0 + b_5X_5 + b_{10}X_{10}$

H10 : $X_1 = b_0 + b_9X_9$

$X_2 = b_0 + b_9X_9$

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system operates as a communication system in channeling flows of people, goods and information. Some insight in the operation of barriers with regard to their spatio-temporal variation is of importance in the understanding of the nature of the process in such a system.

The test of the hypotheses[37].

First, the income assumption. The average income in a region seems to be a poor indicator to explain the growth of T.V. ownership in a region for the whole period. This result, which is reported in table 5.3, supports the third hypothesis. The growth of T.V. sets shows a weak but significant relationship with the income per taxpayer in a region, in the early part of the diffusion process, 1958, and to a lesser degree in 1960. After this date there is no association at all. The intro-

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[37] The correlation matrices which give some additional information about the relationship between the variables are presented in Appendix 3.

table 5.3 Regression coefficients for the simple linear hypothesis

Equation	$X_1=b_0+b_3X_3$		$X_1=b_0+b_8X_8$		$X_2=b_0+b_6X_6$		$X_2=b_0+b_7X_7$	
Year	b_3		b_8		b_6		b_7	
1958	1.52		1.33		155.04		33.60	
T		2.75		8.99		2.51		1.50
R		0.30		0.72		0.28		0.17
F		7.55		80.97		6.28		2.26
1960	0.43		1.44		55.06		64.39	
T		1.60		11.58		1.83		4.13
R		0.14		0.72		0.16		0.35
F		2.56		134.07		4.93		4.69
1963	0.20		1.42		-3.17		52.86	
T		0.73		9.38		- 0.09		3.02
R		0.07		0.64		0.00		0.26
F		0.53		87.94		0.00		9.15
1965	0.05		0.77		186.88		33.53	
T		0.15		6.70		3.49		1.55
R		0.04		0.51		0.30		0.13
F		0.15		44.93		12.15		2.39

duction of the second hypothesis, which compensates for the skewness of the income distribution in a region, supports the simple hypothesis (see table 5.4). Here we also observe a support of the third hypothesis. The income effect is in comparison much stronger for the whole period with the exception of 1965 in which there is no significant relationship. The sign of the regression coefficient of variable X_4, indicating the skewness, is of the hypothesized nature. Thus, the larger the difference between the median and the mean, the smaller the growth over the period.

table 5.4 Regression coefficients for the multiple linear hypothesis

Equation $X_1 = b_0 + b_3X_3 + b_4X_4$

Year	b_3		b_4		R	F
1958	1.89		-0.75		0.30	4.17
T		2.74		-0.90		
1960	2.60		-3.44		0.30	6.44
T		3.57		-3.18		
1963	1.88		-2.68		0.22	3.54
T		2.65		-2.55		
1965	0.51		-0.70		0.08	0.85
T		1.30		-1.25		

Interesting in this case is 1958 where this coefficient is not significant. This may indicate that the pure income effect played the most important role at the early stages in the process. The results from the simple hypothesis (table 5.3) supports this suggestion by the larger regression coefficient for 1958. The second hypothesis then is most operative as an explanation for the process in the diffusion stage 1961-1964, where we observed a rapid growth of T.V. ownership in considerable quantities. As far as the relative growth rate is concerned there is a significant relationship both for 1958 and 1960 (see table 5.5). The weak, but significant relationship increases for this case. It seems that the relative rate of growth is much closer associated with the average income in the innovation stage (1957-1961) of the process and not with later stages in the diffusion process. For these stages there is no significant relationship and the hypotheses H1 and H2 must be rejected for 1963 and 1965.

Second, the urbanization assumption. Population density seems to be of considerable importance in the explanation of the growth of T.V. ownership. The results listed in table 5.3 all indicate significant relationship for the four periods concerned. Thus, there is no reason to reject the eighth hypothesis. Moreover, we can observe a strong positive association for most of the period which weakens to a moderate correlation coefficient of 0.52 in 1965. This gradual decline from 1960 to 1965 supports H9 in which there is postulated a declining relation over time. If we turn, however, from the absolute growth in a one-year period to the relative rate of growth, the picture becomes much more pronounced. From a strong positive relationship in 1958 (R=0.67), the relationship is not significant in 1963 and turns into a negative, but significant, relationship in 1965 with a weak correlation of R=-0.39. These results reinforce the interpretation of the map patterns (fig.5.7 to fig.5.17), where the rate of growth decreases in the urban areas as time proceeds and accelerates in the rural, lower density, areas in the last stage of the process. The map patterns then are not an artefact of cartographic design, but do reflect true and testable aspects of the diffusion process. Even the not significant result for 1963 can get a meaningful interpretation in the following way. Around this period the rate of growth slows down in the urban areas and has about the same magnitude before it starts to accelerate in the more rural areas. This gives rise to indeterminacy in the postulated relationship which, in turn, becomes not significant.

Third, the communication assumption. The two hypotheses H4 and H5 express the role of social communication and physical relocation in the diffusion in an urban system. The basic assumption is related to the influence which is exerted by these two factors on the rate of growth of T.V. ownership caused by an above average telling or relocation effect. The role of social communication (H4) is of importance for the whole period, with the exception of 1965 (see table 5.3). There is a weak but significant relationship which declines over the period 1958-1963. The reason for this decline is that migration, and thus here external social communication, has become more specifically an inter-urban phenomenon than an urban-rural characteristic. The shift from urban to rural growth over the period as discussed above is, of course, closely associated to this phenomenon, although there exists no direct relationship between the two types of explanations offered by H8 and H4.

table 5.5 Regression coefficients for the linear hypothesis

Equation	$X_2 = b_0 + b_3X_3 + b_4X_4$		$X_2 = b_0 + b_3X_3$	$X_2 = b_0 + b_8X_8$
Year	b_3	b_4	b_3	b_8
1958	0.006	-0.0015	0.005	0.002
T	5.68	-1.27	6.10	8.06
R		0.58	0.57	0.68
F		4.44	4.43	64.89
1960	0.008	-0.008	0.002	0.002
T	6.54	-4.79	5.31	7.79
R		0.56	0.43	0.57
F		4.18	4.52	60.62
1963	0.0015	-0.0020	0.0003	0.0002
T	1.25	-1.12	0.565	0.60
R		0.07	0.05	0.05
F		0.79	0.319	0.36
1965	0.0012	-0.0020	0.0002	-0.0016
T	1.39	-1.20	0.39	-4.80
R		0.06	0.03	-0.39
F		1.14	0.15	23.03

The physical relocation assumption (H5) has to be rejected for 1963 because the relationship is not sifnificant for this period (see table 5.3). This may be caused by the specific nature of the development of interregional migration in the period 1960-1965. This author showed in another study that the rate of growth of both the inter- and intra-provincial migration decreased between 1960 and 1963 and in 1964 the intra-provincial rate was back at the 1960 level[38]. It may well be that this is also the case at the level of the economic geographic regions and this could explain the non-significant nature of the relation in view of a continuing growth of T.V. ownership and a temporally declining rate of migration. In view of the existing knowledge about the nature of the migration process, it seems that the relocation hypothesis needs further analysis before a definite conclusion about its usefulness can be made.

Fourth, the household characteristics assumption. The level of education is brought forward as H10 and we may note that there is a significant relationship between a completed secondary education and the growth of T.V. ownership in 1960 (see table 5.6). This relationship holds both for absolute and the relative rate of growth. The strongest association is with the relative rate of growth where a correlation of R=0.63 can be observed against an R=0.33 for the absolute rate. More interesting in this case is the comparison with the income relationship (table 5.5). The simple association with the relative rate of growth is R=0.43, while the adjusted association (H2) shows an R=0.56. This may indicate that the importance of education and eventually more willingness to accept an innovation is somewhat more important than just having a high enough income. It goes without saying that there has always been a strong correlation between income and education, which is in this case R=0.74. However, there are a whole number of factors which explain the level of income in a region, amongst those is education.

The household structure assumption about the effect of the size of the family (H6) and the joint relationship with the age structure in an associative formulation (H7) gives a significant relationship for the two hypotheses (see table 5.6). The signs of the regression coefficient are negative in all cases. This implies that H6 and H7 have to be rejected as the hypotheses did postulate a positive relationship. The original formulation by Törnqvist was that this relationship was positive in the beginning of the period and changed towards the end into a reverse relationship. This

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[38] Van der Knaap, G.A., Een analyse van de stabiliteit van de binnenlandse migratie patronen in Nederland (1960-1970), in Een sociaal geografisch spectrum, J. Hinderink and M. de Smidt, eds., Utrecht, 1974, pp.115-144.

table 5.6 Regression coefficients for the household characteristics hypothesis

Equation	$X_2 = b_0 + b_9X_9$	$X_1 = b_0 + b_9X_9$	$X_1 = b_0 + b_5X_5$	$X_1 = b_0 + b_5X_5 + b_{10}X_{10}$	
Year	b_9	b_9	b_5	b_5	b_{10}
1960	0.70	192.93	-1497.31	-1036.75	-82.31
T	9.39	3.87	-3.24	-1.96	-1.75
R	0.64	0.33	-0.28		-0.31
F	88.26	14.95	10.46		6.85

cannot be the case here, as 1960 is the beginning of the diffusion period and, from a more general point of view, belongs more to the beginning of the whole period (1957-1967) than to the end. If from a structural point of view 1960 could be regarded as a turning point, then the results from this analysis would have been inconclusive in the sense that there would have been a non-significant relationship. The present results, however, lead to the postulation of the reverse hypothesis for the case of the Netherlands, that large households with a young-age composition tend to buy later their first television set than other households. This result also indicates that over the study period there is a considerable difference in the level of income for young and large families in Sweden when compared with the Netherlands for the same type of family composition.

5.6 Conclusions

The functional spatial organisation of the urban system has been examined on the basis of the diffusion of T.V. ownership in this system. The diffusion in an urban system can be characterized by the formal and functional aspects of the diffusion process. These aspects relate to three important regularities of the diffusion of the diffusion process in space and time. The temporal path follows a S-shaped curve, while in combination with this feature the spatial path can be described by a hierarchical diffusion.

The graph describing the total acceptance pattern showed a near linear pattern. This was explained by the fact that the beginning of the diffusion process (1951) occurred before the beginning of the study period (1957) at which there were already 100,000 television sets. The fast rate of growth of T.V. ownership which caused this linear pattern could be interpreted as a positive skewness of the logistic, because of decreasing prices and increasing incomes during the period. The influence of these two factors is to raise continually the saturation level which had not been hit at the end of the study period.

An inter-temporal comparison of the map patterns for 1957-1967 on a yearly basis leads to the identification of three stages: (1) an innovation stage (1957-1961), (2) a diffusion stage (1961-1964), and (3) a consolidation stage (1964-1967). These stages are somewhat overlapping for the different regions because of regional variations in the speed of the process. In the innovation stage the urban centres emerge emphasizing the polynuclear aspect and the linkage structure of the urban system. The second stage reflects the neighborhood effect as there is an outward spread around the urban centres which became dominant in the previous stage. Finally, in the consolidation stage there is a gradual filling up and there is a tendency towards a rather uniform spatial distribution of T.V. ownership per capita.

The hierarchical diffusion within the urban system is clearly evident from the map pattern analysis. The maps show the polynuclear aspect of this innovation-diffusion process, where the Western part of the country seems functionally more integrated with the South than with the North and East. In these two major regions the diffusion process seems to be rather slow in the early stages of the process, but especially the Northeast exhibit an extremely fast rate of growth in the later stages. Besides the polynuclear aspect there is also a neighborhood and wave effect noticeable on the maps. Especially the map showing the development of the innovation wave very clearly demonstrates the occurrence of barriers of resistance in various parts of the country, which are all predominantly rural in character.

Four main assumptions have been tested, using regression analysis, in the last part of this chapter: (1) the urbanization hypotheses, (2) the communication hypotheses, (3) the income hypotheses, and (4) the household characteristics hypotheses. The first two sets of hypotheses are related to the formal and functional aspects of the innovation-diffusion process. The third and the fourth set are formulated to measure the influence of the regional variations in these characteristics on the spatial pattern of the innovation-diffusion process.

The urbanization assumption has been formulated in a hypothesis where the urban structure is reduced to a population density structure. The results very clearly indicated the strong influence of the urban centres in the beginning of the period, while both the absolute and relative rate of growth diminished in these centres over time. Contrasting to this, the growth rate became much stronger associated with low, rural, population densities in 1965 and this supports the map pattern analysis for this period.

The communication hypotheses are closely associated with the urbanization assumption in that they should measure some aspects of the linkages structure of the urban network. Social communication usually plays an important role in the diffusion of an innovation. This communication aspect of the network is measured via a migration communication index, which was used to explain a higher than average growth in acceptance rate. The importance of this factor declined over time, as was evident from the decreasing regression coefficients. This preliminary conclusion is contradictory to Rogers' statements that personal communication becomes more important at a later stage in the diffusion process, while the influence of mass-media plays the most important role in the early stages[39]. It is, however, much more in line with Brown's

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[39] Rogers, E.M., op.cit. 3.

findings for Southern Sweden, where he observed that the degree of social communication diminished towards the end of the period as the innovation ceased to be an innovation[40].

The diffusion of an innovation is usually studied with the assumption that during the diffusion period there is neither population growth nor migration, i.e. a stationary, non-mobile population. In the case of migration the acceptors of the innovation do not only relocate themselves, but also take part in a physical diffusion process. It appeared, however, that differences in growth rate over time could not be explained consistently by the migration relocation hypothesis.

The income assumption was studied on the basis of a relation between the average income in a region and the growth of T.V. ownership, both in an absolute and relative sense. It appeared that this relationship was positive and significant but only for the beginning of the period. The association decreased and disappeared towards the end of the study period, which indicates that the income and price explanation is only a partial explanation and not valid for the process as a whole.

The household characteristics assumption could only be tested for 1960, as the operationalization of the associated hypotheses required information which is only collected at censusses. These hypotheses express the willingness to adopt the innovation in relation to the level of education, size of the household and the age composition. The level of secondary education in a region appeared to have a rather strong association with the relative rate of growth in 1960 and only a weak relationship with the absolute growth in T.V. ownership. The hypotheses related to household size and age structure were both rejected, because of a significant but negative relationship which was the reverse of the postulated relations based on research results in Sweden and the United States.

On the basis of the above results we may conclude that a consistent explanation of the diffusion process can only be given when we stress the urban element in the analysis. Other factors do contribute to the understanding of spatial variations at one point in time, but they occur in changing combinations over time. The hierarchical and polynuclear character of the innovation-diffusion process points very strongly towards the presence of an urban system as a spatial organizational structure. The nodes in this system have been studied in the previous chapter. It is hypothesized that the innovation process follows the linkage structure of this system. Time lags and spatial variations can thus be attributed to the characteristics of this structure. The spatial variations in the adoption rates in the main centres of

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[40] Brown, L.A., op.cit. 4.

the urban system thus indicate differences in the way in which the linkages are present and operative. The observed differences over space and time suggest that cities in the North have a different set of linkages between themselves and with the other nodes in the system then the centres located in the South. Thus, we may hypothesize that there are two types of organizational subsystems operative within the national urban system, viz. a West-North and a West-South subsystem.

GENERAL CONCLUSIONS

The geographical scale of the analysis and description has a considerable influence upon the spatial relationships of the phenomena under examination and on the processes at work. The scale of the analysis of the study presented above is predominantly urban, ranging from the spatial structure of cities and city regions to the system of cities. Thus, it is only possible to draw here some tentative conclusions for the national scale, involving the system of regions and their spatial organisation. Let us, because both space and time are involved here, first consider the way in which time has been incorporated in this analysis.

The study of the evolution of the urban system has thrown some light on the operation of the urban system at various points in time. The influence exerted by geographical inertia on the spatial organisation of this system could be examined on the basis of a detailed analysis of the changing nature of the spatial relationships (see chapter 3) and the changing functional structure of the largest urban centres (see chapter 4). A study of change presupposes stable points of reference, such as an unchanging regional delimitation, which has been applied throughout the study. Associated with this is the problem of a consistent definition of the measurement criteria over time. Threshold values or size-class divisions may lose their significance over time, because they are part of a spatial organizational structure which changes over time. A consistent definition in this context thus aims at structural comparability over time.

There are obviously two ways in which one may try to find a solution for this problem. First, in the absence of complete information, assumptions can be made to incorporate the idea of changing threshold values over time (see chapter 3). Second, the changes in the frequency distribution of the phenomenon under examination can be studied, starting from arbitrary thresholds or boundary values over time. The latter approach has been followed in the study of the population distribution by size class (chapter 2). In this way the changing nature of the distribution was revealed and at the same time additional insight was gained about the operation of certain boundary (threshold) values over time. It appeared that there were considerable differences over time between size classes, with respect to the time a city belonged to a particular size class. A detailed study of these values will throw additional light on the process of urban growth and they need more attention from researchers in the field than they have received until now.

The questions raised about the evolution of the Dutch urban system have been formulated to gain some understanding of the spatial structure and the processes at work in this system. This study is carried out against the background of the regional structure as presented in fig.1.2. It can be argued that the division of the country in the three parts shown on this map, viz. the North, the West and the South, is the result of a process of functional and regional specialisation. This specialisation was caused not only by an increase in regional functions but also because of a loss of some functions and these three regions can be classified respectively on the basis of rural-urban, urban-industrial and higher-order urban activities. Important factors in the explanation of the processes which gave rise to this regional pattern are: (1) the operation of initial advantages and inertia, and (2) the increasing scale of the spatial organisation of society.

It has been hypothesized that a spatially integrated urban system emerged over time, which contributes to this regional structure. In order to examine this hypothesis both the evolution of the linkages in the urban system between the urban centres and the evolution of the functional structure of the centres themselves have been studied. A large number of simplifying assumptions had to be made to describe this real-world system operationally, to measure the elements of this system and to study those in a quantitative way. Of course, another set of assumptions could have revealed different aspects of this urban system, but as these assumptions are made to analyse the same hypothesis, also the same basic structure should appear. This last aspect will be the case in an integrated analysis of the urban system. The present study examines aspects of this system independently of each other. The integration is not carried out within a formal analytical structure, but conceptually as part of the theoretical framework presented in chapter 1. The conceptual basis of this study thus generates the hypotheses and they are examined at the same time against it to test their validity.

It has been shown, that the development of the inter-urban linkages favoured the larger cities and thus reinforced the spatial pattern of the population distribution. This culiminated in 1910 when about 25 per cent of the total population of the Netherlands was concentrated in the four largest cities, viz. Amsterdam, Rotterdam, The Hague and Utrecht. For the regional level we can observe that the spatial nature of the evolution of the transport networks indicates a relatively strong connection of the South and North with the West and, to a lesser degree, between the South and the North. This physical linkage pattern reflects in part the different structural relationships and linkages which exist, but points at the same time to the role of the physical environment here, viz. the nature of the Rhine delta which has a predominantly East-West orientation.

The dynamic nature of the inter-urban linkages is further pursued in chapter 5. Here the spatial pattern of the diffusion of T.V. ownership was studied. It was shown that the highest acceptance ratios appeared first in the urban centres in the West, closely followed by the centres in the South, while the urban centres in the North were the last to show the same high rates. This diffusion path suggests that the inter-urban contacts between the West and South are more frequent than those between the West and North. An explanation for this different contact structure can be given, if one considers the differences in possible types of contacts which exist in the three types of central place systems discussed by Christaller, Lösch and Pred. The functional elements of these three systems may validly represent the contact (sub)systems of respectively the North, South and West[1].

The above comments raise questions as to the functional nature of the urban centres which constitute the urban system. From the analysis in chapter 4 it is evident that the city of Groningen is the highest order centre in the North and of the same quality as the four largest urban centres located in the West[2]. For this reason a large number of external contacts of the centres in the Northern region as a whole will be channeled through this city. It can be argued that this type of contact pattern exists already for some time, as these five urban centres occupy at least since 1930 a stable position in the top of the urban hierarchy. When changes do occur, such as a shift from the manufacturing sector to the service sector, they occur in each city at the same rate and this does not affect their relative position to the system as a whole. As regard the main centres in the Southern part of the Netherlands, they were characterized by second order urban and industrial, mainly manufacturing, functions. This kind of urban functional organisation supports the use of a Löschian scheme of explanation for the different kind of contact patterns which can be observed in this part of the country.

It will be obvious from the changes in the functional structure of a large number of cities which belong to one group of cities in one period and to another in the next, that the spatial order which is suggested here is by no means perfect nor absolutely stable over time. What becomes clear, however, is that there exists an urban system which is focussed on the four largest urban centres in the

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[1] For the North there is even some evidence of a spatial coincidence with a Christaller type of central place system. See, Thijsse, J.P., A rural pattern for the future in the Netherlands, Papers and Proceedings of the Regional Science Association, 1962, Vol.10, pp.133-141.
Thijsse, J.P., Second thoughts about a rural pattern for the future in the Netherlands, Papers and Proceedings of the Regional Science Association, 1967, Vol.15, pp.69-75.

[2] This result is also supported by a study of the spatial structure of the hierarchy of regional service centres in the Netherlands. See, Buursink, J., De Nederlandse hiërarchie der regionale centra, Tijdschrift voor Economische en Sociale Geografie, 1971, pp.67-81.

West. These centres, together with the city of Groningen, can be thought to act as control centres in the urban system. The organizational structure of the urban system, however, cannot be explained by one single theory of urban functional organisation, as different parts of the system show a different type of functional organisation.

A further analysis of the nature of the processes at work in the urban system may throw more light on regional policy issues, such as questions regarding a national population (re)distribution policy for a population moving towards a stable size. The differences in the functional organisation of parts of the spatial structure cause differences in the rate and speed of the circulation of the population through the system as a whole. At the same time, because of the evolution of the system itself, we can expect a further integration between the urban subsystems of the South and West in terms of their functional organisation. A consideration of the joint outcome of these two processes will be of importance in the understanding of the future patterns of population distribution.

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APPENDIX 1 : The construction of transport networks and a list of consulted maps

The construction of the transport networks, fig.3.3 to fig.3.17, is based upon a series of decisions regarding the representation of the routes and the nodes in the network. The source for the construction of the railway, road and waterway networks, which is listed below, did not always coincide with the selected years, viz. 1850, 1870, 1910 and 1940. The date shown on the maps refers to the actual year of the source map. The time interval between these two dates is, however, rather small and accordingly the maps are a good approximation of the actual network. This approximation also holds in a locational sense as these networks are used for both a visual interpretation and actual measurement.

The waterway networks have been established on the principle of a minimum economic capacity which varied over time from 80 tons in 1850 to 600 tons in 1970. The definition of a road is based on the current definition of a main road or national highway. The use of this indication is also variable over time and will implicitly refer to the changing function of the road in the national network. This problem is only present to a certain degree in the railway network, where difference between single and dual carriage ways have been ignored, as well as between sections which are electrified and which are not.

The routes of the networks connect the nodes which have been identified on their 1970 population. In chapter 2 a minimum number of 5,000 inhabitants was considered, leading to the incorporation of 502 municipalities. In view of the recommendations made in the 1973 study, discussed there, on the minimum economic size, a population size of at least 10,000 was taken as the population of the smallest town. This gave rise to a reduction from 502 to 278 municipalities, which are all represented on the maps by a black dot. There are, however, three types of dots on the map, viz. a node (black dot), a junction or terminal point and a semi-node. The location of the node coincides with the centre of gravity of the population using the 1960 population distribution as given on the dot map in the Atlas of The Netherlands. The semi-node does not possess this feature, but it records the transection of the municipal territorium by a route of the network and thus expresses here the actual physical location of the route. The introduction of the semi-node is based on the possibility of a municipality having access to the network, while it is located outside the population centre. Finally, the junction has to be mentioned, which is a technical link of the routes of a transport network outside a population centre, or of a centre which has a population below the threshold level. The latter is also applicable in the case of terminal points.

APPENDIX 1

List of consulted maps

Nieuwe etappe-kaart van het Koninkrijk der Nederlanden, 1848, scale 1:200,000.

Nieuwe kaart van het Koninkrijk der Nederlanden, 1870, scale 1:200,000.

Kaart der rivieren en kanalen in Nederland met aanduiding van de scheepvaartbewegingen daarop in 1883, scale 1:600,000.

Kaart van de hoofdwegen van Nederland, 1907, scale 1:400,000.

Scheepvaartwegen in Nederland, 1908, scale 1:400,000.

Spoor- en tramwegkaart van het Koninkrijk der Nederlanden, 1915, scale 1:400,000.

Kaart van de Nederlandse Spoor- en Tramwegen, 1930.

Autokaart van Nederland, 1931, scale 1:200,000.

Autokaart van Nederland, 1948, scale 1:200,000.

Overzichtskaart der Nederlandse Vaarwegen, 1953, scale 1:400,000.

Overzichtskaart der Nederlandse Vaarwegen, 1960, scale 1:400,000.

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APPENDIX 2 : Correlation matrices for the analysis of the urban structure in 1930, 1947 and 1960

Correlation matrix for 1930

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.47	1.00								
3	0.40	-0.63	1.00							
4	0.28	-0.72	0.07	1.00						
5	-0.13	0.26	-0.41	0.25	1.00					
6	-0.05	-0.08	0.34	-0.39	-0.91	1.00				
7	0.08	0.02	0.30	-0.43	-0.88	0.81	1.00			
8	-0.52	0.87	-0.74	-0.42	0.47	-0.25	-0.24	1.00		
9	-0.62	0.72	-0.63	-0.22	0.61	-0.40	-0.42	0.89	1.00	
10	0.09	-0.17	-0.27	0.40	0.15	-0.20	-0.18	0.00	-0.03	1.00
11	-0.41	0.80	-0.48	-0.71	-0.06	0.18	0.23	0.59	0.45	-0.27
12	-0.11	-0.35	0.01	0.45	0.16	-0.10	-0.31	-0.04	-0.01	0.42
13	-0.36	-0.06	-0.23	0.22	0.01	0.08	-0.18	0.17	0.17	0.04
14	-0.10	-0.06	-0.23	0.18	0.09	-0.09	-0.13	0.11	0.10	0.59
15	0.29	-0.51	0.56	0.27	-0.10	0.08	0.01	-0.59	-0.41	0.11
16	0.65	-0.60	0.60	0.38	-0.11	-0.10	0.06	-0.70	-0.56	-0.14
17	0.48	-0.41	0.38	0.29	-0.08	-0.03	0.09	-0.50	-0.38	-0.14
18	0.66	-0.57	0.47	0.35	-0.11	-0.13	-0.01	-0.62	-0.57	-0.00

	11	12	13	14	15	16	17	18
11	1.00							
12	-0.66	1.00						
13	-0.04	0.48	1.00					
14	-0.33	0.57	-0.13	1.00				
15	-0.39	0.04	-0.27	0.01	1.00			
16	-0.50	-0.31	-0.49	-0.24	0.45	1.00		
17	-0.38	-0.34	-0.50	-0.17	0.29	0.88	1.00	
18	-0.40	-0.25	-0.34	-0.16	0.35	0.80	0.60	1.00

APPENDIX 2

Correlation matrix for 1947

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.64	1.00								
3	0.23	-0.67	1.00							
4	0.14	0.31	-0.51	1.00						
5	-0.15	0.52	-0.52	0.56	1.00					
6	-0.07	-0.24	0.39	-0.55	-0.88	1.00				
7	-0.08	-0.14	0.35	-0.49	-0.85	0.84	1.00			
8	-0.56	0.92	-0.69	0.33	0.64	-0.36	-0.29	1.00		
9	-0.51	0.81	0.57	0.39	0.76	-0.47	-0.45	0.88	1.00	
10	-0.43	0.47	-0.43	0.19	0.11	0.05	0.13	0.38	0.29	1.00
11	-0.53	0.47	-0.14	-0.35	-0.20	0.46	0.44	0.44	0.29	0.24
12	0.01	-0.08	-0.12	-0.19	0.09	-0.14	-0.22	-0.06	-0.09	0.01
13	-0.31	0.12	-0.08	-0.11	0.05	0.01	-0.11	0.17	0.13	0.03
14	0.10	-0.05	-0.18	-0.13	0.03	-0.09	-0.14	-0.05	-0.14	0.02
15	0.06	-0.16	0.19	-0.13	-0.08	0.08	0.06	-0.21	-0.17	-0.07
16	0.54	-0.55	0.52	0.17	-0.08	-0.12	-0.03	-0.58	-0.42	-0.39
17	0.41	-0.45	0.19	0.21	-0.15	-0.02	0.05	-0.53	-0.49	-0.17
18	0.64	-0.67	0.42	0.14	-0.08	-0.22	-0.15	-0.62	-0.54	-0.48

	11	12	13	14	15	16	17	18
11	1.00							
12	-0.34	1.00						
13	0.15	0.49	1.00					
14	-0.31	0.64	-0.14	1.00				
15	-0.02	-0.03	-0.10	-0.13	1.00			
16	-0.54	-0.32	-0.50	-0.19	0.37	1.00		
17	-0.46	-0.19	-0.56	0.07	0.30	0.73	1.00	
18	-0.56	-0.16	-0.34	-0.01	0.18	0.76	0.61	1.00

Correlation matrix for 1960

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	-0.63	1.00								
3	0.42	-0.78	1.00							
4	-0.21	0.68	-0.79	1.00						
5	-0.14	0.44	-0.68	0.67	1.00					
6	-0.07	-0.12	0.48	-0.48	-0.87	1.00				
7	-0.11	-0.08	0.45	-0.45	-0.85	0.84	1.00			
8	-0.60	0.86	-0.84	0.67	0.69	-0.41	-0.38	1.00		
9	-0.60	0.66	-0.63	0.49	0.71	-0.43	-0.40	0.86	1.00	
10	-0.38	0.21	0.04	0.15	0.19	0.04	0.04	0.26	0.44	1.00
11	-0.49	0.53	-0.24	0.04	-0.18	0.42	0.42	0.39	0.31	0.16
12	-0.26	0.25	-0.36	0.16	0.10	-0.06	-0.16	0.28	0.10	-0.08
13	-0.28	0.09	-0.20	0.01	0.05	-0.02	-0.12	0.28	0.13	-0.07
14	-0.02	0.02	-0.22	0.07	0.07	-0.10	-0.18	-0.01	-0.04	-0.01
15	0.00	0.14	0.03	-0.08	-0.18	0.31	0.25	0.11	0.03	-0.12
16	0.51	-0.58	0.65	-0.47	-0.22	0.05	0.15	-0.55	-0.34	0.02
17	0.43	-0.36	0.36	-0.23	-0.29	0.08	0.19	-0.57	-0.51	-0.20
18	0.64	-0.63	0.52	-0.34	-0.14	-0.15	-0.08	-0.59	-0.45	-0.27

	11	12	13	14	15	16	17	18
11	1.00							
12	-0.04	1.00						
13	0.02	0.58	1.00					
14	-0.23	0.60	-0.04	1.00				
15	0.37	-0.14	-0.12	-0.42	1.00			
16	-0.34	-0.70	-0.52	-0.36	0.05	1.00		
17	-0.32	-0.29	-0.43	0.01	-0.05	0.51	1.00	
18	-0.40	-0.52	-0.34	-0.22	-0.10	0.73	0.50	1.00

List of variables

Variable no.	Name
1	population density per ha
2	% of the population, 0-15 year
3	% of the population, 65 year and above
4	% women, 15-39 year
5	% roman catholic
6	% dutch reformed
7	% reformed
8	average number of persons per household
9	average number of persons per dwelling unit
10	finished number of new dwelling units
11	% employed in agricultural activities
12	% employed in manufacturing industries
13	% employed in textile industry
14	% employed in metal industry
15	% employed in building and construction
16	% employed in tertiary activities
17	% employed in transportation
18	% employed in banking and insurances

APPENDIX 3 : Correlations between variables used in the regression analysis to explain the distribution of T.V. ownership in 1958, 1960, 1963 and 1965

Correlation matrix for 1958

	1	2	3	4	6	7	8
1	1.00						
2	0.65	1.00					
3	0.30	0.57	1.00				
4	0.10	0.24	0.59	1.00			
6	-0.05	0.27	0.52	0.30	1.00		
7	-0.11	0.17	0.44	0.31	0.41	1.00	
8	0.72	0.68	0.29	0.09	-0.01	0.03	1.00

Correlation matrix for 1960

	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	0.49	1.00								
3	0.14	0.43	1.00							
4	0.03	0.27	0.93	1.00						
5	-0.28	-0.38	-0.25	-0.11	1.00					
6	-0.09	0.16	0.39	0.26	0.05	1.00				
7	-0.08	0.35	0.59	0.55	-0.20	0.56	1.00			
8	0.72	0.57	0.18	0.07	-0.31	-0.03	0.04	1.00		
9	0.33	0.64	0.74	0.69	-0.30	0.34	0.60	0.48	1.00	
10	-0.27	-0.39	-0.12	-0.06	0.50	0.04	-0.07	-0.29	-0.26	1.00

APPENDIX 3

Correlation matrix for 1963

	1	2	3	4	6	7	8
1	1.00						
2	0.20	1.00					
3	0.06	0.05	1.00				
4	-0.02	0.09	0.93	1.00			
6	-0.11	-0.01	0.16	-0.07	1.00		
7	-0.16	0.26	0.44	-0.39	-0.03	1.00	
8	0.64	0.05	0.17	-0.05	-0.12	-0.02	1.00

Correlation matrix for 1965

	1	2	3	4	6	7	8
1	1.00						
2	-0.01	1.00					
3	0.03	0.01	1.00				
4	-0.01	-0.03	0.93	1.00			
6	-0.25	0.30	0.27	0.13	1.00		
7	-0.15	0.14	0.55	0.50	0.41	1.00	
8	0.51	-0.39	0.15	0.10	-0.28	0.04	1.00

List of variables

Variable no.	Name
X_1	Absolute annual growth in T.V. ownership between t and t+1
X_2	Relative rate of growth in T.V. ownership between t and t+1
X_3	Average income per taxpayer
X_4	Difference between the average and median income
X_5	Average number of persons per household
X_6	Population growth due to migration
X_7	Migration communication index
X_8	Population density
X_9	Percentage of the population with at least secondary education (V.H.M.O.)
X_{10}	Percentage of the population in the age group 0-19 year

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