THE ROLE OF TRAFFIC NETWORK DESIGN IN CIRCULATION SYSTEMS AND IN THE FORMATION OF URBAN PATTERNS

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

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In this study, the role of traffic network design in the formation of urban space is investigated. In general, the meaning of traffic network design is reduced to the design of street patterns as a subset of traffic planning and management.

The study concentrates on how the existing street patterns restrict the performance of transportation and traffic planning. In fact, the solution to such conflicts should be sought in the urban design process. Since urban design is the process of combining street networks, both for vehicular and pedestrian circulation, with activities and their adapted spaces, planners and designers should consider the principles of traffic planning to minimize possible conflicts. It should not be forgotten that the design principles of street networks, that might either restrict or increase the level of performance of traffic planning, at the same time structure the urban space.

In this context, twentieth century urban space design processes have produced a variety of solutions to street networks (or circulation patterns) leading to diverse urban forms. In some of the solutions, street networks have been used solely for the subdivision of land without any regard to traffic planning principles. In central areas, traffic planners had to produce solutions to the problems originating from conflicts between existing street network and traffic volume through management procedures, while in the outskirts new solutions were sought to segregate vehicles from pedestrians in the form of Radburn systems and clusters. More recent solutions tend to incorporate, this time, the urban space into suburban developments.

The thesis is an attempt to evaluate such alternate urban design solutions from the point of view of traffic efficiency and to integrate traffic planning principles with urban design. It is believed that if, designers of urban space consider such principles from the beginning, then possible future problems might be overcome without compromising from urban form.

Key words: Movement Pattern, Circulation Principle, Circulation Network, Street Pattern, Movement Channel, Routing Patten, Traffic Network.

ÖZ

DOLAŞIM SİSTEMLERİNDE VE KENTSEL DOKU OLUŞUMLARINDA TRAFİK AĞI TASARIMININ ROLÜ

Zorlu, Fikret
Yüksek Lisans, Şehir ve Bölge Planlama Bölümü, Kentsel Tasarım
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Bu çalışmada, kentsel tasarım sürecinde trafik planlama perspektifli yol ağı tasarımı çalışmaları trafik ağı tasarımı olarak tanımlanmış ve trafik ağı tasarımının dolaşım sistemlerinde ve kentsel doku oluşumundaki rolü tartışılmıştır.

Bu çalışmada, ulaşım ve trafik planlaması süreçlerinde kent gelişim planları ve tasarımları ile üretilen yol ağı şemalarının ulaşım ve trafik planlarının altlığını oluşturduğu ve bu süreçlerde çözüm önerilerinin bu altlıklardan üretilebilecek alternatifler ile sınırlı olduğu saptanmıştır. Bu saptamadan hareketle kentsel planlama ve tasarım sürecinde üretilen yol ağlarının ne şekilde ulaşım ve trafik planlarının başarı düzeyini kısıtladığı açıklanmaya çalışılmıştır.

Bu çalışmada bu tür kısıtlamaların çözüm noktalarından biri olan kentsel tasarım sürecindeki müdahale biçimleri üzerinde durulmaktadır. Bununla birlikte, kentsel tasarım sürecinde, trafik plancılarının kıstlanmasına neden olan veya başarı düzeyini arttıran bu ağların aynı zamanda kentsel mekanların oluşumunun da bir parçası olduğu belirtilmektedir.

Bu kapsamda, 20. Yüzyılda kentsel mekan üretim süreçlerinde, mekansal tasarımların dolaşım sistemlerine ne tür çözümler üretmeyi amaçladıkları ve dolaşım sistemleri odaklı bu tür tasarımların ne tür kentsel dokular ürettiği tartışılmıştır.

Anahtar Sözcükler: Yolculuk Sistemi, Dolaşım Sistemi, Dolaşım Ağı, Sokak Dokusu, Dolaşım Kanalı, Yönlenme Sistemi, Trafik Ağı Tasarımı.

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CHAPTER 1

INTRODUCTION

1.1 Aim of The Study

The purpose of this study is to discuss the role of circulation systems in spatial design process to determine the influence of the circulation systems on urban pattern formations.

Since the street layouts are the determining factors in traffic planning and management. to some extent the possibility of proposing alternative solutions are determined by the characteristics of street layouts.

A method of street traffic network design in which the proposals would subordinate traffic planning and management solutions is searched. Therefore a method for a process which aims efficient use of road space shall be discussed. In this respect it the paths where traffic management and urban design goals and/or problems intersect or interrelate have become crucial.

> Directing and encouraging drivers and pedestrians to follow an efficient routing pattern is one of the main goals of traffic planning and management The paths followed by vehicles in urban areas are densely interwoven, and some of the accidents and congestion that occur in city centres can be attributed to the 'conflicts' that arise when these paths intersect. Hence, it is desirable to encourage circulation patterns in which the frequency and severity of conflicts are minimised. (Wright,1995:1).

At present, "neither network optimisation programs nor traffic simulation programs allow drivers to follow simple routes in short time periods", even though different combinations of flow patterns are experienced (Wright et all, 1989a). This problem arises from traffic network configurations. Although sophisticated traffic control programs are applied, these programs do not satisfy the users, because drivers are still facing accidents and congestion especially in city centres. This problem arises when network does not allow a variety of alternative solutions

In the last decades the common view among urban planners and transportation planners was the integration of transportation planning and urban land use planning principles. (See Figure 1.1) According to this approach, the solution of common circulation problems could be overcome. This argument is relevant if the problem is related to general circulation system of city. However, if the problem is related to a part of city, (it might be the centre or a peripheral area), regulations, devices and techniques of this approach may not be capable to overcome circulation problems. Such problems might be related to flow quality, safety and accessibility, as well as space quality.

Traffic networks proposed by urban planners and designers are base maps in transportation and traffic planning studies, therefore, transportation and traffic planners have to take into account the morphological characteristics of road networks.

In the motor age, even though the traffic network design concept was not clearly formulated, this concept sometimes was ignored (See Figure 1.2), was sometimes overemphasised (See Figure 1.3). At the end of process 1, traffic engineering solutions would be inevitable if efficient and uninterrupted run is aimed. Therefore external impacts on environmental quality might be observed. When this concept is overemphasised, the process of spatial design might include external predetermined urban patterns.

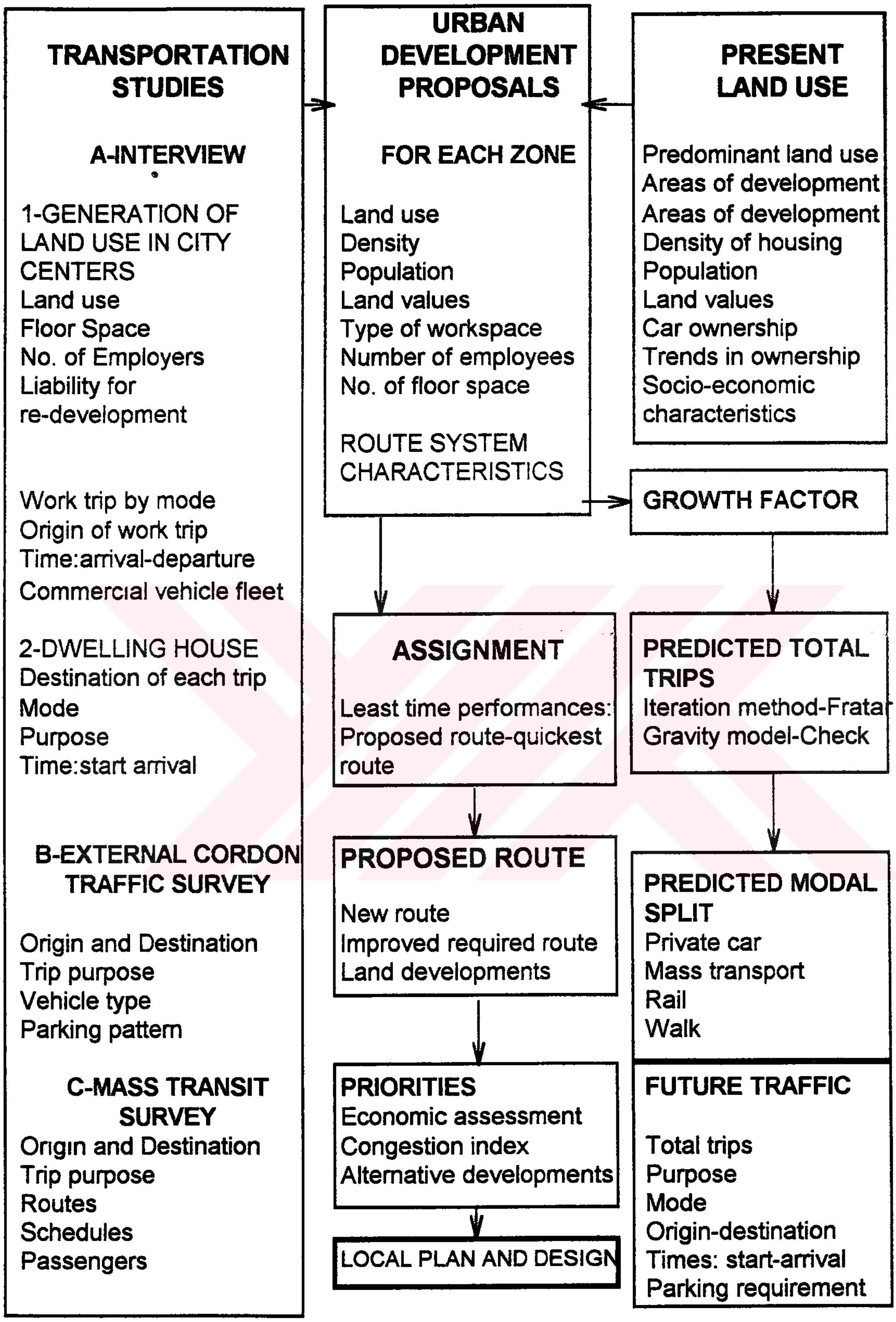


Figure 1.1:Integrated process of land use planning and transportation planning. Source: Ritter, 1963.

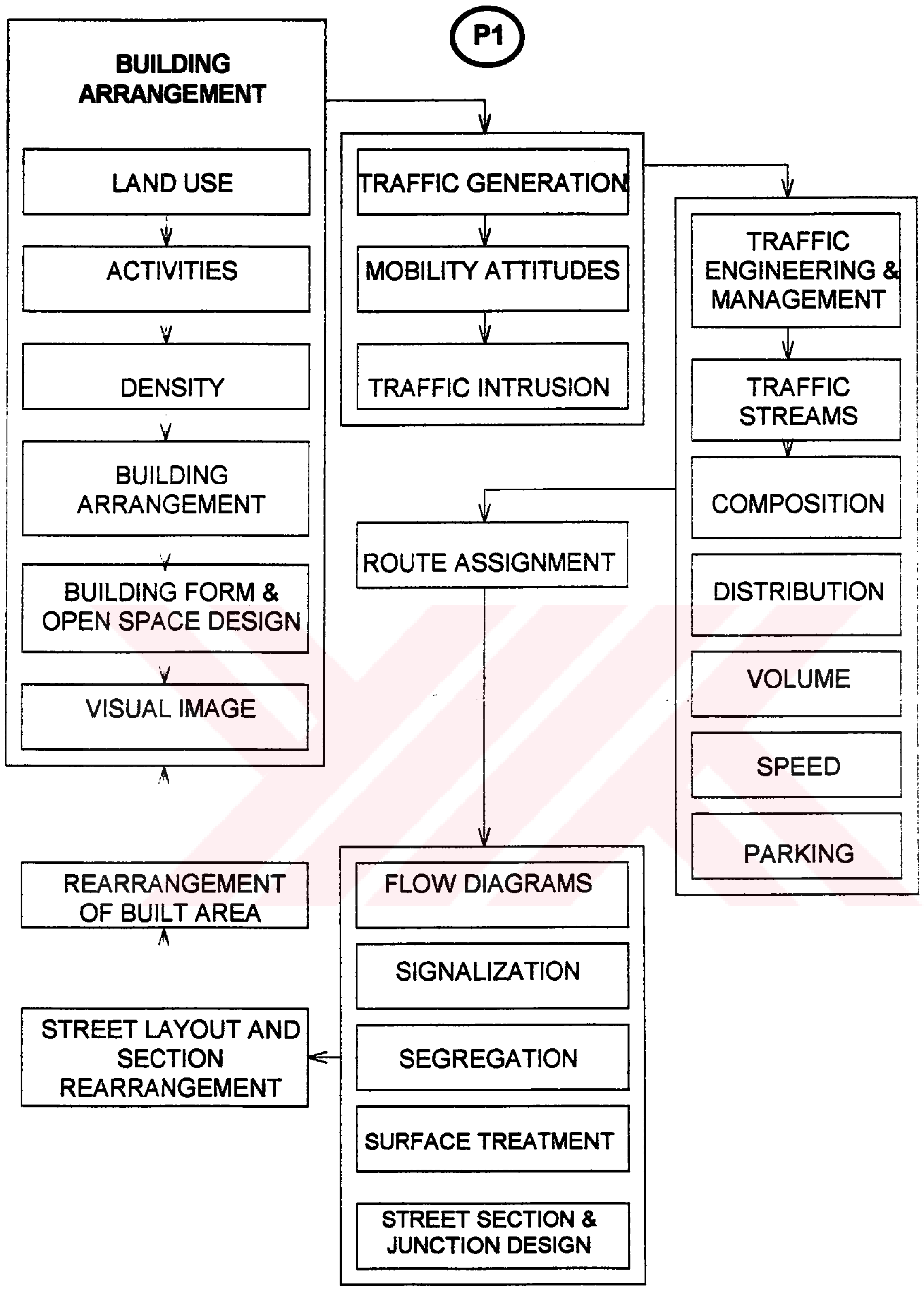


Figure 1.2 The process of building arrangement-traffic network design and traffic management. (p1:situation 1) Source:Antoniou,1971

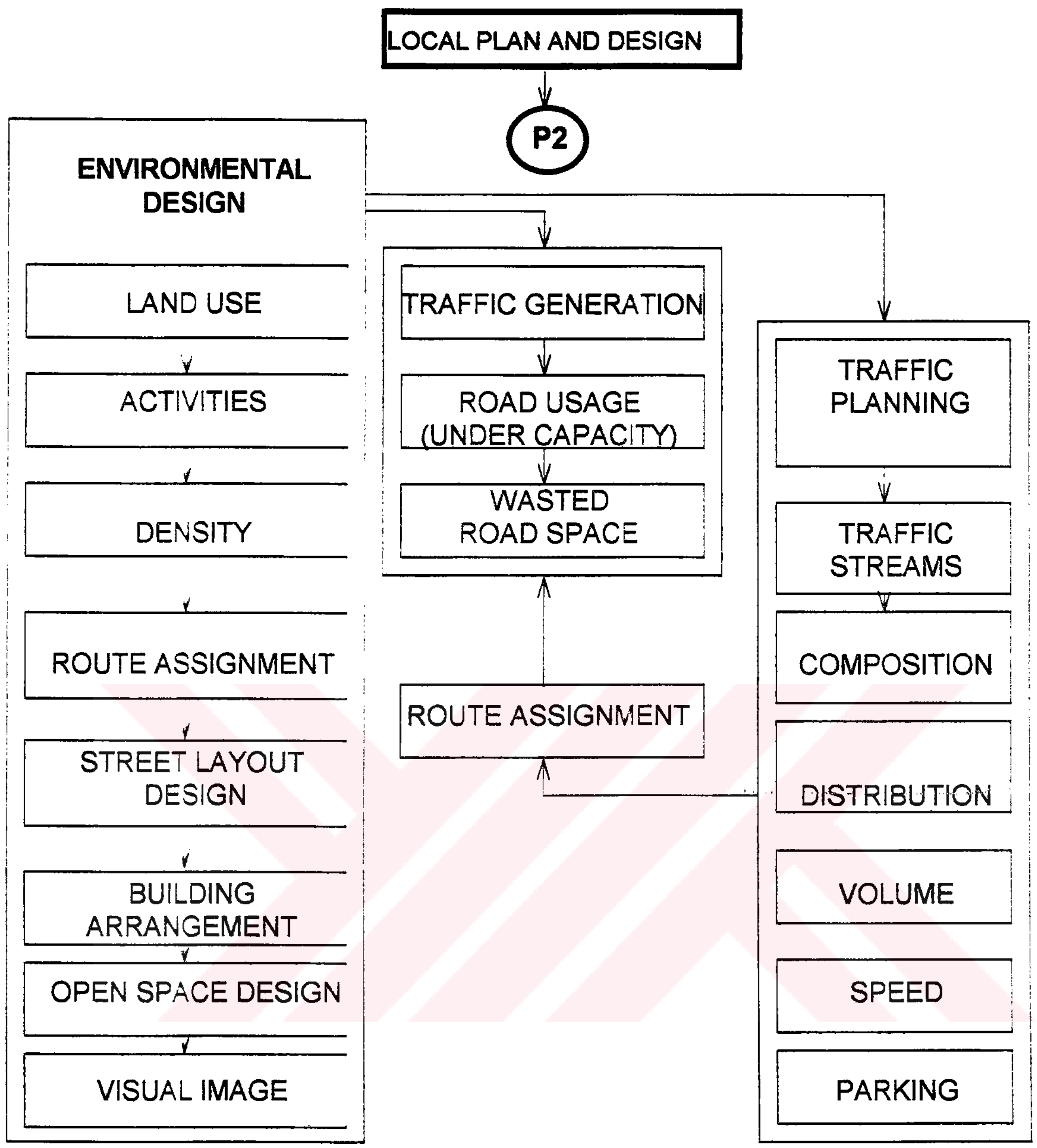


Figure 1.3 The process of building arrangement-traffic network design and traffic management. (p2: situation 2) Source:Antoniou,1971

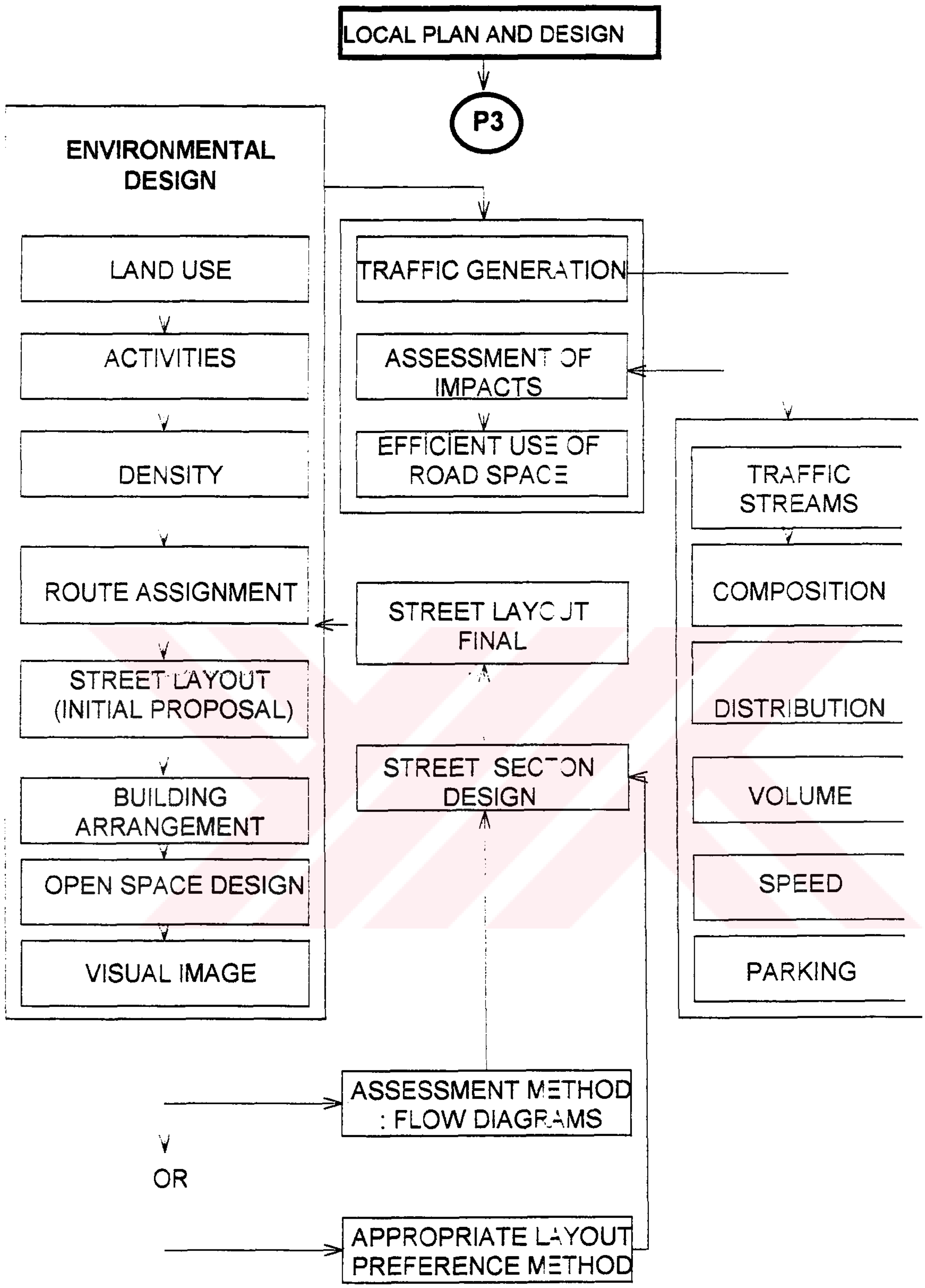


Figure 1.4 The process of building arrangement-traffic network design and traffic management. (p3: proposed situation)

There is no single accepted formula or philosophy for organising traffic into a spatial pattern. The purpose of the study is to consider some "idealised traffic networks" and circulation systems that have simple geometrical configurations. and to identify those systems that are relatively efficient in terms of efficient use of road space and "path crossings" adaptability to movement systems, flexibility and integrity with building arrangement (Wright, 1995). Therefore, the model shown in Figure 1.4 is proposed. In this model, the argument is traffic network design as a part of urban design and influencing movement patterns shall be a way of organisation of traffic into spatial design

The purpose of traffic planning and management is to minimise travel distance, potential accidents, potential delays, and travel times . According to Wright (1995) it can be said that among urban planners and designers, little is known about relative advantages or disadvantages of alternative traffic networks. There is no sophisticated formulation of accommodation of efficient and flexible circulation systems within existing or proposed urban networks.

Parallel to technological improvements, traffic planners are often expected to find out better ways to regulate traffic in existing networks in order to improve safety, to reduce congestion and consequently to improve space quality. Although urban activities and human behaviours are continuously changing, traffic networks and street patterns are almost certain.

As it is experienced among traffic planners, "prediction of drivers shortest path" choices and "assignment of routing pattern" are initial points of the process of problem solving (Ran and Boyce 1996). Route assignment requires definition and formulation of movement patterns under consideration of trip types and trip desire maps.

Formulation of designing circulation patterns involves sketching possible alternatives and evaluation of performances of alternatives with respect to possible movement patterns.

Traffic assignment methods and models are used to predict passenger choices in alternative particular schemes. Evaluation of alternative "routing patterns" needs comparative analysis of flow characteristics of such schemes. Network characteristics include conflict minimisation performances, efficiency with respect to volume/capacity distribution, flexibility, adaptability, integrity, simplicity, time efficiency, space quality improvement performances and cost of construction and installation.

In this study the first four performance criteria were used in the evaluation of street networks. Other criteria relatively depend on these four. In addition, total distance travelled by vehicles within the system is also considered, but for present purposes this is treated as a secondary criterion.

Although the circulation systems are initially very simple forms of network, it may be possible to apply them to more complex networks. This can be done by reducing a complex network into a simpler form.

The study concerns the application of performance evaluation model to get critical principles of street network design to clarify the role of traffic network design considerations in dealing with circulation related studies.

In addition, the study aims to discuss the severity of street network based circulation problems and to discuss the street design considerations of twentieth century land subdivision approaches. These approaches are classified with respect to the urban land subdivision implications :

- -early developments with rectangular grid pattern,
- -garden city and Radburn principle,
- -planned-unit developments and
- -new urbanism approaches (Gallion- Eisner, 1986)

In urban design perspective, such an evaluation might be defined as artificial; however, in the evaluation classification is made due to street layouts. This provides merits and outcomes of different street patterns to clarify the role of traffic design in urban space formation.

In the second chapter of the study, movement systems are analysed to discuss possible routing patterns. In addition, different approaches (or fields) dealing with circulation problems are discussed. Approach to the problem, tools and outcomes of these fields are evaluated briefly. This helps us to clarify the role of traffic network design in urban circulation problems, whereby a general framework of definition of a method for traffic network design is defined. Then, twentieth century street patterns are evaluated. Political and social background of land subdivision and principle street layouts in land subdivision are criticised. In addition, designers approach to circulation problems in the process are criticised. The process of street layout design (a part of traffic network design) as spatial aspect of circulation systems is also reformulated. The formulation addresses process of traffic network design approach to circulation problems.

In the third chapter of the study, the issues of network evaluation method are defined. In this part, circulation networks are evaluated and possible street layouts are classified. Traffic systems are combinations of "urban patterns" (Lynch, 1981; McCluskey, 1881) and "possible routing patterns" (Wright, 1988). In this part, advantages and disadvantages of alternative circulation networks are searched within the evaluation model.

In the fourth chapter of the study, the circulation networks are compared with respect to criteria described in the evaluation model.

In the fifth part of the study, the process of building arrangement and street layout design is criticised. The advantages and disadvantages of urban patterns are discussed. Circulation problems faced at present are demonstrated to the attention of designers.

At the end of the study, the role of designers in traffic network design process is discussed.

1.2 Method of The Study

In this study, the circulation problems are related to the urban morphology. Over the last fifty years, the traffic network that is most suitable for traffic routes of towns was discussed (Buchanan,1953;1963; Smith,1959 Mitchell-Rapkin,1964; McCluskey,1881).

It is crucial to discuss the traffic planning, traffic management and traffic engineering principles, and their approaches to circulation problems. Although these fields are not definitely separated professions, the classification is based on devices and implications. The concerns of the fields related to traffic to minimise the congestion are:

route assignment concerns
circulation control concerns and
dynamic control concerns, (Wright,1989a)

In this study, the approach to circulation problems is based on network topology concerns. Though sophisticated programs and strategies are used to overcome congestion, the level of success is limited by the geometry of networks. That is, it may not be possible to overcome problems without network manipulations (or rearrangements). The network topology approach considers the range of alternative solutions for given networks or appropriate circulation networks based on movement systems for a new designed site.

For such studies relative advantages and disadvantages of circulation networks and circulation systems should be examined. In addition, such a morphological evaluation requires comparative urban design trends to be evaluated under consideration of street patterns.

It is argued that such an evaluation requires both analytical and descriptive studies. On the other hand, network classification requires to be based on origin-destination link possibilities. That is, a large number of alternatives can be explored for the same amount of origin-destination units. Since the purpose is to understand the implications of practical networks, it is necessary to employ network representation models.

In such a study, two main evaluation methods may be used; case study and principal evaluation method. In a case study, results of practical evaluation might be interrelated to theoretical discussions. On the other hand, in a principal evaluation method the evaluation would be based on a theoretical basis. Here the results might be addressed to practical studies. Hypothetical assignment or graph theoretical evaluation methods are two possible methods for theoretical evaluation.

ALTERNATIVE METHODS FOR EVALUATION OF CIRCULATION NETWORKS

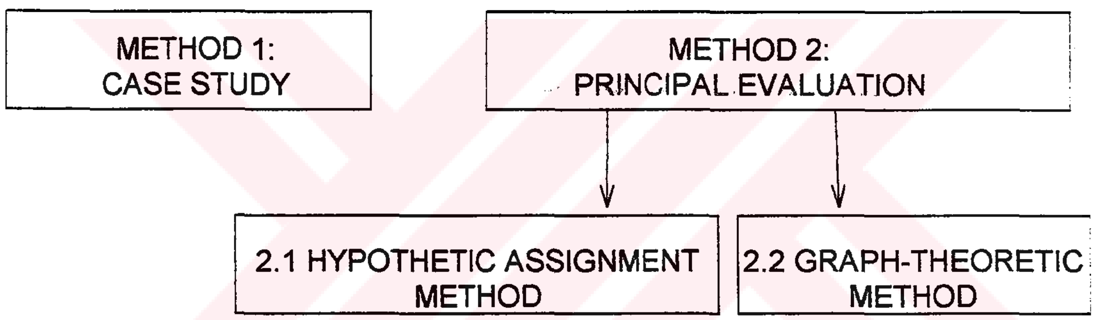


Figure 1.5. Alternative methods for network evaluation.

In a case study, required data are based on traffic analysis of studied site. In addition to observation, traffic counts, O-D analysis, speed and travel time analysis, delay analysis, before-after analysis, parking analysis and accident analysis are necessary. In such studies; travel time, travel costs, accident rates and efficiency of road surfaces are used as evaluation parameters and criteria. Observation of real problems and assessment of possible solutions are main advantages of case studies. On the other hand, when the study is based on morphological analysis, it is hard to find out the role of network configurations in circulation problems. Such problems might result from land use and density patterns of sites or the attributes of the links or traffic engineering and management implications. Therefore, it might not be possible to formulate a general policy on traffic network design. In addition, it might not be possible to analyse a variety of urban patterns in an example, therefore it would not be possible to discuss the role of movement systems in urban pattern formations.

METHOD1 : CASE STUDY

SELECTION OF CIRCULATION NETWORKS THAT HAVE DIFFERENT CONFIGURATIONS

TRAFFIC ANALYSIS AND PROBLEM DEFINITION

↓

OBSERVATION

TRAFFIC COUNTS
Vehicle Counts:
Junction&Section
Pedestrians

O-D ANALYSIS
SPEED AND TRAVEL TIME ANALYSIS
DELAY ANALYSIS
BEFORE-AFTER ANALYSIS
PARKING ANALYSIS
ACCIDENT ANALYSIS

↓

THE CIRCULATION PROBLEMS MAY ORIGINATE FROM:

- -LAND USE AND DENSITY PATTERN OF THE SITES
- -THE ATTRIBUTES OF THE METWORKS (STREET WIDTH, JUNCTION CAPACITIES)
- -THE TRAFFIC MANAGEMENT AND ENGINEERING IMPLICATIONS ON THE NETWORKS
- -THE CONFIGURATION OF THE NETWORKS

→ **IT MIGHT NOT BE POSSIBLE TO CLARIFY THE ROLE OF THE NETWORK CONFIGURATIONS**

Figure 1.6. Case study method for network evaluation.

An alternative evaluation method is hypothetical assignment. In such a study, data attributed to possible networks are defined. The required data are the street width, length, junction capacities, theoretical speeds and flow directions. In addition, trip desire maps are defined considering the possible movement systems.

Then the distributions of trips on networks are assessed. The evaluation of networks is based on the speed and travel time, travel costs, delay, and potential accident assessment.

In such studies, the results could address practical guidelines and a comparative analysis of many possible networks is possible even though it requires very long time. In this study, a simple hypothetical assignment method is used as a part of evaluation method, since it is very hard to evaluate 33 circulation networks.

METHOD 2.1. HYPOTHETICAL ASSIGNMENT

A HYPOTHETIC TRIP GENERATION MATRIX

DEFINITION OF ALTERNATIVE CIRCULATION NETWORKS

TRIP DISTRIBUTION MODEL

CONFLICT ASSESSMENT
SPEED AND TRAVEL TIME ASSESSMENT
DELAY ASSESSMENT
POTENTIAL RISK ASSESSMENT

THE TRIP GENERATION MATRIX MAY NOT REPRESENT ALL POSSIBLE MOVEMENT SYSTEMS, THEREFORE

TO MAKE AN OBJECTIVE EVALUATION IS NECESSARY TO CONSTRUCT

IT MIGHT NOT BE POSSIBLE TO CLARIFY THE ROLE OF NETWORK CONFIGURATIONS

Figure 1.7. Hypothetical assignment method for network evaluation.

"In graph-theoretical evaluation model some idealised networks and circulation systems that have simple geometrical configurations are considered" (Wright, 1989a). In this respect routing patterns that are relatively efficient in terms of path crossings and total distance travelled could be identified in a theoretical framework derived from graph theory.

Although circulation systems are reduced to simple forms of network, it may be possible to apply them to more complex cases. The results may provide a general strategy for efficient circulation in urban areas by providing possible traffic management policies to be adapted. In a graph theoretical analysis, the distribution and density of four different conflict types on the networks are analysed through mathematical methods, so that evaluations may be based on a clear and more definite basis. These four conflict types are, intersecting, merging, diverging and weaving.

METHOD 2.2 GRAPH-THEORETIC EVALUATION

DEFINITION OF MOVEMENT SYSTEMS

↓

DEFINITION OF POSSIBLE ROUTING PATTERNS

↓

DEFINITION OF POSSIBLE CIRCULATION SCHEMES

↓

EVALUATION OF PRINCIPAL PERFORMANCES OF ROUTING PATTERNS

↓

CONFLICT GENERATION
TREVEL DISTANCE

↓

EVALUATION OF CIRCULATION SCHEMES

↓

IT IS POSSIBLE TO DISCUSS THE PRINCIPLE DIFFENERNCES OF
BASIC NETWORK CONFIGURATIONS

Figure 1.8. Graph-theoretic method for network evaluation. Source: Wright (1988).

In this study three complementary evaluation methods are used to formulate a traffic network evaluation model: hypothetical assignment method, graph-theoretic method, and practical evaluation method.

In this part, advantages and disadvantages of alternative street layouts are searched with respect to issues taken into account in the evaluation method.

In an evaluation method based on hypothetical assignment three possible movement systems are defined and their presentation as trip desire matrices are formulated. In addition, terminal nodes, junction nodes and link attributes are depicted. These three trip desire matrices are applied to three circulation network groups; the grid, the hexagonal and the radio-centric. In such an evaluation, travel times are taken into account, hence the details of road network are specified to assess travel times. Each group of network has similar link attributes, but different junction properties. For instance, a group of convex polygon network consists of a grid, a radio-centric and a hexagon version of a routing pattern.

Then distribution of trips on networks are assessed. Efficiency performances with respect to road use and efficiency performances with respect to flow speeds are taken into account. That is whether trips are distributed on networks homogenous or heterogeneously are searched. Then the circulation networks are classified with respect to their junction configurations; interconnected networks, semi-connected networks, linear networks and tree networks

In "graph-theoretical evaluation model" (Wright, 1989) circulation system is displayed as a directed graph constitutes links (each link represent a particular direction of movement along a road) and nodes. The nodes fall into two categories; junction nodes and terminal nodes. Junction nodes represent places where the paths intersect, weave, merge or diverge at junctions (See Figure: 1.9).

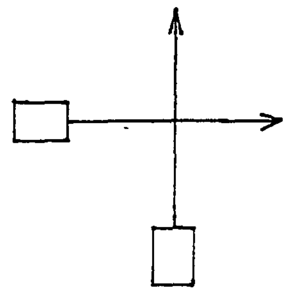
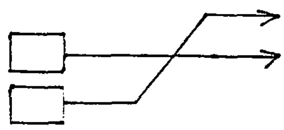
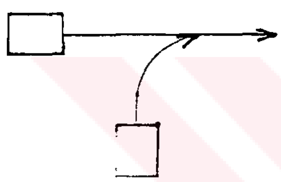
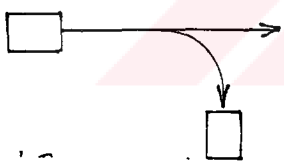
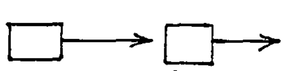
	**a-Intersecting conflicts**: When the paths of two vehicles cross intersecting conflict occur. In general approach angle of two vehicles is between 30^0 to 150^0 In traffic engineering studies, intersecting conflicts are generally regarded as the most severe type of conflicts.. The risk, is recognised by the angle that vehicles follow. The angle of intersection determines sight area related to distance of deceleration, and momentum of collision.
	**b-Weaving Conflicts:** These conflicts are expected to occur between two vehicles if their paths merge and diverge subsequently: the first vehicle approaching from the offside of the second vehicle and departing on the second vehicles nearside In addition, the weight of delay and accident severity is relatively small, because the approach angle of two approaching vehicles is between 0^0 and 30^0 or between 330^0 to 360^0.
	**c-Merging conflicts:** Such conflicts occur only at junction exits. Their weight and intensity varies with the circumstances; if an exit consists of two or more lanes and the merging vehicles choose exit lanes, that is their paths do not actually overlap, potential delay and accident will be less than the otherwise case. The approaching angle of two vehicles varies between 330^0 to 360^0.
	**d-Diverging conflicts:** Similar considerations of merging conflicts can be applied to diverging conflicts. The approaching angle of two vehicles varies between 0^0 to 30^0.
	**e-Shunt conflicts:** These conflicts occur when a vehicle is following another on the same path. That is, the approaching angle of two vehicles is almost 0^0. Along any section of a road, moving vehicle may delay the vehicle behind, or has potential of a collision with it.

Figure 1.9. Conflict types. Source: Wright,1988

Terminal nodes represent places where the traffic enters or leaves the study area, or represent parking areas where trips start or finish. Total potential conflicts (merging, diverging, intersection, weaving, and shunt; (See Figure 1.9), and total potential distances of such patterns are compared under similar conditions and similar study area according to the data attributed to their networks.

Then considering the circulation (routing) patterns, an analytical evaluation should be made. Circulation pattern alternatives of base patterns are examined under consideration of the principles of network simplification. These patterns (the grid, the hexagonal and the radio-centric) are conceptually arranged to get fifteen routing patterns. Since all circulation networks can not be adopted to these three patterns, possible practical examples are discussed in the study.

Adaptability of such street patterns to different urban areas are evaluated under consideration of trip types (interbase trips, regular round trips, incidental round trips; See Figure 1.10). Adaptability of street patterns in residential areas and in central areas are discussed in the study.

An evaluation of the differences among networks might guide designers to decide appropriate network type for given environment. In addition, the adaptability of such practical examples to the different parts of the city is searched. At the end of evaluation stage, traffic networks are categorised with respect to specified performance criteria defined in each evaluation method. At first the networks are classified with respect to interconnection types and their adaptability to different movement patterns. Then the networks are classified with respect to conflict frequencies. In addition, the networks are classified with respect to flexibility and adaptability performances. At the end of this stage practical criteria and guidelines for traffic network design are discussed. Then, the roles of professionals dealing with traffic network design (in direct or indirect ways) are discussed.

CHAPTER 2

GENERAL OUTLOOK TO MOVEMENT SYSTEMS, CIRCULATION RELATED STUDIES AND URBAN DESIGN IMPLICATIONS

2.1 The Role Of Movement Systems In The Formulation Of A Morphological Analysis

2.1.1 General Outlook To Definitions Of Movement Systems

Movement has been the basic requirement of interaction of establishments and individuals. Traffic is the movement of persons (pedestrians) or vehicles transporting persons or objects. Analysing the factor that produce traffic is much more complex than analysing the movement of persons or goods, since analysing the amount and type of traffic requires analysis of individual mode choices and vehicles' route choices.

To analyse the determinants of traffic, it is necessary to distinguish people's and goods' movement systems. The amount and nature of movement are determined by the nature and volume of urban activities. According to Mitchell (1974:17), the activities can be observed as resulting from:

1-the existence of certain needs which change from time to time
2-the organisational structure of individuals and groups interacting
3-the institutionalised processes and the routines of action.

The structure of traffic by its distribution in time and space is "dependent upon how many people choose to use a particular mode or route of travel at a particular time" (Mitchell,1974:17).

The description of a structure of movement can be made in terms of composition, volume, distance, time, rhythms, location (routes, channels), density, kinds of trip and kinds of establishments.

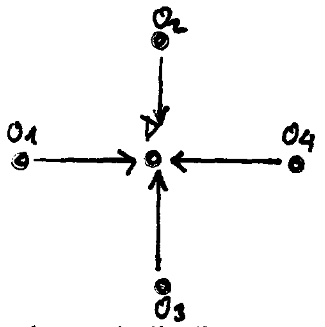
In this study, the structure of movement is analysed in terms of distance, routes choices and kinds of trip to evaluate their effects upon designing the morphology of streets. In general, movements can be distinguished into two categories; individual movements and mass movement. Designing a method of traffic network design practically requires dealing with mass movement. Mitchell classified mass movement into three categories according to kinds of trip:

1-assembling movement: in which the movement is defined in terms of area where the movement (O-D) is assembled,
2-disperse movement: in which persons are dispersed from particular points to dispersed destinations,
3-random movement: in which both origins and destinations are dispersed. (Mitchell,1974).

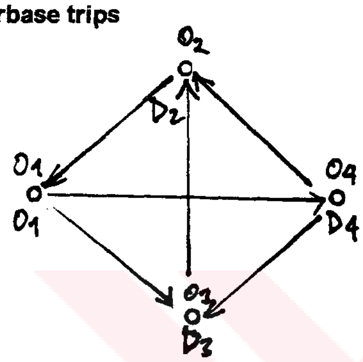
2.1.2 Movement Systems Based On The Kinds Of Trip

Movement systems are described as "abstract generalisations of large groups of individual movements which occur within a particular period of time although they are not necessarily concurrent" (Mitchell,1974; 60).

In order to define and classify movement systems, it is necessary to define characteristics of individual movements which enable us to understand the movement patterns. "Movement systems can be based on process of action, kind of trip or purpose of trip" (Mitchell,1974). Since the study is related to the circulation patterns rather than land use relations, it deals with the movement systems based upon kinds of trip. Movement systems based on kinds of trip can be distinguished into three groups; interbase movements, round trip movements and through movements. (See Figure 2.1)



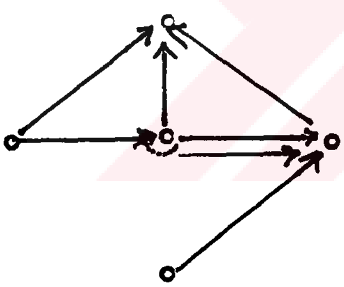
a-Single destination oriented interbase trips



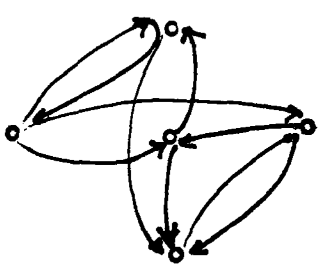
b-Uniform distribution of interbase trips

Interbase Trips

Inter-base trips constitute the largest group of peak hour trip types. Travel between home to work and home to school are the largest parts of interbase movements. Distribution of residential areas, distribution of workplaces, socio-economic pattern of inhabitants means of transportation and distribution of work hours are factors of interbase trip distribution pattern.



c- regular round trips



d-incidental round trips

Round Trips

Trips with single-destination which are not as certain as inter-base trips, are called "**regular round trips**". Such trips constitutes intermediate destinations. An intermediate destination may be a terminal point or a certain destination. Regular round trips might be pertinent to both vehicular or pedestrian modes.

Trips with multiple destinations which may not be certain within an area of assembly are called "**incidental round trips**". In city centre, shopping are typical incidental round trips. Most of the "incidental round trips" fall into category of pedestrian movements.

Figure 2.1 Movement systems based on kinds of trip. Source: Mitchel, 1974

2.1.2.1 Interbase Trips

"Inter-base trips constitute the largest group of trip types" (Mitchell,1974; 63). "Travel between home to work and home to school are the largest parts of interbase movements trips" (Mitchell,1974; 63). According to Mitchell the study of interbase trips is relatively less complicated than round trips (Mitchell,1974; 63).The separation of home and workplace is the main concern of studies based on interbase trips. Distribution of residential areas, distribution of workplaces, socio-economic pattern of inhabitants, means of transportation and distribution of work hours are the main factors that affect the of interbase trip distribution pattern (Mitchell,1974). The estimation of the distribution of interbase trips is necessary to formulate circulation systems.

In most transportation planning studies, trips are assumed to be interbase trips with or without intermediate destinations. Then, management and engineering studies concerning road design, junction design or mass transportation line assignment studies take into account such inputs.

In such studies inter-zonal trips are assumed to be mostly pedestrian movements. However, the distribution of vehicles and pedestrians within a zone should be taken into account; any vehicle, departing from zone A and entering zone B, needs to circulate in zone B. Physical arrangements are inter-zone distribution oriented, though, traffic management solutions are short-term and mostly intra-zonal.

Any movement departing in zone B, having more than one destination may be defined as round trip. Such kind of movements are not easy to estimate, requiring flexible circulation methods within any zone.

Systems of inter-base movement may be estimated for the present and projected for the future for whole urban areas. Various dimensions of the structures of such movements may be estimated and projected by studying trends in land use change.

2.1.2.2 Round Trips

The second group is round trips which constitutes the "second large group of persons movement" (Mitchell,1974; 64). Since the destinations are not single, analysis of round trips is more complex than other types. Round trips are classified into two groups; regular round trips, incidental round trips.

Trips with single-destination that are not as certain as inter-base trips are called "regular round trips" (Mitchell,1974;64). Such trips constitute intermediate destinations. An intermediate destination may be a terminal point or a certain destination. Regular round trips might be pertinent to both vehicular or pedestrian modes.

Trips with multiple destinations which may not be certain within an area of assembly are called "incidental round trips" (Mitchell,1974;64). In city centre, shopping is a typical example for incidental round trips. Most of the "incidental round trips" fall into category of pedestrian movements.

In general, round trips occur as midday activities; business, shopping and leisure. For such trips the routes are not commonly used by drivers therefore they may not be as certain as in interbase trips.

In urban transportation planning studies, analysis of systems of round-trip movements may be taken into consideration through persons daily or weekly activities. In such studies, definition and distinction of characteristics of establishments and characteristics of persons employed in is necessary. This distinction is also significant when analysing the linkages and relationships among kinds of establishment, such as those in a business area. Sometimes establishments are located close to other kinds of establishments giving service to their personnel. Sometimes establishments of the same kind are located close to each other giving service to form up a market.

These linkage factors and relationships help experts to analyse the trends in land use development in specialised urban districts. Mitchell (Mitchell,1974;

68) concluded that in such studies, the emphasis should be on the relative independence of establishments as destinations that attract trips.

2.1.2.3 Through Movements

The third major group of trips with respect to trip type is through traffic, which has minor significance in great cities, but in small towns an important part of inner city traffic may result from this kind of movement (Mitchell,1974; 68). There is a necessity to give significant roles to some kinds of through trips which originate from or end in any zone of the city. In a local level (within a zone) traffic management study, inter-zonal traffic may be assumed as through traffic.

In general, pedestrian movements are not considered in through movements.

2.2 A General Outlook To Studies Dealing With Circulation Concepts

2.2.1 Traffic Planning

The problem definition of traffic planning refers to route assignment, circulation control and dynamic network control. Although the terms "traffic management", "traffic engineering" and "traffic architecture" are used to define differences among technical considerations on circulation, there are no significant professional differences among them (Mitchell 1974:6). All of them deal with network configuration and flow characteristics on route choice.

Traffic planners estimate "equilibrium patterns" by using traffic simulation models (Wright, 1988). In the last decades, traffic planning studies are rather travel demand oriented. In addition, network optimisation by using dynamic assignment models is the contemporary concept among traffic planners (Ran and Boyce, 1996).

According to Erpi (1980) traffic planning is a complex field requiring teamwork of many disciplines; town planning, urban design, traffic engineering, and architectural principles and terminology are involved. In traffic planning studies, if the results are unsatisfactory, proposals of land use plans, urban design projects, or engineering projects should be revised. According to Wright (1988) traffic design (deals with circulation at network topology level) and traffic management (deals with circulation at flow control level) approaches have been comparatively neglected. Therefore, an inappropriate network structure or circulation system may generate unnecessary conflicts by forcing traffic streams. Although sophisticated signal co-ordination systems are used the network will limit the capacity and the performance of the system as a whole.

Although traffic management is not a distinct profession by itself, traffic planning studies dealing with problems of control and regulation of traffic are called "traffic management" (Mitchell 1974:6). In addition, traffic management studies focus on the provision and improvement of physical channels of movement. Such studies concern the availability of routes on the network. For any given physical network and given pattern of land use, the range of alternative routes can be proposed, such as imposing one-way restrictions, turning restrictions and other rules. These rules define the "set of permissible traffic routes throughout the network" refers to the circulation system (Buchanan Report, 1964; 56). Buchanan Report covers an initial definition of the subject:

> Traffic management started when 'Keep to the Left' was first thought of in Britain, but only in the last few years it has been consciously developed with the objective of 'getting the most out of the existing street system'. One-way streets and the elimination of right-hand turns have been the main features that have caught public attention, but there are also 'clear ways', elaborate linked signal installations, the banning or strict control of parking and waiting in many streets, and the closer control of pedestrians. While these measures have been of benefit to the movement of vehicles, they often inhibit its unique ability to penetrate to individual buildings and to stop there. (Buchanan Report, 1964:57)

Traffic planners dealing with circulation control problems need to have the knowledge of existing traffic on various movement channels: the amount of vehicles on the channels, peak loads, direction, timing and flow pattern. It is also necessary to analyse the capacities of channels under varying conditions, requirements for terminal facilities, and probable effects of alternative implications.

In recent years Advanced Traffic Management Systems (ATMS) and Intelligent Transportation Systems are developed in circulation related studies. These systems depend on advanced transportation network models and control models. Therefore, integration or co-ordination of traffic management and traffic engineering systems are necessary.

Co-ordination of traffic planners and engineers include;

-travel forecasting models,
-optimal routing methods,
-dynamic route choice models,
-traffic simulation models,
-network-wide optimisation models and
-driver/traveller behaviour model (Ran and Boyce 1996).

Traffic planning studies dealing with the problems of dynamic control are called "traffic engineering" (Ran and Boyce 1996). The traffic engineer usually assumes a fixed routing pattern and installs co-ordinated traffic signals and other junction control tools.

Professions dealing with dynamic control problems are primarily concerned with the task of seeking solutions to the problems of vehicular mobility and accessibility. They acquire the knowledge of mathematical aspects of traffic flow and capacity. Later on, by experience they need to be sensitive to the immediate cost of construction or installing. Thus, according to this approach, design of movement channels are dominantly based on engineering and economics.

Urban highway projects are typical implications included in this approach. A major highway and local transportation network for an entire city is designed with respect to the general transportation plan. At this stage, the design is made in general terms, the specific locations and traffic capacity of the various channels. Specific route analysis and general plans for individual sections, or channels are developed. A detailed design of highways and other channels of traffic and improvements in the existing road network is undertaken.

Various methods have been devised to control the operation of vehicles, because traffic networks of cities may not be sufficient to cope with traffic. It might be more accurate to describe these measures of control. The calculation and administration of these measures are called "traffic engineering".

Compared to urban planners, traffic planners have limited effects in the formation of movement channels; because their solutions and approach to traffic are indirect. That is, traffic planners' proposals are in general related to existing networks. Signs at intersections, slow-down warnings, speed limits, parking limits and prohibitions, safety islands at boarding points for buses, mechanical devices, etc. are typical "solutions" and "devices".

The aim is to maximise the number of vehicles that can be accommodated by the traffic network. For instance, the average cycle for change of the traffic signal is one minute; vehicles travelling in one direction are stopped for approximately 30 seconds and moved for 30 seconds. Therefore, a street can accommodate only one half of its capacity. A general signalisation strategy is used to maximise this number.

The conversion of streets from two-way to one-way travel is a familiar system. It is a method for channelling traffic that avoids the conflict of left-hand turns across lanes moving from the opposite direction. But the traffic signal is still necessary to permit the passage of pedestrians.

2.2.2 Dealing With Circulation At Land Use Planning and Design Level

It is commonly known that different kinds of land use generate different kinds and amounts of traffic and it is observed that a change in land use, which means a change in amount of traffic generated, change the amount and kind of movement in a particular part of city or even in whole city. It might be observed that a change in the amount of movement or an expected change in the traffic at a particular site has a considerable effect on the location pattern of the land uses. That is why there is a necessity of knowledge about the mutual relationship between land use and movement patterns.

As cities grow or transform, the provision of services which are designed to accommodate traffic may require reconstruction of the traffic network, and such alterations may be dramatic; redevelopment of large sites or construction of highways may be necessary. In such cases, when land use pattern is reorganised (trip generating activities are relocated) physical rearrangements may not be necessary. Briefly, dealing with traffic at land use level refers to non-traffic solutions to circulation problems.

Dealing with circulation at land use planning level is a long run approach to circulation problems and consists of planning, guidance, and control of change in the pattern of land uses. This change may be guided toward reducing the amount and/or distance of movement necessary between activities having high rates of interchange, removing the areas of congestion generating establishments. Separating and/or relocating activities generating conflict is the main concern of this approach.

In addition to other approaches, architectural design implications may aim to solve circulation problems. After 1950's architectural approach has implications in central parts of cities (Buchanan Report,1963). In Buchanan Report (1963) this approach is called "traffic architecture".

Traffic architecture studies deal with the problems that refer to circulation and accessibility oriented building design. On the other hand, it is not a common concept or a large field of design. It involves counter arguments against the idea that "urban areas must consist of buildings sets and streets differentiated; design of each other is segregated (Buchanan Report,1963: 68).

According to the architects dealing with circulation, if buildings and access ways are thought together, they can be combined in a variety of ways, and this process shall be more advantageous than other conventional methods (Buchanan Report,1963: 68). Buchanan Report covers a clear definition of the subject (1963: 68):

> The central area of a town might be redeveloped with traffic at ground level underneath a "building deck". This deck would, in effect, comprise a new ground level, and upon it the buildings would rise in a pattern related to but not dictated by the traffic below. On the deck it would be possible to re-create, in an even better form, the things that have delighted man for generations in towns-the snug, close, varied atmosphere, the narrow alleys, the contrasting open square, the effects of light and shade, the fountains and the sculpture. The deck would be so literally new ground that buildings could be erected upon it and in due course taken down and replaced, and sites could be sold or leased in the normal way.

Here, in such studies redevelopment of existing area is the main concern of such studies. If it could be possible within city centres, at the same time, carriage ways could be redesigned to serve increasing demand.

2.2.3 A Framework For Definition of The Role of Traffic Network Design In Circulation Systems

Traffic network design studies deal with circulation problem by provision and improvement of physical channels of movement. The problem definition of traffic network design studies refers to the "network topology problem" Wright (1988). Experts (urban planners or engineers) are concerned with the physical layout of the traffic network in which the nodes, links are connected in a topological point of view. In existing urban areas, networks are almost fixed, but for development areas there is always potential of organisation of alternative traffic networks. Any alteration in core or peripheral parts of city centres require the application of network topology oriented studies.

In existing parts of cities, the street pattern is necessary to be taken into consideration. That is, traffic network design proposals are expected to be based on evaluation of advantages and disadvantages of existing street pattern. Because, each pattern has its own potential obstructions, limitations or advantages with respect to alternative circulation systems. This idea as a part of traffic network design refers to morphological approach to circulation systems.

In Buchanan Report (1964:60), initial definitions of traffic network design refers to the integration of building arrangement street layout arrangement.

> The areas need to be tied together by the interlacing network of distributor roads on to which all longer movements would be canalised without choice, in principle, like a gigantic building with corridors serving a multitude of rooms. The relationship between the network and the environmental areas would therefore be essentially one of service: the function of the network would be serving the environmental areas and not vice versa.

This study is rather related to "network topology problem" to approach circulation control problems. The main concern of traffic network design is the street pattern which defines the physical area of movement channels available for movement.

The study deals with the street network system based problems to approach circulation control. "The street system constitutes the framework of a city; to a considerable degree the size, shape, and orientation of blocks, and lots are determined by the street pattern" (Mitchell,1974;128). The discussion of whether they are determined under consideration of accessibility, service installation or movement clarifies the role of circulation in the formation of urban space.

Streets as the channels of movement have not always been formed under consideration of movement of people and vehicles; they are sometimes designed just as means of access to parcels. In many cities, urban redevelopment planners design street networks to provide accessibility to parcels, that can be defined as the main reason behind the circulation problems. In addition, streets are possible paths of infrastructure. Briefly, streets do not serve just for movement, but also for other requirements.

Compared to all other factors, the main alterations in streets are based on movement dynamics; any drastic change in the demand of movement may result in dramatic changes in streets, such as extension, widening, speed increase, etc.

The change in demand of movement may result from city growth, land use changes or land use intensification without addition of new movement channels. The more intensive use of urban land means more interaction between city parts, that generates an increase in volume of movement. Such changes cause pressure to increase street capacity by widening, by traffic management or even by construction of new streets.

Changes in the kind of movement on a part of city or on a channel occur as a result of shifts in land use pattern. Trip generation characteristic of a city part changes as a result of new developments or transformations. In addition, significant influences on movement channels are brought in technological improvements and life standards of inhabitants. In the twentieth century, automobile has been the greatest factor in alteration of the morphology of street systems (Buchanan Report, 1963; Ritter, 1963; Antoniou,1971). Such an alteration occurs as a result of functional requirements of the street systems.

Changes in the intensity of use of private automobile has brought alterations in streets to serve access to automobile which means street widening and junction turning to some extent (Buchanan Report, 1963; Ritter, 1963; Antoniou,1971). In addition, orientation and morphology of streets have changed to provide time efficient and secure movement. In such cases, structural changes have been inevitable.

Design of any movement and accessibility oriented infrastructures (streets as movement channels) requires taking into account movement patterns. On the other hand, location dynamics of activities are determined by the access and movement facilities of street systems. Thus, design of a new street system or any alteration in street use should be a process of iteration.

A street system constitutes a network. Each network has its own characteristics such as capacity of carrying vehicles, potential of delay, potential of conflict and potential of adaptability to serve different movement systems. An examination of the differences provides designers to decide the appropriate network for a given environment.

Many studies were made by designers on morphological characteristics of streets; some of them are analytical while some of them are more descriptive.

Mc Cluskey (1981:9) examined the "diversity of choice" which is made by the definition of characteristics of different network types. Mc Cluskey (1981:9) proposed eight solutions to access problem in townscape. When all places are linked together on a line is called the serial pattern. If each place is connected to a given origin directly by means of its own unique route, a radial pattern is obtained. A modification to simple radial pattern which may improve its performance a web pattern. Another way of modification to the radial pattern is the branching pattern. And if all branches are joined up, resulting network is a form of grid pattern.

Mc Cluskey's study indicates theoretically possible network combinations. His classification in general coincide with Lynch' classification.

In this study twentieth century street patterns as movement channels are evaluated. These patterns refer to traffic networks. Traffic networks are combinations of "urban patterns" (Lynch,1981; Gallion-Eisner, 1985) and possible "routing patterns" Wright,1988). That is, three main urban patterns, grid, hexagon and radio-centric and fifteen routing patterns constitute 33 possible circulation networks.

Although all of these 33 circulation networks are not well applicable, twentieth century street patterns represent a great proportion of possible networks that provide a systematic evaluation.

2.3 Evaluation of Twentieth Century Street Layout Design Implications

2.3.1 Principal Design Trends in Twentieth Century:

The concern of urban design is to integrate buildings and infrastructure systems into a whole system (Lang, 1994). During the motor age traffic network as a part of infrastructure systems has not always been integrated to the process of urban design. In this section, disadvantages of disintegration or the merits of integration are discussed.

According to Lang (1994: 39) twentieth-century was shaped by a combination of factors one of which was advanced technology of transportation that had dramatic impacts on formation of urban patterns. Even though geometric design standards of streets and roads are redefined, traffic planning, management and engineering solutions have been inevitable to accommodate automobile in urban streets.

In some cases, many of the problems traffic planners tried to deal with are still faced today. The reasons behind these problems are should be searched in procedures of traffic network design within land subdivision process.

A historical approach can provide professionals dealing with traffic network design to establish some bases for understanding the historical background of current concepts of circulation problems which they deal with.

This historical review deals specifically with land subdivision concepts, circulation concepts, and traffic design elements in Motor Age. In this part of the study, political and social basis of land subdivision as well as new concepts in street design, both in existing layouts and new developments are analysed.

This review identifies four principal trends in subdivision design and regulation. In actuality, many of the trends overlapped, and were practised simultaneously.

The periods refer to the time in which the trend first appeared or become manifest in an actual land development. Each design trend has unique implication for the state of the street layouts interrelated to circulation system.

Such a classification might be defined artificial but the concern of the study is to discuss on traffic networks as elements of urban space design. The categories may refer to Lang's (1994: 42) differentiation based on "self-consciousness" or "unself-consciousness", some examples of these approaches fall into "unself-conscious process" category, while others are in "self-conscious process" category in terms of approach to circulation phenomenon.

The argument about "self-conscious process" is whether the road pattern integrated and "coordinated" with land uses and pattern of buildings. The overall street layout has a "hierarchical geometric order". (Lang, 1994: 43)

The categories might based on urban design movements; "traditional", "modernist" and "post-modernist". Since the study is not concerned with philosophical, social and political background of such approaches, it is aimed to make a movement based classification. However, to some extent all of the twentieth-century land subdivision approaches are inevitable distinguished into a political manner.

2.3.2 Early Developments With Gridiron Patterns (1900-1928)

Definition of predominant pattern is "to enable to create as many lots as possible from a tract" (Gallion-Eisner, 1985); enable to create as many circulation patterns as possible from a unique division as an "unconscious" process in urban design (Lang,1994).

2.3.2.1 Political and Social Background

Up to 1930's, in U.S., land development as a real estate has not been distinguished with respect to environmental quality, "land speculation was the main reason behind the pushed away developments" (Gallion-Eisner, 1985:179). Housing provision was the main concern rather than environmental quality. "The rights to a piece of land on which to build a home was the desire of homeless citizens" (Gallion-Eisner, 1985:179).

According to Gallion-Eisner, (1985:179) in this period, developers have played the role of acquiring large parcels of land, preparing plans for the proposed use of the property, processing the plans through the necessary public agencies and installing the utilities that are required.

According to Ryan (1992) the style of land subdivision was not motivated by a purpose of Garden City approaches, unlike Britain. The land subdivision process was a result of "competitive necessity" (Ryan 1992:88). In design history this period is defined as "motorius" due to the absence of regulations and the expansion of land speculation (Ryan 1992:88). As Gallion-Eisner (1985) claimed during the early years of the century, land was viewed as simply a commodity to be brought and sold for profit.

According to Ryan (1992) during this period, high land costs empowered single family dwellings at outskirts of cities, the city development moved out up to the boundaries where urban facilities were accommodated. Although in this period the development was called some kind of decentralisation bound to transportation infrastructure, it differs from contemporary decentralisation processes.

2.3.2.2 Design Aspects

"Land developers were involved in the layout design of the land subdivision taken by urban planners (See Figure: 2.2). The gridiron system (the rectangular form of grid) was typical street layout of real estate development" (Ryan, 1992). As Ryan argued, the main reason behind this was its advantage of surveying, parcel subdivision, recording deeds easily. "This form enabled the land owner to create as many lots as possible from a tract" (15 meters width and 30 meters length at average) (Ryan, 1992). This form provided maximum private parcels and minimum "land lost" for public uses. Therefore, minimum improvements in streets, for sidewalks, water, electricity and gas distribution were required. Ryan criticised this form of subdivision:

> The gridiron acquired a reputation as an almost cruel form of development which forced suburban dwellers to succumb to a monotonous, lifeless environment. The most likely reason for the unfortunate subdivision of this period was the total lack of amenities, including infrastructure, public spaces, schools and civic buildings. Support for this argument can be seen in the use of gridiron occurring prior to the late 1800s and early 1900s, when planners chose this pattern based on thoughtful consideration of town planning and community goals. (Ryan 1992:88)

The gridiron did not appear in history as the obvious pattern for towns; "it was invented and its use spread throughout the world most likely because of its inherent advantages" (Gallion-Eisner,1985). The gridiron was believed to provide a coherent pattern which could grow indefinitely without losing shape or threatening the "organic unity" of the city (Lynch,1981; Gallion-Eisner,1985) This version (rectangular) was thought to offer a "sense of order and clarity" and to provide efficient distribution of land (Ryan 1992). This form used in street layout designs was neither based on environmental responsible design nor on circulation based objectives.

According to Ryan (1992) in city centres, urban poor stayed and new moderate income groups migrated to city centres. "Unhealthy living conditions and increasing number of traffic resulted from outskirts inhabitants' movement, brought some kind of urban management implications" (Ryan,1992:89). Traffic management, including signalisation and two dimensional segregation were experienced as the number of cars increased and traffic jam emerged (Buchanan Report, 1963).

According to Ryan (1992) city planners believed that relief from traffic congestion could be possible by designing broader streets or by street widening. However, neither major and secondary highway projects, nor junction projects, intersection controls, right of way diagrams of traffic engineers, flow diagrams of traffic managers could succeed. According to Gallion-Eisner, moving short-haul traffic mixed with vehicles, left turns occurred at all intersections, trucks and passenger vehicles, parking vehicles and pedestrian traffic were conflicted, therefore, frequent intersections and interrupted flows brought chaos to the city. (Gallion-Eisner, 1986)

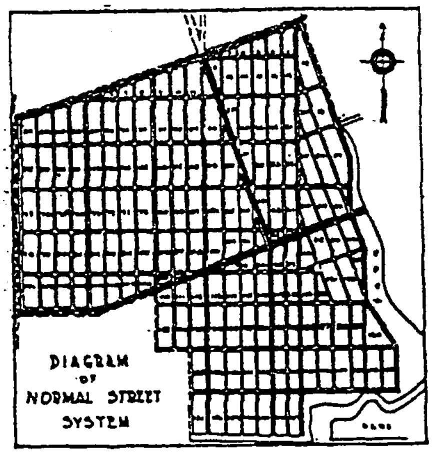


Figure 2.2 Real estate development street layout system. (Sorce:Stein, 1971)

2.3.3 Garden City Approaches and Radburn Principle (1928-1945)

2.3.3.1 Political and Social Background:

The next period in the history of land subdivision design can be defined as a "reaction to the period of land speculation and land consumption" (Freilich-Levi, 1975). An emphasis was given to "public welfare". That is basic improvements to the land were provided so that "at least the general public welfare would be protected".

According to Lang (1994:47) planning and design principles of garden city approaches illustrate principles of empiricist branch of modernist movements. In this branch, the group of designers concerned with new town design are called "garden city movement".

As Freilich-Levi (1975) argued, this movement was stated as a reaction to land speculation. This act included provisions for the arrangement of streets according to "other existing or planned streets and to the master plan for adequate and convenient open spaces". These open spaces are referred to "traffic, utilities, access of fire fighting apparatus, recreation, light, air". These open spaces are supposed to have minimum area. (Freilich-Levi, 1975).

According to Ryan (1992) along with this period legislative implications were observed by the way of planning profession's legislative tools. This period in subdivision design was also influenced by the ideas of the utopian planners. They provided the thought and theory behind "good design and community well-being" (Ryan,1992).

2.3.3.2 Design Aspects

The principal planners behind this new Garden City movement in United States were Henry Wright and Clarence Stein. To explain the Garden City concept and the issues it is helpful to address Radburn design principles.

Gallion-Eisner (1985) argued that the design characteristics of Radburn reflect the "designer's respond to severe shortcomings in land development practices of the late 1800s and early 1900s". "Stein and Wright tried to deal with the solutions for the breakdowns of their time: overcrowding, monotony, ugliness, unsafe conditions" due to increased use of automobile and unsanitary conditions (Gallion-Eisner, 1985). The Radburn plan can be placed upon the beginning of two major trends that are still in progress in land subdivision design: decentralisation of land development and the rearranging of the circulation system to accommodate both the automobile and the pedestrian in residential areas.

Sunny Side (a pseudo-Garden City development in Long Island that preceded Radburn) is another typical example. In this style, the designers arranged houses in such a way that they fronted on interior courtyards and open spaces, instead of building in the typical gridiron fashion with houses fronting along streets (Gallion-Eisner, 1985). In Radburn the houses were arranged in cul-de-sacs clusters within large superblocks. This allowed the interior of the superblock to be used as a continuous park (See Figure 2.3).

In terms of circulation system, several important techniques were employed to prevent the hazards and displeasure of living with the automobile, including

1. superblocks,
2. distinction between road types,
3. separation of pedestrian and automobile traffic,
4. extensive use of cul-de-sacs. (Stein,1957)

Although examples of these design elements can be found throughout history, Radburn was called as a "landmark community" in American suburban history because of the way it integrated these design elements as a response to the emerging automobile society (Ryan,1992). The superblock was used as a way to eliminate through traffic from residential areas. In this example, the desirability of living spaces was the objective rather than vehicular movement oriented design. A distinction between road types occurred with the use of superblocks. Instead of the gridiron's homogenous street system, the superblock created a need for different classes of streets (Ryan 1992). In Radburn principle designers used local access streets to service 10 or less dwelling units within a superblock, collectors for moving around within the community and highways to connect with cities beyond. (Stein,1957)

Another element of the design was to provide completely separate right-of ways for the pedestrian and the automobile. They, desire to turn houses away from the street and the automobile by actually turning all of the houses around was the typical building arrangement and street design principle. Therefore, the kitchen and living rooms were facing the interior of the superblock.

Ryan (1988:89) summarises the approach to problem in the Radburn design:

> American cities were not places of security in the twenties. The automobile was a disrupting menace to city life in the USA -long before it was in Europe. In 1928 there were 21,308,159 automobiles registered......The flood of motor cars had already made the gridiron street pattern, which had formed the framework for urban real estate for over a century, as obsolete as fortified town. Pedestrian risked a dangerous motor street crossing twenty times a mile (90 meters of each block) . The roadbed was the children's main play space... The checkerboard pattern made all the streets equally inviting to through traffic. Quiet and peaceful response disappeared along with safety. ... Parked cars, had grey roads and garages replaced gardens. It was in looking for the answer to such questions that the Radburn plan evolved.

A key aspect of the problem in this concept is to emphasise on the automobile. The design concept was motivated by the automobile on the human environment. The Garden City designers wanted to separate the automobile from the human environment by providing distinct right-of ways for vehicular and non-vehicular travel and by reorienting houses away from the streets. Radburn Plan was rather a form of circulation model of gridiron pattern. Therefore, the solution is somehow traffic design approach related to integration of building arrangement and traffic management problem. Proposal of a new design concept is rather related to rearrangement of patterns of its time (the superblock is a version of gridiron pattern) rather than formation of a new urban block design which refers to urban pattern design.

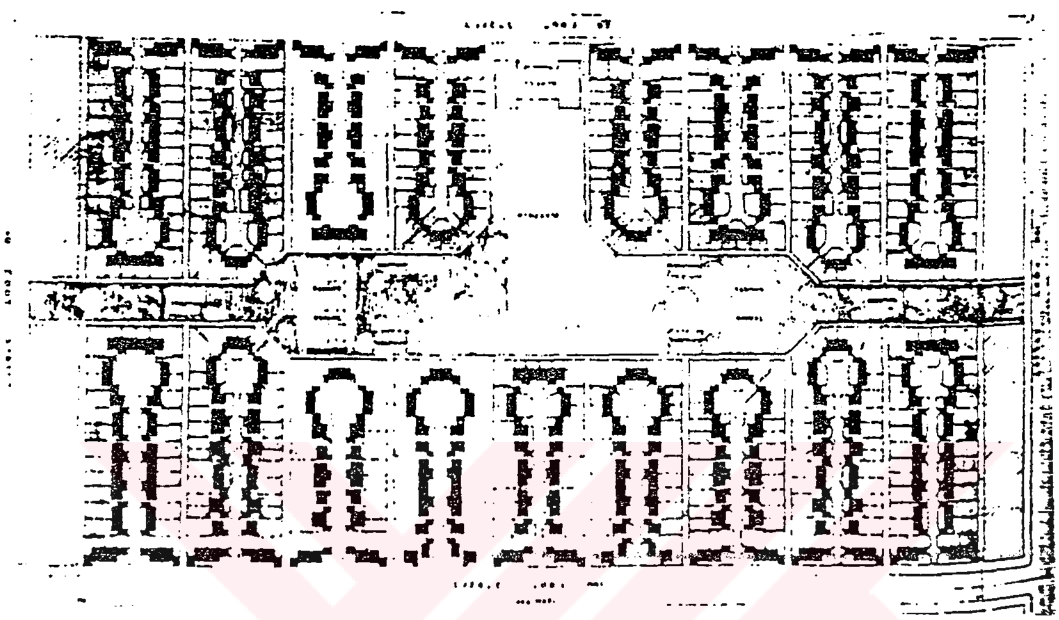


Figure 2.3 Radburn street layout system (Sorce: Stein,1971)

The next period of garden city approaches is called "third garden city approach" (Gallion, 1985). This period in subdivision history is not characterised by the emergence of a new design concept; it is rather characterised by a quantitative shift in land development (Krueckeberg, 1983). According to Gallion (Gallion, 1985) construction occurring in this period was completed primarily in the previous period. According to him in this period although there was a new development concept affected by country's regional landscape, there were also major transitions occurred in central parts or at city boundaries.

According to Krueckeberg (1983), his post-World War II transition in land development practices resulted primarily from the influence of four newly funded federal programs:

a) public housing,

b) urban renewal,

c) home mortgage insurance and

d) highway construction

The combined effect of these programs created a situation in which widespread suburban development was financially, politically and technologically possible. As Krueckeberg (1983) summarised;

> Public housing and urban renewal were set in the late 1930s and 1940s which refers to the beginning of the federal government's role in funding urban development. Public housing involved in contracting with private developers to increase the supply of adequate housing, whereas urban renewal allowed states to apply for federal funds for assistance in redeveloping blighted areas or actually razing neighbourhoods to construct entirely new developments.

The supply of land suitable for development increased dramatically as the federal government started to construct the Interstate Highway System after the preparation of Federal Highway Act of 1956 (Krueckeberg, 1983), The national highway system drastically changed the fact of suburban development, that is builders or speculators were able to reach farther away from centres in search of cheaper land. The suburban developments of build-out period was criticised by Duanny and Plater-Zyberk for its role in changing human life styles and behaviours;

> Suburbanites sense what is wrong with the places they inhabit. Traffic, commuting time, and the great distances from shopping, work, and entertainment all rank high among their complains. The only public space is the shopping mall, which in reality is only quasi-public, given over almost entirely to commercial ends. The structure of suburb tends to confine people to their houses and cars; it discourages strolling, walking, mingling with neighbours. The suburb is the last word in privatisation, perhaps even its lethal consummation, and it spells the end of authentic civic life. (Duanny and Plater-Zyberk, 1992)

About much of the suburbs a question is raised that whether emphasising the automobile through subdivision design is a reasonable or possible goal (Duanny and Plater-Zyberk, 1992). This question is raised especially as results of land development practices of the post-WW II build out period. Some maintain that the forces set in by the construction of the interstate highway system and new life styles are possibilities, while some argue that the facilities are reasonable solutions for the chaos in urban areas.

2.3.4 Planned-unit and cluster developments (1960-1980)

2.3.4.1.Political and social background

According to Gallion-Eisner (1985) the post-World War II housing boom occurred within a planning framework that probably originated from previous period. Gallion-Eisner (1985) argued that land local planners took attention to basic public services provided to the residents of expansive new developments.

The "build-out era resulted in planners becoming aware of the limitations" in subdivision regulation and land use controls (Gallion-Eisner, 1985). This phase of subdivision history is characterised by efforts to deal with these background. According to Lang (1994:93) most housing projects of this planning and design trend followed "rationalist" branch of modernist movement while a small part followed garden city models based on "empiricist" branch.

The period from 1960 to 1980 shows a dramatic increase in the number of municipalities that had subdivision regulations (Gallion,1985). Regulations were becoming an acceptable form of control over the side effects of land development. Moreover, the regulations adapted were increasingly demanding of the developer (Gallion,1985). By 1970, land developers were almost universally required to provide on-site improvements such as streets, sewerage and water lines (Listokin & Walker, 1989). Other considerations were also beginning to take root, such as environmental protection and timing controls to avoid premature development.

2.3.4.2. Design aspects

The predominant subdivision design produced during this period can be referred to planned-unit development and cluster development. Both design models indicated a "higher level of regulation in planning than ever before". (Harman, O'Donnell, & Henniger Assoviates, 1961).

Instead of subdividing and selling parcels of land to be built by an individual land owner, a single owner or corporation developed an entire community and sold not only the lot but also a built house. In other words, "an integrated community instead of the individual lot became a unit for planning". (Harman, O'Donnell, & Henniger Assoviates, 1961). This community concept included homes, apartments and shopping centres as "unified development, together with the needed school and recreational facilities for completeness" (Harman, O'Donnell, & Henniger Assoviates, 1961) (See Figure:2.4).

According to Lang (1994), the design of infrastructure was given by the "capital web of human settlements" of integrated community. According to him, getting the capital web into a form of provision of infrastructure reflects to "rectilinear geometry". That is, in such a manner the "design of infrastructure systems is the basis for all urban design because it deals with the linkages between places" (Lang,1994). This concern refers to "rationalist" branch of modern movement while "empiricists" concerns refer to more "intricate patterns".

In the examples based on "rationalist" principles, motorists and vehicles were horizontally or vertically segregated. In horizontal segregation principle, "buildings were set away from streets", however in vertical segregation principle, "buildings were plugged into the infrastructure" of movement (Lang,1994). In the examples based on "empiricists" approach principles, residential land uses are well segregated from other land uses. Main roads bisect the development, and cul-de-sacs are used extensively in an effort to discourage cut-through traffic and provide quiet, protected residential streets. The curvilinear design of the street network reflects a complete break from the use of the gridiron. A mild form of the hierarchical street network is apparent.

The cluster development follows most of the same themes and patterns of the planned-unit development, although it also seeks to address the specific issue of environmental damage and wasteful land composition. Through cluster development, planners hoped to rearrange land uses, by reducing land composition and building costs so that the most efficient use of space would result. The arguments for cluster development are made clear by a comparison of the site characteristics. Acres used for streets and building sites are less in cluster development. At the same time, the number of dwelling units in the cluster development is approximately greater. The design of the cluster development is based on curvilinear streets, which are used to provide variety and changing street vistas, cul-de-sacs and loops (a more advantageous form of cul-de-sacs) to discourage speeding and promote quiet and safety.

The planned-unit and the cluster development represent two important points of concern for land subdivision. The first point involves the complete sophistication of designing communities to accommodate traffic and the automobile. The use of hierarchical street network becomes essentially codified by this period. The street network of typical planned-unit development and cluster is entirely designed for efficient and safe neighbourhoods. Although these design approaches have many positive aspects associated with them, many designers have reacted against them.

Some designers (Duanny and Plater-Zyberk, 1992) claim that the irregular and disconnected street patterns of the planned-unit and cluster developments have unnecessarily forced Americans to rely on their automobiles for trip making. They claim that the dominance of the automobile is destroying the community well-being that planned-unit developments initially desire to provide.

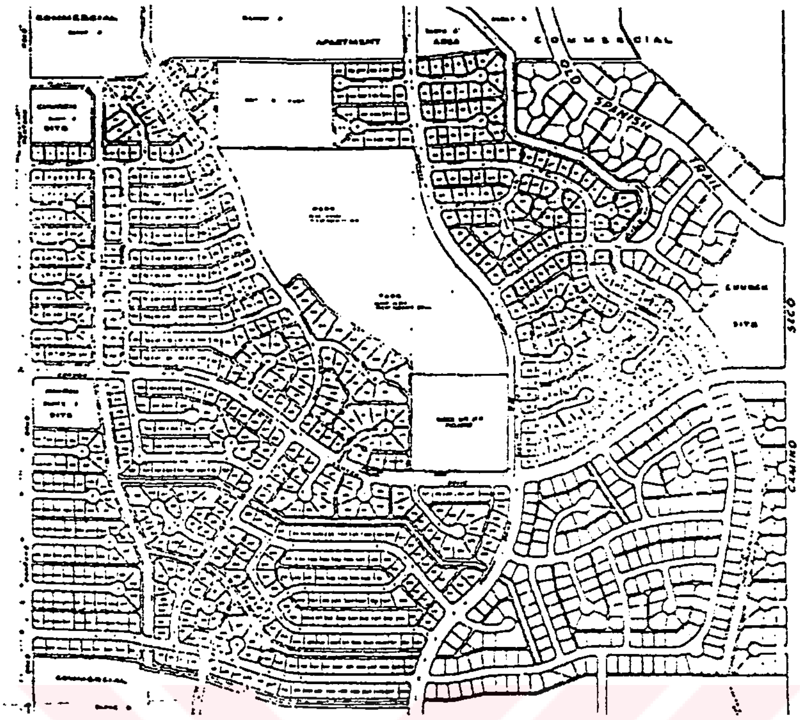
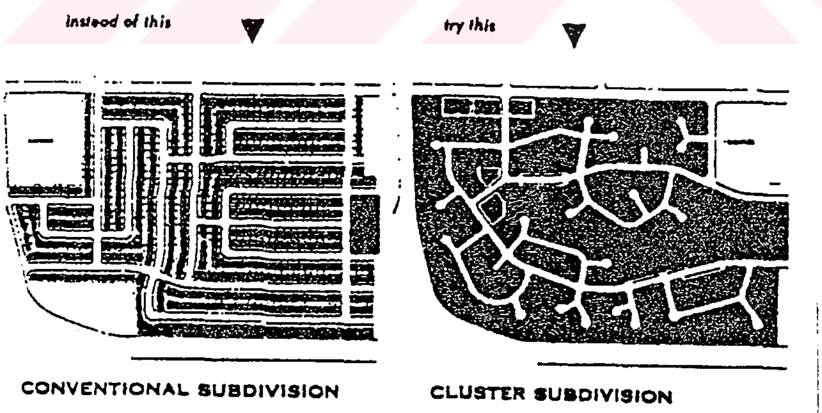


Figure 2.4 A typical example of planned unit development street layout system; Tucson, Arizona. (Source: Harman, O'Donnell, & Henniger Associates, 1961)



32	ACRES IN STREETS	24
22,500	LINEAR FEET OF STREET	16,055
29	PERCENT OF SITE IN STREETS	19
80	ACRES IN BUILDING SITES	41
590	DWELLING UNITS	604
0	ACRES OF USABLE OPEN SPACE	51

Figure 2.5 A typical example of cluster development street layout system. (Source: Whyte, 1964)

2.3.5.New urbanism: (1980-present)

2.3.5.1.Social concerns

The period of subdivision design beginning in 1980s is explained as "a reaction to the previous period", the concepts "dictated" by the planned-unit development and cluster development were criticised (Rabinowits, 1991). The planned unit development represents success of the automobile-oriented suburb. This pattern offered a satisfying and important way of life especially for American society. The problem facing suburban designers were facing for the past 15 years, however, has been dependent on whether it will be possible to continue the pattern typically offered by the planned-unit development. Rabinowits (1991) points to the impending failure of the American automobile-oriented suburb:

> The success of this type of suburb (the automobile-oriented suburb), however, is a part of its own undoing. Many metropolitan areas, particularly in sunbelt, have grown enormously, and most of that growth has been in the suburb, and almost all of the suburban growth has been low-density, detached housing. Community has become untenable as metropolitan populations have substantially increased, community distances have grown, and families contain two working spouses, owning two or more cars,... Not only has there been a loss of convenience, but a by-product of this lifestyle, air pollution, has increased to the crisis stage in some areas.

2.3.5.2 Design aspects

In this approach four types of emerging concepts appear; "the upgrading of traditional street-oriented retail areas into high-rise multifunctional centres", "the transformation of suburban shopping malls into mini-cities", "the central areas of new suburbs" and "the automobile oriented shopping strip" (Rabinowits, 1991b).

The design characteristics of this approach is that the concept of new suburb "have primarily risen out of planners' decision" and that extensive auto dependence "should no longer be promoted". (Rabinowits, 1991b) (See Figure: 2.6)

New urbanists' approach to the automobile and community is to design new growth that provides greater transportation options, particularly walking and mass transit (Calthorpe, 1991). This transportation emphasis entirely changes the scale at which development and arrangement of land uses occur (Calthorpe, 1991, p.51). New urbanists want to take all of the components currently found in the suburbs and rearrange them into real towns. places that have "centres, edges, integrated diversity. and clear public spaces" rather than isolated developments. (Calthorpe, 1991, p.51)

According to this approach, "pedestrian has no place in planned-unit development", therefore an integration of pedestrian-vehicle movement systems is aimed (Calthorpe, 1991). Streets lead to nowhere of use to someone on foot, intersections require pedestrians to cross up to eight lanes of traffic and sidewalks are landscapes lined by garage doors. This movement draws on several elements from earlier design periods, including mixed land uses, distinct neighbourhood centres and an interconnected street network such as that one provided by the gridiron, sometimes grid is integrated with curvilinear street system.

Although many of the new urbanism design elements are reorganised, today's economic, social and technological situation is entirely different from that is faced by the original planners of traditional American towns. The challenge is to design communities held together by the human element, like the traditional American town, but also not to ignore the automobile or the suburb's dramatic demand for convenient travel.

In the examples, the concept is typified as a transit-oriented development (See Figure 2.5). In addition pedestrian pocket concept is popular in Radburn principle developments (Kelbaugh, 1989). The plan is relied on cul-de-sacs, although the street network remains interconnected. There are purposefully placed public greens to define distinct neighbourhoods. The arrangement provides a centralised location for retail and office space. Mass transit has been planned in the form of feeder bus lines. A separate network of pedestrian and bicycle paths has been provided for easy movement throughout the development. Cul-de-sacs open for through pedestrian access.

Residential streets have narrowed in a manner to slow travel speeds and discourage cut-through traffic in residential areas. They are trying to adapt these "older principles" to new settings in a way that is "functional for the new society" (Calthorpe, 1991).

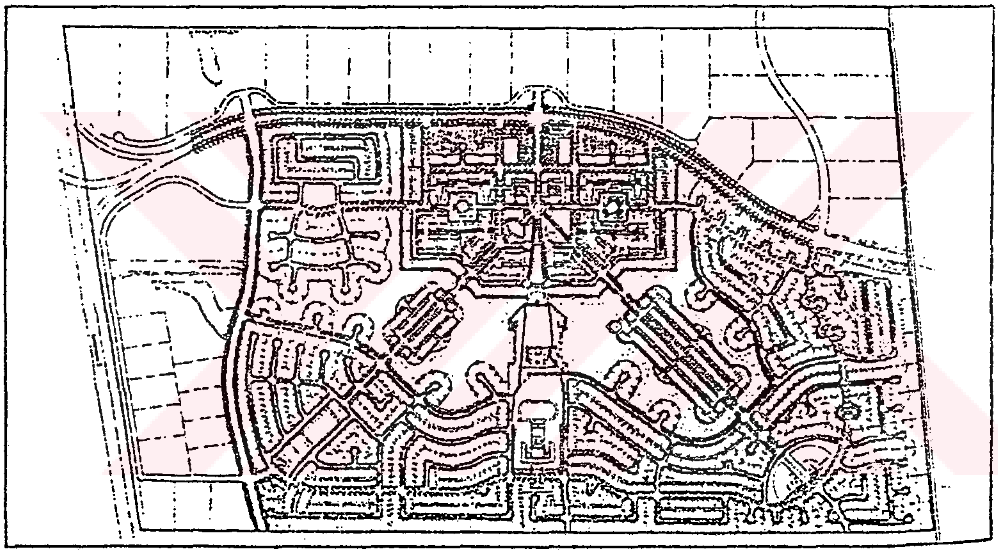


Figure 2.6 A typical example of new urbanism approach street layout system; Laguna West Project, Sacramento. Source: (Caltrope and Associates, 1991)

CHAPTER 3

A FRAMEWORK FOR THE METHOD OF EVALUATION OF CIRCULATION NETWORKS

3.1 A Framework For Conceptualisation Of Circulation Patterns

To accommodate large numbers of vehicles in cities for liability of functions, substantial physical changes are necessary; that is an expensive way of achieving such goals. Therefore, a method aiming accommodation of vehicles involves two designing an appropriate circulation network within existing street geometry.

A great deal and more work is required to develop a quantitative concept for the assessment of costs. But a graph theoretic approach is capable of putting a rational quantitative basis including conceptual quantitative evaluation.

There are absolute limitations to the amount of traffic that can be accepted in a part of city. However, the objective of this method is not to maximise the number of vehicles that a substantial site of a city can absorb or to accommodate maximum number of vehicles in that site. The concern of the method is to discuss the relative merits and outcomes of alternative schemes.

A study aiming to understand relative merits and outcomes of different types of traffic circulation systems forming the basis for local traffic management systems in urban centres or in other sites requires conceptual descriptive and analytical evaluations. Both for existing traffic networks and for new networks almost infinite number of alternative circulation systems may be planned. However, most of such alternatives would not be remarkably different. Such an evaluation requires large efforts and time. Therefore, evaluating conceptual differences are thought to be practical.

The analysis of traffic routing pattern on idealised network is not a new concern for traffic planning and traffic management agenda (Wright 1995;2).

3.2.Evaluation of Trip Distribution Performances of Traffic Networks

3.2.1.Definition of the Assignment Model

Intelligent transportation systems are applied to traffic networks in order to relieve traffic congestion, reduce travel times, improve safety, reduce accident risks to increase the productivity of networks. In addition, advanced traffic management systems are applied to optimise traffic signal systems, route choice systems in order to improve the capacity of networks.

A variety of network assignment models are developed to predict flow patterns on networks, such as congestion, route choice and travel times (Ran et al, 1996:2). Advanced traffic management systems provide formal base to real time control strategies.

Although advanced traffic management systems and intelligent transportation systems are applied to traffic networks, capability of network control strategies are limited by the performance of the pattern of networks. Therefore, it is necessary to integrate morphological aspects into circulation control strategies.

In this part, a comparative analysis of network patterns is presented in order to make a definition of morphological aspects in circulation control systems. The first part of evaluation model includes five steps:

-quantified presentation of movement patterns;
-definition of studied network patterns;

-assessment of distribution of movements on the networks;

-assessment of distribution of efficiency of road section usage;

-classification of networks with respect to distribution of movements on the networks.

In this part, a version of deterministic network assignment model (See Appendix) is applied to predict congestion and travel route choice on the networks. In such models, drivers are assumed to have perfect information about the network loads.

According to Ran and Boyce (1996:2), although static network assignment models are not suitable to analyse and evaluate complex and dynamic network systems in short term operations. They have been applied for long-term planning purposes. (Ran and Boyce, 1996:4).

The concern of this study is to discuss long-term network design purposes since physical operations on traffic networks are not as easy as management operations. Today, complex and dynamic models such as "User Equilibrium Based Dynamic Route Choice Models" are developed to predict travel routes. However, in this study a great number of networks are compared, therefore, a version of static assignment model is useful and practical.

For such traffic network assignment models, required data are:

-time dependent O-D matrices,

-network geometry and design capacities of link,

-traffic flow data for link travel time functions.

In route assignment models, is assumed that travellers are directed to specified destinations;

-seek to minimise his/her actual travel time within a variety of alternative routes,

-seek to the current best route at each intersection (he/she is assumed to be informed) (Ran and Boyce, 1996:2).

In this stage the aim is to test the performances of the urban street patterns within three conditions of movement systems. Each movement system is represented as trip desire matrix.

The characteristics of the volume/capacitypattern is searched to see if the case is homogenous or heterogenous distribution. Heterogenous distribution is observed when the travel speeds are at dramatic levels at certain parts of the network and drivers are obliged to follow the routes with low speeds. Homogenous distribution is observed when the travel speeds are at lower levels at certain parts of the network drivers have alternative shortest paths to follow.

-if alternative circulation schemes are expected within a time horizon, hierarchical networks are not prefered. That is some part of the links will serve below average network capacity, and the rest will serve over average network capacity. And, if the links serving below average are proposed to serve at higher levels, this will cause higher costs of rearrangement.

-if alternative circulation schemes are not expected within a time horizon, hierarchical networks may be prefered. That is some part of the links will serve below average network capacity, and the rest will serve over average network capacity, this will be a desired case.

To make an objective evaluation among the networks (the grid, the hexagon and the radio-concentric), it is assumed that each network has equal amount of road length (in examples 17.600 meters of total link length). That is, for the radio- concentric pattern the length of each radial line segment is assumed to be 200 meters. Similarly, the length of each line segment is assumed to be 221 meters for the grid pattern and 211 meters for the hexagonal pattern (See Figure 3.1). Total trip distribution for each pattern is assumed to be equal (34560 trips), in all examples.

Uniform distribution of interbase trips refers to a trip distribution matrix in which equal number trips exists between each O-D pair (See Figure:3.2). That is, each origin is also a destination. These kinds of trip are observed in mixed land use patterns or in city centres; peak-hour or off-peak hour work trips or business trips are typical examples.

Weighted distribution of interbase trips refers to a trip distribution matrix, in which unequal number of trips exists between O-D pairs. That is, some centroids are just origins while some are just destinations. These kind of trips are observed between separated land use patterns; peak-hour business trips are typical examples.

Round trips are represented as a trip distribution matrix in more than 60 trips exists which among some O-D pairs, while the number of trips are less than 60 for some O-D pairs (See Figure:3.2). That is some centroids are just origins, some are both origins and destinations and some are just destinations. These kind of trips are observed in city centres; off-peak hour shopping trips or business trips are typical examples.

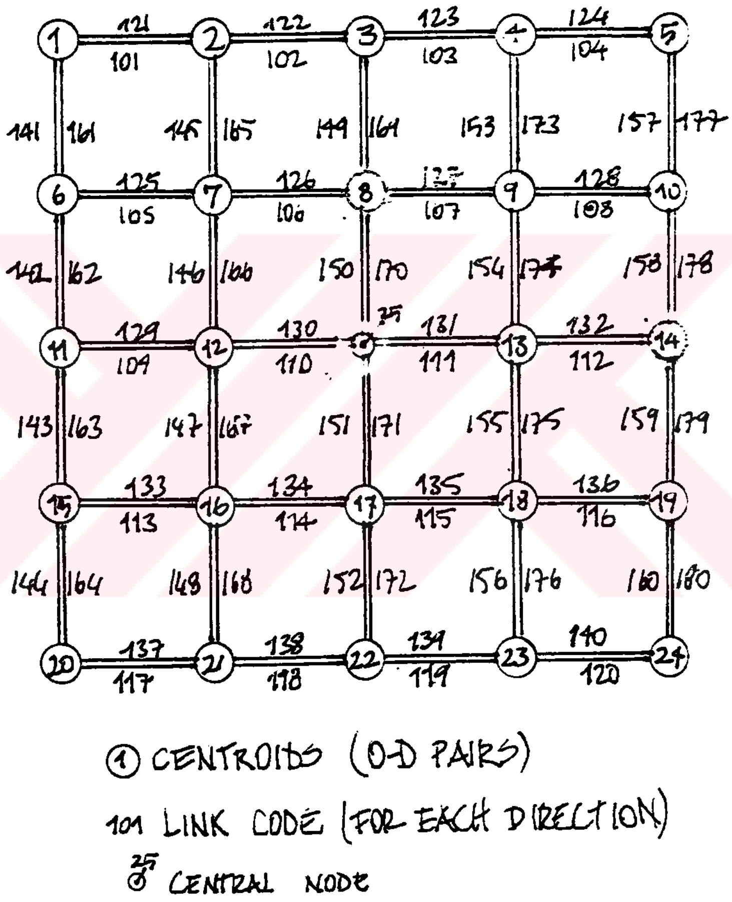


Figure 3.1:Network representation for traffic networks

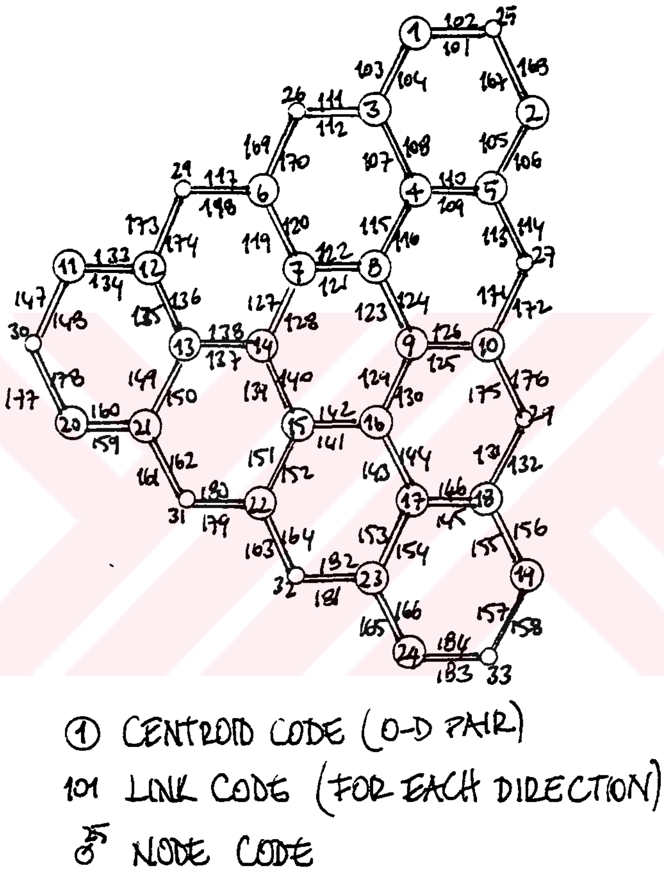


Figure 3.1: continued

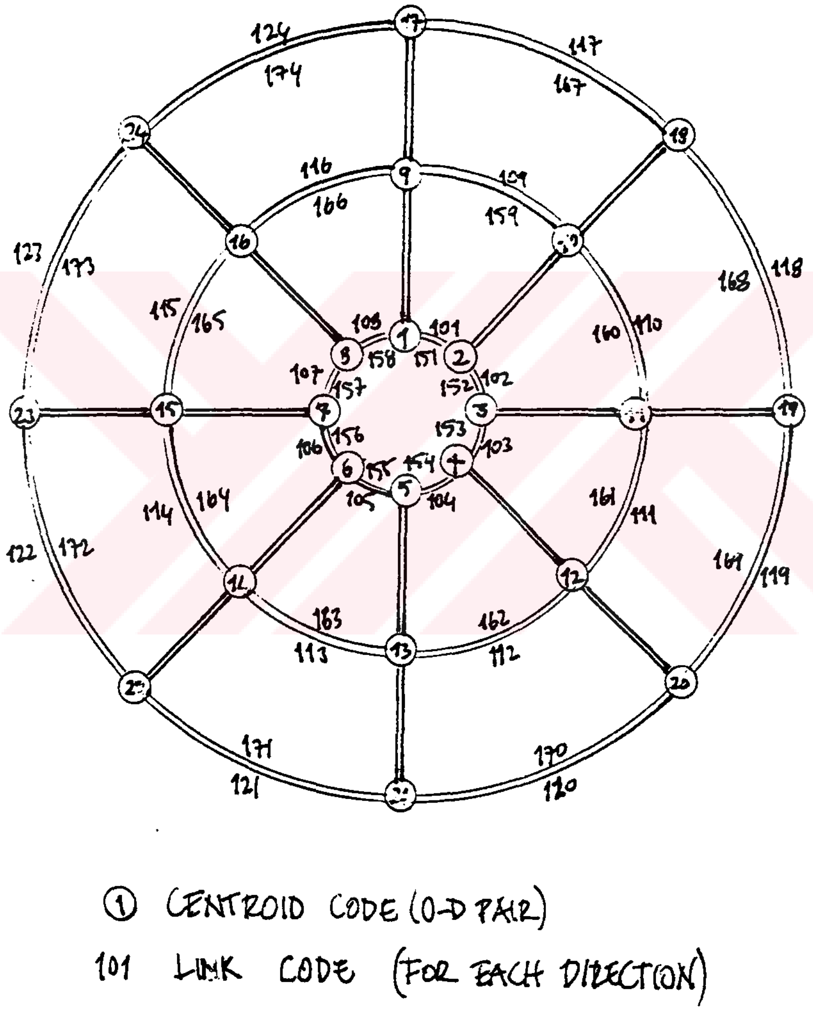
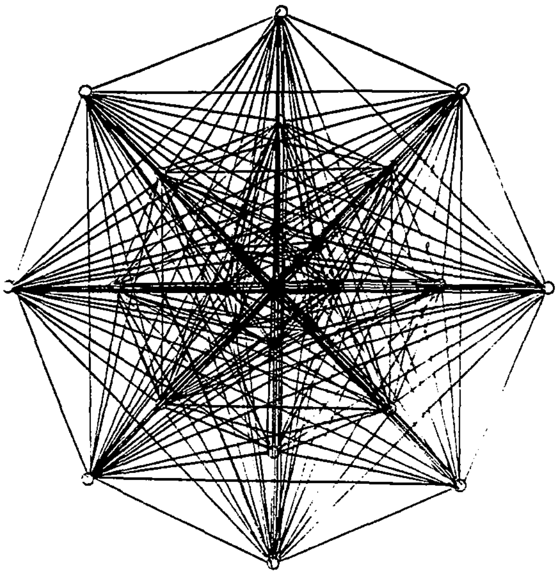


Figure 3.1:continued



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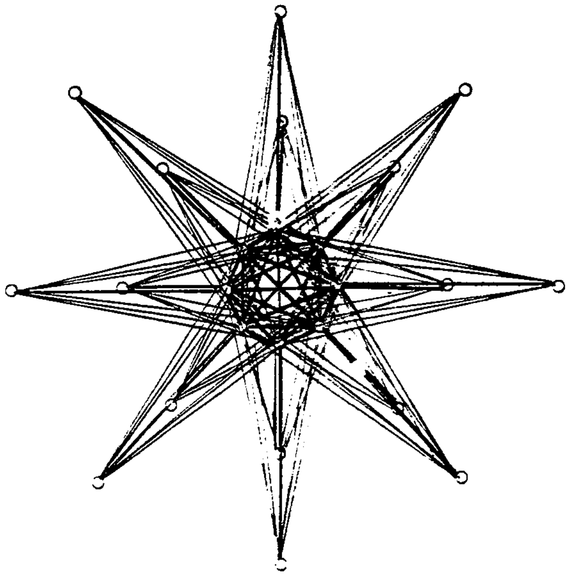
24	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60

Figure 3.2: Representation of trip types as trip desire maps

a: uniform distribution of interbase trips



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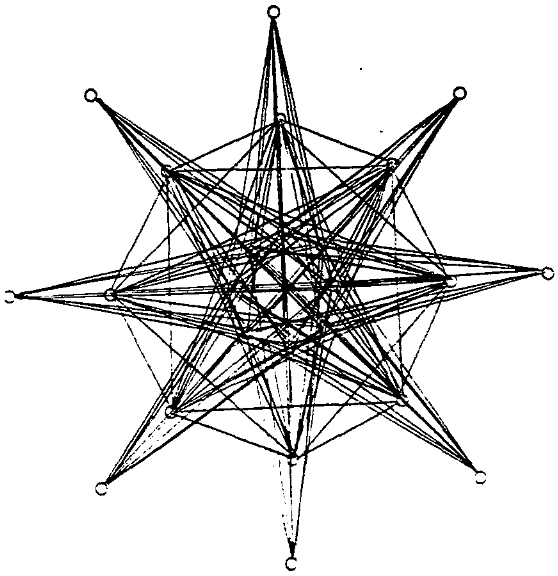
24	20	20	20	20	20	20	140	140	140	20	20	140	140	20	20	140	140	140	20	20	20	20	20	20

Figure 3.2: Representation of trip types as trip desire maps

b: weighted distribution of interbase trips



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6	30	30	30	30	30	70	90	90	90	30	30	90	90	30	30	90	90	90	30	30	30	30	30	30
7	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
8	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
9	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
10	30	30	30	30	30	30	90	90	90	70	30	90	90	30	30	90	90	90	30	30	30	30	30	30
11	30	30	30	30	30	30	90	90	90	30	70	90	90	30	30	90	90	90	30	30	30	30	30	30
12	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
13	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
14	30	30	30	30	30	30	90	90	90	30	30	90	90	70	30	90	90	90	30	30	30	30	30	30
15	30	30	30	30	30	30	90	90	90	30	30	90	90	30	70	90	90	90	30	30	30	30	30	30
16	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
17	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
18	70	70	70	70	70	70	90	90	90	70	70	90	90	70	70	90	90	90	70	70	70	70	70	70
19	30	30	30	30	30	30	90	90	90	30	30	90	90	30	30	90	90	90	70	30	30	30	30	30
20	30	30	30	30	30	30	90	90	90	30	30	90	90	30	30	90	90	90	30	70	30	30	30	30
21	30	30	30	30	30	30	90	90	90	30	30	90	90	30	30	90	90	90	30	30	70	30	30	30
22	30	30	30	30	30	30	90	90	90	30	30	90	90	30	30	90	90	90	30	30	30	70	30	30
23	30	30	30	30	30	30	90	90	90	30	30	90	90	30	30	90	90	90	30	30	30	30	70	30
24	30	30	30	30	30	30	90	90	90	30	30	90	90	30	30	90	90	90	30	30	30	30	30	70

Figure 3.2: Representation of trip types as trip desire maps

c: round trips

3.2.2. Evaluation of Travel Distribution Patterns on the Networks

In circumstances, when any section of a network serves with overcapacity, it is expected that the drivers have equal time distance alternative routes to follow. When it is possible to follow any other short paths, the distribution will be homogenous. Otherwise, drivers have two alternative decisions: in first case they follow the shortest distance, travel speeds will be reduced to lower levels. On the other hand if drivers follow longer paths with respect to distance, average travel time will increase. This kind of distribution is heterogenous.

In this stage following performances are tested:

Step 1:

-A trip desire map is given in which low levels of uniform distribution of interbase trips are represented (See Figure:3.2). This matrix includes 30 trips between an origin-destination pair to observe distribution of trips on networks. Shortest paths are also analysed.

Compared to other patterns, it is observed that trip distribution is homogenous on the grid pattern. That means for given link capacities distribution of volumes are almost homogenous, therefore the links are efficiently used. Then the hexagonal pattern follows it.

The paths followed in radio-centric pattern are shortest paths with respect to travel distance, however when time distances are considered, this pattern fails. Although, trip desire maps are homogenous, in all three patterns trips are loaded on central links. Among three patterns, most dramatic results are observed in radio-centric pattern (See Figure 3.3).

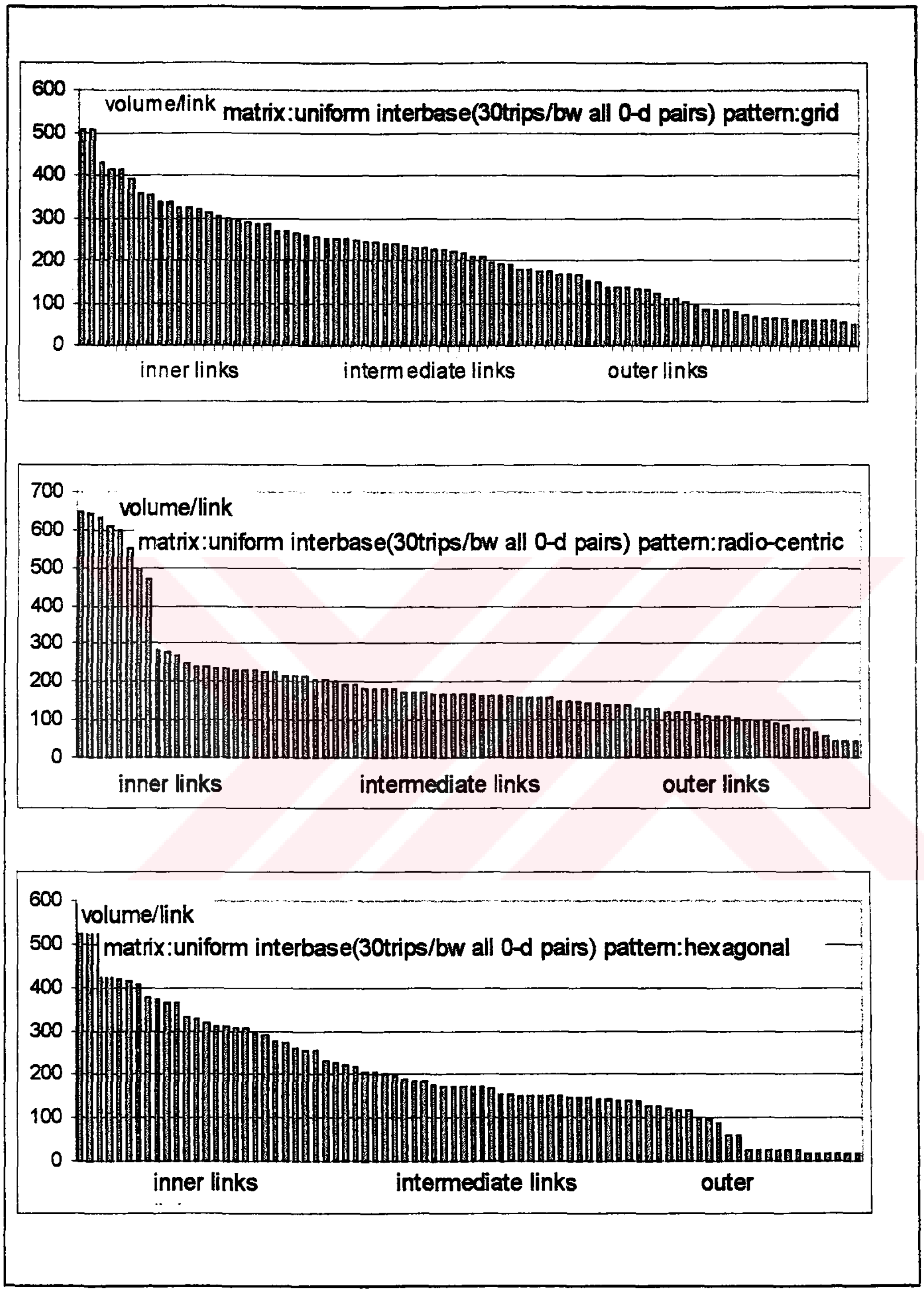


Figure 3.3: Trip distribution on traffic networks (case 1:uniform interbase 1)

Step 2:

-A new trip desire map is given in which moderate levels of uniform distribution of interbase trips are represented. This matrix includes 60 trips between an origin-destination pair to observe distribution of trips on networks. The aim is to observe new pattern of distribution of trips on networks. Therefore, new pattern of shortest path distribution is analysed. Compared to other patterns, it is observed that trip distribution is still homogenous on the grid pattern. There are no significant changes in trip distribution compared to previous situation. When the hexagonal pattern is analysed, compared to grid, in central parts dramatic increases in central link volumes are observed, however, to some extent peripheral links are used as alternative paths. When the paths followed in radio-centric pattern are analysed, this pattern fails. Even though. trip desire maps are homogenous, in all three patterns trips are loaded on central links. Among three patterns, most dramatic results are observed in radio-centric pattern (See Figure 3.4).

Step 3:

-A new trip desire map is given in which higher levels of uniform distribution of interbase trips are represented. This matrix includes 99 between an origin-destination pair. The aim is to observe new pattern of distribution of trips on networks. Therefore, new pattern of shortest path distribution is analysed.

Compared to other patterns, it is observed that trip distribution is still homogenous on the grid pattern. There are no dramatic changes in trip distribution compared to previous situation. When the hexagonal pattern is analysed, compared to grid, in central parts dramatic increases in central link volumes are observed, however, to some extent peripheral links are used as alternative paths. When the paths followed in radio-centric are analysed, this pattern fails. Even though, trip desire maps are homogenous, in all three patterns trips are loaded on central links. Among three patterns, most dramatic results are observed in radio-centric pattern (See Figure 3.5).

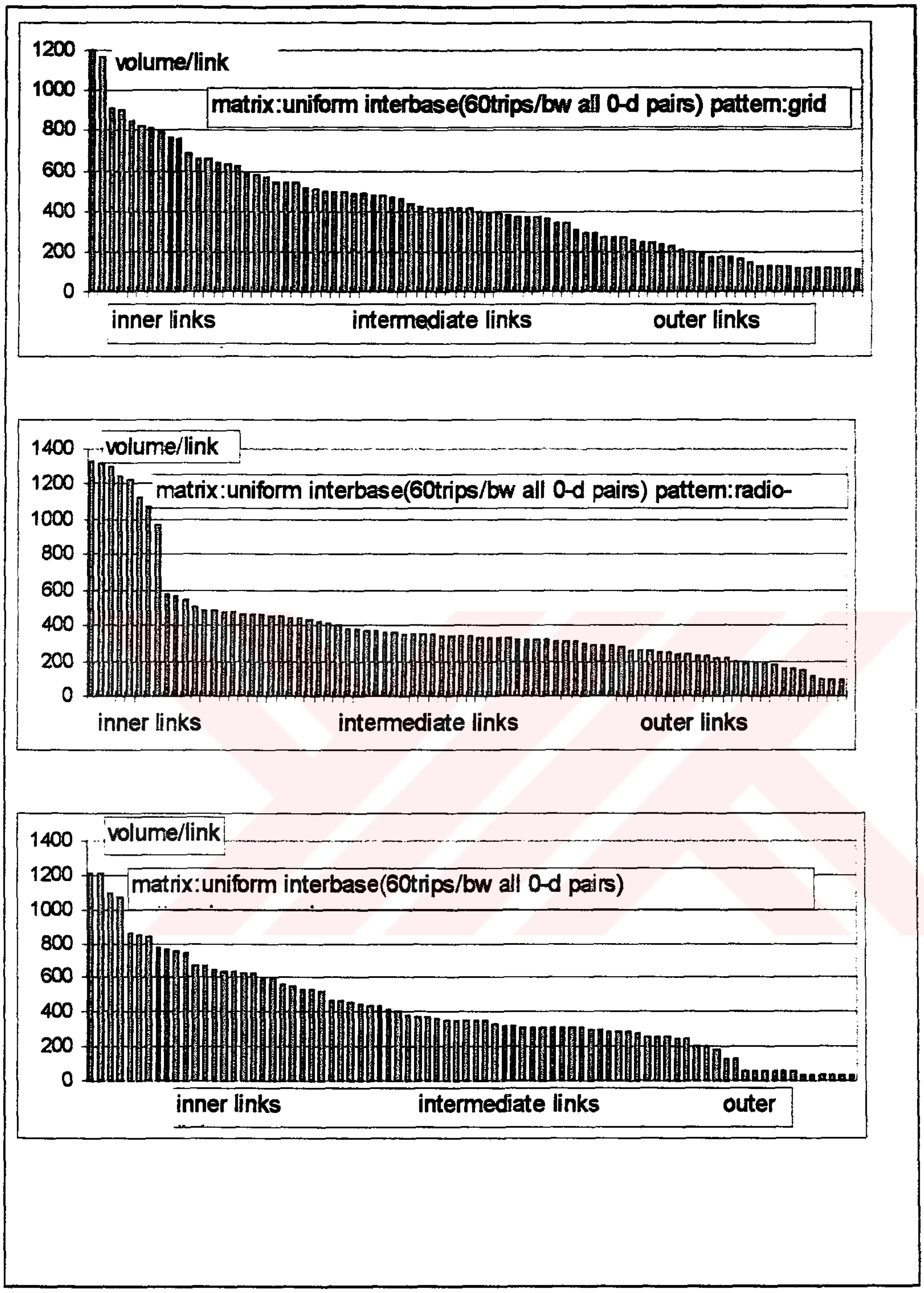


Figure 3.4: Trip distribution on traffic networks (case 2:uniform interbase 2)

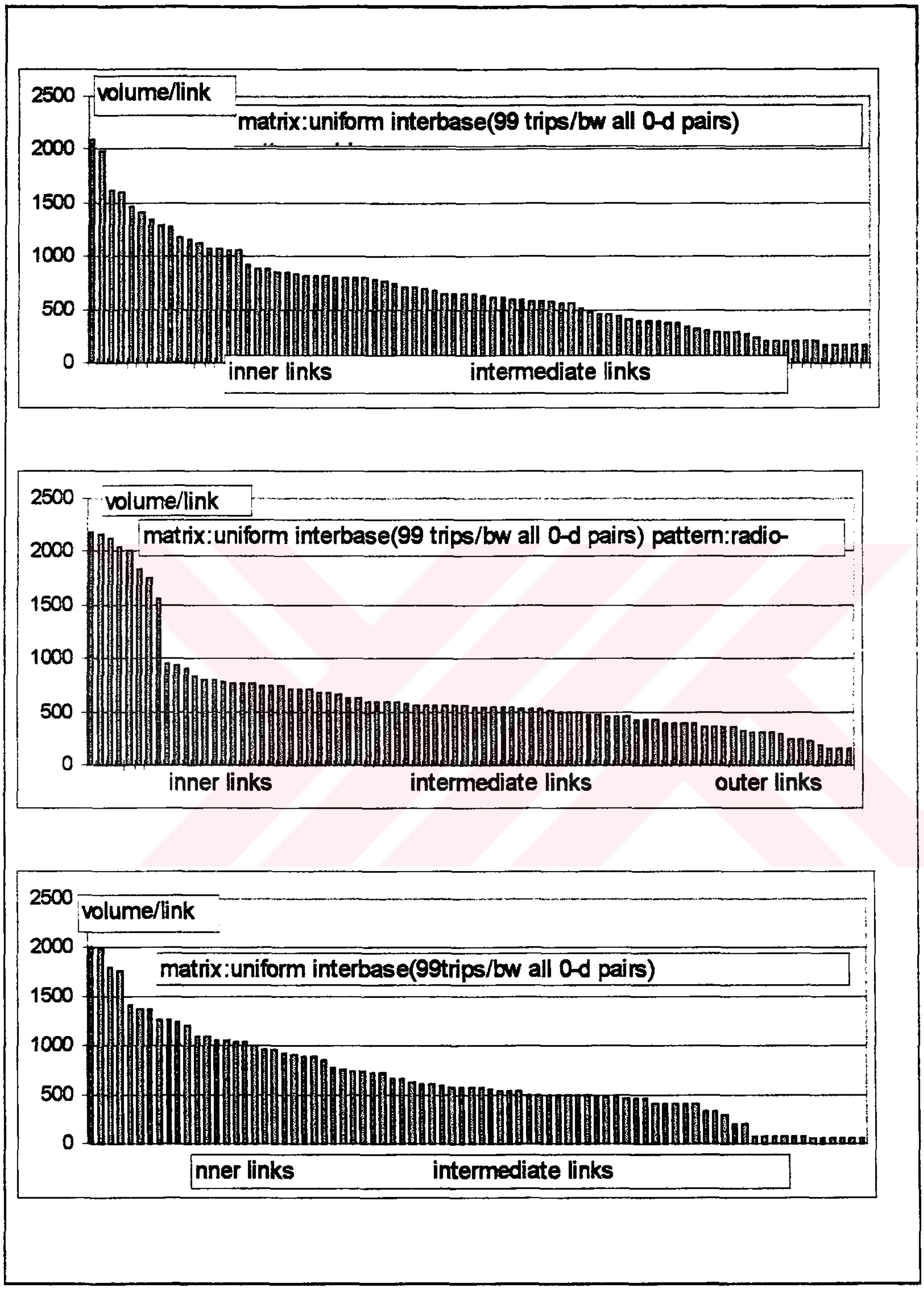


Figure 3.5: Trip distribution on traffic networks (case 3:uniform interbase 3)

Step 4:

-A trip desire map is given in which weighted distribution of interbase trips are represented. This matrix includes 20 trips between an origin-destination pair located on peripheral part and 140 trips between an origin-destination pair located on central part.

The aim is to observe distribution of trips on networks. Shortest paths are also analysed. In all three patterns similar results are observed, that is, for given link capacities distribution of volumes are almost central oriented, therefore the links are not efficiently used; central parts are overloaded and outer parts are serve under given capacities.

In such cases, there is no necessity of interconnection in outer parts, that is such kind of trip distribution requires less connected networks. Among three patterns, radio-centric one performs better. In this pattern paths followed by drivers are shorter with respect to distance and time. Then the hexagonal pattern follows it (See Figure 3.6).

Even though trip desire maps are central oriented, in grid pattern trip distribution pattern is more homogenous. That is, if alternative routes are developed, (pedestrian axes proposals, accidents, road maintenance etc.) the grid pattern is more advantageous.

When alternative roads are designed average travel distance and average travel time will be less than other patterns.

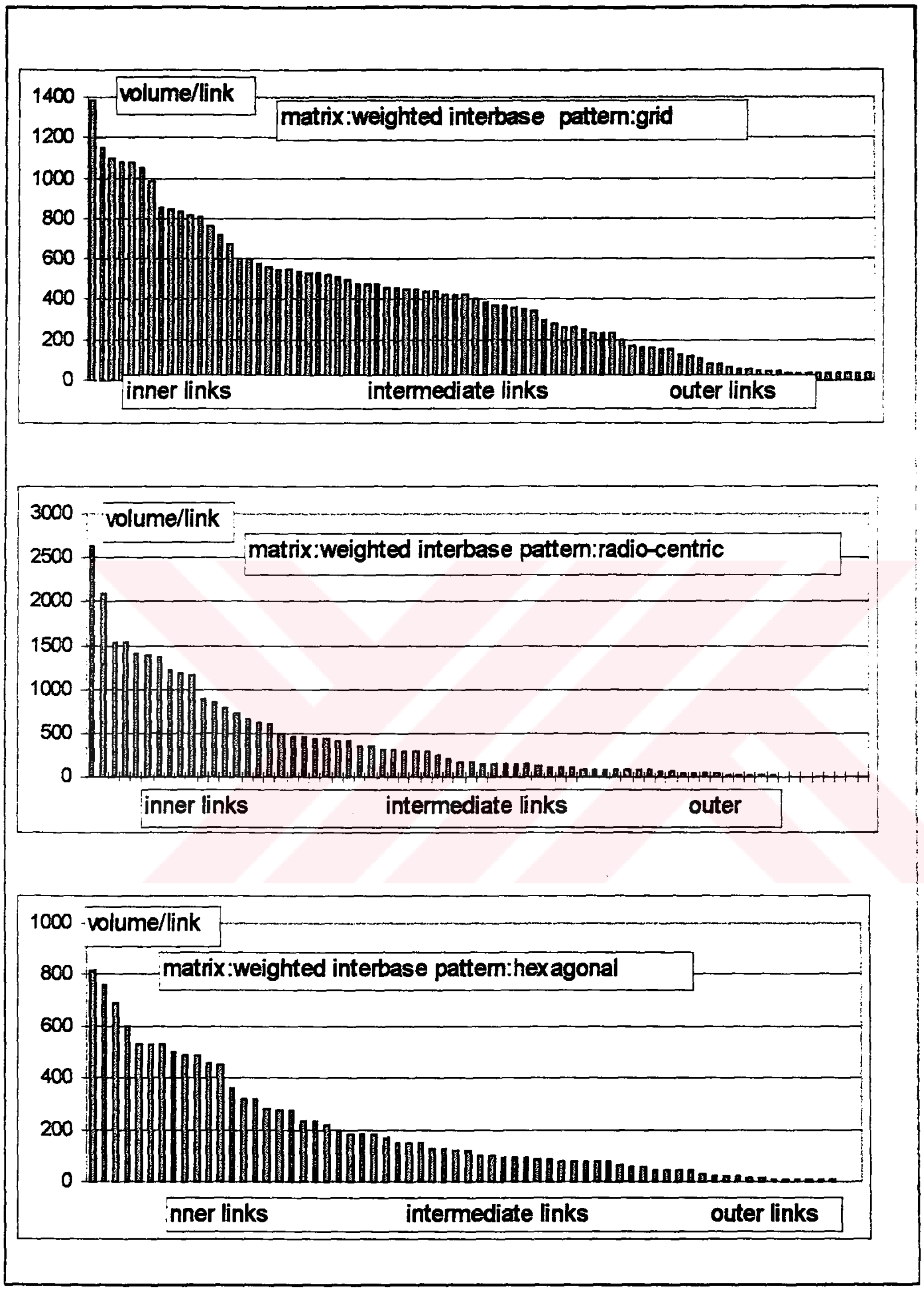


Figure 3.6: Trip distribution on traffic networks (case 4:weighted interbase)

Step 5:

-A trip desire map is given in which round trips are represented. This matrix includes 30 trips between an origin-destination pair located in peripheral part. In addition, this matrix includes 70 trips between two origin-destination pair; in this case an origins are located on peripheral parts and a destinations are located on central part. In addition, this matrix include 90 trips between two origins and destinations; in this case origins are located on central parts.

In reality this case means there are intermediate destinations, therefore there are intermediate origins. In this case the aim is to observe distribution of trips on networks. Shortest paths are also analysed (See Figure 3.7)

Among three patterns the grid pattern is more advantageous to lesser extent. Distribution of volumes are more central oriented, therefore the links are not efficiently used; central parts are almost overloaded and outer parts serve under given capacities. In such cases, there is no necessity of interconnection in outer parts. However, for intermediate links higher degrees of interconnections are necessary. That is such kind of trip distribution requires semi-connected networks. In this case, the hexagonal pattern follows the grid.

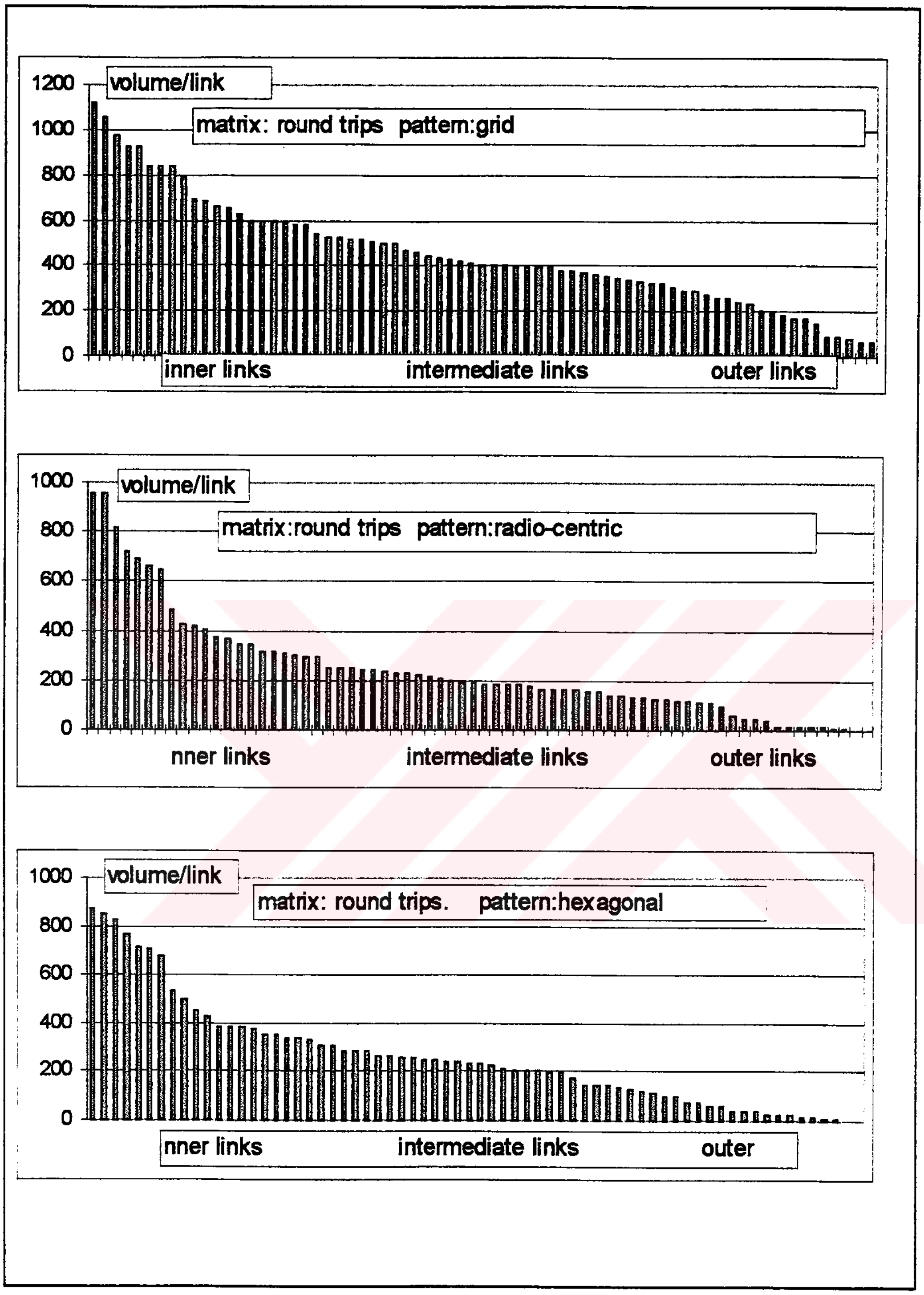


Figure 3.7: Trip distribution on traffic networks (case 5 :round trips)

-With respect to movement patterns three network types can be classified; interconnected, semi-connected and tree systems. In addition to these three, linear systems are also included, but among three street patterns (the grid, the hexagon and the radio-concentric), there are no significant differences. Therefore linear systems fall into a different category by itself.

-For the uniform (non-weighted) distribution of interbase trips, grid pattern performs best, then hexagonal pattern follows it. That is, when interconnected systems are considered, among three patterns, grid is preferred. Then the radio-concentric follow it.

-For the weighted distribution of interbase trips, hexagonal pattern performs best, then radio-concentric pattern follows it. That is, when tree systems are considered, among three patterns hexagon is preferred. Then the radio-concentric one follows it.

-For the uniform (non-weighted) distribution of round trips, grid pattern performs best, then the hexagonal pattern follows it. That is, when interconnected systems are considered, among three patterns, grid is preferred. Then the radio-concentric follow it.

-For the weighted distribution of round trips, radio-concentric pattern performs best, then grid pattern follows it. That is, when semi-connected systems are considered, among three patterns, radio-concentric is preferred. Then the grid follows it.

-if alternative circulation schemes are expected within a time horizon, hierarchical networks are not prefered. Hierarcial networks are arranged for certain movement patterns and flow schemes. That is, flow diagrams are expected to be heterogenous. When link capacities are appropriately designed for a certain kind of flow distribution the network is expected to perform well. However, when momenet patterns and flow diagrams are expected to change into a new form, rearrangement of the network is inevitable. It is hard to change any hierarchial scheme into a new form, since such a scheme is also a kind of routing pattern. On a uniform street pattern the number of adaptable alternative routing patterns is more than any circulation scheme that is heterogenous with respect to distribution of link capaities.

In general, chages in movement pattern and flow pattern changes are observed in urban centers or in sites with mixed activity.

-if possible alternative circulation schemes are not expected within a time horizon, hierarchical networks can be prefered.

3.3 A Framework For Graph Theory

"Traffic assignment methods can be used to predict how drivers will behave in any particular scheme", so that flow volumes, intersection loads and journey times can be estimated (Wright,1988). Hence, various street flow schemes and intersection design and control systems can be numerically compared in a systematic way. Such evaluations enable traffic managers and professionals responsible for street design to make desirable operations. New one-way street configurations, turning restrictions, junction design and controls, segregation in two or three dimensions, and similar methods can be employed to control vehicle flows into new configurations.

The subject is not directly interested in the methods that are used to control and change trip desire maps (O-D matrixes) of the city; that is rather an urban land use planning concern. Therefore, the aim of this method is not to construct models to change routing patterns directly. However, traffic managers and traffic designers can manipulate a circulation system by using street design, segregation and flow control methods. Therefore, it is useful to understand the circumstances, in which what kind of traffic management and traffic design strategies result in what kind of circumstances in a circulation system.

The aim of this section is to discuss and compare some idealised networks and circulation systems that have simple geometrical configurations. In this respect routing patterns that are relatively efficient in terms of path crossings and total distance travelled shall be identified in a theoretical framework derived from graph theory.

Although circulation systems have been devised for simple forms of network, it may be possible to apply them to more complex cases. The results may provide land subdivision experts a general strategy for efficient circulation in urban areas by providing possible traffic management policies to be adapted.

In the study a mathematical formulation is used to identify optimal, flexible patterns that are represented as graphs.

There are several ways in which traffic routes may be represented as a graph. Traffic routes may be shown in the form of road map. Although, a road map does not give sufficient indicators of the potential conflict between traffic streams, it suggests the potentially conceptual routing patterns. In other words, traffic routes may be represented in the form of a circulation system, that is, a road map which determines the rules for circulation, one way streets and other rules.

The model structured on circulation system, represented by a planar graph whose vertices are distinguished into two main categories (junction vertices and terminal vertices) to conceptualise routing patterns is called the "graph-theoretic approach" (Wright 1989a)

3.3.1 Assumptions and Definitions:

In the studies with given networks it is necessary to assume that the existing network is almost fixed, in order to make a comparative evaluation under equal conditions.

Circulation systems refer to "the system of rules for traffic circulation within the network, in permissible movement directions, in permissible turning movements at functions" (Wright et all,1989a:116).

Routing pattern refers to "the pattern of movement that vehicles actually follow"; it is assumed that routing pattern is consistent with the circulation system (Wright et all,1989a:116).

In Wright's study (1989a), fifteen routing patterns are simplified to refer to possible circulation networks (See Figure 3.8):

1-SIOT :Star, interlocking offside turns(O-D pairs are connected to central junction)
2-SNIOT : Star non-interlocking offside turns
3-CUP :Convex Polygon
4-TWC :Two way corridor
5-TWS :Two way spine
6-2OWCU :Two one-way corridors uniform alignment
7-2OWCS : Two one-way corridors single alignment
8-NL :Nested loops
9-OWR :One way ring
10-2OWR :Two one way rings
11-2WRES :Two way ring, equal split
12-2WRUS :Two way ring, unequal split
13-NSEW :North South - East West Split
14-CP :Concentric Polygons
15-BT :Binary Tree

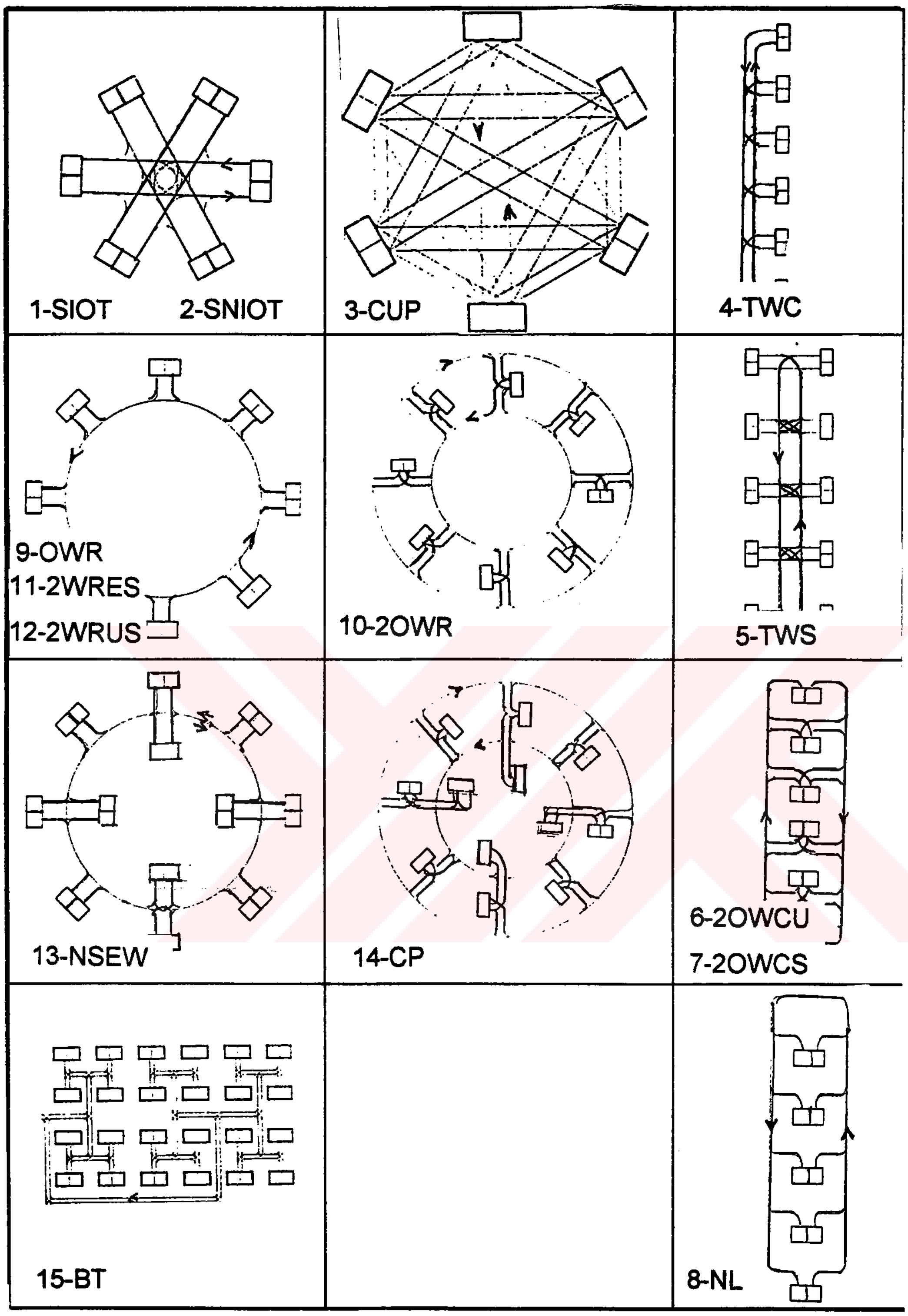


Figure 3.8: Possible routing patterns. Source: Wright (1989a)

Particular movement does not necessarily occur, routing pattern may exploit a subset of various possibilities within the circulation system. In Wright's study (1989a), the circulation system is pictured as a directed graph made up of nodes and links. Each link represents a particular direction of movement along a road. There are two node categories; junction nodes (where the links intersect, interlock, weave, merge, or diverge) and terminal nodes (where traffic enters, leaves, begins, or terminates).

Terminal nodes are assumed to be connected to circulation system with a two way link (street), and each node is assumed to have an origin and destination. There is no space between the origin and the destination belonging to a node. Each O-D pair is called "duplex node". (Wright et all,1989a:116)

The first basic evaluation criterion is amount of conflict between vehicles in terms of path crossings per unit trip. The conflicts differ with respect to vehicle approaching angles in a junction.

Intersecting conflicts: In traffic engineering studies, "intersecting conflicts are generally regarded as the most severe type of conflict". (Wright 1994:6) That is intersecting conflicts have relatively high potential for delay and accident risk. This potential for risk is recognised by the angle that vehicles follow. The angle of intersection determines sight area related to distance of deceleration, and momentum of collision. An intersection conflict may occur only at a junction, and it is necessary for two vehicles to arrive at intersection from different directions for their paths to cross. In general approach angle of two vehicles is between 30^0 and 150^0 (See Figure 3.9).

Weaving Conflicts: These conflicts are expected to occur between two vehicles if their paths merge and diverge subsequently; the first vehicle approaching from the offside of the second vehicle and departing on the second vehicle's nearside (Wright 1994:6). Any weaving manoeuvre implies a merging conflict of first vehicle as well as the intermediate conflict of the second vehicle.

Weighting these conflicts to fully reflect their characteristics is not a very clear process; if the weaving traffic is confined to a single lane, the manoeuvre is distinguishable from a merge/diverge manoeuvre. That is their paths do not actually cross. In such a case, the weaving component can be ignored practically. The paths of two vehicles may cross more than once if they frequently switch the lanes, but this is a practical flow type; theoretically they are assumed to cross just once. It is relatively easy to enumerate weaving conflicts in graph-theoretical terms. In addition, the weight of delay and accident severity is relatively small, because the approach angle of two approaching vehicles is between 0^0 and 30^0 or between 330^0 and 360^0 (See Figure 3.9).

Merging conflicts: Such conflicts occur only at junction exits. Their weight and intensity varies with the circumstances; if an exit consists of two or more lanes and the merging vehicles choose exit lanes, that is their paths do not actually overlap, potential delay and accident will be less than the otherwise case. (Wright 1994:6). The approaching angle of two vehicles varies between 330^0 and 360^0 (See Figure 3.9).

Diverging conflicts: Similar considerations of merging conflicts can be applied to diverging conflicts. The approaching angle of two vehicles varies between 0^0 and 30^0. In the model, at enumeration stage, equal weight is given to all merging and diverging conflicts. But at evaluation stage, the weighting is differentiated under consideration of the location of the junctions (See Figure 3.9).

Shunt conflicts: These conflicts occur when a vehicle is following another on the same path. (Wright 1994:6) That is, the approaching angle of two vehicles is almost 0^0 . Along any section of a road, moving vehicle may delay the vehicle behind, or has potential of a collision with it. The potential conflict sites are not well-defined in terms of road links or junctions. In fact, shunt conflicts could be described as dynamic events in a graph; the weight of each

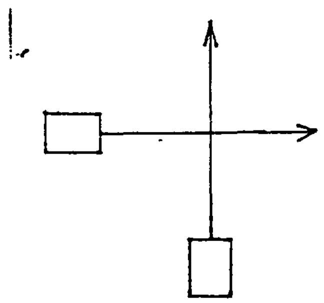
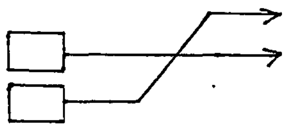
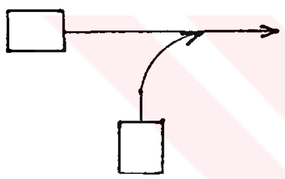
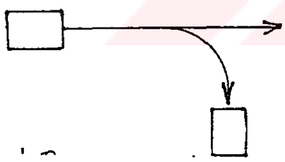
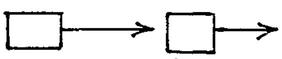
	**a-Intersecting conflicts**: When the paths of two vehicles cross intersecting conflict occur. In general approach angle of two vehicles is between 30^{0} to 150^{0} In traffic engineering studies, intersecting conflicts are generally regarded as the most severe type of conflicts.. The risk, is recognised by the angle that vehicles follow. The angle of intersection determines sight area related to distance of deceleration, and momentum of collision.
	**b-Weaving Conflicts:** These conflicts are expected to occur between two vehicles if their paths merge and diverge subsequently; the first vehicle approaching from the offside of the second vehicle and departing on the second vehicles nearside In addition, the weight of delay and accident severity is relatively small, because the approach angle of two approaching vehicles is between 0^{0} and 30^{0} or between 330^{0} to 360^{0}.
	**c-Merging conflicts:** Such conflicts occur only at junction exits. Their weight and intensity varies with the circumstances; if an exit consists of two or more lanes and the merging vehicles choose exit lanes, that is their paths do not actually overlap, potential delay and accident will be less than the otherwise case. The approaching angle of two vehicles varies between 330^{0} to 360^{0}.
	**d-Diverging conflicts:** Similar considerations of merging conflicts can be applied to diverging conflicts. The approaching angle of two vehicles varies between 0^{0} to 30^{0}.
	**e-Shunt conflicts:** These conflicts occur when a vehicle is following another on the same path. That is, the approaching angle of two vehicles is almost 0^{0}. Along any section of a road, moving vehicle may delay the vehicle behind, or has potential of a collision with it.

Figure 3.9: Conflict types. Source Wright (1988)

shunt conflict increases with respect to volume of the section; therefore the volume/capacity levels of road sections guide traffic managers to estimate potential delays and accident risks. Since these conflicts are dynamic events, they are taken into account at evaluation stage rather than enumeration stage.

The second basic evaluation criterion is the total journey distance actually travelled per unit trip.

In the graph theoretical approach, some possible circulation systems are idealised. All nodes are assumed to be duplex nodes. A potential for movement between any two duplex nodes exists, and there may be several alternative routes for each direction of flow.

> It is not a necessary condition for vehicles travel from duplex A to duplex B to use the same route that is used by vehicles travel from duplex B to duplex A. Therefore each flow direction is considered separately.
>
> To simplify the movement, and to make a basic evaluation, it is assumed that there is just one unit of traffic flow (vehicle per unit time) travelling in each direction between each duplex node pair (Wright,1988).
>
> In principle, the traffic moving from any given duplex A to any other duplex B could be split between two or many alternative routes. A simple rule can be used; if two routes R1 and R2 exist between a given duplex pair, and the number of path crossings of route R1 is less than R2, the vehicles using R2 will be transferred to R1. It follows until the number of path crossings of both routes become equal.
>
> It is necessary to assume that the number of vehicles loaded onto the "optimum " route can be accommodated within any capacity constraint that depends on the physical width of the road links, left-turn line widths at junctions.
>
> The graph formed by the actually used routes is called "bipartite graph" (Wright,1988:119).

If there are inner links between the complementary nodes within each duplex, this graph is called "complete bipartite graph" (Wright,1988:119).

Harary (1971) formulated minimum number of crossings for bipartite planar graph with N origin nodes and M destination nodes. The graph is represented by $k_{M,N}$ and minimum number of crossings is represented by $V_{(M,N)}$.

Here, $V_{(M,N)} = (M/2)*(M-1)/2*(N/2)(N-1)/2$ (1)

if number of origins and destinations are equal;

$$V_{(M,N)} = (N/2)^2*(N-1/2)^2 \qquad (2)$$

In actual spatial relationship, it is not certain that equation (2) can really be applied to road traffic (Wright,1988). However it can be applied in a theoretical assessments.

It is not very clear how the most efficient bipartite systems could be applied to real road network.

An alternative layout that could actually form the basis of a feasible road network is not formulated by traffic planners or urban designers. This study also does not cover an argument whether such a feasible layout could be found or not, however, comparative advantages and disadvantages of different layouts are shown to the attention of urban traffic planners and designers.

3.3.2.Method for Calculation of Path Crossings and Travel Distances

The method, used by Wright to calculate the number of path crossings for specified routing patterns on simple road networks consider all the paths radiating from a particular node (Wright et all,1988). The exercise was repeated for all nodes. The procedure is illustrated by using a simple one-way ring system as an example. The nodes are arranged at intervals on the inner ring (Wright et all,1989a).

For such a system, "there is only one feasible routing pattern" that needs to be considered. "The vehicles departing from any particular origin travel clockwise around the ring, turning off when they reach their destination" (Wright et all,1989a:119)

The ring has been cut and straightened out for simplicity. The arrows represent conflicting streams of traffic, whose origins lie counter-clockwise relative to the selected node (Wright et all,1989a).

At the first node, to the right of the selected node, one of the paths turns off, leaving N-2 to continue round the ring. Conflicting with these are N-2 paths arriving from nodes to the left, of the selected node to produce $(N-2)^2$ path crossing. At the next node to the right, there are $(N-3)^2$ path crossings, and so on. Therefore, total number of crossings associated with paths originating from the selected node is;

$C= (N-2)^2+(N-3)^2+\ldots\ldots\ldots\ldots 3^2+2^2+1^2$

$C= N(N-1)(N-2)(2N-3)/6$

Using examples, "total crossings of any routing pattern" can be simply calculated (Wright et all,1989a).

In fact, there are different types of crossings with different weights of risk factors. That is "2 crossings", "3 crossings", and "4 crossings" types are involved.

For such patterns, each distinct combination of two duplexes generates a fixed number of 2-crossings;"a_2". Similarly, each combination of three duplexes generates a fixed number of 3-crossings; "a_3", and each combination of four duplexes generates a fixed number of 4-crossings; a_4.

Therefore, there are $(^{N}_{2})$ sets of double, $(^{N}_{3})$ sets of three, and $(^{N}_{4})$ sets of four crossings.

Where total number of crossings;

$$C = a_2(^{N}_{2}) + a_3(^{N}_{3}) + a_4(^{N}_{4})$$

Wright's original method was checked for different nine circulation systems. For each of these networks:

Either the number of 3-crossings generated by a set of 3 duplexes or the number of 4-crossings generated by 4 duplexes vary with N, however it is possible to compare these 9 networks with equal N (Wright et all, 1989a).

Such crossings refer to the unit-volume in a junction. If the number increases, in practice, we need to adopt signalisation, or three dimensional segregation. That is the number of less crossings refers to area-wide solutions; the number of more crossings refers to intensive volume oriented solutions.

The path conflicts as the only evaluation criterion is not enough, it is useful to take into account different types of conflicts, since each conflict has a different potential to generate accidents and delays. In this circumstance, each conflict has a different weight in junction control procedure; each network may not reside all kinds of conflicts with equal weights. In other words, any type of a conflict may have a different value in different networks. For example, weaving conflicts may cause different potential accidents or delays in one way ring or in binary tree patterns; in general, one way rings are designed under consideration of high level of weaving conflicts, therefore, junction types, street width and lane design do not result high risk weights.

In a graph theoretical analysis, five different conflict types need to be recognised, so that evaluations may be made at more local levels. These five conflict types are, intersecting, merging, diverging, weaving and shunt.

3.3.3 Quantitative Results of The Conceptual Evaluation Model

In this part that efficiencies of routing patterns in terms of path crossings and total distance travelled are compared. The results may guide designers to select appropriate circulation systems. Comparative advantages and disadvantages of routing patterns in terms of path crossings and total distance travelled are as follows:

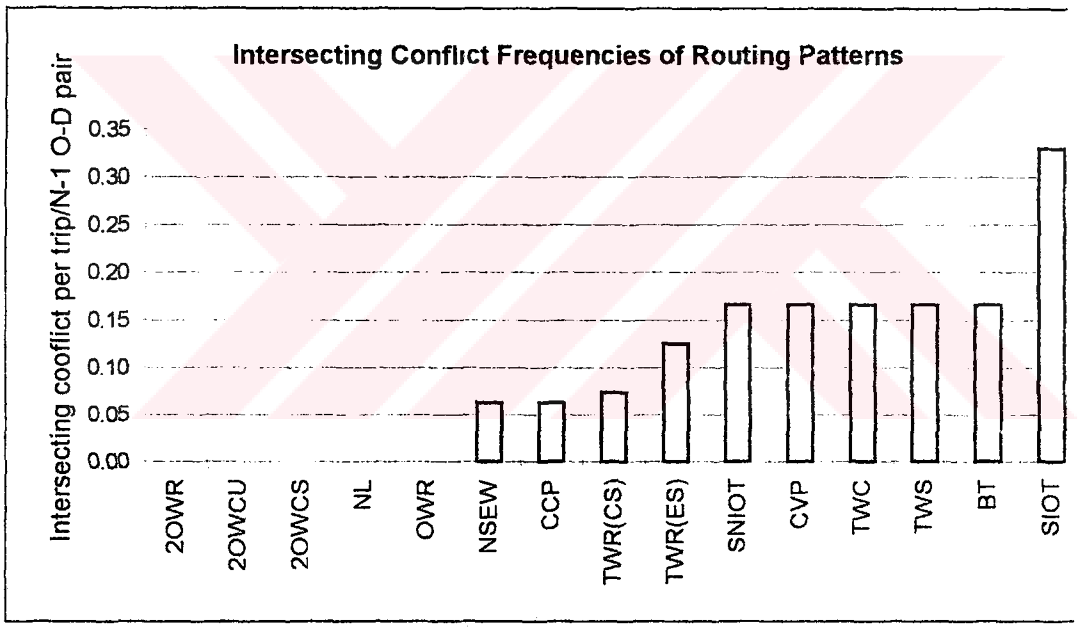


Figure:3.10 Intersecting conflict frequencies of routing patterns. (Source: Wright,1988)

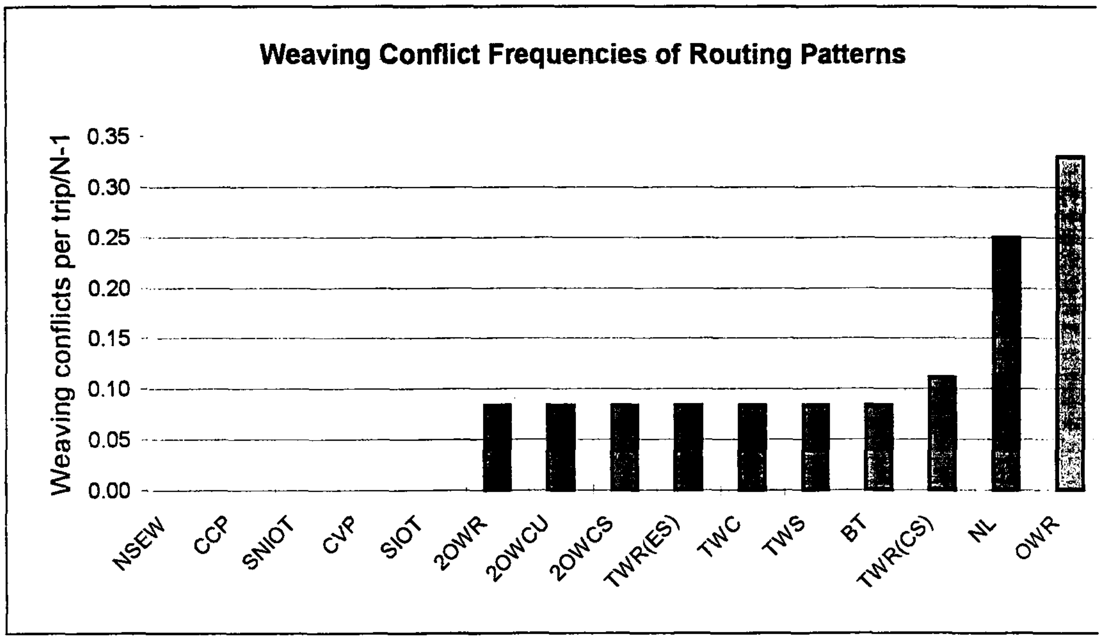


Figure:3.11 Weaving conflict frequencies of routing patterns. (Source: Wright,1988)

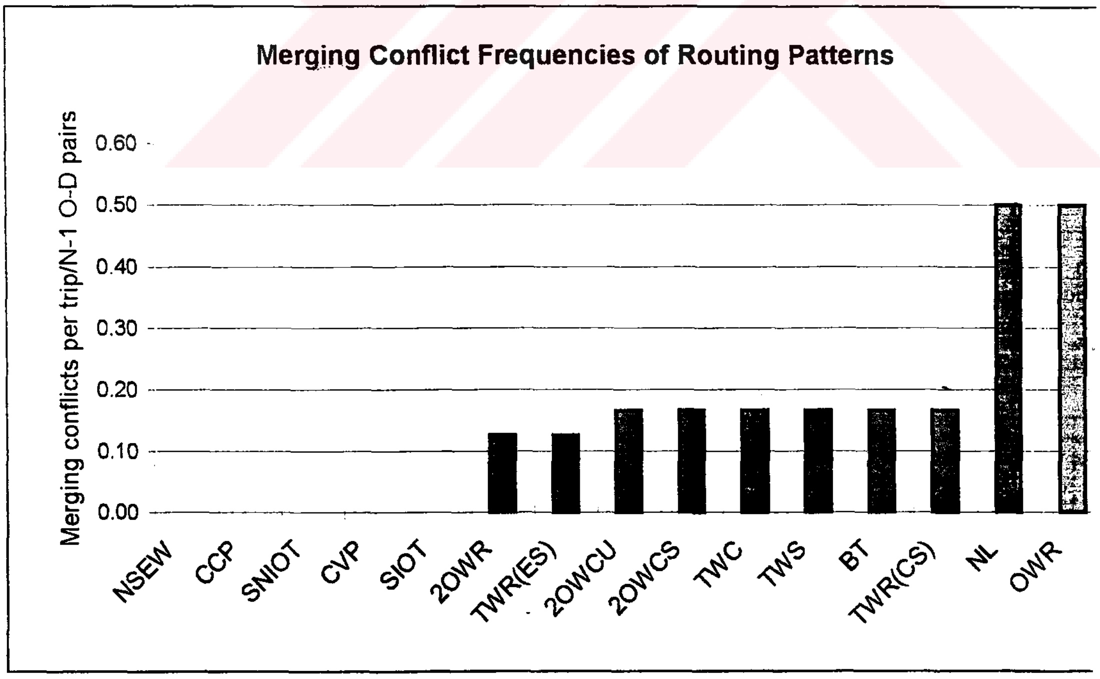


Figure:3.12 Merging conflict frequencies of routing patterns. (Source: Wright,1988)

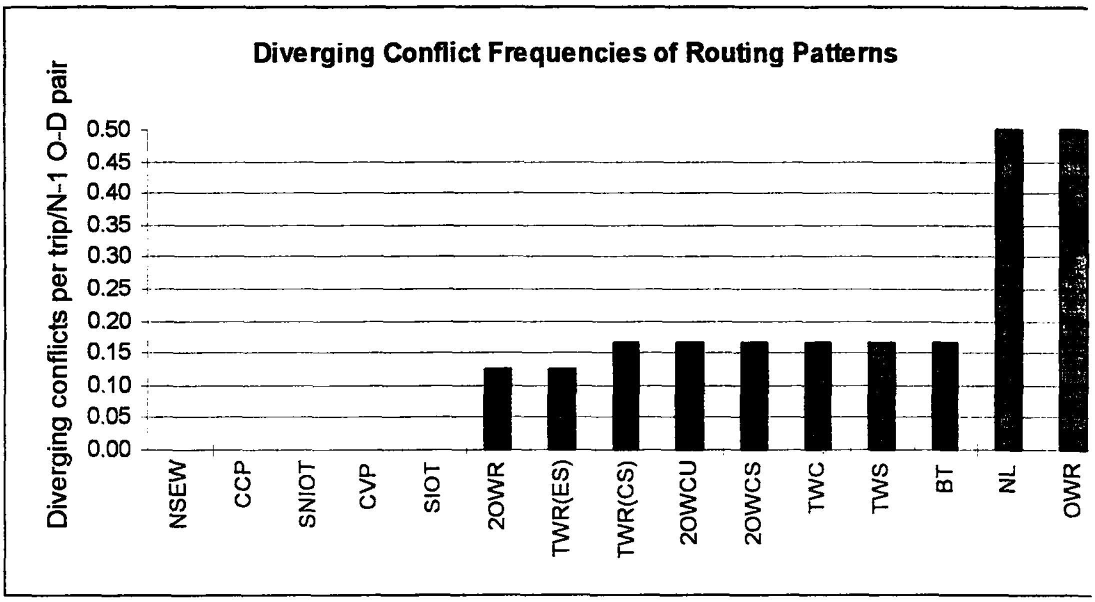


Figure:3.13 Diverging conflict frequencies of routing patterns. (Source: Wright,1988)

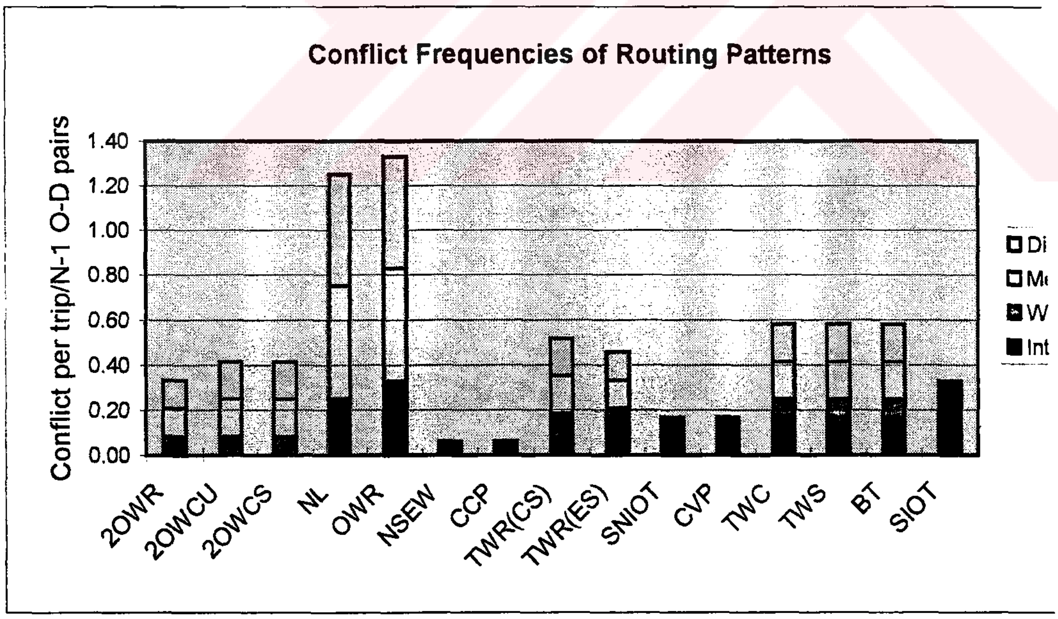


Figure:3.14 Total conflict frequencies of routing patterns. (Source: Wright,1988)

The star systems and convex polygon have high numbers of intersecting conflicts. "Therefore they are less attractive" (Wright 1988) (see Figure:3.10)

> At large number of duplex nodes, two one way rings (2OWR), two one way corridors with uniform alignment or symmetrical alignment (TOWCU,TOWCS), one-way ring (OWR) and nested loops (NL) generate almost zero intersecting conflict per unit trip. However OWR and NL generate high number of total conflicts. Two-one-way rings (20WR), two-one-way corridors-uniform alignment (20WC-UA) and two-one-way corridors-symmetrical alignment (20WCS) generate almost zero intersecting conflicts per unit trip. These patterns are based on similar principle; the duplex nodes are arranged in a single row between two parallel distributors. In addition, total conflict generated in these networks is relatively less than the others. (Wright et all, 1989a) (See, Figure:3.10, 3.11, 3.12, 3.13 and 3.14)

When merging conflicts are given low weighting, "two-one-way rings (2OWR)" performs best (See Figure:3.12,3.13).

The patterns, "two-one-way rings (2OWR), north-south-east-west split (NSEW) and concentric polygon (CP)" have less conflict frequencies compared to others when intersecting conflicts are given high weights; weaving, merging, diverging following these (Wright et all, 1989a).

> Star with interlocking offside turns (SIOT), nested loops (NL) and one way ring (OWR) has high intersecting, weaving, merging and diverging conflict levels per unit trips. If low weights are given to merging and diverging conflicts compared to intersecting conflicts, star (SIOT) performs best. Nested loops (NL) and one way ring (OWR)" perform worse when "merging and high weights are given to merging and diverging conflicts. Whatever weights are given to any conflicts, one way ring (OWR) performs worse (Wright et all, 1989a).

"The dual one-way corridor and dual one-way ring systems generate half the number of path crossings of the best of routing patterns" (Wright et all,1989a). Other things being equal, there would be less congestion and fewer accidents.

"If the total journey distance was taken into account, the convex polygon and two way spine are better than the rest" (Wright et all,1989a).

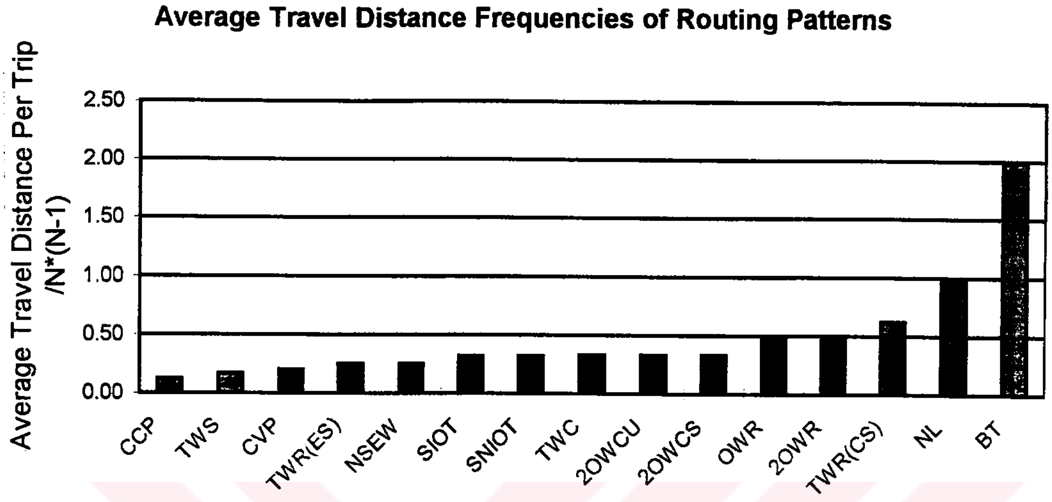


Figure:3.15 Total travel distance frequencies of routing patterns. Source: Wright et all, 1989a)

In this study an interesting result is that, the two way ring is defined as a more efficient circulation system. This system can be manipulated with the relative proportions of traffic going either directions around the ring. That is there are two alternative routes for every trip. If the trips are allocated strictly to the shortest routes, the traffic leaving any one node divides equally in either direction. As they enter the ring, half of crossings can be reduced by forcing more vehicles turn left and half turn right. However the number of crossings can be reduced by forcing more vehicles to turn left than right. If the nodes are arranged outside the ring, this means that the majority will go clockwise. For large number of trips (N) the traffic generated from each node goes clockwise. In engineering terms, this is a counter result; circulation systems are conventionally arranged, so that vehicles travel predominantly counter-clockwise. This means that the vehicles that turn left as they emerge from each node, are subject to large numbers of conflicts with vehicles arriving from the left, and these numbers can be reduced by directing some of them to the opposite direction of flow (Wright et all,1989a:124).

In such an evaluation, if journey times were taken into account, it would be necessary to specify the details of traffic network and the details to use a method of traffic control at junctions. That level of detail is not appropriate for generalised evaluations. Detailed evaluations concerning the traffic network performances are displayed in examples. Since the aim of traffic management is to minimise journey times with less accidents, such a detail concerning conflict numbers allow principal comparisons of alternative networks.

The results offer a strategy to evaluate practical circulation systems. The discussions can be structured on the basis of following performances:

1-The networks composed of one-way streets generally permit routing patterns with fewer conflicts than the networks composed of two way streets (Wright et all,1989a).

2-In a circulation network including a ring road, the best results (according to total conflict and total travel distance) are achieved when traffic origins and destinations are located enclosed within inside of the ring-road (Wright et all,1989a).

3-If the networks are based on a two one-way streets (2OWR or 2OWC) with terminal nodes located between them, the optimum circulation system requires first direction of flow to be reverse of another (Wright et all,1989a).

4-For the two way ring (2OWR) with terminal nodes on the outside of the ring, the conflicts are minimised when half of the trips are routed clockwise and the rest half are routed counter-clockwise (Wright et all,1989a).

5-Other things being equal, at junctions, if turning movements are right turn, then less conflicts might be observed. Therefore, keeping the area wider (large urban blocks with flow channels around) with clockwise flow direction is advised. If the flow channel is within the area served, left turns are inevitable.

At large number of trips the problem might be observed as high accident rates (Wright et all,1989a).

6-The system based on two one way rings (2OWR) or two one way corridors (2OWC) have less conflict and less distance travelled. That is, in a two one way rings system, if one of the flow channels is located outbound of the area served (the area is enclosed by the first ring) and another is located within the area served (encircled around the second ring), both total conflict and total distance travelled are less than other systems. Here keeping the inner ring as small as possible is recommended. Similarly, in two one way corridors, by the way of right turn principle similar advantages could be observed (Wright et all,1989a).

7-1-If the duplex nodes (O-D pairs) are enclosed and/or encircled by flow channels in which the duplexes are indirectly connected to external networks. In these systems, external flows can be prevented. However, in such systems, because of indirect connection between a duplex to external network additional conflict is created on the system. The patterns 2OWCU, 20WCS, NL, 2OWR, NSEW, CCP have potentials to be adapted to such solutions (Wright et all,1989a).

7-2- In some of the patterns the duplex nodes (O-D pairs) are easily accessible from external networks. In such systems direct connection between a duplex to external network does not crate additional conflict on the system. However, isolation objected solutions are not easily adapted to such systems. These patterns are SIOT, TWS, OWR, TWRES, TWRM and BT (Wright et all,1988).

If external network connections are excluded, the networks in the first group generate fewer conflicts compared to second group.

Among all patterns, the north-south east west split (NSEW) and the concentric polygon (CP) generate much smaller number of conflicts than the others. These two have more geometrical structure than the others.

For each of the three cases, road links encircle and/ or enclose some or all of the duplex nodes, so that they can function isolated from wider surrounding networks without any structural modification.

Under consideration of total travel distances, among all patterns, nested loops (NL) generate the greatest total travel distance per unit trip. One-way-ring (OWR) pattern is the second worst pattern.

The concentric polygons (CP) pattern generates the least travel distance per unit trip.

In city centres total travel distance is a factor of travel time and delays. However, at high conflict levels, area wide solutions require increasing carrying capacity of the streets; the higher the total travel distance the higher the carrying capacity will be. That means the accident risk will be lowered, or flow-lock will be prevented.

3.4. Evaluation of Junction Types

Principal differences among three base patterns (the grid, the hexagon and the radiocentric) are based upon configurations. These three intersection types are T, Y and +. In addition, Traffic networks as configurations of base patterns are differentiated with respect to flow diagrams. For instance, even the traffic networks are arranged by similar principles, the grid constitute +, the radiocentric constitute T and the hexagon constitute Y type intersections.

The capacities of intersections are primarly dependent on the ratio of the flows approaching from connected roads (O'Flaherty, 1994:367). According to O'Flaherty (1994:367) the crical gap or acceptable level of traffic stream in any road and maximum acceptable delay time determine junction capacity.

In this part, junctions are compared with respect to capacities and collision severity under the conditions of off-signalisation and signalisation.

Empirical studies shows that, when equal number of vehicles approaching from the roads, following results are observed:

Table:3.1 Junction classification and comparison,. (Source: O'Flaherty, 1994)

JUNCTION CAPACITY		**Junction Type**	
Conditions	+	T	Y
without signalisation	disadvantageous	advantageous	moderate
signalisation	advantageous	moderate	moderate

JUNCTION RISKS		**Junction Type**	
	+	T	Y
collision severity	moderate	advantageous	disadvantageous
sight distance	disadvantageous	moderate	advantageous

These results are taken into account to evaluate distribution of vehicle volumes on junctions, therefore, omparative analysis of base patterns could be clear.

3.5.Practical Performance Evaluation Method

3.5.1.Definition of Evaluation Method

1.Adaptability: The circulation system should be capable of implementation on existing road networks in central areas or in peripheral parts if required; and should run effectively with the arterial roads feeding traffic into and out of the study area.

2.Robustness: The system should be able to adaptable to a wide range of demand conditions; including variations in the relative flows between O-D pairs; it may be required to support alternative routes for dealing with traffic under emergency conditions.

3.Simplicity: Simple circulation systems are easier for drivers to understand. Therefore unnecessary paths are not followed.

4.Compliance: The circulation systems should effectively control routing by channelling drivers into the desired pattern. It should allow the application of many possible circulation schemes.

Speed and pedestrian factors: Speed is a factor of time efficiency, on the other hand it determines safety and accident risks.

3.5.2 Evaluation of Practical Performances of The Networks

The circulation system should be capable of all kinds of trip demand conditions. To test the robustness of alternative networks, a complete uniform O-D matrix is constructed and imposed to the networks, and the performance of the networks are criticised under consideration of any changes in this O-D matrix. That is, in a given spatial interaction environment a network may perform best, however if the trip generation is concentrated on some parts of the network it may not perform as well.

The number of possible shortest paths with respect to travel time is the main factor of flexibility, robustness and compliance, since the number of possible shortest paths determines the number of possible alternative circulation schemes. That is, the more the number of possible routes between an origin and a destination the more flexible, robust and compliant the network is.

In a network consisting of 24 O/D pairs (duplex nodes, or centroids);

If the network is in a uniform grid from first centroid to the last one (the furthest on) 70 possible equal shortest paths exist.

If the network is in a uniform radiocentric form 2 equal shortest paths exist, and equal but longer pairs of paths in a sequence follow them. In this case total number of possible equal shortest paths is 52.

If the network is in a uniform hexagonal form 8 equal shortest paths exist, and equal but longer pairs of paths in a sequence follow them. In this case total number of possible equal shortest paths is 48.

-When uniform (non-weighted) distribution of interbase trips are considered grid pattern performs best, then hexagonal pattern follows it.

-When weighted distribution of interbase trips are considered radio-concentric pattern performs best, then hexagonal pattern follows it.

-When uniform (non-weighted) distribution of round trips considered grid pattern performs best, then the hexagonal pattern follows it.

-When weighted distribution of round trips are considered radio-concentric pattern performs best, then grid pattern follows it

The circulation system should provide potential for implementation, in existing traffic networks in urban centres or peripheral parts.

All street patterns (grid, hexagon or radio-concentric) are not suitable for rearrangements based on principles of alternative circulation systems. Similarly it is hard to formulate a distinct traffic design principle to design street system that fits to these routing patterns.

When grid pattern is accepted as the frame of a network, it is not suitable to arrange a circulation network based on the principles SIOT-SNIOT (star, interlocking or non-interlocking offside turns), OWR (one-way ring), 2OWR (two one-way rings) or TWR (two-way ring). When these configurations of grid pattern are compared to other patterns; average travel distance and average travel time is higher than configurations of radio-concentric and hexagonal pattern. If the concern is adaptation of routing patterns on existing patterns grid pattern is not adaptable for these routing patterns.

When radio-concentric pattern is accepted as the frame of a network, it is not suitable to arrange a circulation network based on the principles of TWC (two way corridor), TWS (two way spine), 2OWC (two one-way corridors) or NL (nested loops). When these configurations of grid pattern are compared to other patterns; average travel distance and average travel time is higher than configurations of grid and hexagonal pattern. If the concern is adaptation of routing patterns on existing patterns radio-concentric pattern is not suitable to be adapted to these routing patterns.

When hexagon pattern is accepted as the frame of a network, it is not suitable to arrange a circulation network based on the principles of TWC (two way corridor), 2OWC (two one-way corridors), NL (nested loops), NSEW (north-south; east-west split) or CCP (concentric polygons). When these configurations of hexagonal pattern are compared to other patterns; average travel distance and average travel time is higher than configurations of radio-concentric and grid pattern. If the concern is adaptation of routing patterns on existing patterns; hexagonal pattern is not suitable to be adapted to these routing patterns.

Among three patterns, the grid is the most adaptable one. That is, when this pattern is used as the frame of traffic network, the network can be arranged to adapt most of the routing patterns. However, it is not suitable to arrange tree type circulation schemes onto this pattern (as a frame). Tree type networks are efficient when the flows are oriented toward weighted destinations, that is network design requires orientation. However, this pattern with its uniformity does not allow orientation.

Simple circulation systems are easy for drivers to understand. It is more practical to form a circulation system on existing network. Traffic managers, in general, only manipulate the circulation by control devices and method that are ways of indirect control of routing pattern rather than direct control. Direct control includes physical arrangements on networks.

The circulation systems should allow traffic managers to adapt control systems. All kind of traffic management strategies may not applied on traffic networks. These strategies affect the performance of the flow quality (level of service) of any given pattern.

Among three network systems (interconnected, semi-connected and tree) interconnected networks are more applicable to many possible circulation schemes.

Among three patterns, grid pattern is more adaptable to many possible circulation schemes.

Speed: When conflict frequencies are considered, network performances are compared with respect to time efficiency and accident risk. On the other hand, if pedestrian and vehicle safety have priority in a particular scheme, the speeds are expected to be lower. In such cases, two methods are used; roads may be designed for higher capacities. In this case, orientation and link configurations do not allow alternative paths. In the second method, road design allows alternative shortest paths, therefore vehicle volumes on particular sections are expected to be low. In such cases, acceptible delay time will not be much, therefore speed reduction, signalisation or similar regulations could be employed.

Pedestrian: there are two types of pedestrian trips; interbase trips and round trips. With respect to routing patterns there are two Additional types; single destination oriented and multi-destination oriented. With respect to distribution of origins single destination oriented pedestrian trips may represent tree type or radial type. However, multi-destination oriented pedestrian trips do not represent certain patterns, such as incidental round trips. For this type of trip grid patterns are advisable since more alternative circulation systems can adapted onto this pattern.

CHAPTER 4

EVALUATION AND INTERPRETATION OF THE ROLE OF TRAFFIC NETWORKS IN CIRCULATION SYSTEMS

4.1 The Definition of The Role of Traffic Network Design in Circulation Systems

In the study, traffic network design is reduced to re-designing the physical arrangement of the streets and buildings in order to cope with better use of vehicles. Traffic design field has two main dimensions of interest; street layout design and street section design; however the second part is meaningless without proposals in the first part. In the first part of the study main determinants of the second part are discussed. Therefore, in this study problem definition is based on the discussions and evaluations about street layout design.

The problem of street layout design is to achieve the efficient circulation of vehicles which refers to the environment integrated with movement and accessibility oriented arrangements of buildings and urban blocks. The objective should be achieved in with a satisfactory standard of environment. Another question is the way to achieve this objective in existing towns and cities with established complex street networks. The problem refers to efficient use of existing layout of streets by rearrangement to adapt appropriate flow diagrams without any interruption to environmental quality. A street layout may allow organisation of infinite traffic networks; however, if a street network is arranged for a certain trip type of circulation system only few appropriate networks can be organised.

In this part many possible circulation networks are discussed to get principal solutions for different sites of cities where many urban exist. In addition within the process of building arrangement and street layout arrangement principal proposals on street layouts can be evaluated.

4.2.Classification Of Circulation Networks

Table 4.1: Circulation network classification

CLASSIFICATION OF NETWORKS

WITH RESPECT TO NETWORK CONFIGURATION	WITH RESPECT TO CIRCULATION SYSTEMS	WITH RESPECT TO MOVEMENT SYSTEMS
GRID	POLYGONS, SPLITS	INTERCONNECTED
RADIO-CENTRIC	CORRIDOR, SPINE	SEMI-CONNECTED
HEXAGONAL	TREE, STAR	TREE

CIRCULATION NETWORKS

Table 4.2: Interconnected networks

INTERCONNECTED SYSTEMS	ROUTING PATTERNS			
CONFIGURATION PATTERNS	Convex Polygons	Concentric Polygons	Two one-way Corridors	Two one way Rings
GRID	Uniform Grid	Grid Polygons	Grid twin Corridors	Grid twin Rings
HEXAGONAL	Uniform Hexagonal	Hexagonal Polygons	Hexagonal twin Corridors	Hexagonal twin Rings
RADIO-CENTRIC	Uniform Radio-centric	Radio-centric Polygons	Radio-centric twin Corridors	Radio-centric twin Rings

Table 4.3: Semi-connected networks-1

SEMI-CONNECTED SYSTEMS	CIRCULATION SYSTEMS		
CONFIGURATION PATTERNS	Two-way Corridors	Two-way Spine	Nested Loops
GRID	Grid Corridors	Grid Spine	Grid Loops
HEXAGONAL	Hexagonal Corridors	Hexagonal Spine	Hexagonal Loops
RADIO-CENTRIC	Radio-centric Corridors	Radio-centric Spine	Radio-centric Loops

Table 4.4: Semi-connected networks-2

SEMI-CONNECTED SYSTEMS	ROUTING PATTERNS	
CONFIGURATION PATTERNS	NS-EW Split	Two way Ring or One way Ring
GRID	Grid Split	Grid Ring
HEXAGONAL	Hexagonal Split	Hexagonal Ring
RADIO-CENTRIC	Radio-centric Split	Radio-centric Ring

Table 4.5: Tree networks

TREE SYSTEMS	ROUTING PATTERNS	
CONFIGURATION PATTERNS	Star (interlocking or non-interlocking offside turns)	Binary Tree
GRID	Grid Star	Grid Tree
HEXAGONAL	Hexagonal Star	Hexagonal Tree
RADIO-CENTRIC	Radio-centric Star	Radio-centric Tree

Table 4.6: Linear networks

LINEAR SYSTEMS	ROUTING PATTERNS	
CONFIGURATION PATTERNS	Two-way Corridors	Two-way Spine
Uniform Linear	Corridor	Spine

4.3.Evaluation of Traffic Networks

Table 4.7: Traffic network evaluation criteria

EVALUATION CRITERIA	EVALUATION METHOD	PERFORMANCES OF NETWORK GROUPS		
Robustness (with respect to Movement Syst.)	Network Assignment (Simplified)	Efficient (distr. of v/c)	Less Efficient (distr. of v/c)	Inefficient (distr.of v/c)
Conflict Generation	Graph-theoretical	Low Conflict Frequencies	Moderate Conflict Frequencies	High Conflict Frequencies
Adaptability, Compliance and Flexibility	Practical Performance	Adaptable Systems	Less Adaptable Systems	Non-Adaptable Systems

4.3.1 Interconnected Networks

These networks represent the most complex group of networks. That is such networks are designed for all kind of movement systems. Since the movement systems are more complex network systems are relatively more complex.

According to Alexander, (1982) people use many centres, for different purposes and service areas overlap in complex ways. Within the concept of individual relations "the city is not a tree" (Alexander,1982). Alexander's definition can be defined to the traffic network which is the frame of city constituted by a network of overlapped trees.

Although Alexander's definitions addresses interconnected systems, such a generalisation based on assumptions of complex urban systems may not be pertinent to less complex systems. That is, the degree of complexity is expected to determine the connectivity level of a network. In most American cities traffic networks are based on interconnected grid systems which refer to high degree of interconnection.

When optimum distribution of road space for an appropriate movement pattern is aimed, unlike interconnected systems, semi-connected systems, tree systems or linear systems might be efficient. In this concept, Alexander's proposals may be inspired from traffic networks of American cities.

Alexander claimed that city regions should be multinucleate, and they should have a whole series of centres for special purposes (Alexander,1982) . His viewpoint represents a land use planning aspect of circulation problems. According to him, people are obliged to follow certain routes because of convergent inward routes oriented to a single centre. Therefore people are obliged to follow congested routes. The solution of congestion is based on a new concept of land use distribution; "proper distribution of contemporary centres" (Alexander,1982).

Contemporary centres refer to complex and dispersed individual relations which reflects to complex networks or interconnected networks. When this approach is applied to certain sites of a city the concern is the centre or its surrounding even a residential area. The viewpoint may be based on distribution of business, commercial and public activities, or distribution of non-residential uses within residences. In both cases the problem definition would be would be the appropriate circulation network.

4.3.1.1.Convex Polygons (CVP)

It is almost impossible to apply this "circulation system" (circulation principle) on base street patterns because of the inefficient design of the urban blocks. That is, excess amount of land would be arranged for road space, rest of the area would be a limited and strictly predetermined building space. When this circulation system is applied to base street patterns three circulation networks may be structured; **the uniform radio-centric, the uniform gridiron and the uniform hexagon**. When this circulation pattern is proposed in a new design, the syntax of urban blocks may be based on grid, hexagon or radio-centric. Junction types and configurations are principally well differentiated.

This circulation principle is more complex, therefore the networks are highly interconnected to allow direct connection to most of destination points for drivers. On the other hand, the radial network is the simplest network among the others. This is a convenient network in central parts of many European cities. The uniform grid is used in many American cities, where rectangular grid form is more convenient. The uniform hexagonal is not a convenient network. Among three networks there are no significant differences with respect to adaptability; none of these three networks can be applied in correct form of "convex polygon" system.

If interbase trips are considered this circulation system performs well, however, in networks many line segments may serve under their capacity (See Appendix). Among three networks, when a great number of trips are destinated in a node, the uniform radial network performs better; since the arterials are directed toward the main junction node. If each node has given equal weight (uniform distribution of interbase trips) the uniform grid network performs better.

If round trips are considered, the uniform grid network performs better. When a uniform distribution of interbase and round trips are considered the uniform hexagon network is preferred (See Appendix).

When through trips are considered neither of these three networks organise any appropriate route for through trips. Therefore interior roads are not segregated from through traffic. However, when inner roads are overloaded, through traffic may follow outer roads. Among three circulation networks uniform radio-centric network is more advantageous. Compared to other circulation systems CVP is more advantageous.

If intersecting conflicts are given high weights this circulation system performs worse (Wright et all, 1989a). Among three networks significant differences can be observed; at low vehicle volumes, if the right of way at Y junctions are well-controlled, the uniform hexagon has less potential of accidents, since at each junction there are just three intersecting points. The uniform radio-centric follows it; some of the junctions are + shaped and right of way is inevitably defined; in practice volume distribution determines right of way. On the other hand in uniform radio-centric network is the central links may be overloaded. Distribution of volumes at central links may result serious levels of congestion, therefore it might not be preferred. In addition at high vehicle volumes, similar problems may be observed. At Y and T type of junctions the signalisation phases are two, or at most three, However at + type of junctions, such as in uniform gridiron, sometimes 4 phased signalisation might be necessary. Therefore, the uniform grid network has disadvantages.

If weaving conflicts are considered, this circulation system generates almost zero conflicts (Wright et all, 1989a). When the configurations of this system are compared; if most of the trips are weighted interbase type, the uniform radio-centric performs better. For round trips or uniform distribution of interbase trips, the uniform grid is preferred, the radio-centric one follows it. When equal distribution of interbase and round trips are considered the uniform grid network is also preferred. Here the hexagon network is the least preferred one (See Appendix). If merging and diverging conflicts are considered, this circulation system generates fewer conflicts compared to others (Wright et all, 1989a). Among three networks, the hexagon is preferred.

If total travel distance is considered, this circulation system is one of the most advantageous patterns (Wright et all, 1989a). Among three networks, the uniform hexagon performs best, because the junction nodes are located on the gravity centres of the links, they provide shortest access to these three links. However in uniform grid and in uniform radio-centric networks the junction nodes are joined to two links. In this respect if weighted interbase trips are considered the uniform radio-centric network, if round trips are dominant, the uniform grid network is preferred.

The CVP is one of the most robust and compliant circulation systems. This circulation system performs well in many movements systems, therefore many circulation management strategies can be applied to these three networks because this circulation system is based on modules (or units). It is hard to make a definite comparison among three networks since they are uniform systems therefore many different flow diagrams can be implemented. However, it can be said that the uniform grid network enable traffic managers to adapt many possible circulation networks. This network can be considered as the most flexible one since its junction configurations can be rearranged, its uniform alignment allow many possible rearrangements.

If any node is dominant, such as a city with a single CBD, the uniform radio-centric network is preferred. If the site is located in city centre where the assessment of trip distribution may not be possible, uniform grid pattern is preferred. In this system inner part of the network is not well separated from vehicle movements, it is not hard to accommodate pedestrian movements. If the site is a residential area with separated nodes the preferred pattern is uniform hexagon. In three cases, the movement systems are expected to change in time. That is these three traffic networks could be proposed for new sites.

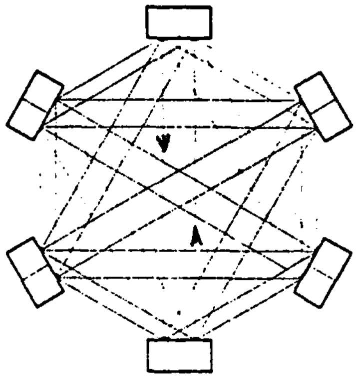
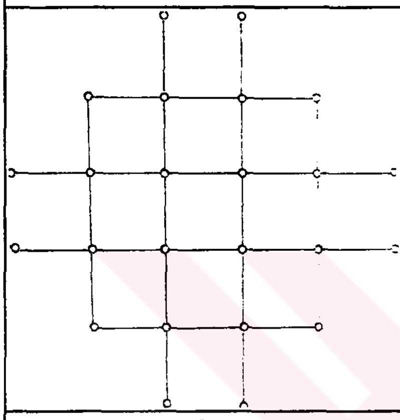
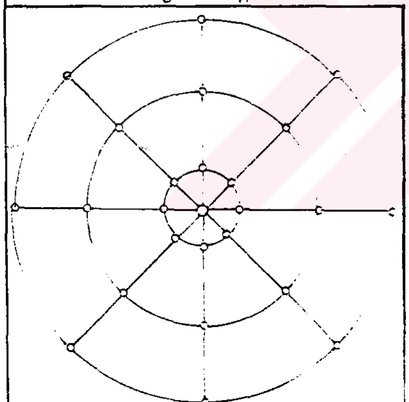
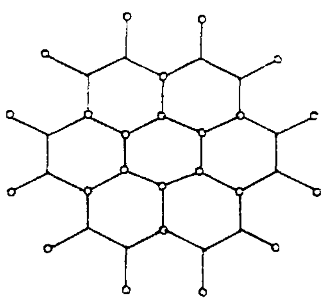
	**3-CVP** :Convex Polygon
	**Convex Grid :** Suitable in mixed land use patterns, central parts or in residential areas surrounding the city centre. If existing pattern is based on grid, convex pattern is adaptable. therefore it is advisable. A variety of alternative circulation schemes can be proposed. In most of American cities, traffic networks are based on this system.
	**Convex Radio-concentric:** Efficient in central parts, density of outer parts are expected to be higher than the central point. However in residential parts it is not advisable. Advisable for existing patterns rather than new ones. Compared to grid fewer circulation schemes can be proposed. In most of European city centres, traffic networks are based on this system.
	**Convex Hexagonal:** Suitable in mixed land use patterns or residential areas rather than central parts. If existing pattern is based on hexagon, convex pattern is adaptable. A variety of alternative circulation schemes can be proposed. Just a few examples are based on this system, such as traffic network of New Delhi.

Figure 4.1. Circulation Network Configurations of CVP

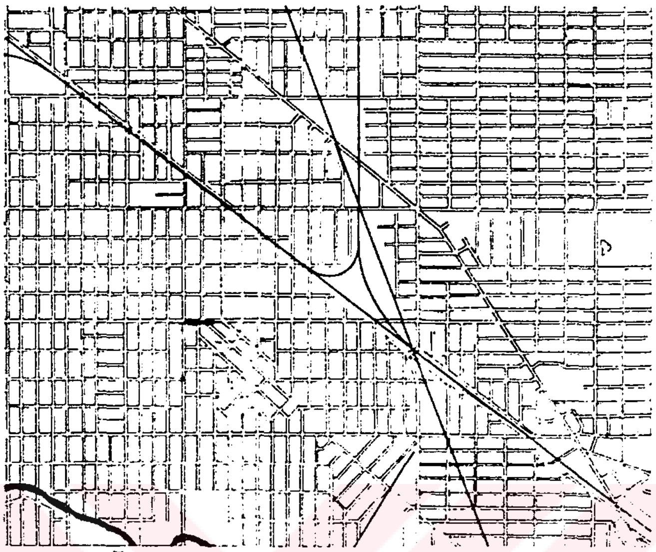


Figure 4.2 An example of CVP: Chicago, USA. Source: Ritter, 1963

4.3.1.2.Concentric Polygons (CCP)

Concentric polygons is an applicable circulation principle; however, when this system is applied to base patterns (grid, hexagonal, and radio-centric) urban blocks may not be designed efficiently. However the location of trip generators may not be similar to the original form. When this circulation system is applied to base patterns three circulation networks may be designed; **the radio-centric polygons, the grid polygons and the**

hexagonal polygons. Junction types and configurations are well differentiated. The circulation system is not a simple pattern compared to other patterns. It is an applicable circulation system. Among three networks radio-centric polygon is the most applicable network, the hexagonal polygon network is the least applicable network. Coventry (Britain) traffic network is based on "concentric polygons" circulation principle (See Figure. 4.4).

When weighted interbase trips are considered, the radio-centric polygon performs better; since the area served by each line segment is more efficient. Then the hexagonal polygon network follows it (See Appendix). If round trips or uniform distribution of interbase trips are considered, the radio-centric polygon performs better (See Appendix), because the distribution of line segments for trip generating nodes is uniform. On the other hand, if alternative routes are required to be accommodated in networks the grid polygons network performs better. When equal distribution of interbase and round trips at low levels or at high levels are considered the radio-centric polygons network is also is preferred. When through trips are considered, these three networks provide alternative routes. This circulation system is one of the most advantageous systems. However the complete network is not used by through traffic, except for outer line segments; inner part of the ring is well separated from through movements.

If intersecting conflicts are given high weights, this circulation system performs at moderate levels (Wright et all, 1989a). Among three networks, when intersecting volumes are at low levels hexagonal polygons performs better. In these networks, the junction configuration allow less conflict per intersection. On the other hand, at high volume levels this network is disadvantageous (See Appendix). If weaving conflicts are considered, this circulation system generate relatively less conflicts (Wright et all, 1989a).

Among three networks, when weaving conflicts are considered, the grid polygons network performs better. Among three networks the hexagonal polygons network is the least advantageous one; since it generates additional weaving conflicts (See Appendix). If merging and diverging conflicts are considered, this circulation system generates less conflicts (Wright et all, 1989a). When interbase and round trips are considered, there are no significant differences between the radio-centric one and the grid one. However, the hexagonal one is least advantageous (See Appendix).

If total travel distance is considered, it is one of the most advantageous circulation systems since the network is highly interconnected. Among three networks, the radio-centric polygons network performs best, since the vehicles follow the shortest routes. Then the grid polygons network follows it (See Appendix).

The CCP is a very robust and well-compliant circulation system. Three network configurations of concentric polygons system are efficient in many movements systems. Therefore, many different circulation management strategies can be implemented on these networks. Among three networks, the grid one performs best (See Appendix).

This circulation system is mostly preferred for traffic networks of central parts in which activities are highly interconnected. In addition, peripheral parts of city centres might have mixed land use, and interconnection may be necessary. In this system inner part of the network is well separated from through movements.

This system may also be preferred to accommodate pedestrian movements. If required, one way solutions can be adapted. Since conflicts per intersection are less than two-way systems, signalisation periods in one way flows are comparatively less. In addition, less interruption may be observed in case of the extension of city centre. If high vehicle volumes are observed in inner ring three dimensional segregation may be inevitable, which may not be desired.

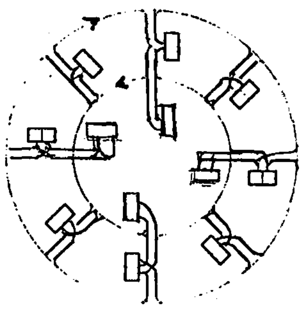
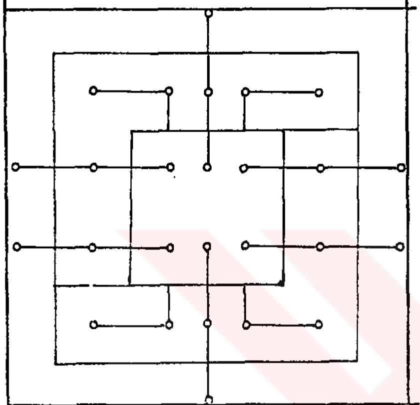
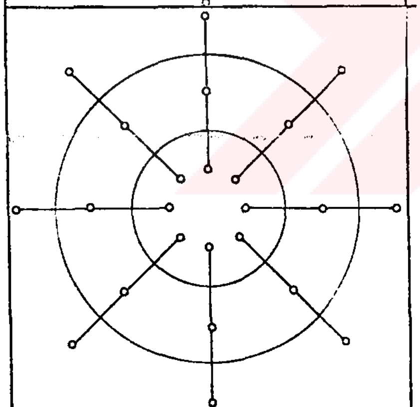
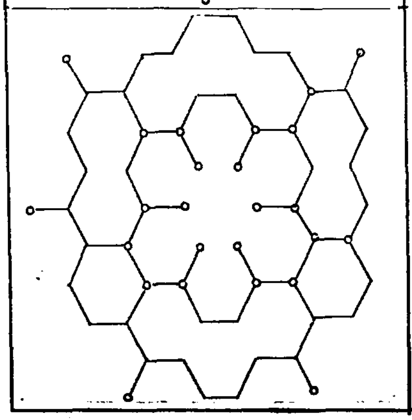
	**14-CP** :Concentric Polygons
	**Grid Polygons :** Suitable in mixed land use patterns or in central parts. This network type is usually applied to existing structures. If existing pattern is based on grid, polygons pattern is adaptable, therefore it is advisable. A variety of alternative circulation schemes can be proposed. Compared to others grid is not preferred.
	**Radio-centric Polygons** Suitable in mixed land use patterns or in central parts. This network type is usually applied to existing structures. If existing pattern is based on radio-centric, this pattern is adaptable. A variety of alternative circulation schemes can be proposed. Compared to others radio-centric is the most advantageous network.
	**Hexagonal Polygons** Suitable in mixed land use patterns or in central parts with low density. This network type is usually applied to existing structures. If existing pattern is based on hexagons, this pattern is adaptable but compared to other patterns it is not efficient. A variety of alternative circulation schemes can be proposed. This network is not commonly used.

Figure 4.3 Circulation Network Configurations of CCP

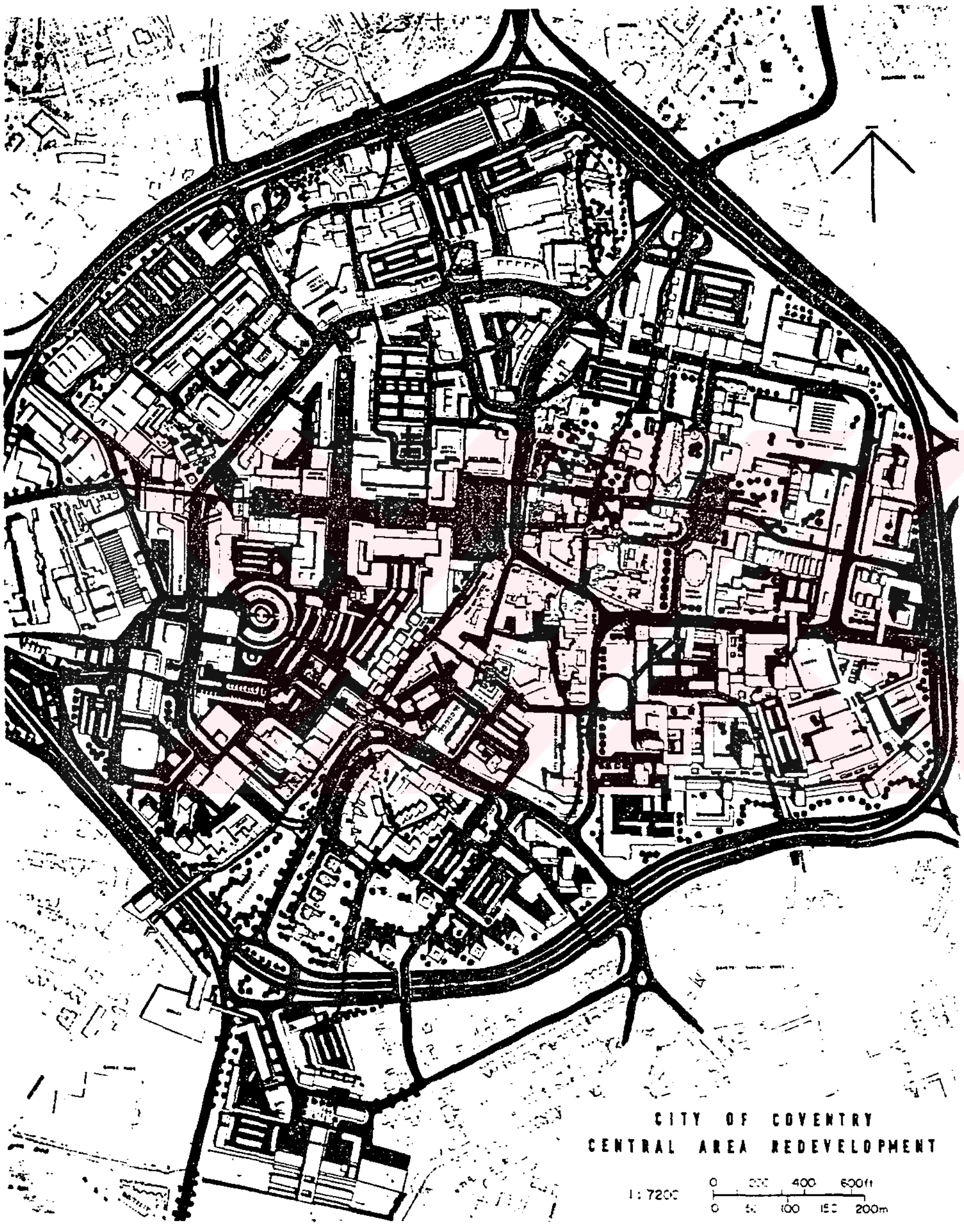


Figure 4.4 An Example of CCP: Coventry, Britain. Source: Ritter, 1963

4.3.1.3.Two One Way Corridors (2OWC)

Two One Way Corridors is one of the most applicable circulation systems. When this circulation system is applied to base patterns, three circulation networks may be designed; **the radio-centric twin corridors, the grid twin corridors and the hexagonal twin corridors**. The configurations are well differentiated. Traffic network of Neu-Winsen, Germany (See Figure.: 4.6) is based on "two one-way corridors" circulation system.

The circulation system is a simple pattern compared to other patterns. On the other hand, the radio-centric twin corridors is the least applicable network among the others. Among three networks, the grid twin corridors is the most adaptable one.

When weighted interbase trips are considered the radio-centric twin corridors system performs better. (See Appendix). Then the grid twin corridors follows it. If round trips or uniform distributed interbase trips are considered, the grid twin corridors system performs better. Then the radio-centric twin corridors follows it. When equal distribution of interbase and round trips are considered the grid twin corridors is preferred (See Appendix).

When through trips are considered, neither of these three networks offer alternative routes, therefore it is disadvantageous. However the complete network may not be used by through movements. These three networks are relatively more advantageous than other networks.

If intersecting conflicts are given high weights this circulation system performs at moderate levels (Wright et all 1989a). Among three networks, when the intersecting volumes are at low levels both the grid and the radio-centric networks perform well. In these networks, one way corridors can easily be arranged. On the other hand, at high volume levels there is no significant difference among radio-centric and the grid networks.(See Appendix).

If weaving conflicts are considered, this pattern generates comparatively less conflicts (Wright et all 1989a). Among three networks, if the great amount of the trips are interbase trips, the radial twin corridors perform better. If round trips are considered, the grid one is preferred, and the radio-centric one follows it. When equal distribution of interbase and round trips are considered the grid twin corridors is preferred. The hexagonal one is not preferred (See Appendix).

If merging and diverging conflicts are considered, this pattern generate relatively less conflicts (Wright et all 1989a). When interbase and round trips are considered the grid twin corridors network is preferred. If total travel distance is considered, 2OWCU circulation system does not perform well. Among three networks, the grid twin corridors performs best, since the corridors follows the shortest route. In this respect if interbase trips are dominant the radio-centric twin corridors network is preferred and if round trips are dominant, the grid twin corridors is preferred.

The 2OWCU is a robust but not well-compliant system. That is, these three networks may be efficient in many movements systems. On the other hand ,many different circulation management strategies can not be implemented on these networks. Because the circulation system itself is based on one way system. Among three networks, the grid twin corridors performs best (See Appendix). In addition the grid one is the most compliant network. This circulation system in general reflects to the systems within or around central parts of cities. However, if this pattern is preferred in new development areas, road space could efficiently be used.

When the "two one way corridors with uniform alignment" system is applied to base patterns three circulation networks may be structured; **the radio-centric twin corridors-2, the grid twin corridors-2 and the hexagonal twin corridors-2**. However there are no morphological difference among the combinations of 2OWCU. There are no significant differences between 2OWCU and 2OWCS with respect to conflict criteria.

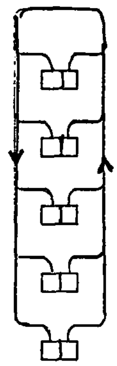
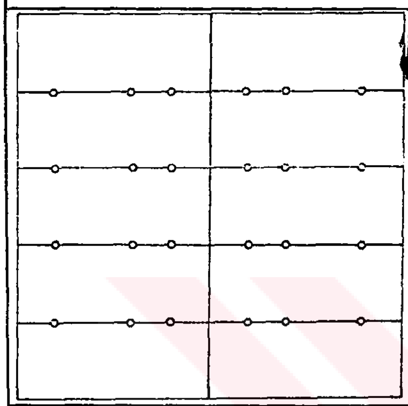
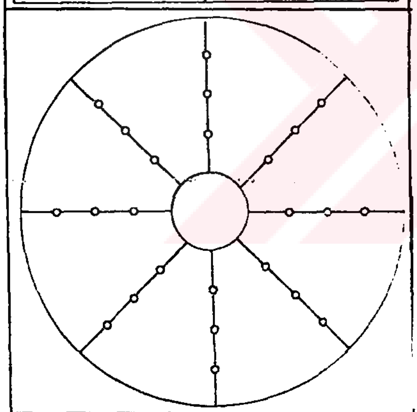
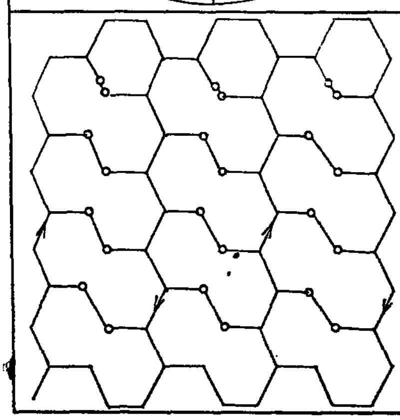
	**6-2OWCU** :Two one-way corridors uniform alignment
	**Grid twin Corridors:** Suitable in mixed land use patterns or in residential areas surrounding the city centre. If existing pattern is based on grid, convex pattern is adaptable. If the activities change in time this network can be rearranged for different networks since a variety of alternative circulation schemes can be proposed..
	**Radio-centric twin Corridors:** Efficient in central parts or in mixed land uses. Advisable for existing patterns rather than new ones. Compared to grid fewer circulation schemes can be proposed.
	**Hexagonal twin Corridors:** Suitable in mixed land use patterns or in residential areas. If existing pattern is based on hexagon, convex pattern is adaptable. If the activities change in time this network can not be rearranged for many different networks. This network in performance does not differ from grid one.

Figure 4.5 Circulation Network Configurations of 20WCS and 20WCU

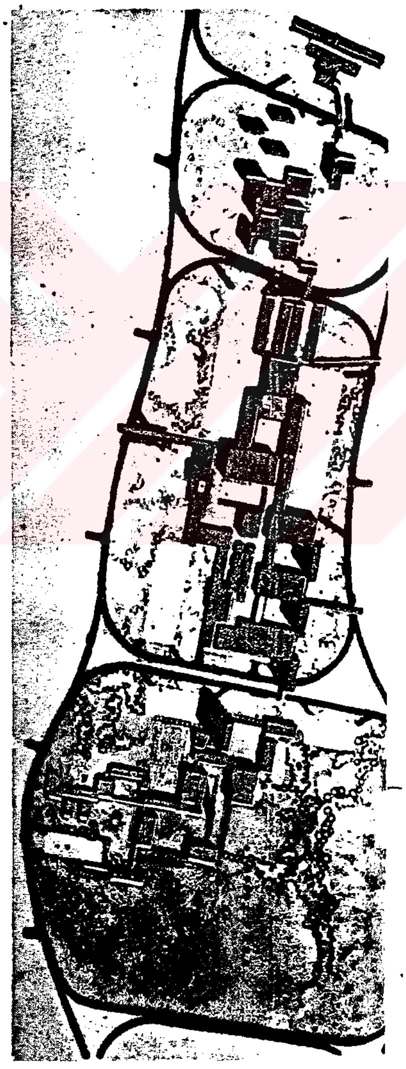


Figure 4.6 An example of 20WCS and 20WCU:Meu-Winsen,Germany.
Source: Ritter,1963.

4.3.1.4.Two One Way Rings (2OWR)

If the street system is not designed in an hierarchical order, this system can be applied. Application onto base patterns does not require severe physical changes, thus urban blocks may be designed efficiently. When this circulation system is applied to base patterns three circulation networks may be designed; **the radio-centric twin rings, the grid twin rings and the hexagonal twin rings**. There are no significant differences among the configurations.

The circulation system is not a very simple pattern compared to other patterns. Although it is an applicable system, the grid twin rings network is the least applicable network among three networks. On the other hand, radio-centric twin rings network is the most adaptable and practical network.

When interbase trips are considered the radio-centric twin rings network performs better (See Appendix). Then the hexagonal twin corridors network follows it. If round trips are considered, the grid twin corridors performs better. Because the distribution of trip generating nodes may be uniform, and alternative routes can be added to the network. When uniform distribution of interbase and round trips at low volumes are considered the uniform hexagonal twin rings network is preferred. When equal distribution of interbase and round trips at high levels of volumes are considered, the grid twin rings is preferred. When through trips are considered, these three networks may offer alternative routes. At entrance and exit points of outer ring, through movements generate intersecting conflicts. However, the whole network may not be effected, inner parts of the ring are well separated from through movements.

When intersecting conflicts are given high weights this circulation system performs best among all (Wright at all, 1989a). Among three networks, when intersecting volumes are at low levels the grid and the radio-centric networks perform well. In these networks, the junctions are T shaped, that is the right of way is well defined. On the other hand, at high volume levels there is no significant difference among three networks since signalisation periods are expected to be similar. If weaving conflicts are considered, this pattern generates relatively less conflicts (Wright et all, 1989a). Among three networks, when weaving conflicts are considered, and if the great amount of the trips are interbase trips, the radial twin rings network performs better. If round trips are considered, the grid one is preferred, and the hexagonal one follows it. When balanced distribution of interbase and round trips are considered the grid twin corridors network is preferred. If merging and diverging conflicts are considered, this pattern generates conflicts at moderate levels. When interbase and round trips are considered the hexagonal twin rings is preferred.

For the total travel distance, 2OWR circulation system does not perform well (Wright et all). Among three networks, the grid twin corridors performs best, since the corridors follow the shortest route. In this respect if interbase trips are dominant the radio-centric twin rings network, if round trips are dominant, the hexagonal twin rings network is preferred.

The 2OWR is a robust but not well-compliant circulation system, because the circulation system itself is based on one way system. Among three networks, the grid twin corridors network performs best within different movement systems and possible circulation management strategies. This circulation system is mostly preferred in central parts; to minimise conflicts at intersections and to accommodate high numbers of vehicles in short time periods, uniform distribution of vehicles on all parts of the network is objected. Therefore, total travel distance is more than other circulation systems. In addition, one way streets may be arranged if street widening is almost impossible.

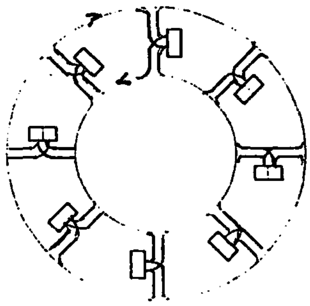
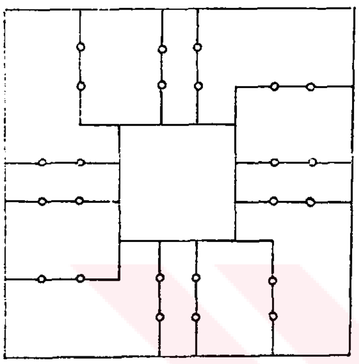
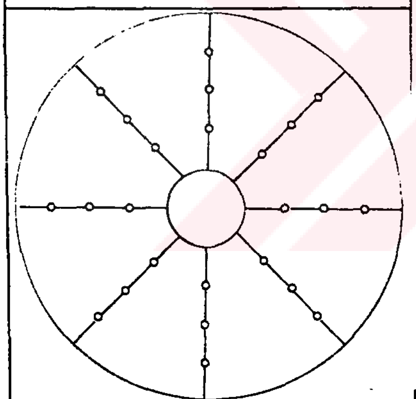
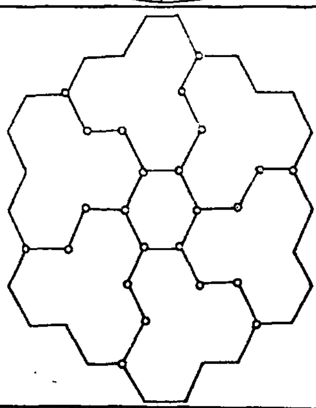
	**10-2OWR** :Two one way rings
	**Grid twin Rings :** Suitable in mixed land use patterns, or central parts. If existing pattern is based on grid, convex pattern is adaptable. Pedestrian circulation schemes can be adapted easily. A variety of alternative circulation schemes can be proposed.
	**Radio-centric twin Rings:** Suitable in mixed land use patterns, or central parts. If existing pattern is based on radio-centric, convex pattern is one of the most suitable circulation schemes. Pedestrian circulation schemes can be adapted easily.. Among three patterns radio-centric pattern is the most adaptable and efficient one.
	**Hexagonal twin Rings:** Suitable in mixed land use patterns. If existing pattern is based on hexagonal, convex pattern is not an efficient circulation scheme. Pedestrian circulation schemes can be adapted easily. Among three patterns hexagonal is the least efficient one

Figure 4.7 Circulation Network Configurations of 2OWR.

4.3.2.Semi-Connected Networks

Semi-connected networks were manifested when pedestrian circulation networks came as a design principle in urban design agenda after 1930's (Ritter 1963). These networks aim balanced distribution of vehicle and pedestrian circulation paths in urban areas.

4.3.2.1.Two Way Corridors (TWC)

Two Way Corridors system is one of the most applicable circulation systems. When this principle is applied to base patterns three circulation networks may be designed; **the radio-centric corridor, the grid corridor and the hexagonal corridor**. The configurations are not extremely differentiated. The circulation principle is a relatively simple system. The grid corridors network is the most applicable one. On the other hand, the radio-centric corridor network is the least applicable network among the others.

If interbase trips are considered, the grid corridors network performs better. This advantage arise from orientation of 0-D pairs on links. Then the hexagonal corridor follows it (See Appendix).

If round trips are considered, the grid corridor performs better (See Appendix). In this network travelled distance is less. Then the hexagonal corridor follows it. In hexagonal network the load of main corridors are more than the average of other two (See Appendix).

When balanced distribution of interbase and round trips considered, the grid corridors network is preferred. Then the hexagonal one follows it (See Appendix). When through trips are considered, these three networks do not allow alternative routes; main corridors are inevitably used by through trips. The grid corridor is the most advantageous network. The radio-centric one is not preferred.

If intersecting conflicts are given high weights this circulation system is one of the most disadvantageous systems (Wright et all, 1989a). When low vehicle volumes are considered, significant differences can not be observed among three networks.

If weaving conflicts are considered, this circulation system generates more conflicts (Wright, et all, 1989a). When the configurations of this pattern are compared; when weaving conflicts are considered, and if the great part of the trips are interbase trips, the grid corridor performs better. If round trips are considered, the grid corridor is also preferred. When uniform distribution of interbase and round trips are considered, the hexagonal network is preferred, since the weaving distance is relatively more than the others.

If merging and diverging conflicts are considered, this circulation system generate comparatively more conflicts (Wright, et all, 1989a).

For the total travel distance, the grid corridor performs best among three networks, because the main corridor follows the shortest route. In this respect if interbase trips are the dominant the grid corridors network is preferred, because of the orientation. If round trips are dominant, or if the equal distribution of interbase and round trips are considered the grid corridor is preferred.

The TWC is one of the least robust and least compliant circulation systems. In general this circulation system is used in low dense city centres or residential parts where any barriers exist. If existing network is arranged in a hierarchical manner, it is not hard to adapt this pattern. Main difference among three networks is based on geographical conditions of the sites.

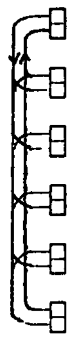
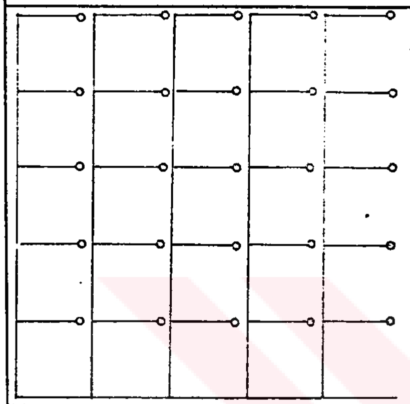
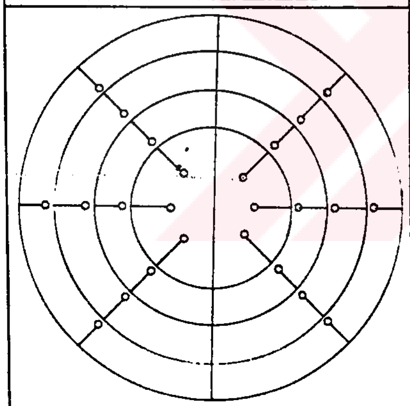
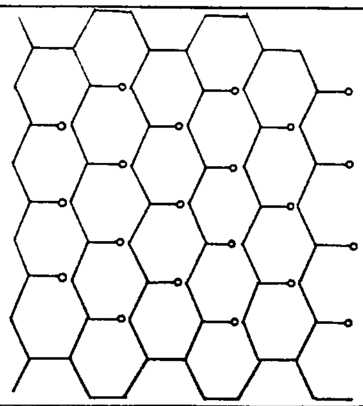
	**4-TWC** :Two way corridor
	**Grid Corridors:** Suitable in residential areas. When land use is mixed and separation of movement channels are needed to be segregated this network type is advised. Secondary links can be used by vehicles and pedestrian. If existing pattern is based on grid this circulation principle can be easily adapted. Woonerf example is based on this principle.
	**Radio-centric Corridors:** Suitable in residential areas surrounding city centre. Compared to other patterns the radio-centric pattern is the least efficient one. If existing pattern is based on radio-centric and if residences are required to be isolated from other uses this circulation principle can be adapted.
	**Hexagonal Corridors:** Suitable in residential areas. This network does not differ from the grid one with respect to performance; it is commonly used in when topography requires. If existing pattern is based on hexagonal this circulation principle can be easily adapted. In some of suburban developments traffic networks are based on this principle.

Figure 4.8 Circulation Network Configurations of TWC

Figure 4.9 An example of Circulation Network Configurations of TWC: Cumbernauld, Glasgoe. Source: Ritter, 1963.

4.3.2.2.Two Way Spine (TWS)

Two Way Spine is one of the most applicable circulation. When this circulation system is applied to base patterns, three circulation networks may be designed; **the radio-centric spine, the grid spine and the hexagonal spine**. Junction types and configurations have significant differences.

The circulation system is a simple pattern compared to other patterns, therefore the networks are also simple. On the other hand, the radio-centric spine is the least applicable network among the others. Among three networks the grid spine is the most adaptable network in built areas. Whereas the hexagonal spine can be applied on various geographical sites.

If interbase trips are considered the hexagonal spine performs better, the grid spine follows it (See Appendix). If round trips are considered, the grid spine performs better, direct connection between links are possible. Then the hexagonal spine follows it. When balanced distribution of interbase and round trips at low volumes are considered, the hexagonal spine network is preferred. When a uniform distribution of interbase and round trips at high volumes are considered the grid spine is preferred (See Appendix).

When, through trips are considered, these three networks do not offer alternative routes, main spine serve through trips. The radio-centric spine is the most advantageous network. The other two are not preferred.

If intersecting conflicts are given high weights, this circulation system performs worse (Wright,1989a). Among three networks the hexagonal spine performs best. The grid spine and the radio-centric spine are not preferred. In these networks, the junctions are + shaped, that is the right of way is well defined but accident risk is more; number of intersecting conflicts are at more than 8 even 16. On the other hand, in hexagonal spine at Y type junctions right of way is not well defined, therefore most of the intersecting conflicts may be observed in a form of weaving conflicts.

If weaving conflicts are considered, this pattern generates more conflicts (Wright,1989a).

This circulation system generates more conflicts than the average. If merging and diverging conflicts are considered, similar results are observed among three networks. For the total travel distance, radio-centric spine performs worst. Then the hexagonal spine follows it. Because, the spine follows an indirect route to join the links. In this respect both for interbase trips and for round trips, the grid spine network is preferred.

The TWS is one of the least robust and compliant circulation systems. Among three networks, the grid spine performs best within different movement systems and possible circulation management strategies. Because, this network enables different junction and link configurations.

This circulation system is convenient in low dense city centres or residential parts. There is predetermined street hierarchy, therefore if existing network is arranged in a hierarchical manner, it is not hard to adapt this pattern. Main difference among three networks is based on geographical conditions of the sites.

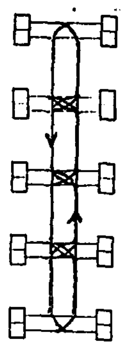
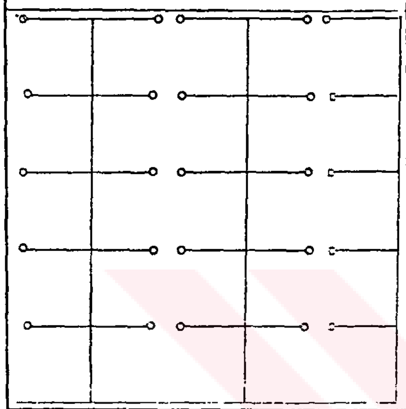
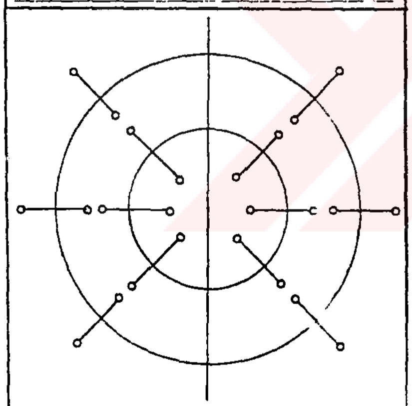
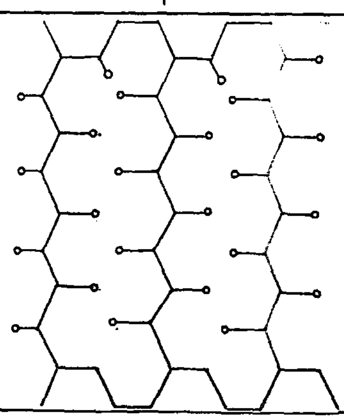
	**5-TWS** :Two way spine
	**Grid Spine** Suitable in residential areas. When land use is mixed and separation of movement channels are needed to be segregated this network type is advised. If existing pattern is based on grid this circulation principle can be easily adapted. With respect to performance, compared to radio-centric and hexagonal grid is the most advantageous pattern
	**Radio-centric Spine**: Suitable in residential areas surrounding city centre. Compared to other patterns the radio-centric pattern is the least efficient one. If existing pattern is based on radio-centric and if residences are required to be isolated from other uses this circulation principle can be adapted. Compared to radio-centric corridors it is more advantageous.
	**Hexagonal Spine:** Suitable in residential areas. This network does not differ from the grid one with respect to performance; it is commonly used in when topography requires. If existing pattern is based on hexagonal this circulation principle can be easily adapted. In most suburban developments traffic networks are based on this principle.

Figure 4.10 Circulation Network Configurations of TWS

Figure 4.11 An example of Circulation Network Configurations of TWS: Sabende, Guinea, Africa. Source: Ritter, 1963.

4.3.2.3.Nested Loops (NL)

Nested Loops is one of the most applicable and convenient circulation systems. When this circulation system is applied to base patterns, three circulation networks may be designed; **the radio-centric loops, the grid loops and the hexagonal loops**. The configurations are not well differentiated.

The circulation system is a simple system compared to others. The hexagonal loops system is the least applicable network among the others. Among three networks the grid loops network is the most adaptable and practical network.

If interbase trips are considered, the radio-centric loops performs better (See Appendix). Then the grid loop follows it. If round trips are considered, the grid loops network performs better. Then the radio-centric one follows it. When a uniform distribution of interbase and round trips at low levels of volumes are considered, there is no significant difference among these two. When distribution of interbase and round trips is are balanced, the radio-centric loops network is preferred since this pattern provides a circulatory movement without direction changes.

When through trips are considered, the radio-centric loops is the most advantageous network. In this network outer links provide alternative routes for through movements.

If intersecting conflicts are given high weights, this circulation system performs well (Wright et all, 1989a). There are no significant differences among three networks.

If weaving conflicts are considered, this pattern generate relatively much more conflicts (Wright et all, 1989a). There are no significant differences among three networks.

If merging and diverging conflicts are considered, this pattern generate relatively much more conflicts (Wright et all, 1989a). There are no significant differences among three networks.

For total travel distance, NL circulation system does not perform well; It is one of the worst circulation systems (Wright et all, 1989a). If interbase trips are dominant the radio-centric loops network, if round trips are dominant, the grid loops network, and in the case equal distribution of round trips and interbase trips the grid one or the hexagonal loops networks are preferred.

The NL is neither a robust nor compliant circulation systems. In this circulation system the travel distance is much, therefore it is not preferred. Among three networks, the grid loops network performs better within different movement systems and possible circulation management strategies.

This circulation system is usually adapted in pedestrian oriented central parts or in traffic calming areas. In addition grid loop network is convenient in residential area designs. A partial hierarchy is observed in examples.

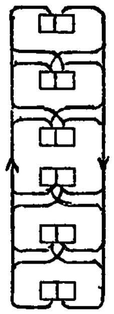
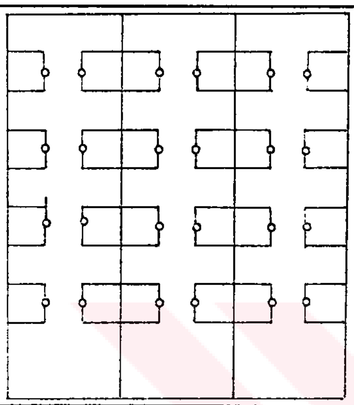
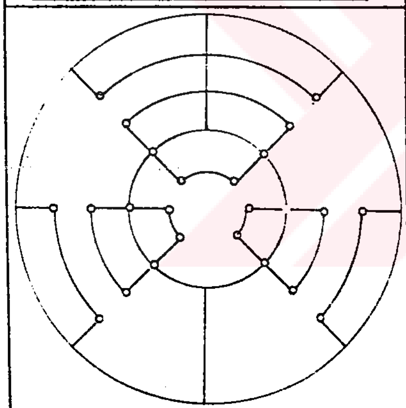
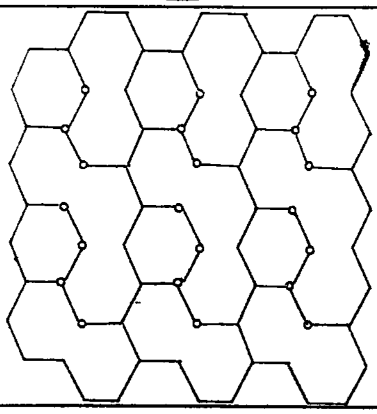
	**8-NL** :Nested loops
	**Grid Loops:** Suitable in residential areas. If existing pattern is based on grid this circulation principle can be easily adapted. In residential areas surrounding city centres networks are rearranged for this principle. In some suburban developments traffic networks are based on this principle.
	**Radio-centric loops:** Suitable in residential areas. If existing pattern is based on radio-centric this circulation principle can not be adapted easily. In residential areas surrounding city centres networks are rearranged for this principle. This network type is not commonly used.
	**Hexagonal Loops:** Suitable in residential areas. If existing pattern is based on hexagonal this circulation principle can not be adapted easily. Only in a few designs traffic networks are based on this principle.

Figure 4.12 Circulation Network Configurations of NL

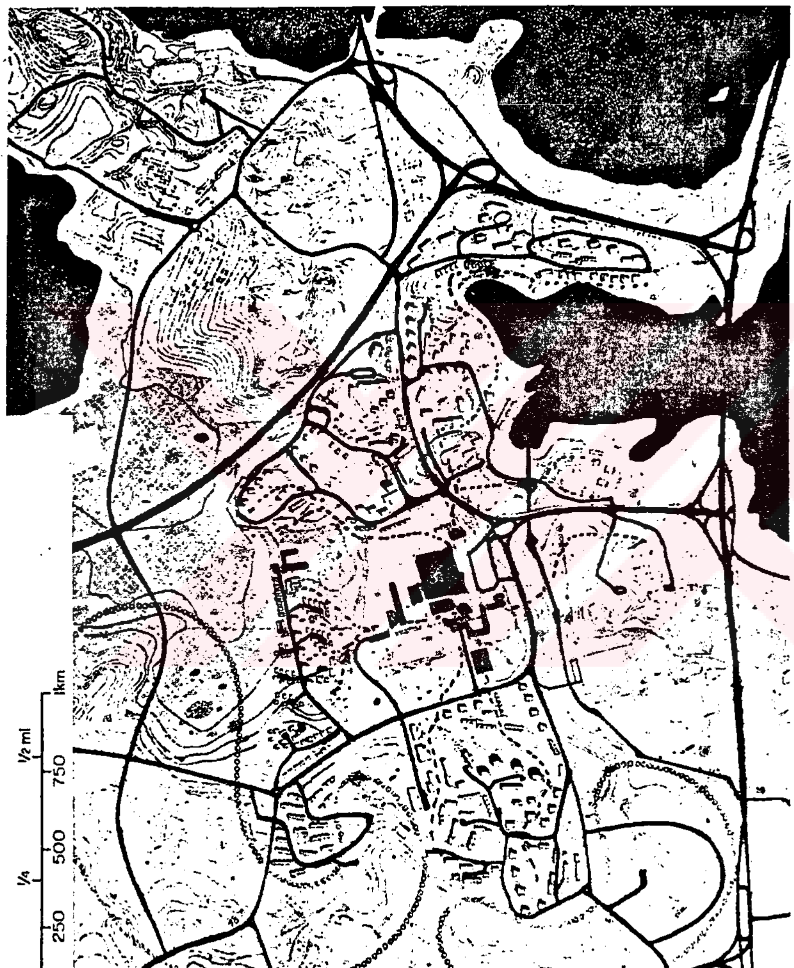


Figure 4.13 An example of Circulation Network Configurations of NL. **Source:** Ritter, 1963.

4.3.2.4.North-South East-West Split (NSEW)

North-South East-West Split is not a perfectly applicable circulation system. In build up areas, application onto street patterns does not require significant physical changes. Therefore urban blocks may be designed efficiently. However the location of line segments among trip generators may not be completely possible. When this circulation system is applied to base patterns, three circulation networks may be designed; **the radio-centric split, the grid split and the hexagonal split**. The configurations are well differentiated.

The circulation system is a simple system compared to others and it is still an applicable circulation system. The radio-centric split network is the most applicable and the hexagonal split network is the least applicable network among the others.

When interbase trips are considered the radio-centric split performs better; since the area served by each line segment is more efficient (See Appedix). Then the hexagonal split network follows it. For round trips, the radio-centric split performs better, because the distribution of line segments for trip generating nodes is uniform. On the other hand if alternative flows are required to be accommodated the grid split performs better; alternative routes can be adapted to the network. When distribution of interbase and round trips is uniform the radio-centric split is also is preferred.

When through trips are considered, these three networks may offer alternative routes, however an interruption may be possible. Both at entrance and exit points, through movements generate mostly merging and diverging conflicts. However, the complete network is not disturbed except the outer line segments; inner part of the ring is well separated from through movements.

If intersecting conflicts are given high weights, this circulation system performs at moderate levels (Wright et all, 1989a).

If weaving conflicts are considered, this pattern generates relatively less conflicts (Wright et all, 1989a).

For total travel distance, it performs better than most of the circulation systems (Wright et all, 1989a). Among three networks, the radio-centric split performs best.

The NSEW is a robust and well-compliant circulation system. Among three networks, the radio-centric split performs best.

This circulation system is mostly preferred in central; the inner part is well separated from through movements, mostly designed to accommodate pedestrian and rail public transit. If required, one way solutions can be adapted. In addition, if extension of city centre is aimed, an interruption may be observed. If the intermediate ring is obliged to high volumes the perpendicular line segments allow extension of centre, which is not a desired case.

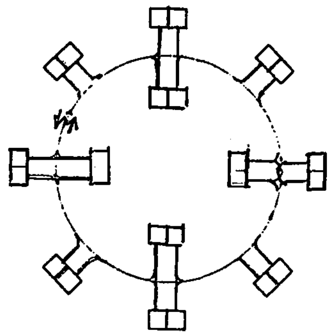
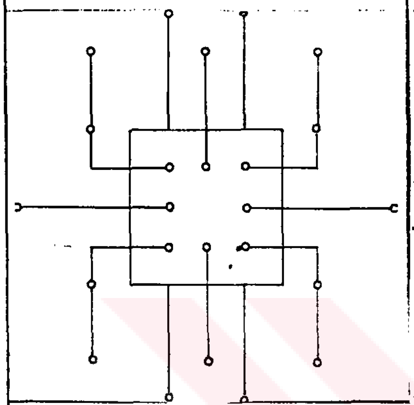
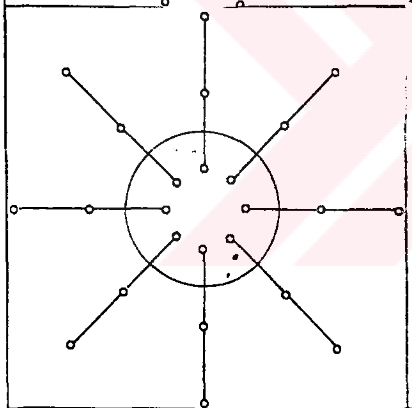
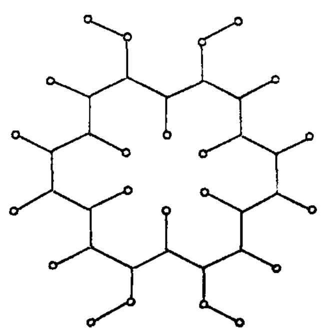
	**13-NSEW:** North South- East West Split
	**Grid Split:** Suitable in mixed land use patterns, or central parts. If existing pattern is based on grid, split system is adaptable. Pedestrian circulation schemes can be adapted easily. In this scheme the centre is assumed to be based on pedestrian movement.
	**Radio-centric Split:** Suitable in mixed land use patterns, or central parts. If existing pattern is based on radio-centric, split system is one of the most adaptable systems. Pedestrian circulation schemes can be adapted easily. A variety of alternative circulation schemes can be proposed. In this scheme the centre is assumed to be based on pedestrian movement.
	**Hexagonal Split:** Suitable in mixed land use patterns, or central parts. If existing pattern is based on hexagonal, split system is not well adaptable. Among three street patterns hexagonal is the least adaptable one. Pedestrian circulation schemes can be adapted easily. In this scheme the centre is assumed to be based on pedestrian movement.

Figure 4.14 Circulation Network Configurations of NSEW

4.3.2.5.Two Way Ring, One Way Ring (TWR-OWR)

It is an applicable circulation system, since the street layouts can be arranged without structural changes. When this circulation system is applied to base patterns three circulation networks may be designed; **the radio-centric ring, the grid ring and the hexagonal ring**. Junction types and configurations are not well differentiated among these three.

The circulation system is a simple pattern, therefore the networks are also simple and allow drivers to follow easily even though it is a one way solution. The radio-centric ring is the most applicable and convenient one. Then the hexagonal ring follows it. The grid ring is the least applicable network among the networks.

If interbase trips are considered, OWR circulation system is a well performing circulation system. This pattern is mostly used in central parts of cities where pedestrian zones and public transport lines are integrated. Among the three networks, the radio-centric ring performs better than the other two (See Appendix).

For round trips, OWR circulation system is not a well performing circulation system since the streets are not fully interconnected. Neither of three networks can accommodate round trips efficiently (See Appendix).

When through trips are considered, OWR is an advantageous circulation system.

When intersecting conflicts are given high weights, this circulation system performs well (Wright et all, 1989a). If through movements are excluded almost zero intersecting conflicts are generated.

If weaving conflicts are considered, this circulation system generates relatively much more conflicts (Wright et all, 1989a).

If merging and diverging conflicts are considered, this pattern generates relatively much more conflicts (Wright et all, 1989a).

For total travel distance, OWR circulation system does not perform well; it is one of the worst circulation systems (Wright et all, 1989a). Among the three networks, the radio-centric ring performs best. In this respect if, interbase trips are the dominant the radio-centric ring network, if round trips are dominant radio-centric ring is also preferred.

The OWR is neither a robust nor a well-compliant circulation system. Because the circulation system itself is based on one way system. In addition in this circulation system the travel distance is much more than the others. Among three networks, the radio-centric ring is preferred.

Two way ring is also an applicable circulation system. When this circulation system is applied to base patterns, possible circulation networks are similar to the configurations of OWR except for the outer ring; **the radio-centric ring, the grid ring and the hexagonal ring**. This circulation system is not clearly differentiated from the OWR with respect to performance criteria. When intersecting conflicts are considered, OWR performs better; when weaving, merging and diverging conflicts are considered, TWRES performs better (Wright et all, 1989a). When total travelled distance is considered, TWRES is also more advantageous (Wright et all, 1989a). This circulation system is not different from the TWRES; circulation networks are similar to the configurations of OWR and TWRES except for the route choice on the outer ring; here half of the flows are clockwise and half of the flows are counter-clockwise (Wright et all, 1989a).

The circulation networks are similar to the configurations of OWR and TWRES **radio-centric ring, the grid ring and the hexagonal ring**. This circulation system is not clearly differentiated from the TWRES with respect to performance criteria except for total travelled distance; TWRCS is also more advantageous.

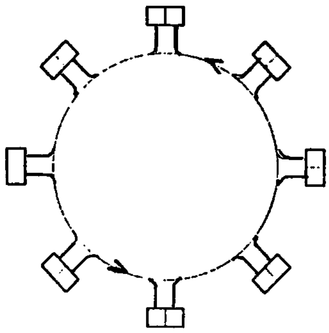
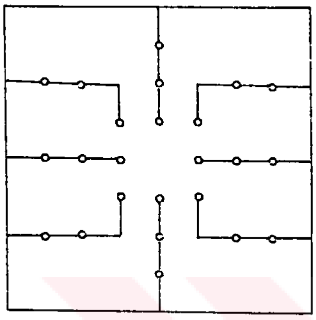
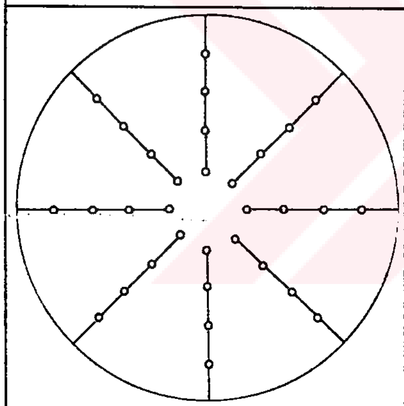
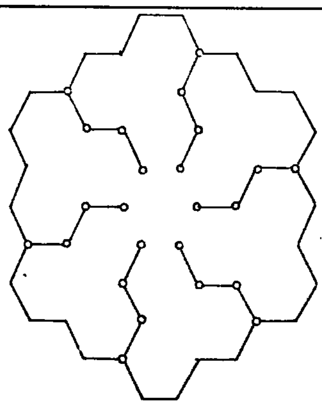
	**9-OWR** :One way ring
	**Grid Ring:** Suitable in central parts where a public transport centre and pedestrian zone are arranged. If existing pattern is based grid, rind system is suitable to apply. Pedestrian circulation schemes can be adapted easily. Among three street patterns there are no significant differences except for orientation.
	**Radio-centric Ring:** Suitable in or central parts where a public transport centre and pedestrian zone are arranged. If existing pattern is based radio-centric, ring system one of the most adaptable systems. Pedestrian circulation schemes can be adapted easily. Among three patterns radio-centric pattern is the most adaptable and efficient one.
	**Hexagonal Ring:** Suitable in or central parts where a public transport centre and pedestrian zone are arranged. If existing pattern is based on hexagonal, ring system is adaptable. Pedestrian circulation schemes can be adapted easily.

Figure 4.15 Circulation Network Configurations of OWR, TWRES and TWRMCS

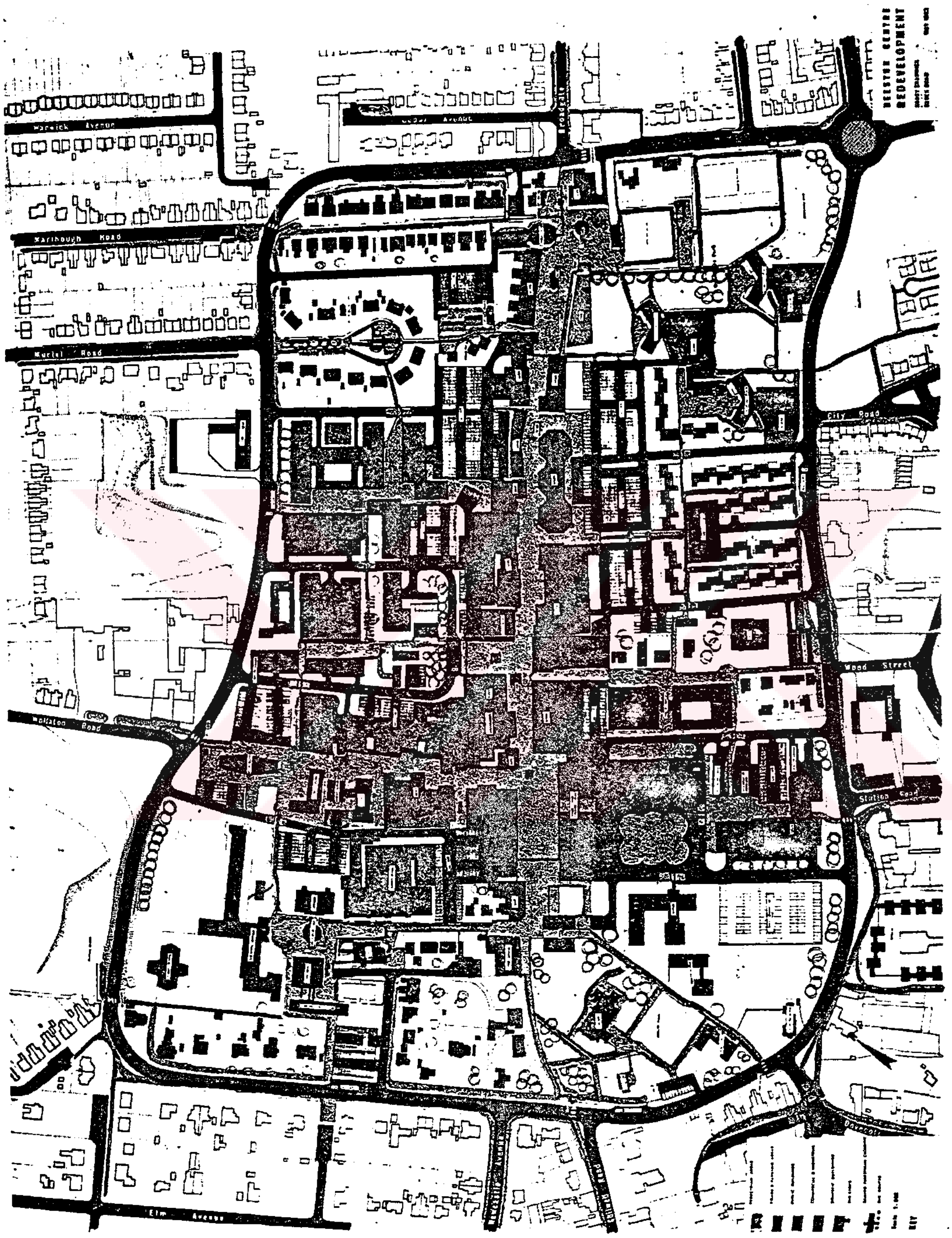


Figure 4.16 An example of Configurations of OWR. TWRES and TWRMCS.
Source: Ritter, 1963.

4.3.3.Tree System Networks

4.3.3.1.Star Interlocking or non-Interlocking Offside Turns (SIOT-SNIOT):

When this circulation system is applied to base patterns, three circulation networks are structured; **the radial star, the grid star and the hexagonal star**. For all networks junction configurations does not have significant differences. The circulation system is one of the simplest patterns. The circulation networks are in general observed in Medieval European cities.

When the volume of trips are at low levels and centrally oriented, such as in a small city centre, this circulation system can be applied. The radial is the simplest network among the others. Compared to the others, the radial is most suitable network to be adapted to this circulation system. Direction of each arterial to the main junction node, and the efficient distribution of trip generators on each arterial enable radial network to perform better than others. When interbase trips are considered, there are no significant differences among the three networks. For round trips non of these three networks are preferred. When through trips are considered, neither of them are preferred.

If intersecting conflicts are given high weights, this circulation system performs worst among fifteen circulation systems (Wright et all, 1989a). Among three circulation networks there are no significant differences. If weaving conflicts are considered, this pattern generate fewer conflicts compared to others (Wright et all, 1989a). If merging and diverging conflicts are considered, similar conditions are observed (Wright et all, 1989a). The less the leg numbers the easier to merge or diverge. Therefore radio-centric star is preferred.

For total travelled distance, this circulation system sits on moderate levels (Wright, et all, 1989a).

SIOT is not a robust and compliant circulation system.

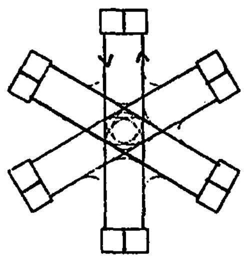
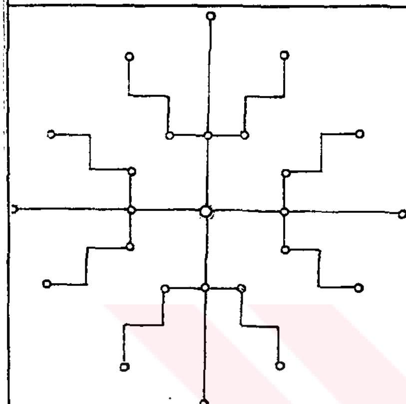
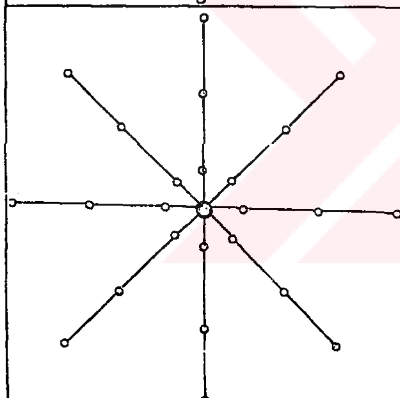
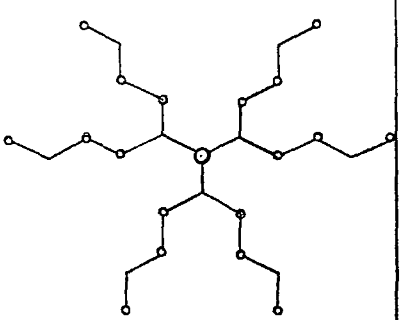
	**1-SIOT:Star, interlocking offside turns**
	**Grid Star:** Suitable for neighbourhoods and small town networks. When land use is mixed and this network type is also advisable. If existing pattern is based on grid this circulation principle can not be well adapted. It is suitable to organise a pedestrian circulation scheme.
	**Radio-centric Star:** Among three street patterns the radio-centric one is the most adaptable one. Suitable for neighbourhoods and small town networks. When land use is mixed and this network type is also advisable. It is suitable to organise a pedestrian circulation scheme.
	**Hexagonal Star:** Suitable for neighbourhoods and small town networks. When land use is mixed and this network type is also advisable. It is suitable to organise a pedestrian circulation scheme. If existing pattern is based on hexagonal this circulation principle can be adapted easily.

Figure 4.17 Circulation Network Configurations of SIOT and SNIOT

4.3.3.2.Binary Tree (BT)

Binary Tree is not a completely applicable circulation system. Since an extreme hierarchical arrangement is required, application onto base patterns may require severe physical changes such as street widening or speed arrangement. However, urban block designs may be very flexible.

When this circulation system is applied to base patterns, three circulation networks may be designed; **the radio-centric tree, the grid tree and the hexagonal tree**. Junction types and configurations are not clearly differentiated. The circulation system is not a very simple pattern compared to other patterns. The radio-centric tree is the least applicable and the hexagonal tree is the most applicable network. If orientation of line segments are considered, hexagonal tree is the most advantageous network

This pattern is commonly arranged to serve especially for interbase trips. When interbase trips are considered, the hexagonal tree performs better; since the area served by each line segment is more efficient. Then the grid tree network follows it (See Appendix).

For round trips, the hexagonal tree also performs better (See Appendix). When the distribution of interbase and round trips are balanced, the hexagonal tree network is also preferred.

When through trips are considered, this circulation system is the least efficient one among all circulation systems. Neither of these three networks offer alternative routes, an interruption by outer movements is inevitable.

If intersecting conflicts are given high weights, this circulation system does not perform well; it is the second worst one (Wright et all, 1989a).

If weaving conflicts are considered, this circulation system generates relatively more conflicts (Wright et all, 1989a).

If merging and diverging conflicts are considered, this circulation system generates more conflicts (Wright et all, 1989a).

For total travel distance, it is the worst circulation system. (Wright et all, 1989a), since the network is highly based on hierarchical order. Since the network is not interconnected, the total travelled distance is much more than others. Among three networks, the hexagonal tree performs best while the radio-centric tree performs worst, since the orientation of the line segments do not fit the flow directions.

The BT is neither a robust nor a compliant circulation system. On the other hand, this system is preferred for interbase trips. Among three networks, the hexagonal tree network is preferred.

This circulation system is mostly preferred in low dense trip generating city parts which are highly separated from each other except for the focal point. Most of the trips are expected to be interbase trips. Round trips and through trips are expected to be at very low levels. On the other hand, under expected movement systems the wasted land arranged for circulation may be prevented.

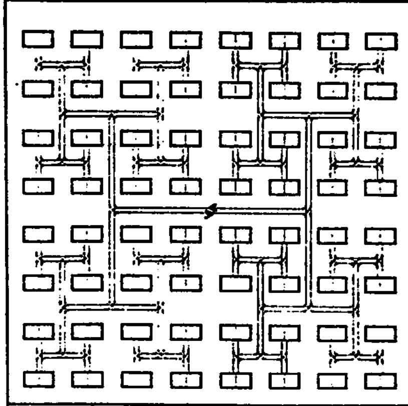
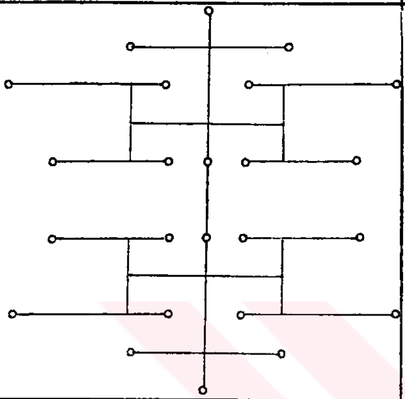
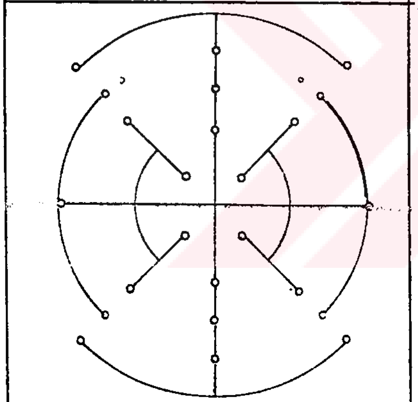
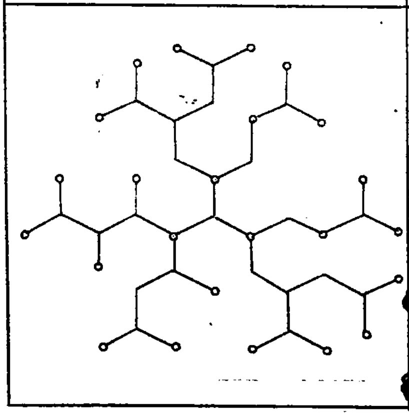
	**15-BT** :Binary Tree
	**Grid Tree:** Suitable for neighbourhoods and small town networks. When land use is mixed and this network type is also advisable. If existing pattern is based on grid this circulation principle can not be well adapted. It is suitable to organise a pedestrian circulation scheme.
	**Radio-centric Tree:** Among three street patterns the radio-centric one is the most adaptable one. Suitable for neighbourhoods and small town networks. When land use is mixed and this network type is also advisable. It is suitable to organise a pedestrian circulation scheme
	**Hexagonal Tree:** Suitable for neighbourhoods and small town networks. When land use is mixed and this network type is also advisable. It is suitable to organise a pedestrian circulation scheme. If existing pattern is based on hexagonal this circulation principle can be adapted easily.

Figure 4.18 Circulation Network Configurations of BT

Figure 4.19 An Example of Circulation Network Configurations of BT: Tolouse la Mirail, Paris. Source: Ritter, 1963.

4.3.4.Linear Networks

Linear network concept, as a frame of whole city or as a frame of an appropriate part of city has not been a conventional method; "this concept is rarely applied" even though it has been a new theoretical idea (Lynch 1981;376). If the concem is whole city, this network is based on a continuous transport line, and the form of city is also based on linear concept. Roadside or coast-side cities, cities within a strong topography represent a linear development. If the concern is the centre of a city, the form of whole city is not required to be based on linear concept. That is, in such a city the form might be based on grid and the extension might be multidirectional, however because of a single arterial road the main activities might locate along it.

When total conflict and volume/capacity distribution along whole network is considered, the network is advantageous compared to other network groups, however when travelled distance is considered, greater results are observed. According to Lynch (Lynch 1981;377) lack of a dominant or intensive centres is a handicap of linear development. That is, it is hard to keep the linear development through its pure form. That problem arise from high travel distances as a factor of access costs. For either the city centre or the whole city further developments are expected to occur on perpendicular lines. Conventional methods to prevent perpendicular developments are commonly observed as additional service installations or improvement of level of service along the main arterial; whether perpendicular development is an handicap or not can be questioned.

As Lynch claimed, at macro scales MARS Group's proposals for London, N.A. Miliutin's plan for Stalingrad, Soria y Mata' s plan for Madrid; at micro scales Kenzo Tange's plan for harbour of Tokyo are based on linear concept." (Lynch,1981).

CHAPTER 5

EVALUATION AND INTERPRETATION OF THE ROLE OF TRAFFIC NETWORK DESIGN IN THE FORMATION OF URBAN PATTERNS

5.1 Interpretation of Traffic Network Design in Urban Systems

Traffic network design includes two main issues; formation urban patterns and formation of circulation patterns. The former refers to the integration of circulation concerns to urban design and the latter refers to integration of morphological concerns to circulation systems.

If the problem is the integration of morphological aspects into circulation systems, the problem refers to the discussion of the impacts of traffic networks on movement systems. In other words, circulation control system policies require searching alternative circulation control system proposals based on the configuration of a given network and the preferences of alternatives. The performances of alternatives are determined by the network configurations. Such studies require the knowledge of the performances of street patterns as traffic networks.

If the problem the integration of circulation aspects into urban design, the problem refers to the discussion of the impacts of movement systems on urban patterns. Here the urban patterns are reduced to the form and geometry of movement channels, that is, structure of street network constitutes the units of urban patterns.

The impacts of traffic networks on movement systems are discussed in Chapter 3 and Chapter 4 in detail, where the problems based on street networks are discussed to get key concepts for the problem of circulation control. In this part, the evaluation is rather related to impacts of movement systems on urban patterns. Each street pattern (grid, hexagon or radio-concentric) potential of adaptability to organise circulation systems.

When grid pattern is accepted as the frame of a network, it is not suitable to arrange a circulation network based on the principles SIOT-SNIOT (star, interlocking or non-interlocking offside turns), OWR (one-way ring), 2OWR (two one-way rings) or TWR (two-way ring).

When radio-concentric pattern is accepted as the structure of a network, it is not suitable to arrange a circulation network based on the principles of TWC (two way corridor), TWS (two way spine), 2OWC (two one-way corridors) or NL (nested loops).

When hexagon pattern is accepted as the structure of a network, it is not suitable to arrange a circulation network based on the principles of TWC (two way corridor), 2OWC (two one-way corridors), NL (nested loops), NSEW (north-south; east-west split) or CCP (concentric polygons).

Among three patterns, the grid is the most adaptable one. That is, when this pattern is used as the frame of traffic network, the network can be arranged to adapt most of the circulation systems. However, it is not suitable to apply tree type circulation networks onto this pattern (as a frame).

In this respect role of traffic networks in circulation and control systems are determined by the morphological characteristics.

Ran And Boyce (1996:6) classified flow control types as; total control, partial control and no control. In total control drivers have no choice to select a route at intersections. Some examples include traffic signal control at intersections. In partial control, the aim is to influence drivers' choices. Some examples include route guidance advices and changable message signs, therefore this kind of control is flexible. No control provides real-time traffic information to travelers, For total control and partial control types, the flexibility and compliance of network (potential of alternative routes) are critical factors. Flexibility and compliance of a network are determined by its junction and link configurations. For instance in a network consisting of 24 O/D pairs (duplex nodes, or centroids);

-if the network is in a uniform grid from first centroid to the last one (the farthest one), 70 possible equal shortest paths exist.

-if the network is in a uniform radio-concentric form, 2 equal shortest paths exist, and equal but longer pairs of paths in a sequence follow them. In this case total number of possible equal shortest paths is 52.

-if the network is in a uniform hexagonal form, 8 equal shortest paths exist, and equal but longer pairs of paths in a sequence follow them. In this case total number of possible equal shortest paths is 48.

5.2 The Role of Movement Systems in Traffic Network Design As A Frame of Urban Patterns.

As Mitchell (1974;128) claimed, "street system constitutes the framework of a city"; that is to a considerable degree the size, shape, and orientation of blocks, and lots are determined by the street pattern. Lynch (1981:357) claims that the urban pattern can be seen as a network. This definition is clearly appropriate when the description is related to flows. A network itself "can have a form, a degree of specialisation and many of these characteristics can be described in the mathematical language of graph theory" (Lynch 1981:357).

The discussion of whether they are determined under consideration of accessibility or movement clarifies the role of circulation in the formation of urban space. Streets as the channels of movement, have not always been formed under consideration of movement of people and vehicles; they are sometimes designed just as means of access to parcels. Sometimes urban designers arrange street networks to provide accessibility to parcels, that can be defined as the main reason behind the circulation problems. In addition, streets are possible paths of infrastructure. Briefly, streets do not serve just for movement, but also for other requirements.

It can be said that compared to all other factors the main alterations in streets are based on movement dynamics; any drastic change in the demand of movement may result in dramatic changes in streets, such as, extension, widening, speed increase, etc. The change in demand of movement may result from city growth, or land use changes, or land use intensification without addition of new carriage ways. The more intensive use of urban land means more interaction between city parts, that generates an increase in the volume of movement. Such changes cause pressure to increase street capacity by widening, or by traffic management, or even by construction of new streets.

Changes in the kind of movement in a part of city or on a channel occur as a result of changing human activities which may be a result of shifts in land use pattern, technological improvement, life standards or human preferences. Trip generation characteristics of a city part changes as a result of new developments or transformations. In addition, significant influences on movement channels are brought in technological improvements and life standards of inhabitants. In the twentieth century, automobile has been the "greatest factor" in the alteration of the morphology of street systems (Mitchell 1974). Such an alteration occurs as a result of circulation based requirements of the street systems.

Changes in the intensity of use of private automobile have brought alterations in streets to serve access to automobile, which means street widening and junction turning to some extent. In addition, to enable time efficient and secure movement, orientation and morphology of streets have changed.

Design of any movement and accessibility oriented infrastructures (streets) requires taking into account the dynamics of kind of movement. On the other hand, location dynamics of activities are determined by the access and movement facilities of street systems. Thus, design of a new street system or any alteration in street use should be a process of iteration.

A street system constitutes a network. Each network has its own characteristics such as capacity of carrying vehicles, potential of delay, potential of conflict and potential of adaptability to serve different movement systems. A review of the differences provides designers to decide on the appropriate network for a given environment.

According to many writers (Buchanan,1963; Antoniou, 1971; Mitchell 1974) existing layout of the streets in most cases are not suitable for the movement of motor vehicles as desired, even though approximately one third of the land in urban areas belongs to roads. According to Antoniou (1971) drivers require "reasonably clear" and "uninterrupted" flows, but in most of existing layouts of urban streets "there are intersections at very frequent intervals at high volumes". Therefore each of them is a potential obstruction to the flow which causes so much delay. As a result, almost all streets in urban centres serve at lower levels of their theoretic capacities

Many of the streets are too narrow for the number of vehicles. The vehicles themselves have increased in number, as a result of the growth of motor vehicle usage. The more intense the more activities the more traffic will be generated. Thus the need to insert new distributors will greater. Unfortunately the more intense the development is, the more difficult it becomes to design a proper distributor system. In addition, increase in the size and amount of buildings dramatically increases the traffic on existing streets and this is a factor affecting the level of flow quality. If arrangement, size and amount of buildings and their close connection with the motor traffic had been understood, this might not have happened.

As it is well known, traffic is a function of activities, and activities take place in buildings. It is a fact in which the streets on which vehicles move are closely related to the manner that buildings are arranged. If the accessibility concern is the question, access ways are arranged or designed to serve buildings. However, if the question is mobility of large groups of vehicles, a conflict emerges between building arrangement and street design with respect to priorities.

Two components of the problem, uninterrupted flow and the urban environment tend to be defined as in conflict at present.

The first side of the problem refers to a definition of good environment with respect to movement caused by the application of inappropriate flow diagrams on existing layout of streets which are rearranged to adapt mobility oriented or engineering based flow diagrams.

The second side of the problem refers to a definition of good environment with respect to building and open space design. In special cases it might be possible to secure buildings by reducing traffic at extreme levels. In some places this might not cause any real hardship to vehicle users, but for an overall policy for a city part, it may seriously discourage the functioning and liability of the place.

On the other hand, the accessibility problem would certainly not be solved by sacrificing environment, that is without an uninterrupted flow the meaning of accessibility is premature. Yet, accessibility still is often poor. That is also a kind of approach that tends to define uninterrupted flow and environment to be without conflict at present.

After all, the main purpose of nearly every street in every town is to give access to the buildings along it. Moreover, it has been shown that certain streets need to be arranged just for movement on well examined schemes. In such cases, accidents have been reduced. The general affect of these schemes is to increase the speed of traffic on the principle of spreading the load. Otherwise, providing mobility and increasing traffic on the streets is quite unsuitable and harmful effects may be experienced in the surroundings.

There is no accepted predetermined principle to accommodate traffic in towns and cities, whether it is a design for a new town on an open site or a design for adaptation to an existing town.

There must be areas of "good environment-liveable environment" -urban rooms- where people can live, work, shop, look about, and move around on foot in reasonable freedom from the hazards of motor traffic, and there must be a complementary network of roads -urban corridors- for the prerequisite flow of traffic to the environmental areas. These areas are not free of traffic - they cannot be if they are desired to be liable- but the design would require that their traffic is related to circulation network. Therefore, volume of traffic is somehow a factor of the environmental quality. Yet, flow quality can be defined as an issue in environmental quality. If this concept is well understood it can easily be seen that it provides a structure to city. This structure consists of environmental areas within an integrated circulation network. It is a simple concept, but without a well-managed urban traffic, remaining is a premature environment.

In a study aiming to integrate two sides of the problem, 33 possible circulation networks should be considered. These schemes are structured with the combination of three base street patterns classified by Lynch (1981) and fifteen base routing patterns are helpful to propose a variety of alternative solutions. This starting point might be the initial stage of traffic design.

In current studies, if the buildings are arranged for environmental quality, the flow quality is considered as a secondary criterion. To solve mobility oriented problems, engineering methods are employed and such solutions may result in adverse effects on environmental quality. This circular or mutual relation will continue until a new model for the process is formulated. In this part of the study a method is formulated and compared to current methods.

There might be many approaches to design traffic network as means of urban space formation. If the problem is considered in terms of the dominance on streets, we need to discuss how such proportion of land came to public ownership. In the first decades of twentieth century, travel on a route at desired standards created "public" roads, hence way the channels of interaction and communication among communities were provided.

Later on, when the problem was considered in terms of access to property, the streets became means of open space, serving emergent facilities to property. The movement of large groups were considered at minimal levels.

The situation continued until 1960's, when the streets were considered as means of subdivision of land. When the right-of-way was dramatically required, street was both a "public" and "private". That addresses conflict between circulation and environmental design.

The conflict between circulation and environmental quality mainly resulted from the physical structure of cities. Although, buildings and streets are put together, if priority is given to one side's objectives, the conflict appears.

If the problem is considered in terms of a network which serves environmental areas, the pattern of the network should depend on the characteristics of the areas, the kinds and quantities of traffic they generate. The traffic among the areas is the function of the associations that exist between one area and another, or between areas and outside world.

In Buchanan Report, essence of the problem is addressed to the balance of building arrangement and street layout design.

> The design problem, essentially, is a matter of rationalising the arrangement of buildings and access ways. At the extreme, this can be seen to encompass the strategic rearrangement of activities to get them into better relationships. Examples would be to remove a wholesale market from an overcrowded centre, to remove a petrol filling station from a busy shopping street, or to get houses and workplaces into improved relative positions. All this could form an

> important aspect of town planning policy. So should the converse need to prevent new, undesirable, faulty relationships arising as a result of new development. But it is still necessary to discern some basic principle for the design of buildings and access ways in order to secure good accessibility and environment. (Buchanan Report, 1964:58)

The pattern is expected to work on its own and still integrated to its surrounding. In design process of a network it might be required, and recommended to start with any circulation principles for relief roads, internal by-passes, spine roads, etc. All these considerations are essential technical issues that needs to be integrated with the distribution of traffic to areas of buildings.

"The circumstances in which a circulation network based on regular geometrical form there would be the base street lines of an area with uniform spread of development" (Buchanan Report, 1964:59). In such a case the network might be a "grid with a definite pattern and module". On a gridiron street pattern formed with rectangular blocks divided into rectangular lots, fewer solutions can be produced compared to square shaped grid. In both cases, there the network enable uniform extension. According to Lynch (1981:378), when the network is a uniform pattern with identical blocks, the pattern has no necessary boundaries, therefore extension to any direction is possible, which is the simplest reason behind countless examples. However, a rectangular pattern requires more complex intersections than uniform grid since on a uniform grid pattern the distribution of traffic flow is more uniform.

Lynch (1981) claims that uniform patterns have no central points at the same time. However, when the flow patterns are considered the central point or site is necessarily determined.

A curvilinear street design might give a semantic character to the city; infinity and monotony of flows are prevented.

A hexagonal pattern can be defined as highly efficient, with economical three-way intersections (the number of intersection, weaving, merging, diverging are less than other kinds of junctions: number of two, three, four groups of intersects, and their impacts and weights in signalisation), but other polygonal patterns are possible. Lynch (1981:379) interpreted six legged form of hexagon as a form of grid pattern; "triangular grid". Therefore, hexagonal pattern is a "modified version of triangular grid pattern" (Lynch 1981:379). He claims that such patterns are theoretically important but practically less valuable since they are rarely applied; the layout of New Delhi is given as an example of hexagonal pattern (Lynch 1981:380)

Although the basic dimension or "module" of the circulation network in such circumstances will broadly depend upon the type and intensities of activities within the area: assembled, determination of base pattern (the syntax of streets) is the essential part of designing a module.

Within the discussions of the problem that the designers are expected to face, the evaluation of such a system may give ideas about the arrangement of street layouts. The discussions on the patterns could guide designers to adapt appropriate circulation schemes.

CHAPTER 6

CONCLUSION

It is understood that up to present three main professions have observable implications for circulation problems in motor age; transportation planning, traffic planning and engineering, and land use planning. To some extent architectural implications have effective solutions for circulation problems.

Although transportation and land use planning are considered in an integrated process, circulation problems have not been solved since problem definition of such studies have been at macro scales.

In the last decades the common view among urban planners and transportation planners was the integration of transportation planning and urban land use planning principles. This argument is relevant if the problem is related to general circulation system of city.

If the problem is related to a part of city, (it might be the centre or a peripheral part), regulations, devices and techniques of this approach may not overcome circulation problems. Such problems to some extent reflect to flow quality, safety, and accessibility, in addition they may reflect to space quality as well. In addition, transportation and traffic planners have to take into account the morphological characteristics of traffic networks.

Within the period of motor age, even though the traffic network design concept has not been clearly formulated, this concept sometimes has been ignored (See Figure: 1.2), sometimes has been overemphasised (See Figure:1.3). At the end of process 1, traffic engineering solutions would be inevitable if the movement concept is a proposal. Therefore external impacts on environmental quality might be observed. When this concept is overemphasised, the process of spatial design might be obliged to include external predetermined urban patterns.

In this respect problem definition of traffic network design refers to the point; where the structure of urban blocks (or patterns) are determined. The assessment of street layout is necessary as a feedback process (See Figure: 6.1), that refers to investigation and evaluation of design proposals where road space might be wasted or lacked for movement.

In this respect, design of a new street system or any alteration in street use should be a process of iteration; which refers to design, assessment, and revisions.

Such a study involved in process of urban design should be parallel to other components of the process. Similar method is defined by Lang (1994), as "design of design guidelines". According to Lang (1994:392), the process involves three basic steps:

> 1-the design and acceptance of a set of overall schemata for the site
> 2-the abstraction of the essential components of these schemata and
> 3-the writing of design guidelines to ensure that these essential characteristics are achieved.

Streets as the channels of movement, have not always been formed under consideration of movement of people and vehicles; sometimes designers might consider street just as means of access to parcels, where streets are possible paths of infrastructure. In such cases, dramatic rearrangements might be necessary. It can be said that compared to all other factors dramatic changes in streets, such as extension, widening, speed increase, have been results of movement which has not been well assessed properly.

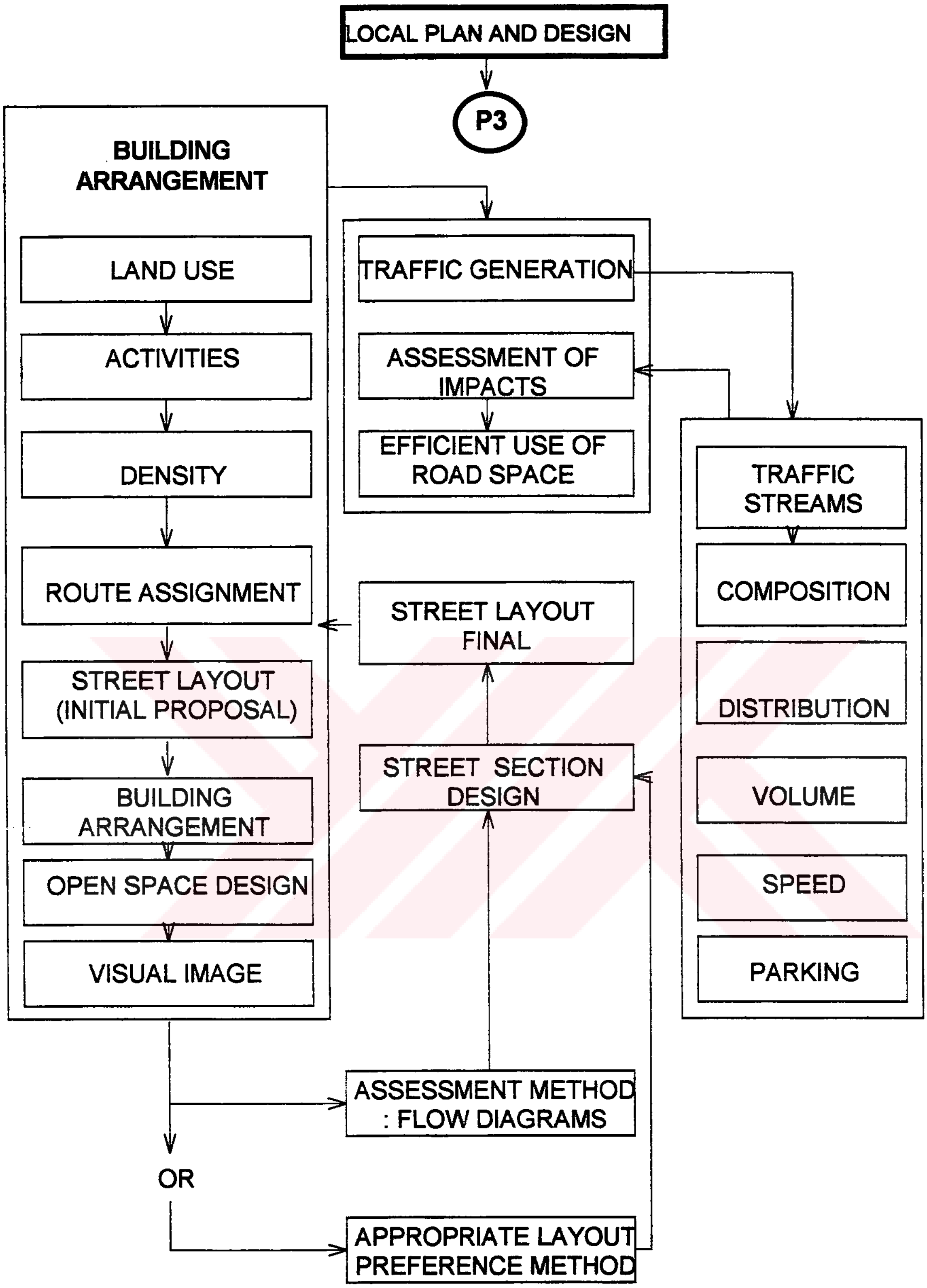


Figure 6.1. The process of building arrangement-traffic network design and traffic management. (p3: proposed situation)

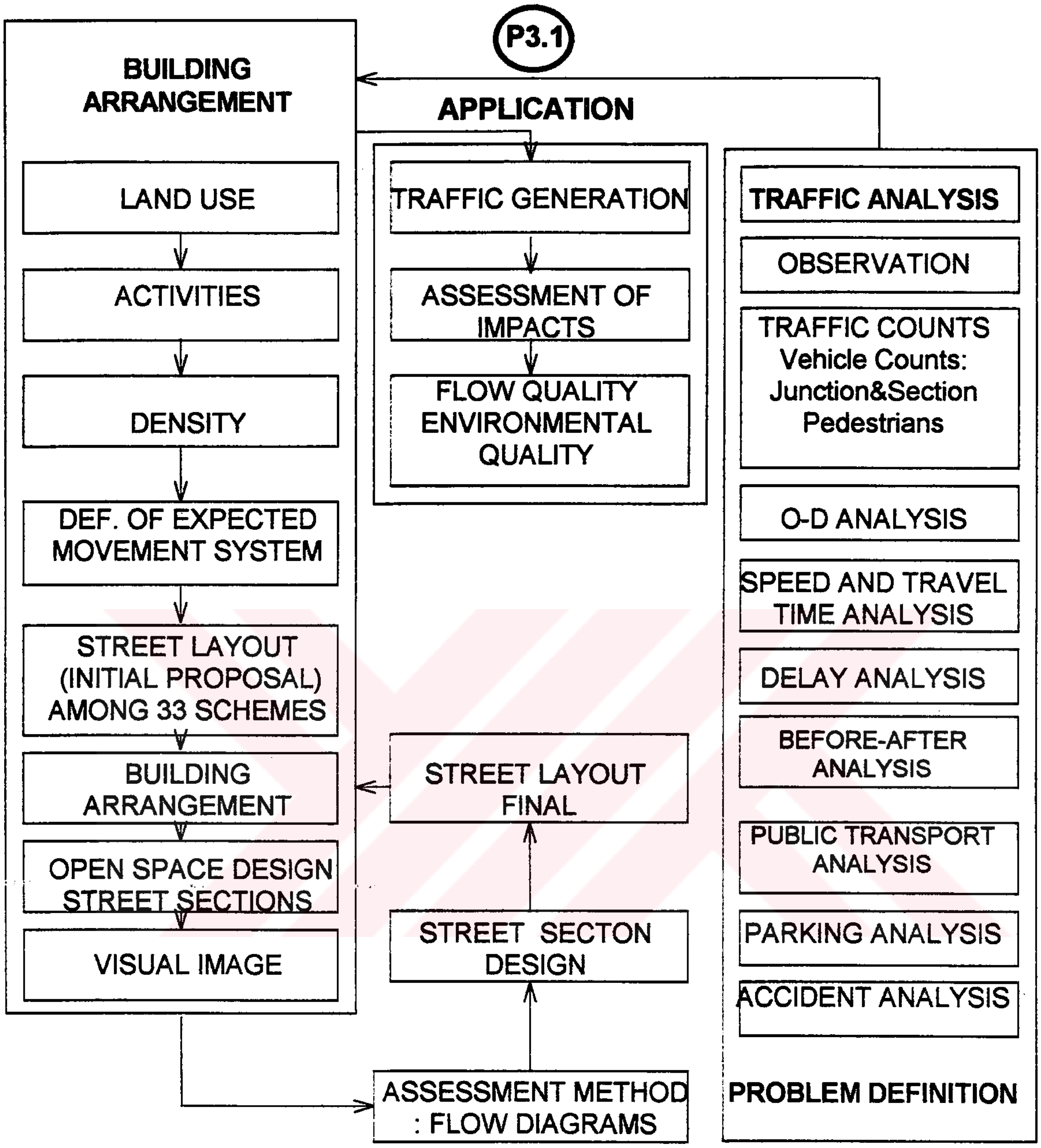


Figure 6.2 The process of environmental design-traffic planning, management and design (p3.1: proposed situation for an existing design area)

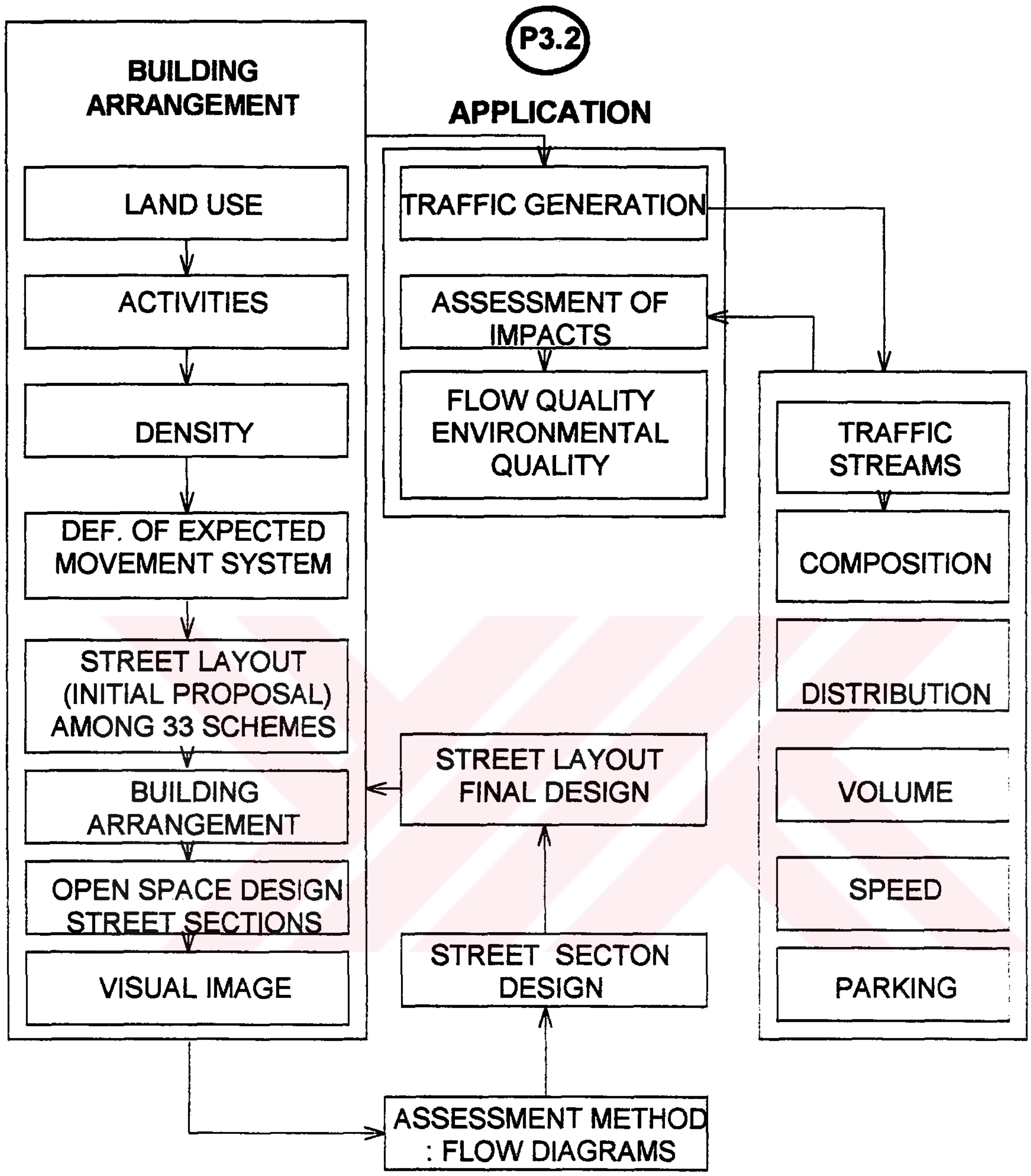


Figure 6.3 The process of environmental design-traffic planning, management and design (p3.2: proposed situation for new design areas

Changes in the intensity and use of vehicles caused circulation implications to enable time efficient and secure movement; orientation and morphology of streets have changed, these are structural changes.

Each network has its own characteristics such capacity of carrying vehicles, potential of delay, potential of conflict and potential of adaptability to serve different movement systems. An overview of the differences is recomended to designers to decide the appropriate network for a given environment.

Morphological approaches have dealt with physical structures and the concepts they are related to. Therefore, the designers could apply discussions and findings into future designs. In this study a circulation aspect to urban morphology and a morphological aspect to circulation systems are discussed in an integrated method.

Each movement system requires design proposals in which appropriate traffic network is applied. The complexity of movement systems which may arise from overlapped movement systems or complexity of distribution of activities.

During the motor age, many approaches to traffic networks has been developed and there have been various implications of network structures. As Lang (1994) claimed there are three main urban design movements and each of them has its own traffic network design implications.

It is not reasonable to accept a certain kind of traffic network design scheme in an urban design movement; since networks are functions of movement systems rather than desires of designers.

According to Lang (1994) during twentieth century three major urban design movements have ultimate impact on urban design history. These are City Beautiful Movement (came to manifest between 1900's and 1930's), Garden City (1930's to 1960's) branch of Modern Movement and International Branch of Modern Movement (1945 to 1980's). In addition to these three, Postmodernism, Neo-Traditionalism and Deconstructionism (after 1980's) have initial impacts on urban design history.

Traffic network design approach of City Beautiful Movement, "which aims efficient and hygienic city", refers to interconnected network design, such as "The Burnham and Bennet Plan for Chicago" (Lang, 1994:45). In this plan, the traffic network constitutes an overlapped grid and radio-centric form. It is understood that the complexity of trips (multi destination oriented interbase trips or incidental-round trips) requires interconnected grid networks with diagonals.

It is observed that among interconnected systems (convex polygons, concentric polygons and two one way rings), grid patterns are more advantageous than hexagonal and radio-concentric patterns. The proportion of regular and incidental round trips determine the advantages. When the proportion of interbase trips is greater, diagonals are complementary parts of the networks. That is the reason behind successful implications of European garden cities.

Proposals of Empiricist branch of Modern Movement are based on "learning from observation and designing idealised future social systems to housed in idealised geometrical world" (Lang, 1994:46). Lang categorised Empiricist movement into two groups; "Garden City" approach which is concerned with the concept of "new town design" and "Urbanites" approach which is concerned with the concept of "urbanity" (Lang, 1994:45).

Traffic network designs of Garden City examples are predominantly based on semi-connected or tree network systems. Implications of this approach can be observed in American garden cities. At the beginning of twentieth century, in American cities existing networks were based on grid forms. These networks do not perform well when regular-round and single destination oriented interbase trips are dominant. Therefore, the performance of existing networks might not have inspiring influence on proposals.

It is observed that among tree systems (binary tree, star), hexagonal patterns are preffered rather than grid or radio-concentric patterns. The simplicity of movement patterns is reflected to simple traffic networks. In such cases, grid patterns follow the hxagonal patterns with respect to performance. It was realised that the circulation as a system (tree) , and the pattern (inspired from existing system; grid) as a framework constituted the American Garden City traffic network. The referred network whether it is a super-block system, or a cluster system fall into empiricist category, rather than visionary or imaginary category since the search for the appropriate network is a version of the existing one.

On the other hand, examples of Urbanites approach are based on interconnected networks. Alexander's formulations in his article "city is not a tree" about the interrelations of sets refer to the necessity of interconnected networks. Implications of this approach can be observed in European garden cities since the proposals are based on "inspirations from existing" networks (Lang, 1994). At the beginning of twentieth century, existing networks were based on "radial or radio-concentric forms" in European cities (Lynch, 1981).

Such kind of networks perform well when regular-round and single destination oriented interbase trips are dominant. Therefore, the performance of existing networks might have positive influence on proposals. That is the reason behind European success at garden city implications.

In this study it is observed that among interconnected systems (convex polygons, concentric polygons and two one way rings), grid and radio-concentric patterns are preferred. In addition in semi-connected systems (loops, split, ring, corridor, or spine) grid patterns are recommended. Among empiricist implications, in a small part of American cities, and in most European cities semi-connected systems are preferred.

Examples of Rationalist branch of Modern Movement are based on "models of an unobservable but imagined, idealised future world" (Lang, 1994:50). Traffic network design approach of Rationalist movement is predominantly based on "cartesian geometry" which may constitute either interconnected or semi-connected networks; the structure is expected to be based on the assessment of the "rational" and the "feasible" (Lang, 1994:50).

According to Lang C.I.A.M. and its followers Team 10 as the "major proponent" of the rationalist movement have great influence on American urban design implications which are predominantly based on highly interconnected grid iron networks (Lang, 1994:51). Both in existing and in new developments, Rationalists emphasised modern technology and functionality. Therefore uniform, interconnected and multi-functional networks (installation of below surface infrastructure, extension of the network if required) were basic requirements of designs.

In last Postmodernism, Neo-Traditionalism and Deconstructionism (after 1980's) have been counter arguments to modernist urban design movement. However, it is hard to make a definite categorisation of recent design ideologies, therefore it is hard to assign a traffic network design model for the implications of "neo-rationalism", "neo-empiricism", neo-traditionalism" of "deconstructivism", since up to now the examples have not been referred to a considerable part of a city. That is, in this period the main concern is a search for a synthesis of the "observed" and the "ideal". That might be a result of complexity of movement patterns at dramatic levels, in which modelling and assessment is much more difficult. Therefore. traffic network design approaches are based on the principle of flexibility.

In almost all urban design movements, a certain frame of traffic network is underlined; therefore to some extent preferred networks are manifested. It is not reasonable to accept a certain kind of traffic network design scheme, however, even "rationalist" traffic networks are manifested in predetermined design frames. However, in a "rational" manner, each network has its "rational" basis which is determined by the human activities. A great variety of networks may be possible, and selection of appropriate network depends on network assignment with respect to activities. Thus, determination of appropriate network should be based upon assessment.

This study claims that, if movement system is expected to be very complex, or it is hard to predict the movement pattern, interconnected network types are preferred. Among the interconnected systems, grid or radio-centric network patterns are more advantageous with respect to conflict frequencies, efficient usage of road space and adaptability.

If movement system is expected to be complex, semi-connected network types are preferred. Among the semi-connected systems, grid network patterns are more advantageous.

If movement system is expected to be less complex, or a certain pattern of movement is expected, tree system network types are preferred. Among the tree systems, hexagonal network patterns are more advantageous.

If certain (interbase trips assembled to a certain area) type of pedestrian movement systems are considered, tree system networks are preferred. Among the tree systems hexagonal networks are preferable. On the other hand, if the concern is city centre and the integration of vehicular and pedestrian movement is aimed grid form of networks are preferable.

Urban designers are expected to formulate appropriate network designs referring their knowledge of circulation concepts and preferences. Urban designers, as professionals dealing with traffic network design are expected to have the knowledge of the concepts of circulation. This knowledge includes assessment of relative advantages and disadvantages of traffic networks. In addition to other qualifications, they should have a circulation based approach to urban design.

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APPENDIX

Minimum path assignment procedure for Fortran 77

```
C Maximum No. of Nodes = 510
C
C     DEFINITION OF VARIABLES
C
      INTEGER*4  MINP(520),T(520,5),MINP1(520)
      INTEGER*4  TL(520,5),XA(60,60),TA(60,60,60)
      INTEGER*4  MINL(520),MINL1(520),TP(1400)
      REAL*8     MIN(520),TOTT
      REAL*8     TH(1400)
      INTEGER*4  TN(520,5),TB(1400,60,60),O,D
      INTEGER*4  TJ(1400)
      INTEGER*4  TC(1400,60)
      INTEGER*4  TD(1400),F
      INTEGER*4  DIST1,DIST2,DIST3,DIST4,DIST5
      INTEGER*2  SPD1,SPD2,SPD3,SPD4,SPD5
      INTEGER*4  LN1,LN2,LN3,LN4,LN5
      CHARACTER  NIDF*20,MPOF*20,PATH*20,TRIP*20
C
C     INPUT DATA GETTING FROM FILE AND
C     ASSIGNING THEM TO VARIABLES
C     OUTPUT FILE DEFINITIONS
C
      WRITE(*,1385)
 1385 FORMAT(1X,'Enter Name of Network Data File...>'\)
      READ(*,32229)NIDF
32229 FORMAT(A20)
      WRITE(*,*)
      WRITE(*,30146)
30146 FORMAT(1X,'Enter Name of O-D Trips File Name...>'\)
      READ(*,32229)TRIP
      WRITE(*,*)
      WRITE(*,30145)
30145 FORMAT(1X,'Enter Name of Minimum Path Output File Name...>'\)
      READ(*,32229)MPOF
      WRITE(*,*)
      WRITE (*,73941)
73941 FORMAT(1X,'Enter Name of Link Loading Output File...>'\)
      READ(*,32229)PATH
      WRITE (*,*)
      WRITE(*,55555)
55555 FORMAT(//,1X,'Enter Number of Zones...>'\)
      READ(*,22)ANOFZ
   22 FORMAT(F5.0)
      NEND=INT(ANOFZ)
      OPEN(5,FILE=NIDF)
      OPEN(6,FILE=TRIP)
      OPEN(7,FILE=MPOF)
      OPEN(9,FILE=PATH)
      WRITE(*,6321)
      WRITE(*,*)
      READ(*,6322)AL
      L=INT(AL)
      WRITE(*,*)
      WRITE(*,6921)
      WRITE(*,*)
      READ(*,6322)ALF
      LF=INT(ALF)
      WRITE (*,3647)
 3647 FORMAT (//,1X,'Reading Trips Between O-D')
```

```
      READ (6,140) ((XA(O,D),D=1,24),O=1,24)
      DO 3601 I=1,1000000
3601  CONTINUE
      WRITE(*,3648)
3648  FORMAT(//,1X,'Reading Network Input Data')
   15 READ(5,120,END=45) NF,DIST1,SPD1,LN1,NT1,DIST2,SPD2,LN2,NT2,
     +DIST3,SPD3,LN3,NT3,DIST4,SPD4,LN4,NT4,DIST5,SPD5,LN5,NT5
      DO 3602 I=1,1000000
3602  CONTINUE
      TN(NF,1)=NT1
      TH(LN1)=SPD1
      TJ(LN1)=DIST1
      TL(NF,1)=LN1
      IF(TH(LN1).EQ.0)TH(LN1)=1
      Z1=((TJ(LN1))*60.0)/((TH(LN1))*1000.0)
      S1=((TJ(LN1))*60.0)/((TH(LN1))*1000.0)
      TP(LN1)=S1
      T(NF,1)=Z1
      TN(NF,2)=NT2
      TH(LN2)=SPD2
      TJ(LN2)=DIST2
      IF(NT2.NE.0)THEN
      IF(TH(LN2).EQ.0)TH(LN2)=1
      Z2=((TJ(LN2))*60.0)/((TH(LN2))*1000.0)
      S2=((TJ(LN2))*60.0)/((TH(LN2))*1000.0)
      TP(LN2)=S2
      TL(NF,2)=LN2
      GO TO 2091
      END IF
      Z2=0.0
2091  T(NF,2)=Z2
      TN(NF,3)=NT3
      TH(LN3)=SPD3
      TJ(LN3)=DIST3
      IF(NT3.NE.0)THEN
      IF(TH(LN3).EQ.0)TH(LN3)=1
      Z3=((TJ(LN3))*60.0)/((TH(LN3))*1000.0)
      S3=((TJ(LN3))*60.0)/((TH(LN3))*1000.0)
      TP(LN3)=S3
      TL(NF,3)=LN3
      GO TO 2092
      END IF
      Z3=0.0
2092  T(NF,3)=Z3
      TN(NF,4)=NT4
      TH(LN4)=SPD4
      TJ(LN4)=DIST4
      IF(NT4.NE.0)THEN
      IF(TH(LN4).EQ.0)TH(LN4)=1
      Z4=((TJ(LN4))*60.0)/((TH(LN4))*1000.0)
      S4=((TJ(LN4))*60.0)/((TH(LN4))*1000.0)
      TP(LN4)=S4
      TL(NF,4)=LN4
      GO TO 2093
      END IF
      Z4=0.0
2093  T(NF,4)=Z4
      TN(NF,5)=NT5
      TH(LN5)=SPD5
      TJ(LN5)=DIST5
      IF(NT5.NE.0)THEN
      IF(TH(LN5).EQ.0)TH(LN5)=1
      Z5=((TJ(LN5))*60.0)/((TH(LN5))*1000.0)
      S5=((TJ(LN5))*60.0)/((TH(LN5))*1000.0)
```

```
      TL(NF,5)=LN5
      TP(LN5)=S5
      GO TO 2094
      END IF
      Z5=0.0
 2094 T(NF,5)=Z5
      M=NF
      GO TO 15
   45 IPT=0
C
C     DATA CHECK
C
      WRITE(*,35184)
35184 FORMAT(//,1X,'Checking Reciprocality of Links')
      DO 47294 I=1,100000
47294 CONTINUE
      DO 7852 I=1,M
      DO 7851 J=1,5
      IF(TN(I,J).NE.0)THEN
      KF=TN(I,J)
      DO 7850 K1=1,5
      IF(TN(KF,K1).EQ.I)GO TO 7851
 7850 CONTINUE
      WRITE(*,*)
      WRITE(*,1018)I,KF
 1018 FORMAT(1X,'THERE IS NO RECIPROCAL LINK FOR ',I3,'-',I3)
      IPT=IPT+1
      DO 10092 K=1,100000
10092 CONTINUE
      END IF
 7851 CONTINUE
 7852 CONTINUE
      IF(IPT.GT.0)THEN
      STOP
      END IF
      WRITE(*,4057)
 4057 FORMAT(//,1X,'Checking Procedure Completed')
      DO 4839 I=1,100000
 4839 CONTINUE
C
C     SHORTEST PATH FORMATION
C
 9333 DO 5839 I=1,520
      MINP(I)=0
      MINP1(I)=0
      MIN(I)=99999.
 5839 CONTINUE
      DO 1783 I=1,10
 1783 WRITE(*,*)
      WRITE(*,1291)L
      K=L
      DO 20 M1=1,5
      IF(TN(K,M1).NE.0)THEN
      J=TN(K,M1)
      DO 19 M2=1,5
      IF(TN(J,M2).EQ.K)THEN
      DO 751 X=1,1400
      IF (X.EQ.TL(J,M2)) THEN
      TP(X)=((TJ(X))*60.0)/((TH(X))*1000.0)
      MIN(J)=TP(X)
      GO TO 752
      END IF
```

```
 751 CONTINUE
 752 MINP(J)=K
     MINL(J)=TL(J,M2)
     GO TO 20
     END IF
  19 CONTINUE
     END IF
  20 CONTINUE
     K=L
 750 DO 900 I=1,M
     DO 899 J1=1,5
     IF(I.EQ.K)GO TO 900
     IF(TN(I,J1).EQ.0)GO TO 900
     IF(TN(I,J1).EQ.K)GO TO 899
     J=TN(I,J1)
     G=TL(I,J1)
     IF(MIN(J).EQ.99999.)GO TO 899
     TP(G)=((TJ(G))*60.0)/((TH(G))*1000.0)
     IF(MIN(I).GT.(MIN(J)+TP(G)))THEN
     MIN(I)=MIN(J)+TP(G)
     MINP(I)=J
     MINL(I)=G
     IC=IC+1
     END IF
 899 CONTINUE
 900 CONTINUE
     IF(IC.GT.0)THEN
     WRITE(*,5090)IC
5090 FORMAT(//,1X,'No. of Corrections Made :',I5)
     IC=0
     GO TO 750
     END IF
1001 WRITE(*,1002)K
1002 FORMAT(' Tree Building Process Completed for Centroid ',I3,1X,I3)
     N=1
     H=1
1003 DO 875 J=1,M
     IF(J.EQ.K)GO TO 875
     MINP1(N)=J
     IF(MINP(J).NE.K)GO TO 149
     N=N+1
     H=H+1
     MINP1(N)=MINP(J)
     MINL1(H)=MINL(J)
     GO TO 1672
 149 N=N+1
     H=H+1
     MINP1(N)=MINP(J)
     MINL1(H)=MINL(J)
     NOD=MINP(J)
1525 N=N+1
     H=H+1
     MINP1(N)=MINP(NOD)
     MINL1(H)=MINL(NOD)
     IF(MINP(NOD).NE.K)THEN
     NOD=MINP(NOD)
     GO TO 1525
     END IF
1672 IF(J.GT.NEND)GO TO 8887
     NN=N
     A=H
     DO 4501 B=2,A
     TA(J,K,B)=MINL1(B)
4501 CONTINUE
```

```
      TOTT=0
      DO 2123 B=2,A
      DO 2124 F=1,1400
      IF (F.EQ.TA(J,K,B)) THEN
      TP(F)=((TJ(F))*60.0)/((TH(F))*1000.0)
      TOTT=TOTT+TP(F)
      END IF
 2124 CONTINUE
 2123 CONTINUE
C     WRITE (7,36508) TOTT
      WRITE (7,36500) J,K,TOTT,(TA(J,K,B),B=2,A)
36500 FORMAT (I2,'-->'I2,2X,F5.2,2X,(520(I4,1X)))
C36508 FORMAT (2X,F5.2)
 8887 N=1
      H=1
      DO 4600 B=2,A
      F=TA(J,K,B)
      C=(XA(J,K)/(A-1))
      TB(F,J,K)=C
      TC(F,K)=TC(F,K)+TB(F,J,K)
C       TD(F)=TD(F)+TC(F,K)
 4600 CONTINUE
  875 CONTINUE
      DO 4185 F=1,1400
      TD(F)=TD(F)+TC(F,K)
      IF (TH(F).EQ.0.) GO TO 4185
      IF (TD(F).EQ.0.) GO TO 4185
      IF (TD(F).GT.1000.) TH(F)=20.
      IF (TD(F).GT.750.AND.TD(F).LT.1000.) TH(F)=30.
      IF (TD(F).GT.500.AND.TD(F).LT.750.) TH(F)=40.
      IF (TD(F).LT.500.) TH(F)=50.
      WRITE(9,36495) F,TC(F,K),K,TD(F)
36495 FORMAT (1X,'LINK NUMBER..>',1X,I4,2X,'DIRECTED TRIPS..>',1X,I6,2X,
     +'TO CENTROID..>',1X,I3,2X,'TOTAL TRIPS ON LINK..>',1X,I6)
 4185 CONTINUE
      L=L+1
      IF(L.GT.LF)GO TO 99
      GO TO 9333
   99 STOP
 6321 FORMAT(1X,'ENTER THE FIRST CENTROID NUMBER')
 6322 FORMAT(F3.0)
 6921 FORMAT(1X,'ENTER THE LAST CENTROID NUMBER')
  140 FORMAT (24(1X,I3))
  120 FORMAT (I4,I4,1X,I2,1X,I4,1X,I3,4(I4,1X,I2,1X,I4,1X,I3))
 1291 FORMAT(1X,'CREAT MIN PATH NETWORK FOR CENTROID',1X,I2)
      END
```

NETWORK ATTRIBUTES FOR GRID PATTERN

1 220 50 101 2 221 50 141 6
2 221 50 102 3 220 50 145 7 221 50 121 1
3 221 50 103 4 221 50 149 8 787 50 122 2
4 221 50 104 5 221 50 153. 9 787 50 123 3
5 221 50 157 10 221 50 124 4
6 221 50 161 1 221 50 105 7 221 50 142 11
7 221 50 165 2 221 50 106 8 221 50 146 12 221 50 125 6
8 221 50 169 3 221 50 107 9 221 50 150 25 220 50 126 7
9 221 50 173 4 220 50 108 10 221 50 154 13 221 50 127 8
10 220 50 177 5 221 50 158 14 221 50 128 9 221 50
11 221 50 162 6 221 50 109 12 221 50 143 15 221 50
12 221 50 166 7 221 50 110 25 221 50 147 16 221 50 129 11
13 220 50 174 9 221 50 112 14 221 50 155 18 220 50 131 25
14 221 50 178 10 221 50 159 19 221 50 132 13 221 50
15 221 50 163 11 221 50 113 16 221 50 144 20 221 50
16 221 50 167 12 220 50 114 17 221 50 148 21 221 50 133 15
17 220 50 171 25 221 50 115 18 221 50 152 22 221 50 134 16
18 220 50 175 13 221 50 116 19 221 50 156 23 221 50 135 17
19 221 50 179 14 221 50 160 24 220 50 136 18
20 221 50 164 15 220 50 117 21
21 220 50 168 16 221 50 118 22 221 50 137 20
22 221 50 172 17 221 50 119 23 221 50 138 21
23 221 50 176 18 221 50 120 24 221 50 139 22
24 220 50 180 19 221 50 140 23
25 220 50 170 8 220 50 111 13 221 50 151 17 221 50 130 12

LINK ATTRIBUTES FOR HEXAGONAL PATTERN
1 211 50 101 25 210 50 103 3
2 211 50 105 5 210 50 168 25
3 211 50 104 1 210 50 107 4 212 50 111 26
4 211 50 109 5 210 50 115 8 212 50 108 3
5 211 50 106 2 210 50 113 27 212 50 110 4
6 211 50 170 26 210 50 119 7 212 50 117 28
7 211 50 121 8 210 50 127 14 212 50 120 6
8 211 50 116 4 210 50 123 9 212 50 122 7
9 211 50 125 10 210 50 129 16 212 50 124 8
10 211 50 172 27 210 50 175 29 212 50 126 9
11 211 50 134 12 210 50 147 30
12 211 50 174 28 210 50 135 13 212 50 133 11
13 211 50 137 14 210 50 149 21 212 50 136 12
14 211 50 128 7 210 50 139 15 212 50 138 13
15 211 50 141 16 210 50 151 22 212 50 140 14
16 211 50 130 9 210 50 143 17 212 50 142 15
17 211 50 145 18 210 50 153 23 212 50 144 16
18 211 50 132 29 210 50 155 19 212 50 146 17
19 211 50 157 33 210 50 156 18
20 211 50 178 30 210 50 159 21
21 211 50 150 13 210 50 161 31 212 50 160 20
22 211 50 152 15 210 50 163 32 212 50 180 31
23 211 50 154 17 210 50 165 24 212 50 182 32
24 211 50 183 33 210 50 166 23
25 211 50 102 1 210 50 167 2
26 211 50 112 3 210 50 169 6
27 211 50 171 10 210 50 114 5
28 211 50 118 6 210 50 173 12
29 211 50 131 18 210 50 176 10
30 211 50 148 11 210 50 177 20
31 211 50 179 22 210 50 162 21
32 211 50 181 23 210 50 164 22
33 211 50 158 19 210 50 184 24

LINK ATTRIBUTES FOR RADIO-CENTRIC PATTERN

1	201	50	175	9	158	50	151	2	156	50	108	8				
2	200	50	177	10	158	50	152	3	157	50	101	1				
3	200	50	179	11	158	50	153	4	156	50	102	2				
4	200	50	181	12	158	50	154	5	157	50	103	3				
5	200	50	183	13	158	50	155	6	156	50	104	4				
6	200	50	185	14	158	50	156	7	157	50	105	5				
7	200	50	187	15	158	50	157	8	156	50	106	6				
8	200	50	189	16	158	50	158	1	157	50	107	7				
9	201	50	176	17	315	50	159	10	201	50	191	1	314	50	116	16
10	201	50	178	18	315	50	160	11	200	50	193	2	314	50	109	9
11	201	50	180	19	315	50	161	12	201	50	195	3	314	50	110	10
12	201	50	182	20	315	50	162	13	200	50	197	4	314	50	111	11
13	201	50	184	21	315	50	163	14	201	50	199	5	314	50	112	12
14	201	50	186	22	315	50	164	15	200	50	201	6	314	50	113	13
15	201	50	188	23	315	50	165	16	201	50	203	7	314	50	114	14
16	201	50	190	24	315	50	166	9	200	50	205	8	314	50	115	15
17	471	50	167	18	200	50	192	9	472	50	124	24				
18	471	50	168	19	200	50	194	10	472	50	117	17				
19	471	50	169	20	200	50	196	11	472	50	118	18				
20	471	50	170	21	200	50	198	12	472	50	119	19				
21	471	50	171	22	200	50	200	13	472	50	120	20				
22	471	50	172	23	200	50	202	14	472	50	121	21				
23	471	50	173	24	200	50	204	15	472	50	122	22				
24	471	50	174	17	200	50	206	16	472	50	123	23				