dedicated

to

(Late) Prof. M.N. Chatterji

who
motivated
me
to
attempt
perfection

and

to

(Late) Prof. N.S. Saini

who
motivated
me
to
be
practical

ACKNOWLEDGEMENTS

Ir. C.A. de Bruijn initiated the process of offering me a place and fellowship for pursuing this research. It was rather unfortunate that I could not receive much guidance from him due to his extreme health conditions. While I am thankful to him for putting his trust in me, I hope the present work reaches somewhere near his expectations.

I am thankful to the ITC, The Netherlands and the DGIS, The Netherlands, for providing necessary institutional and financial support for this research. My sincere thanks are due to my employers, SPA, New Delhi, for providing me necessary permission and leave to complete the research at the ITC.

At the ITC, I received supervision from Prof. Dr. Dirk Bolt, Professor and Head of the Division of Urban Planning and Management. It was always a rewarding experience to discuss with him any part of the work, no matter how-minor or crucial. I was rather lucky to have the consent of Prof. Dr. H.F.L. Ottens, Dean of the Faculty of Spatial Sciences at the University of Utrecht, to be my Promoter. He was always so readily available for any discussions, the traditional gap between the candidate and the promoter was bridged soon. His frankness and openness to new ideas played an important role in shaping this research. While I am specifically thankful to him, I am also thankful to the University of Utrecht, The Netherlands, for making the promotion possible.

I am very much thankful to Prof. Dr. J.D.G.F. Howe, Dr. Yousif Ali Hussin, Prof. Dr. A.M.J. Kreukels, Prof. Dr. IT. H.A. Luning and Prof. Dr. M.L. Vellinga for going through the manuscript and making useful comments.

Many learned people in India contributed useful thoughts in the initial and intermediate phases of this research. I specifically acknowledge the contributions made by Prof. Jamal H. Ansari, Mr. S. Arunachalam, Dr. (Mrs.) Atiya Habib Kidwai, Dr. Satish K. Kulshrestha and Prof. (Col.) Prabhakar Misra.

I offer my sincere thanks to the Library of the ITC, without which I could not have completed this work. I was bothering the staff of this library every now and then, and I was always met with the same smile, courtesy and promptness. I also tender my gratefulness to the Library of Instituut Kern, Indologisch Instituut der Rijksuniversiteit at Leiden and the Library of the University of Utrecht. In India, I made exhaustive use of the libraries of the SPA, New Delhi; JNU, New Delhi; ITPI, New Delhi; and the IIRS, Dehradun. I am very thankful to the all these libraries. I also acknowledge the numerous researchers and scholars whose work have been referred to extensively in this research, for they provided the base for this work.

I am thankful to the offices of the NCR Planning Board, New Delhi; DDA, New Delhi; State Departments of T&CP at Haryana, Rajasthan and Uttar Pradesh; Regional Office-NCR of the HUDCO, New Delhi; TCPO, New Delhi; NRSA, Hyderabad; Registrar General of India, New Delhi; and the NIC, New Delhi, for providing a huge amount of data and information used in this research.

A large number of people spent their valuable time by participating in the discussions and site visits during the field work for this research. These discussions and visits were made more fruitful by the participation of Mr. R.C. Aggarwal, Prof. Jamal H. Ansari, Dr. Sreemay Basu, Mr. Amit Bhargava, Prof. Dr. Dirk Bolt, Mr. B.K. Jain, Prof. Kavas Kapadia, Prof. Dr. H.F.L. Ottens, Mrs. Poonam Prakash, Mr. R.P. Rastogi, Dr. Shovan K. Saha, Prof. N.D. Sharma, Mr. Baldeo Singh Sokhi, and Dr. (Mrs.) Parvatham Venkatachalam. I am thankful to them for their contribution in the research. Dr. Ashok Kumar and his "lunch group' kept my morals high during the field work.

Yet another large number of people showed extraordinary kindness by sparing their time and efforts. I could always fall upon them in case any data was required to be sent to the Netherlands or there was a cross reference was to be checked. These kind hearted friends have won me for ever. They include Mrs. Sheeba Ali, Mr. J.B. Kshirsagar, Mr. Sunil K. Mehra, Mr. Rajendra Pandita, Dr. Shovan K. Saha, Mr. Vinod Sakle, Ms. M. Zarina Singh and Mr. S. Surendra. An equally large number of people went beyond their normal official duties and extended help by discussing some complicated issues involved and helping solve some of the technical problems. Included in them are Mr. MirzaM.A. Baig, Dr. S.P. Bansal, Mr. J.N. Barman, Mr. F.H.M. van den Bosch, Drs. Petra E. Budde, Mr. S.K. Jena, Dr. S.P.S. Khushwaha, Drs. R.A. Knippers, Ms. Shilpam Pandey, Dr. Christine Pohl and Mr. G. Reinink.

I am very grateful to the staff of the Division of Urban Planning and Management at the ITC, who contributed to the research by making useful comments at various stages. I am particularly thankful to Drs. Victor F.L. Polle\ for very critical discussions on fractal analysis, urban density coefficients and image interpretation.

While I am at the pleasing job of thanking, I would like to tender my apologies to my neighbour in the office. Mr. R. Ackermann had to bear Indian music at odd hours. I hope, he does not start missing the music now.

The Netherlands is a very lovely country with friendly people. At ITC, I had the support of the staff of the Deptt. of LARUS, student affairs, restaurant and the security and environment. I was made at home by the extraordinary people like Mrs. Aurora Heghes, Mrs. Wilma Grootenboer and Mrs. Nita Juppenlatz; and the Best Western Dish Hotels b.v.

One of my great well wishers once told me that pursuing research is a long and lone struggle. In this long struggle, fortunately, I was not alone. Not only we shared the same office for more than three years, and a couple of paragraphs in our respective theses, we also shared a lot of tensions, pressures, emotions, moments of depressions and joy, ideas and view points. Credit for some of the very fine arguments in this work goes to this finest friend of mine, Ms. Sahar Al-Amir.

My son, Lakshit, is too young (he was only two, when I left him) to understand why his father was not with him for last three years. I hope he forgives me when he does understand.

To my wife, I can not say sorry for what she missed. Nor I can say 'thank you' for what she sacrificed. What I wish to say is, 'Usha, I love you more!'.

My parents have played a great role in moulding my life. I simply can not pay back the care, affection and blessings that they always have for me. I am thankful to God, for having blessed me with such exceptional parents, family, teachers, friends and well-wishers.

Mahavir
June 21, 1996

LIST OF ABBREVIATIONS AND ACRONYMS

CBA	Continuously Built-up Area
CCD	Charge Couple Device
CCT	Computer Compatible Tape
CFI	Composite Functionality Index
CI	Connectivity Index
CSR	Complete Spatial Randomness
DDA	Delhi Development Authority, New Delhi, India
DEM	Digital Elevation Model
DMA	Delhi Metropolitan Area, India
Eurostat	Statistical Office for European Community
FAR	Floor Area Ratio
FCC	False Colour Composite
FSI	Floor Space Index
GISs	Geographic Information Systems
GPS	Global Positioning System
GSD	Ground Sample Distance
HRV	High Resolution Visible
HUDA	Haryana Urban Development Authority, India
HUDCO	Housing and Urban Development Corporation, New Delhi
IDSMT	Integrated Development of Small and Medium Towns
IIRS	Indian Institute of Remote Sensing, Dehradun, India
ILWIS	Integrated Land and Water Information System
IRS	Indian Remote Sensing Satellite
ISRO	Indian Space Research Organisation, Bangalore, India
ITC	International Institute for Aerospace Survey and Earth Sciences, Enschede, The Netherlands
ITPI	Institute of Town Planners, India, New Delhi
JNU	Jawaharlal Nehru University, New Delhi
LISS	Linear Image Scanning System
MCD	Municipal Corporation of Delhi, India
MS	Multi-Spectral
MSS	Multi-Spectral Scanner
NCR	National Capital Region of Delhi, India
NCT	National Capital Territory of Delhi, India
NCU	National Commission on Urbanisation, Government of India
NDC	National Data Centre of the NRSA
NDMC	New Delhi Municipal Committee, India
NGOs	Non-Governmental Organisations
NIC	National Informatics Centre, New Delhi
NNRMS	National Natural Resource Management System, India
NOIDA	New Okhla Industrial Development Area, India
NRSA	National Remote Sensing Agency, Hyderabad, India

PAC	Polarised Activity Centre
PAN	Panchromatic
PCA	Principal Component Analysis
PI	Proximity Index
PRL	Physical Research Laboratory, Ahemadabad, India
RNN	Reflexive Nearest Neighbour
SAC	Space Application Centre, Ahemadabad, India
SPA	School of Planning and Architecture, New Delhi, India
SPOT	Systeme Pour *VO*bservation de la Terre
SWIR	Short Wave Infra-Red
T&CP	Town and Country Planning
TCPO	Town and Country Planning Organisation, Government of India, New Delhi
TM	Thematic Mapper
TRL	Terrain Research Laboratory, Ministry of Defence, Government of India
UN	United Nations
UNCHS	United Nations Centre for Human Settlements (Habitat), Nairobi, Kenya
UNCRD	United Nations Centre for Regional Development, Nagoya, Japan
U.P.	Uttar Pradesh
UPS	Uninterrupted Power Supply
URIS	Urban and Regional Planning Information System
WIFS	Wide Field Sensor

Het Modelleren van Nederzettingspatronen voor Grootstedelijke Gebieden: Ondersteuning door Aardobservatie

Het analyseren van nederzettingspatronen is nuttig bij de besluitvorming over de locatie van nieuwe investeringen en over de mogelijkheden om diensten en faciliteiten op nieuwe wijzen te groeperen. Het gaat daarbij om het vermogen van menselijke nederzettingen om regionale ontwikkeling te bevorderen. De nederzettingspatronen rond metropolen worden steeds belangrijker vanwege de snelheid waarmee stedelijke nederzettingen zowel in aantal als in omvang groeien. Bovendien is in ontwikkelingslanden een nieuwe categorie ontstaan: grote en toenemende aantallen spontaan tot ontwikkeling gekomen menselijke nederzettingen aan de randen van stedelijke gebieden.

De 'natuurlijke' ontwikkeling van bovenvermelde processen leidt tot ondoelmatige en weinig doeltreffende nederzettingspatronen. Teneinde de als gevolg van inefficientie ontstane sociale, economische en milieukosten te verminderen zijn beheersmaatregelen geintroduceerd om deze problemen het hoofd te bieden. In deze studie is een poging gedaan een model te ontwikkelen voor het beschrijven van het nederzettingspatroon en voor het verkennen van alternatieven gericht op het beheersen van de toekomstige ontwikkeling van dat patroon.

Als stedelijke groei onderzocht wordt is e^n van de eerste vragen die beantwoord moet worden hoe de veranderende begrenzing van nederzettingen vastgesteld moet worden. Voor dit doel is een breed toepasbare benadering van het begrip 'aaneengesloten bebouwd oppcrvlak' ('Continuously Built-up Area', CBA) ontworpen. Deze maakt het mogelijk nederzettingen te identificeren op verschillende niveaus van generalisatie. In deze benadering worden de in de werkelijkheid verschuivende begrenzingen van het stedelijk gebied gebruikt en niet gemeentelijke, administratieve of politieke grenzen. Eerstgenoemde zijn zichtbaar op satellietbeelden, kunnen worden vastgelegd en voortdurend geactualiseerd, waardoor 'real time' informatie voor besluitvorming beschikbaar komt. De kracht van de methode, het CBA concept toegepast op aardobservatie-gegevens, is dat het aangepast kan worden aan elk generalisatieniveau dat overeenkomt met de schalen waarop cartografische presentarie en besluitvorming plaatsvinden.

Er bestaan methoden om ruimtelijke patronen vast te leggen en te herkennen, maar die zijn niet omvattend genoeg. De beschikbare methoden (zoals ruimtelijke autocorrelatie) worden in het algemeen gebruikt voor puntpatronen, die het beste deels visueel en deels handmatig geanalyseerd kunnen worden. Ook technieken voor clusteranalyse bleken niet geschikt voor het identificeren van ruimtelijke clusters.

Er is een aantal theorieen en modellen ontwikkeld om menselijke nederzettingspatronen te beschrijven en te verklaren. Een belangrijke conclusie die uit een overzicht van deze modellen kan worden getrokken is dat zij alle behulpzaam kunnen zijn bij het analyseren van bestaande patronen. De meeste kunnen, op beperkte wijze, ook nederzettingspatronen voorspellen. Maar weinige zijn geschikt om veranderingen in nederzettingspatronen te

plannen. Bovendien beschouwen de meest gebruikte modeller! nederzettingen als puntlocaties als het gaat om de analyse van ruimtelijke spreiding. De omvang van de nederzetting, niet in termen van bevolking maar van grondbeslag of vorm, wordt zelden in de beschouwing betrokken.

Een andere conclusie is dat de meeste kwantitatieve modellen van nederzettingspatronen in belangrijke mate uitgaan van aannamen zoals isotrope vlakten en rationed economisch gedrag. De geometrisch en statistisch georienteerde modellen staan ver af van benaderingen die de nadruk leggen op stedelijke besluitvorming ('urban manegerialism'), politieke cultuur en planningstijl.

Er moeten derhalve flexibele methoden ontwikkeld worden, niet alleen vanuit conceptueel oogpunt (CBA), maar ook ten aanzien van hun toepasbaarheid voor het modelleren van regionale nederzettingspatronen. Er zijn geen goed bruikbare technieken beschikbaar om een 'formele' ruimtelijke patroonanalyse uit te voeren. De te ontwikkelen methoden moeten deels gebaseerd worden op visuele en manuele analyse.

Methoden die gebaseerd zijn op traditionele concepten vereisen betrouwbare, complexe ruimtelijke en thematische gegevens over een groot aantal aspecten, gegevens die bovendien actueel beschikbaar moeten zijn. De mate van detail die vereist wordt voor informatie over veel functies verandert vaak en is, met name in ontwikkelingslanden, moeilijk regelmatig te actualiseren. De modellen verliezen hun waarde als er verouderde gegevens gebruikt worden. Bovendien is het voor veel stedelijke en regionale systemen belangrijk om een totaalinzicht te verwerven. Maar de informatie die over het algemeen beschikbaar is of beschikbaar gemaakt kan worden, is meestal gerelateerd aan individuele beslissingen.

Door de mogelijkheid synoptische overzichten te bieden van grote gebieden, kunncn aardobservatiegegevens (satellietbeelden) een nuttiger basis vormen dan aardbeelden met een hoger oplossend vermogen. Beeldgegevens met een ruimtelijke resolutie van 72,5 meter blijken adequaat voor het doel (modelleren van nederzettingspatronen) en geven een samenvattend overzicht van het hele studiegebied. Vergeleken met een resolutie van 10 meter, maakt vooral de relatief lage resolutie de anders moeilijke taak om voor de werkelijkheid het 'bebouwings' beeldpunt te bepalen uit een mix van 64 pixels gemakkelijker.

Het stadsgewest van de hoofdstad Delhi ('National Capital Region', NCR) is uitgegrocid tot een ingewikkeld administratief en planningsysteem. Nog complexer is de planning van het regionale nederzettingenpatroon gegeven het feit dat nederzettingen aanwezig zijn van tussen de vijfhonderd en negen miljoen inwoners. De planningsdienst beschikt niet over methoden en gereedschappen om het nederzettingspatroon in een gebied met de omvang van de NCR goed te begrijpen. Het beschikt ook niet over de methoden en technieken om de ontwikkeling van het nederzettingspatroon te bewaken met een periodiciteit die past bij snel groeiende menselijke nederzettingen. Het CBA concept, ondersteund door gereedschappen als aardobservatie en geografische informatiesystemen, maakt het voor planologen, administratieve medewerkers en beslissers mogelijk om meer inzicht in dezc complexiteit te verkrijgen op een wijze die objectief en consistent door technici kan worden uitgevoerd.

Gebaseerd op dit 'nieuwe' inzicht in nederzettingen is een model ontwikkeld om nederzettingspatronen te beschrijven en er voorspellingen over te doen en aanbevelingen voor te geven. Door een flexibele benadering bij het definieren van menselijke nederzettingen en het gebruik van satellietbeeldcn, kan het model gemakkelijk toegepast worden in situaties met weinig gegevens en met niet goed ontwikkelde werkwijzen voor het plannen van nederzettingspatronen zoals het geval is in ontwikkelingslanden. Het biedt een expliciete mogelijkheid om het begrip 'local' in de context van het 74e amendement van de Grondwet van India beter te definieren en te begrijpen. Dit amendement is gericht op het versterken van de rol van lokale stedelijke lichamen om lokale sociale en economische ontwikkeling te stimuleren en om het milieu te verbeteren.

Verwacht kan worden dat het gebruik van de modellen tot twee algemene voordelen zal leiden: een toegenomen aandacht voor de noodzaak om administratieve en planningsgrenzen te laten samenvallen en een toegenomen inzicht in de noodzaak om fysieke grenzen en telgebieden van de volkstelling te laten samenvallen. De territoriale eenheden kunnen daardoor geintegreerd worden en als een standaard meetsysteem worden opgenomen in de wetgeving. Hierdoor kan de werkelijkheid in plaats van een administratieve abstractie daarvan de basis gaan vormen voor de planning en het beheer van menselijke nederzettingen.

ABSTRACT

Analysis of settlement patterns is useful in making decisions about the location of new investments, and about the potential for clustering services and facilities in new ways to increase the capacity of human settlements to stimulate development in their areas. Settlement patterns in and around metropolitan regions become all the more important when considering the pace with which the urban settlements are increasing, both in number and size. In addition, in developing countries, there is a new category: increasingly large numbers of spontaneous human settlements are coming into existence on the urban fringes.

Left to 'natural' processes, these phenomena produce inefficient as well as ineffective settlement patterns. To reduce the social, economic and environmental cost of inefficiency, management is introduced to address problems arising from the processes. An attempt has been made by this research to suggest a model for describing the settlement pattern, and for exploring alternatives for the management of the future development of that pattern.

In considering urban growth, one of the first questions to be resolved is how to identify the changing extent of the settlements. In response, a transferable approach of the 'Continuously Built-up Area' (CBA) is devised, which allows identification of settlements at different levels of generalization. In this approach, the reality of the moving urban edge rather than municipal, administrative or political boundaries is seen (e.g., through satellite images), recorded and continuously updated so as to provide real time information to support decision-making. The strength of the tool (i.e., the concept of CBA, applied to remotely sensed data) is that it may be calibrated to any level of generalisation, corresponding to different scales of mapped information and decision-making.

No sufficiently comprehensive methods exist for defining and recognising spatial patterns. The methods available (e.g., the spatial autocorrelation) are generally for point patterns, which are best analyzed partly visually and partly manually. Cluster analysis techniques are also not suitable for spatial clusters.

A number of theories and models have been put forward to describe and understand human settlement patterns. One important conclusion that can be drawn from a review of these models is that they all help in analysing the existing patterns. Most of them help, in a limited way, in predicting settlement patterns and, rarely, in planning settlement pattern changes. Moreover, the prevalent models consider settlements as point locations when analysing their spatial distribution. The size of the settlement, not in terms of the population it holds but in terms of the area it covers on ground, or its shape, is hardly ever considered.

Another conclusion drawn is that most quantitative models of settlement patterns rely heavily on assumptions such as isotropic planes and rational economic behaviour. The geometrically and statistically guided models do not really work in the light of 'urban managerialism', political climate and planning behaviour.

Thus, methods will have to be developed which are flexible not only in the conceptual context (e.g., CBA) but also in their application to model settlement pattern in a region. Satisfactory techniques are not available for performing a 'formal' spatial pattern analysis exercise. The methods developed have to be based on a partial visual/ manual analysis.

Methods based on traditional concepts require accurate, sophisticated and timely availability of data, both spatial and attribute, on a variety of subjects. The level of detail required for information on many functions changes frequently and is difficult to update on a regular basis, more so in developing countries. Models lose their sophistication when outdated data are fed into them. Further, in many urban and regional systems it is important to ascertain the overall situation. But the information we usually have, or are likely to have, relates, by and large, to individual decisions.

With the capability of providing synoptic views over large areas, remotely sensed data (e.g., satellite images) can be a useful base for carrying out macro-analyses of settlement patterns, at frequent intervals. It not only provides information more efficiently than field surveys; it also offers a new perception and a new understanding of human settlements.

An interesting finding is that working at the metropolitan regional scale, images with low spatial resolution are actually more useful than images with higher resolution. The remotely sensed data with spatial resolution of 72.5m is found appropriate for the purpose of this task (e.g., modelling settlement patterns), providing a synoptic view of the entire region under study. Specifically, its comparatively low resolution performs the otherwise difficult task of determining the 'built-up' pixel out of a mix of 64 pixels (of 10m resolution compared to ±80m) in reality.

The National Capital Region (NCR) of Delhi, India, has evolved into a complex planning and administrative system. More complex is the planning for settlement pattern for the region, with human settlements in population sizes ranging from less than 500 persons to over 9 million people. The planning board does not have the methods and tools to comprehend settlement pattern over an area of the vastness of NCR. It also does not have the methods and tools to monitor settlement patterns at intervals appropriate to rapidly growing human settlements. The concept of CBA, supported with tools such as remote sensing and GISs, enables planners, administrators and decision makers to gain better understanding of this complexity, in a way that can be impartially, and with consistency, executed by technicians.

A model has been developed for describing, and making predictions and recommendations for settlement patterns based on the new understanding of settlements. Through a flexible approach in defining human settlements, and the use of images from satellites, the model is easily applied in 'data-poor' situations and with not well established practices of settlement pattern planning, as is the case in many developing countries. It literally provides a tool for better defining and comprehending the term 'local', in the context of the 74th Amendment to the Constitution of India, designed to strengthen the role of urban local bodies in promoting local social and economic development, and in improving the environment.

Use of the models may be expected to lead to two general advantages, i.e., increased awareness of the need for coincidence between physical and administrative boundaries, and increased awareness of the need for coincidence between physical boundaries and the survey plan for the census. It, then, becomes capable of being integrated as a system of standard measurement into the legislation. As a result, reality rather than administrative abstraction can become the basis for planning and management of human settlements.

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INTRODUCTION

1.1 RELEVANCE

Man, by nature, lives in groups, or communities. The most widespread community unit was, and as yet is, the village. With social evolution and increasing contact between people living in different communities, the possibility arises of one community serving others by making goods and/or providing services in exchange for other goods and other services, or their equivalent worth in terms of money. In the process of specialisation, one community or part of a community concentrates on producing goods and/or services for others. As increasing specialization requires access to increasingly large markets, networks of these connected activities then trigger the formation of nodes, or towns, of which some then grow to become cities. Consequently, a hierarchy of human settlements develops, consisting of hamlets, villages, towns, cities and, relatively recently the metro and megalopoleis. These large human settlements then serve as economic, political, and cultural centres, provide markets and administrative and educational specialists, and are characterised by extreme diversity in occupation and heterogeneity in population (Cowrin, 1977).

The settlement patterns that thus emerge are influenced by socio-economic, physical and network factors. To recognize these helps to analyse the relation between different constituents of the patterns, both existing and likely to result due to a process of intervention through planning. The analysis can assist planners and policy makers in understanding how the pattern of settlement and the level of development within the region are related. It can help them determine the degree of access that people in different parts of the region have to goods and services (e.g., facilities, infrastructure and organisations); and to judge where this access is inadequate. Moreover, the analysis can be useful in making decisions about the location of new investments, and about the potential for clustering services and facilities in new ways to increase the capacity of human settlements to stimulate development in their areas (Rondinelli, 1985).

Settlement patterns in and around metropolitan regions become all the more important when considering the pace with which the urban settlements are increasing, both in number and size. So much so that for the first time in history, this decade is expected to witness more people living in urban areas than in the countryside. In addition, in developing countries, there is a new category: increasingly large numbers of spontaneous human settlements are coming into existence in the urban fringes.

Left to 'natural' processes, these phenomena produce inefficient as well as ineffective settlement patterns. To reduce the social, economic and environmental cost of inefficiency, management is introduced to address problems arising from the processes. The problems are complex and immense and no single approach to management will suffice. Among the many innovative approaches which are under development are 'Urbwatch' and 'Urbserve', proposed by the International Institute for Aerospace Survey and Earth Sciences (ITC), the Netherlands (ITC, 1993). Whereas the key message in Urbserve is to think and act locally, the key message in Urbwatch is to think and act globally. At the regional level, Urbwatch envisages a programme for monitoring and reporting on changes in settlement patterns utilising data obtained through remote sensing from satellites (Bolt, 1993). With an aim to contribute in line with the Urbwatch approach, an attempt has been made by this research to suggest a model for understanding, monitoring and describing the settlement pattern of a metropolitan region, and for exploring alternatives for the management of the future development of that pattern.

1.2 BACKGROUND

A number of theories and models have been put forth to describe and understand human settlement patterns. Methods generally adopted by geographers, demographers and planners for analyzing settlement patterns can be grouped as based upon morphological classifications, population size classifications and functional classifications. Most of these methods have been developed, tested and applied in varying situations and complexities, mostly in the developed part of the world. They have also been adapted to meet area specific and other conditions. However, most of these methods assume and dwell upon the availability of a large amount of information both on socio-economic and physical factors. It is understood that the type of information suggested to be used by a method is mainly guided by the type of information that was readily available at the time the method was propagated. Many information types that were not considered by these methods (or were thought to be difficult to collect) would be more readily collected today. Application of remote sensing technology opens up a wealth of information related to physical factors directly and many others indirectly. The existing methods of settlement patterns analysis might be enriched by making use of this additional information. Moreover, this additional information is available at shorter and shorter intervals, thereby enabling the researcher to understand settlement patterns of a given situation on a time basis, to point out the changes, and hence to consider possible future patterns. Availability of PC-based Geographic Information System (GIS) packages also makes it more convenient, now, to understand and simulate the settlement patterns under various constraint situations, and to evolve alternative scenarios concerning future changes.

Besides depending heavily on the availability of a large variety of data at a detailed level, most of the existing methods of understanding settlement patterns rarely extend themselves towards predicting or recommending a pattern. Many of the sophisticated models being developed have an added disadvantage. They are far too complicated to be easily understood and comprehended by an average planner working in the regional or local planning authority in a developing country. As a result they remain 'book' models, rarely reach the 'drawing board' and never reach to the ground.

1.3 OBJECTIVES

Within the outlined framework of relevance and background, this research aims at exploring the extent to which existing models of settlement patterns analysis can be modified and updated to take into account the non-availability of data from traditional sources, and the more ready availability of data through remote sensing, with the following objectives:

1.3.1 To investigate, by means other than remote sensing techniques, the applicability of existing theories and models of settlement patterns analysis in the present day context and to identify the information gaps, if any, with specific reference to developing countries;

1.3.2 using remote sensing techniques, to explore and assess the possibility of modifying these theories and models so as to update them, and to fill in the gaps, if any;

1.3.3 to evolve a model, prototype in the context of urbanization in India, which could later be developed to become a generic model relevant to developing countries, for understanding, monitoring and describing settlement patterns in metropolitan regions, dependant primarily on remotely sensed data; and

1.3.4 to evolve a model, as in 1.3.3 above, for predicting settlement patterns in metropolitan regions and recommending management steps that might be undertaken to assist or modify the course of emergence of predicted patterns, dependant primarily on remotely sensed data.

1.4 SCOPE AND LIMITATIONS

The scope and limitations of the research are:

1.4.1 The scope is limited to selected theories and models of settlement pattern analysis concerned with metropolitan regions;

1.4.2 the scope does not seek to challenge or question the validity of the selected theories and models but attempts to modify them to accommodate new kinds of data and human settlement types (i.e., remotely sensed data and spontaneous human settlements);

1.4.3 social and economic (e.g., technical, political, administrative and organisational) as well as physical linkages between human settlements play very important roles in shaping the settlement pattern in a region. However, the models being developed in this research are general models which do not specifically deal with any of these linkages except, to a limited extent, with physical linkages; and

1.4.4 application of the models developed in this research is limited to the National Capital Region (NCR) of Delhi, India.

1.5 ORGANISATION OF THE BOOK

Following this first and introductory chapter, the book is divided into six further chapters. Whereas all the illustrations and tables have been put along with the text relevant to them, all the appendices and references have been placed at the end of the book.

Chapter Two undertakes a critical review of the prevalent concepts and definitions of the two key words used in the research, i.e., (human) 'settlements' and 'settlement patterns'. The chapter identifies the limitations attached to conventional definitions and how these limitations further limit their application towards building a model. A few non-conventional as well as dictionary meanings have also been looked into. Following the same format, a critical review of most models used for analyzing settlement patterns is made in Chapter Three. While an attempt is made in this chapter to identify the limitations attached to these models, some factors beyond the scope of these models, yet important in shaping settlement patterns, are also studied. The findings of these two chapters are used in proposing new definitions and the models in Chapter Seven.

Chapters Four and Five are devoted to appraising the techniques of Remote Sensing and Geographic Information Systems (GISs) respectively. Both techniques are discussed for a general understanding of their application usefulness and their limitations in the field of spatial planning, and more specifically their usefulness and limitations in modelling settlement patterns. As the models developed are intended to be applied in a developing country (i.e., India), a description of the status of the two techniques in India is also presented.

A detailed overview of the growth of Delhi from a walled city of 5 sq. km to the National Capital Region is made in Chapter Six. Besides tracing the history of growth and development, important planning interventions made from time to time are also summarized. The chapter concludes with a description of the region, the policy framework for its planned development, and a scenario in which models for understanding, monitoring and describing, and for predicting and recommending settlement patterns, are developed.

Chapter Seven, last in the book, draws from the preceding chapters. Based on the findings of Chapters Two and Three, it provides the definitions and concepts finally adopted and operationalized to form the basis of model building. It draws from Chapters Four and Five in delineating various human settlements, and developing and applying the models in the National Capital Region of Delhi. The chapter then assesses the models in terms of their advantages and limitations. The chapter concludes with an appraisal of the models with respect to the regional plan, and with suggestions for further research.

2

SETTLEMENTS, PATTERNS AND SETTLEMENT PATTERNS

CONCEPTS AND DEFINITIONS

Human beings easily associate themselves with human settlements. Yet, they differ in their perception of human settlements depending upon their experiences - the settlements that they have lived in or are living or have seen or heard of. When and how does a human settlement transform from a village to a town or a city; what separates two settlements physically; what to expect from a big settlement that the smaller settlement can not provide? Perception of human settlements vary not only among the residents in general but also among professionals dealing with various aspects of human settlements. This variation in perception, subsequently, leads to variation in perceiving and interpreting settlement patterns.

This chapter makes a critical review of the prevalent concepts and definitions of the key words (human) 'settlements' and 'settlement patterns'. It identifies the limitations attached to conventional definitions and how these limitations further limit their application towards modelling settlement patterns. Further, the chapter reviews some of the non-conventional approaches to define the key words.

A major consideration in making survey of literature on the subject was that of relevance. Those parts of the literature, that have an interface with existing planning practices in India were selected. The parts which did not have an interface with the existing situation in India were dropped. The selected parts of the literature represent the perception of these key words by an average citizen (i.e., through dictionary meaning), by an administrator (i.e., through formal definition) and by a spatial planner (i.e., through concepts found in planning literature).

The chapter concludes with a selection of concepts and definitions that were found useful in developing the models, in Chapter Seven.

2.1 (Human) SETTLEMENTS

The word (human) 'settlement' means different to various individuals, professionals and physical planners. It may encompass different levels and scales of space, time and functions. It is an 'establishment of people in a new region; a newly colonised region; a small community' (Morris, 1976).

It has also been described as 'the act of peopling or colonizing a new country or of planting a colony; an assemblage of persons settled in a locality: hence a small village or collection of huts and houses' (Stamp and Clark, 1979). Global Report on Human Settlements (UNCHS, 1986) describes it as 'an assemblage of persons settled in a locality'. The term is used by geographers to cover all groups of human habitations (Stamp, 1966) ranging from even single dwellings (Stamp and Clark, 1979) to the largest city (Mayhew and Penny, 1992).

In spite of these general descriptions, an urgent need for good and generally accepted definition of human settlements has always been felt. Sub-consciously, human settlements were viewed as a fundamental expression of 'man-man' and 'man-land' relationships (Gamer, 1968). The expression 'human settlements' has also often been referred to by terms as 'cities', 'urbanisation', 'housing' and 'cities and towns'. All of these terms are not fully adequate to define 'human settlements'. Moreover, the legal and administrative identifications of human settlements are distorted by their historical and constitutional evolution (Haggett, 1972).

The United Nations Conference on Human Settlements (Habitat), held in Vancouver in 1976, by its very name gave global recognition to the holistic concept of 'human settlements' (Leman, 1987). The Conference gave a first comprehensive description of the concept of human settlements: 'The fabric of human settlements consists of physical elements and services to which these elements provide the material support' (UNCHS, 1976). While this description provided an insight to a human settlement, it was not defined enough to be able to demarcate one.

Keeble (1969) also noted the difficulty in answering the question, 'What is a town?'. 'Something bigger than a village; something smaller than a conurbation; something which, except for ribbon and sporadic development, is separated from neighbouring settlements by agricultural land', was the best answer that he could provide. Alas! This agricultural land, performing the separating function, is diminishing very fast, making the question more difficult to answer. There are indeed no agreed definitions to separate a city from the large metropolis or the smaller town (Goodall, 1987).

2.1.1 Conurbation and Urban Sprawl

Conurbation has also been used to mean a continuous built-up area formed by the coalescing of once-separate settlements into a continuous built-up area, initially through ribbon development. The term has now largely been replaced, notably by Metropolitan Area and Metropolitan Labour Area (Johnston, 1981). A group of towns forming a continuous built-up area has also been referred to as 'conurbation' (Mayhew and Penny, 1992). It is different than urban sprawl, which is used to express the phenomenal spread of urban growth outwards from the town (Ratcliffe, 1981, p.40); housing, shops, and work-shops forming an often haphazard spread of buildings at the edge of the city (Mayhew and Penny, 1992).

Governmental jurisdictions have traditionally been territorially based and bounded (Webber, 1964). The Census of India classifies human settlements into a hamlet, village, town, and urban agglomeration. Other concepts of a urban village, city and metropolitan city are though

non-official, yet widely accepted among planners and other professionals. Census of India further classifies the rural settlements into 7 size classes of less than 200, between 200 to 499, 500 to 999, 1,000 to 1,999, 2,000 to 4,999, 5,000 to 9,999, and 10,000 and more persons; and urban settlements (towns[1]) into 6 size classes of below 5,000, between 5,000 to 9,999, 10,000 to 19,999, 20,000 to 49,999, 50,000 to 99,999, and 100,000 and more persons. All class-I towns (population size of 100,000 or more persons) are generally known as cities. All towns or urban agglomerations of population size of one million or more persons are generally known as metropolitan cities; 5 million or more being known as megacities. The static definition (as applied from census year to census year, i.e., beginning of each decade) adopted by Census of India also brings a large number of settlements from one category to another overnight. There is no concern for the physical extent of the settlement and nor for the fact that in large urban settlements physical extent is also increasing very rapidly. The static definition also does not cover the scope of a number of informal human settlements both within, on the periphery, and outside the urban settlements. These rigid definitions not only pose challenges for planning-researchers, they pose not-easy-to-solve problems for the municipal and city administrators. Computation of the growth of population in cities on the basis of population size of urban centres identified as cities in the respective censuses, has often raised false alarms (Kundu, 1982).

2.1.2 Urban Agglomeration

An urban agglomeration is identified by the Census[2], yet continues to be looked after by a

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1 **As per the definition adopted by the Census of India, towns are places with a municipal corporation, a municipal area committee, a town committee, a notified area committee or a cantonment board; also all places having 5,000 or more inhabitants, a density of not less than 390 [subsequently raised to 400 (Meshram and Bansal, 1993)] persons per sq. km, pronounced urban characteristics and at least three-fourth of its adult male population employed in pursuits other than agriculture (Clark, 1982). A few places not possessing all these characteristics but thought to be predominantly urban are also so designated. A town can be declassified, however, either because of a change in definition or because its total population or number of urban workers declined (Mills and Becker, 1986).**

2 **Most censuses identify urban areas that extend beyond the boundaries of local government jurisdictions. As urban places grow, the urban population may spill over local government boundaries and into what was formerly a rural area. Alternatively, two or more towns may grow together, so that they become one urban place. 'Metropolitan area' is the name most commonly applied to such places.**

The 1961 Indian census introduced the notion of a town group. The subsequent censuses have employed the term 'urban agglomeration'. An urban agglomeration consists of one or more towns or cities and the adjoining urban outgrowths (Mills and Becker, 1986). Some small urban places do also get termed as urban agglomerations under this notion.

Formally, an urban agglomeration constitutes (Census of India, 1981):

- **i. a city or town within a continuous outgrowth, the outgrowth being outside the statutory limits but falling within the boundaries of the adjoining village or villages; or**
- **ii. two or more adjoining towns with their outgrowth as in (i) above; or**
- **iii. a city and one or more adjoining towns with their outgrowths all of which form a continuous spread.**

(continued...)

number of municipalities, as is the case in Bombay, India. The Master Plan for Delhi (DDA, 1990) suggests that the Delhi Metropolitan Area, including the Union Territory of Delhi (now redesignated as National Capital Territory of Delhi), should be considered as one 'urban agglomeration' for the purpose of planning[3]. Even administrative boundaries can not, and have not remained static. The compilers of the United Nations Demographic Yearbook argue that the boundaries that mark off towns, cities and municipalities for local government purposes vary from place to place and constitute an extremely poor basis for urban definition (Clark, 1982). Examples are in plenty where these boundaries have been realigned to accommodate (largely) political and (partially) socio-economic-administrative interests. After all, we do have overbounded or underbounded cities (Goodall, 1987). It is not uncommon for some new statutory towns seeking denotification so as to remain eligible for benefits due to rural areas, including exemption from payment of municipal taxes (Krishan, 1993). After the 74th Amendment to the Constitution of India, in 1992, and subsequent enactment of the Municipalities Act, 1992, a recognition has been accorded for the first time to the areas in transition from rural to urban in the form of *Nagar Panchayat,* a body similar to municipal corporations (Government of India, 1993; Meshram and Ban sal, 1993). In addition to his own theoretical studies, Christaller suggested that geographers could contribute to the resolution of administrative problems related to urban integration and dominance (Preston, 1992). His fourth principle of central place organisation and a mixed marketing-administrative model could form the basis towards removing rigid and static nature of the known definitions of human settlements.

Even though Keeble (1969) identified human settlements as the National Capital, the provincial capitals, local capitals, fully-fledged towns, urban villages or major rural centres, villages or minor rural centres, hamlets, and isolated farmhouses and agricultural worker's cottages, he also pointed out that many places possess characteristics intermediate between two of the grades, and in the last resort it is the function that they perform rather than their populations and visual characteristics which determine their position on the scale. The size and complexity of the modern human settlements means that for most purposes, planners have little choice but to rely upon secondary sources of data and so census authorities play an important role in shaping our views of human settlement structures. Recent technical advances in computing systems, technique of geo-coding and GISs and remote sensing have made it possible for researchers to develop their own aggregation of human settlements from

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2(...continued)

The dictionary (Morris, 1976) meaning of 'agglomeration' is a confused or jumbled mass of things clustered together. It is the concentration of activities, usually industries, in the same location. It may also apply to concentrations of urban settlements (Mayhew and Penny, 1992). It is the association of productive activities in close proximity to one another, as in a major specialized industrial region or in a large town or city. Agglomeration typically gives rise to external economies associated with the collective use of the infrastructure of transportation, communication facilities and other services. Agglomeration also facilitates the rapid circulation of capital, commodities and labour (Johnston, 1981). 'Agglomeration' should not be confused with 'conglomeration', which is referred to a number of industries producing a number of unrelated products (Mayhew and Penny, 1992). The emphasis here is on the heterogeneity aspect of the objects forming the conglomeration (Morris, 1976).

3 **See Chapter Six for a detailed description of the concepts of the Union Territory of Delhi, the Delhi Metropolitan Area and the National Capital Territory of Delhi.**

census data. In the United Kingdom, 1971 census data was released on a grid square basis. Grid squares are easy to map, and as all grids contain the same area of land, all counts are automatically density measures, and absolute numbers can be mapped directly. The availability of geocoded data enables researchers to move away completely from arbitrary administrative definitions of (types of) human settlements and to build up pictures of the urban landscape using a wide variety of indices (Clark, 1982).

2.1.3 Counter-urbanization

There also have been a few non-conventional conceptual approaches to analyse urbanisation processes and urban settlements. A recent field of inquiry deals with the concept of counterurbanization - a process of population deconcentration where large metropolitan areas lose population by net migration to non-metropolitan areas (Johnston, 1981). This may occur spontaneously as cities become expensive, polluted, and congested or may be encouraged by governments (Mayhew and Penny, 1992). It is deemed to be the prevailing tendency when the distribution of population is shifting from larger to smaller places, where 'places' are defined in terms of relatively self-contained areas comprising an urban centre and its commuting and servicing catchment. Counterurbanization does not require the abandonment of all types of urban settlements in favour of the villages and isolated dwellings traditionally associated with the countryside, nor does it necessitate a return to rural life-styles in the sense of giving up the trapping of a modern materialistic society. It does, however, require the faster growth of those smaller places that are not linked to major cities by significant commuting ties or other frequent journeys than those that are, and therefore specifically excludes the long-established processes of suburbanization and metropolitan expansion (Champion, 1989). Though this working definition is not always easy to implement, particulary in heavily urbanized multi-nodal regions, its intent is clear, namely that traditional suburbanization and local metropolitan decentralization are not considered to be aspects of counterurbanization (Champion, 1989). In the case of the National Capital Region of Delhi, though many activities have been encouraged to be deconcentrated, the net result is far from •counterurbanization'.

2.1.4 City Region

The concept of the 'city region' is used to describe those vast areas of continuous or nearly continuous development too large to be considered as a single city, however big, because of their physical extent and because they contain within them the whole range of activities and facilities found within a normal region (Keeble, 1969). The terms 'urban field' and 'urban region' are generally preferred, used to define the territory functionally linked with a town, or to mean the hinterland or trade area (Stamp and Clark, 1979); that area surrounding a city which is influenced by it. Its boundary can not be demarcated by a single line. In the case of very large cities, the urban field is often considered to be global (Batty and Longley, 1994). The concept of 'plug-in-city' (Goodall, 1987) is good working understanding of urban field. The field falls into three zones: a core area composed of the built-up area of the town, an outer area which uses the town for high-order goods and services, and a fringe area which uses the urban area rarely and then only for very high-order goods and services (Mayhew and Penny, 1992). Smailes (1953) draws a distinction between the two, in the sense that

'urban region' refers to relatively homogenous land-use areas within cities, and not to the region for which the city serves as the focus. Essential nature of such an area is that at its core is a very large central area which exerts a dominant effect over a large number of smaller human settlements which are little separated from it or from each other. An urban region is rather similar to a conurbation but can be distinguished from it because 'conurbation' is taken as referring to a more limited area than comprises an 'urban region'. It is, by its nature, very difficult to define in any decisive way the boundary of an 'urban region' (Keeble, 1969). Generally, in practical terms, it is based more on spatially distinct housing, labour and services markets.

Lynch (1960) perceived a metropolitan region as a functional unit of environment and stressed that this functional unit should be identified and structured by its inhabitants. For the imageability of such a unit, it should have enough surface area so that all minor elements can have some reasonably close relation to it.

2.1.5 Urban Realm

Webber (1964) introduced the concept of 'nonplace urban realm', referring to the 'communities of interest-communities' sharing **a** common market or service area, interdependent and interactive with each other in some degree; and at their respective levels of specialization, each heterogenous group of interest-communities making up a complex but organized system of activities and intercourse. An urban region reflects a unitary idea - at any given instant in time, its spatial extent is essentially fixed. An urban realm, in contrast, is neither an urban settlement nor a territory. Webber further identified a hierarchy of realms operating at the world, nation, subnation, sub-subnation, metropolitan and local levels. The participants in each realm are constantly shifting but there are very large numbers of people who devote large proportions of their time to roles associated with local realms.

Contrary to the vertical divisions of territory that accord with place conceptions of region, he viewed the functional processes within the total national urban space as horizontally stratified (Figure 2.1).

Thus, the most specialized people communicate across the entire nation and beyond. At lesser levels of specialization, people interact over shorter distances but the extent varies from person to person and, for any given person, from moment to moment. Thus, the urban settlement is far from being a unitary place. Its composition and its spatial dimensions are relative to the observations of participants in different realms at different instants in time. Each problem defines its own community for solution, and each interests-group defines its own community for satisfaction (Webber, 1964). Creation of a European Economic Community is clearly an example of an effort to selectively break the barriers of unitary, land-based governmental boundaries. Resulting from developments in telematics, these ideas were recently reintroduced under names like 'global village'.

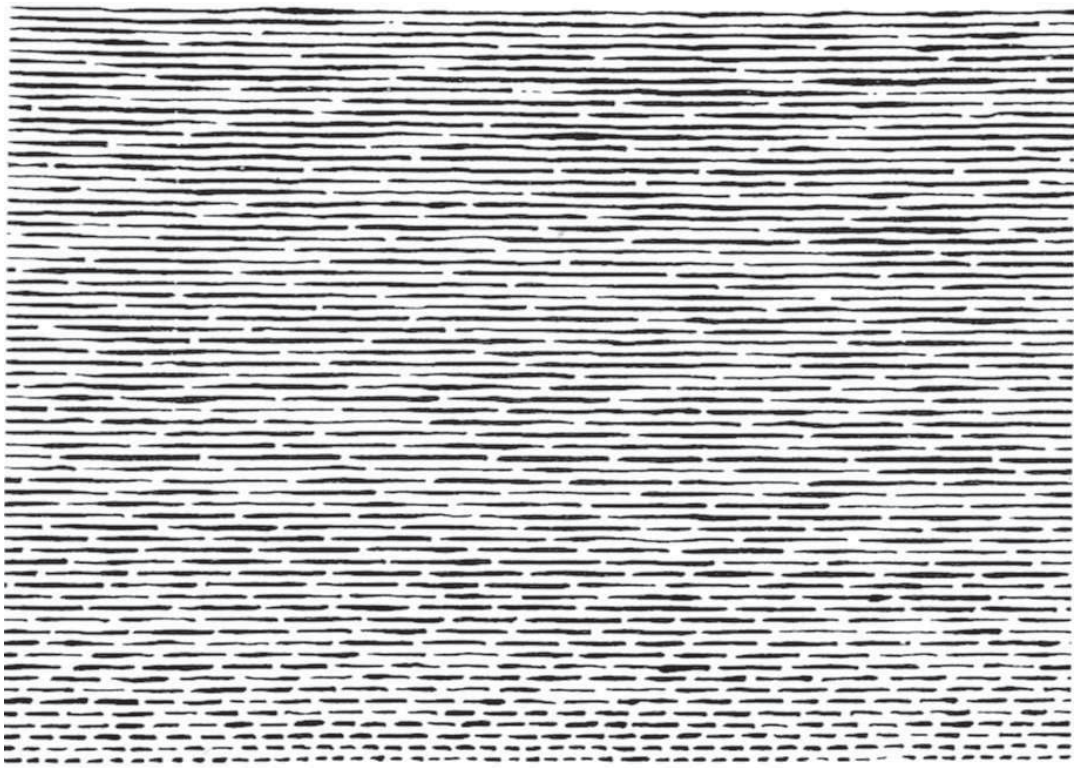

Fig. 2.1 **The** Urban Realm
(after Webber)
Source: Webber, 1964, p. 119

"Geographic space extends horizontally and level of specialization vertically in the drawing. The bars then represent the realms which extend in overlapping patterns across the continent, those at the highest levels being spatially most extensive. Individuals participate in first one then another realm, as they play first one role, then another. The spatial patterns of realms are thus indistinct and unstable.' (Webber, 1964, p. 119).

2.1.6 Spatial Diffusion

Processes of spatial diffusion also occur at many geographic scales. At the micro scale, ideas and innovations spread through social communication networks linking individuals to one another. When considered at a regional level, different network of communication may come into play, probably closely aligned to the pattern of linkages between the central places. Finally, at the national or even at international level, macro flows of information, warped and shaped by great metropolitan fields, diplomatic relationships, political considerations and so on, guide the course and intensity of diffusion processes (Abler *et al.,* 1972).

2.1.7 Spatial Consciousness

Harvey (1973) identified 'spatial consciousness' or the 'geographical imagination' which enables an individual to recognize the role of space and place in his own biography, to relate the spaces he sees around him and to recognize how transactions between individuals and between organizations are affected by the space that separates them. Contrasting it with the 'sociological imagination', he argued, "The trouble is that the use of one sometimes conflicts with the use of the other. Any successful strategy must appreciate that spatial form and social process are different ways of thinking about the same thing. We must therefore harmonize our thinking about them or else continue to create contradictory strategies for dealing with city problems." (Harvey, 1973, pp.26-27). In the same work, Harvey records three basic categories of spatial experience identified by Cassirer (1944, as quoted by Harvey, 1973). The first, organic space, the kind of experience which appears to be genetically transmitted and hence, biologically determined. The second, perceptual space, involves the neurological synthesis of all kinds of sense experience - optical, tactual, acoustic and kinesthetic. The third kind of spatial experience is abstract, called symbolic space, where the space is experienced vicariously through the interpretation of symbolic representation which have no spatial dimension. The three levels of spatial experience are not independent of each other. We need, for example, to find some way of representing events as they occur on the perceptual or organic level by some abstract symbolic system which forms a geometry. Conversely, we may regard it as finding some interpretation at the organic or perceptual level for ideas developed at the abstract level.

2.1.8 Edge City

In the same context, it is also important to mention here the concept of 'edge city'. Garreau (1991) used the expression 'edge' to represent the vigorous world of pioneers and immigrants, rising far from the old downtown, where little save villages or farmland lay only three decades before; and the expression 'cities' to represent all the functions a city ever has, albeit in a spread-out form that few have come to recognize for what it is. By any functional standard, each edge city identified by Garreau (1991) was larger than their corresponding downtown. In providing a functional definition of the edge city, Garreau (1991) included such aspects as leasable office space, leasable retail space, jobs outnumbering bed rooms, and perception by population as one place. However, he does identify the problems in defining these places. One problem is that of history, which the edge city has none. The second is that they rarely have a mayor or a city council, and just about never match boundaries on a map.

"After all is said and done, /w-the citizen-is really the city. The city is going where he goes." (Frank Lloyd Wright, as quoted by Garreau, 1991, p. 11). Perhaps 'edge city' represents taking the functions of the city (the machine) and bringing them out to the physical edge of the landscape (the frontier).

2.1.9 Territorial Arrangements

"What is happening to our cities? We all feel the problems, we see them, smell them, hear them, we are sensitive to them, but we have not really defined what they are." (Doxiadis, 1976, p.l). The first significant contribution in defining human settlements was made by Doxiadis in the year 1976, in his book entitled, 'Action for Human Settlements'. According to this definition, "Human Settlements are the territorial arrangements made by Anthropos for himself." (Doxiadis, 1976, as quoted by Leman, 1987, p.243). The immense benefit of this definition was that, in what until then was an amorphous, dimensionless and concept-less area, a line was suddenly drawn - a 'water mark' appeared -denoting the current level of understanding of a given phenomenon which, only from that point on, could be effectively considered by a number of persons. It offered the first opportunity for testing and evaluating the 'inclusions' and 'exclusions' brought about in the course of developing the definition (Leman, 1987).

2.1.10 Settlement Classification

Haggett *et al.* (1977) provided a human settlement classification as depicted below.

NODES

Settlements (morphological classification)
Urban Settlements — **Rural Settlements**
Irregular
Regular

Clusters (population-size classification)
(e.g., Metropolis, city, town, village, hamlet)

Places (functional classification)
(e.g.. Central places, non-central places)

It was around the same time that Dansereau (1978) attempted to define and classify human settlements based on an ecologically coloured or textured matrix. He viewed human settlements as alternative patterns of sharing and exploiting resources, and of inserting the human presence into widely different environmental matrices. Rationale for such a definition was based on the recognition and mutual inter-relationship of:

a. the ecological characteristics of the supporting landscape and its yields and stresses as a resource basis;

b. the way-of-life of the human population estimated in terms of the array of processes employed towards resource tapping and cycling; and

c. the resulting man-to-environment and man-to-man strategies that involve inner tensions and inter-ecosystem exchanges.

Dansereau (1978) further provided a repertory of human settlements classifying them into four panels of Wild, Rural, Industrial, and Urban settlements. These were divided into 21 types of human settlements as follows.

WILD	*RURAL*	*INDUSTRIAL*	*URBAN*
Nomadic	**Pastor/ Ranger**	**Heavy Industrial**	**Village**
Transhumant	**Planter**	**Craftsman**	**Town**
Gatherer	**Farmer**	**Engineering**	**City**
Hunter/ Fisherman	**Monoculture**	**Manufacturing**	**Metropolis**
Hunter/ Farmer	**Horticulture**	**Service**	
	Non-Producer		
	Mining		

The upper end of the urban settlements could be further extended to Megalopolis and *Ecumenopolis** - the world city put forth by Doxiadis. One interesting feature of Dansereau's approach was that a village, town, city and metropolis had not been distinguished on the basis of their size and density as those in themselves could not be major criteria. Fitness to landscape and to regional systems had been viewed as more useful. The following descriptions for distinguishing a village and a town did not, for instance, use any reference to population size:

> "The *village* has one or more streets, residences that are not too densely clustered, usually an exchange centre (communications and trade), and much adjacent rural land." (Dansereau, 1978, p. 181); and
>
> "The *town* is a larger settlement, comprising many streets, having sidewalks, row upon row of shops, many public buildings and services (including intramural public transport)." (Dansereau, 1978, p. 181).

An important lesson drawn from this scheme to classify the cells of land-occupation on an ecological basis and subsequent classification of human settlements is the ease with which the various criteria can be picked up from remotely sensed data.

2.1.11 The Third Dimension

The approaches to define human settlements, as described earlier, have been generally criticised because of their limited concern based on two dimensions. The third dimension of vertical space is often neglected even though people are distributed in a three dimensional space (Stewart and Warntz, 1958). This neglect is clearly expressed in the manner in which physical planners use the word 'density'. It may be seen as strange that spatial 'density' has

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4 *Ecumenopolis* is "The coming city that will, together with the corresponding open land which is indispensable for man, cover the entire earth as a continuous network of urbanized areas forming a universal settlement." (Doxiadis, 1966-67, Vol.2, p.405).

up till now been predominantly expressed by the planning community as 'population per unit area', whereas the expression in scientific terms could have been as 'population per unit volume (or space)'. Conceptually, density, in relation to planning, means "... the number of objects - houses, rooms, persons, etc. - per unit of space." (Keeble, 1969, p. 143, emphasis added). However, in practice, the three dimensional space was reduced to two dimensional area. Today, for planning purposes, it is the ratio between the population of a given area and the area (Caminos and Goethert, 1978). It may be argued that compared to the areal dimensions the vertical space a human settlement occupies is negligible. However, if the thickness of a sheet of metal is even less than a millimetre, its density is still expressed as 'mass per unit volume'. Was the author of a recent advertisement (Figure 2.2) ignorant when providing the caption, *"One person per cubic mile."* (TIME, 1996)? The message hidden behind the caption was the inclusion of a 'vertical space'.

Neglect of the third dimension, in spatial planning, may have originated in the old times, when most of the buildings in a human settlement had only one floor - the ground floor. The third dimension may have been taken as unit (say, 1 floor). Using the third dimension as unity will not change the figures of density of a human settlement as generally expressed. But it will, and it should certainly, effect its units causing a change from 'population per unit area' to 'population per unit volume (or space)'. Moreover, the assumption of the third unit being unity itself can be challenged in the present day context when residential buildings are commonly not confined to the ground floor and have multi-stories.

The term 'density', as being used today, is often no more than a measure of concentration of population per unit area. This expression is only partially useful while planning for infrastructure in the human settlements. For example, the measure of density does not serve any useful purpose for planning for storm water drainage in urban areas (Mahavir and Sokhi, 1982). But does it serve a purpose when comparing inter-settlement characteristics? Is it safe to assume that two cities having same density of population are equally congested? Does their respective population reside on small plots of land or in high rise apartment buildings?

Some expressions of 'density' have been developed by physical planners in the form of the Floor Area Ratio (FAR) and the Floor Space Index (FSI). But these are instruments for controlling the building activity (Keeble, 1969) and not effective tools for measurement. 'Accommodation density' (e.g., persons per dwelling unit) has been used as a measure, yet the expression is not able to specify whether or not all the accommodation is available on the ground floor.

Although further discussion on the limitations[5] attached to the current usage of the term 'density' at various levels of spatial planning (e.g., the neighbourhood, zonal, city) is beyond the scope of this research, it should be noted that where, in the balance of this book, the term is used, it has a spatial rather than just a geographic meaning.

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5 **See also Tobler (1969); Nordbeck (1971); Dutton (1973); Unwin (1981); Bolt (1983); and Batty and Longley (1994) for more arguments illustrating the limitations to the current usage of the term 'density of population".**

2.1.12 The Time Dimension

Leman (1987) discussed yet another dimension, that of time. Human settlements are not static but dynamic. Towns and cities are inherently difficult to define because they are members of a continuum of nucleated human settlements that grade into one another. Basic distinctions can be drawn between hamlets and towns, villages and cities, and yet differences are not so sharp between adjacent members of the continuum. As one goes down the scale from the largest urban agglomeration to the smallest farmstead, it is extremely difficult to identify dividing lines and terminology that are universally acceptable (Clark, 1982 and Keeble, 1969). Human settlements are not changing from census to census, from one election to another election, or from one municipal survey to another. They are in fact changing every day - moving from one static category to another static category, thus always being dynamic. There' have been attempts to define the city by man's capacity to move within the framework of a certain territory, within a framework of certain time range and always within the space of a single day (Doxiadis, 1966-67). This itself signifies the fact that for individual residents the settlement is changing each day. For the Detroit Urban Area, Doxiadis (1966-67, Vol.2, p.4) writes, "Where the actual...area ends is difficult to determine. This is a dynamically growing city in which the boundaries of people, daily movements, economic and other forces are constantly expanding.". Kulshrestha (1980) considered human settlements (urban or rural) as the articulating point of human habitation and activity location. Bolt (1983) dealt with the element of dynamism by 'open ended' urban communities. They are 'platforms' for the construction of 'unlimited' floor-space, with 'unlimited' population potential. Thus, the concept is dynamic in three ways. Firstly in the open ended development of each community. Secondly in the open ended number of urban communities in each constellation of urban communities. Thirdly in the open ended number of constellations. The 'platforms', however, are limited in size (to human scale dimensions).

EKISTIC grid index[6] for the scale of human settlement(s) continues to be based upon population size (only). However, population size (alone) as indicator of urban status is used in only 33 out of the 133 countries and sovereign territories from which data are assembled by the United Nations. The different population minima employed, ranging from 200 to 10,000, raises questions concerning the utility of a size measure alone (UN, 1977, as quoted by Clark, 1982).

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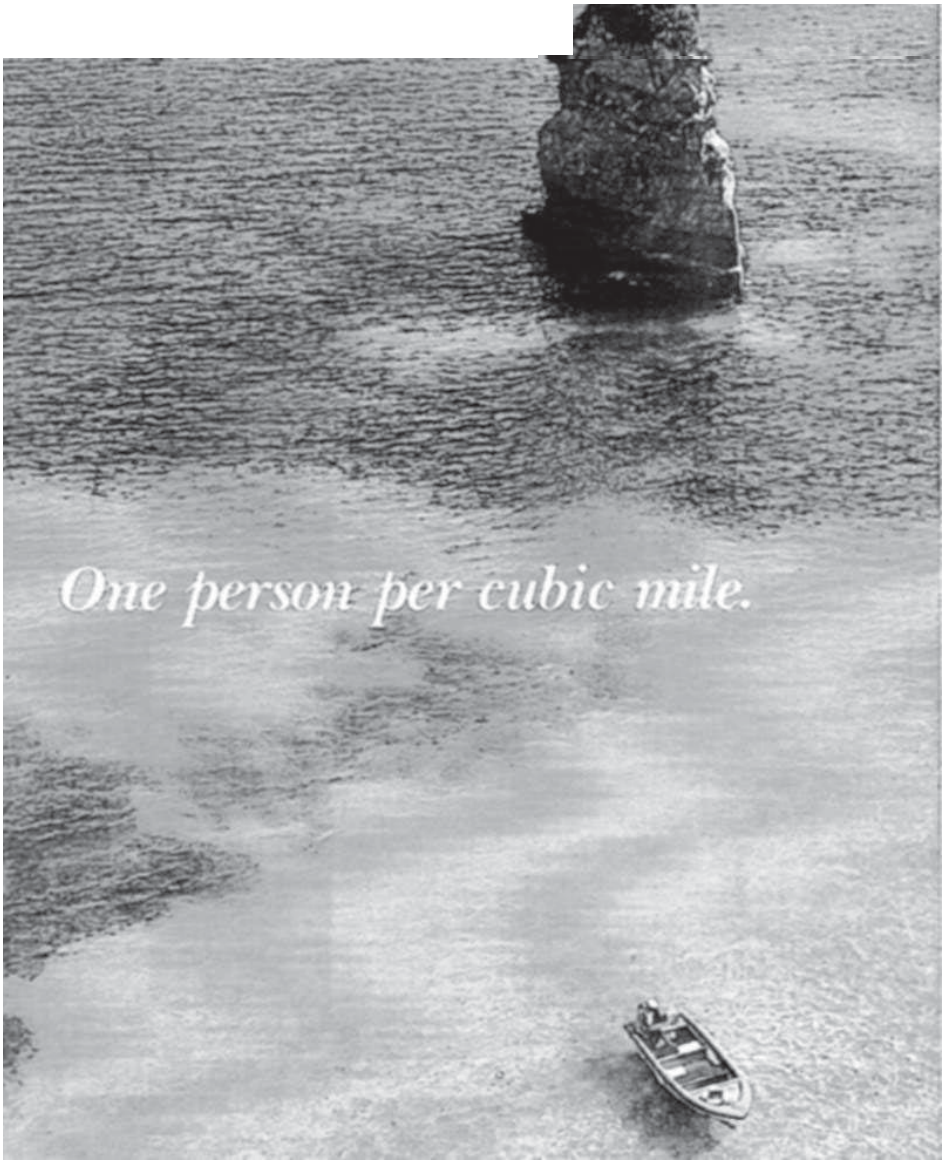
6 t

Anthropos	**I**
Room	**:**
House	**5**
Housegroup	**40**
Small Neighbourhood	**250**
Neighbourhood	**1,500**
Small Polis	**10,000**
Polis	**75,000**
Small Metropolis	**500,000**
Metropolis	**4 million**
Small Megalopolis	**25 million**
Megalopolis	**150 million**
Small *Eptropolis*	**1,000 million**
Eperopolis	**7,500 million**
Ecumenopolis	**50,000 million**



There's little that is more relaxing than a quiet beach.

In coastal Portugal, the opportunities to relax are better than almost anywhere.

With almost a thousand miles of golden sands on offer that's an awful lot of Atlantic coast per person.

For bathers, it's a lot of Atlantic, too.

From the Algarve to the Costa Verde in the north and from Madeira to the Azores you 11 find no end of sun, sea, sand and peace and quiet.

Something, we feel, worth shouting about.

Algarve

MS

J

***The thrill of discovery.* Portugal** j£c

Fig. 2.2 **One Person per *Cubic* Mile!**
Source: TIME, February 19. 1996

One wonders how an entity so organic in nature can be identified by an explanation of static nature! Human settlements are expanding not only spatially (both horizontally and vertically) but also in the form of communication. Distances between human settlements are reducing not only physically on the ground but also in the form of travel time (the jet age) and communication time (the Internet age). Transactions can take place throughout the working day in each of the principal international stock exchanges (i.e., New York, London and Tokyo), by passing on deals from one exchange to other. Their global status emanates from their strategic position within different time zones (Daniels, 1991). All form of documents can be telefaxed to any part of the world in a matter of seconds. The *Ecwnenopolitan* thinking of Doxiadis was based on similar observations. Introducing the concept of space of time, Leman (1987, p.247) put forth the definition as, "Human Settlements are spatial/operational arrangements made by humans within certain scales in order to support life and to pursue their aspirations, goals and target.".

2.1.13 Continuously Built-up Area

As Leman (1987) pointed out, even the term 'definition', might be somewhat misleading in the context of human settlements. It implies a definitive, final statement of what human settlements are: yet, humans are just beginning to learn and to understand what the phenomenon is all about. Abandoned human settlements (e.g., Fatehpur Sikri in India); floating human settlements (e.g., *klongs* in Bangkok, Thailand); space settlements and satellites are perhaps not covered by any of the mentioned definitions. For the traditional nomad the human settlement has no permanent substance. For rural migratory people or tribes, human settlements may be duplicated following seasonal patterns of migration or periodic wage labour migration to and from urban settlements (Haywood, 1985). An estimated[7] 10 million people are travelling on Indian railways at any given point of time. Simply going by the numbers, this would suffice to make a dozen or so large cities. "You could imagine a cruise ship concept being developed into a floating city that could be towed south for the winter...Taisei Corporation in Japan had already developed a floating resort concept, called Floating Station Jonathan, an underground dwelling, called Alice City, and a high-rise city that would take 30 years to build and house 700,000 people, called X-Seed 4000...and the Takenaka Corporation had unveiled Sky City 1000, a 1000 metre tall structure that would have 35,000 inhabitants and 100,000 workers." (The Daily Telegraph, September 22, 1995, London, p. 15). In principle, these ideas are simply a follow up of the visualisation of Frank Lloyd Wright of a structure a mile high. Can all these be considered as 'human settlements'?

The cultural distinctions that once differentiated the urban from the rural are fading anyway. In a study for a prediction of the total population of a city, entire contiguous urban areas were included rather than trying to delimit administrative borders (Henderson, 1979). The concept of 'Continuously Built-up Area' (Perovic, 1987) seems to be the most appropriate working definition having the advantages of physical characteristics, spatial extent and dynamism - not dependant on the time gap between census years. The term 'urban agglomeration' (though of limited application to very large urban areas), used by Census of

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7 **Estimated by the author.**

India is a positive step in this direction. The Continuously Built-up Area (in the urban context) encompasses suburban settlements, industrial complexes and airports, etc. if they are easily accessible by public transport (Perovic, 1987). The concept of Continuously Built-up Area (CBA) provides a method that is useful in interpreting remotely sensed images of cities, as discussed in Chapter Four of this book.

A difficulty here lies in the question of what is meant by 'continuous' (Haggett, 1972). What happens when the various criteria do not all give the same answer? Keeble (1969, p.62) illustrated this problem with a classic example, "...the impression of huge, continuous, fully built-up areas is to some extent a misleading one. Anyone inefficient at packing a suitcase will have noticed how much more a really good packer can get into the same cubic capacity than he can. This is a very valid comparison; the results secured by the skilful packer are very similar to those to be expected from the skilful Town Planner given a similar chance.".

In the Swedish context, Nordbeck (1971) described the urban area as one with at least 200 inhabitants. Any point belonging to such an area was situated within a distance of 100 meters from at least one populated dwelling house. He divided built-up areas into three groups, compact, mean and spacious built-up areas, for his studies on urban allometric growth.

A similar concept of 'urban morphological zone' was adopted by the Eurostat (The Statistical Office of the European Community) in its recent project entitled, 'Remote Sensing and Urban Statistics' (Barnsley, 1993). This concept relates to the physical extent of the built-up area modified by criteria based on the minimum size and the spatial continuity of urban areas. In the European context, this requires spatial aggregation of those areas of urban land use identified in the satellite-sensor image that are separated by less than 50m on the ground; removal from further analysis of those areas smaller than 20 hectares after aggregation; and aggregation of the remaining 'urban' areas that are separated by less than 200m.

Poll6 (1988) used the concept of CBA in his case study with SPOT images of Bandung, Indonesia, though he faced the problem of deciding on the inclusion or exclusion of small pockets of urban landuse from the CBA. Such a decision requires elaborate rules on the minimum curtilage (smallest area to delineate), agglomeration based on distance and size of 'islands' of new urban land, generalization and idealization. In any case, the urban settlement - the town, the city, the metropolitan area - is a physically separate unit that is visually identifiable from the air (Webber, 1964).

Rapid urban change requires constant monitoring, which is possible through remote sensing (see Chapter Four). The concept of CBA is useful and conveniently applied on remotely sensed data. It has fewer disadvantages than others for the purposes of this research. This and similar concepts not only allow for the element of spatial dynamism, they also enrich the temporal dynamism from 10 years (census years) to, theoretically, about 20 days (temporal resolution of satellite images). Moreover employing an all-inclusive definition and data source, i.e., satellite images, minimizes the possibility of excluding smallest and isolated human settlements by a traditional census survey*. The concept has been further elaborated with the rules of operationalization as detailed out in Chapter Seven.

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8 **An underenumeration of 2.8 per cent was reported at the 1981 census of India officially (Krishan, 1993).**

2.2 PATTERNS

The Oxford Guide to the English Usage (Guild Publishing, 1985, London) defines pattern as 'regular manner in which things occur'. It is a 'representative sample'; 'specimen' (Morris, 1976). A pattern is the description of an object. It is a detectable organization of spatial units (Johnston, 1981).

In the language of digital image processing, pattern is the regular repetition of tonal variations on an image or photograph, (Sabins, 1987); or a regular repetition of values or tones in an image (Curran, 1985). This is a familiar idea in the literature about architecture, textile, garment and packaging design, music, which all hint of repetitiveness. Although regularity is implied by most definitions of pattern, it is also possible to speak of random patterns.

The literary world offers a further understanding of pattern. The contrast between the repetitiveness and randomness of patterns has been brought out by Amy Lowell (1916, p.75-76) in her poem, entitled, 'Patterns'. While she frequently used 'patterned garden paths', she did also use I too am a rare Pattern." and ".., In a pattern called a war. Christ! What are patterns for?".

In spatial sciences, pattern refers to a 'regular arrangement of objects', which may be explained in terms of structures, processes and systems. It refers to the manner in which a phenomenon is arranged in time and space (Nangia, 1976). It is a characteristic of spatial arrangement which describes the spacing of a set of objects with respect to each other. In the context of geography, it is the geometrical expression of location theory (Haggett *et al.*, 1977).

Others hold that pattern is that characteristics of a spatial arrangement that is given by the spacing of individuals in relation to one another. In this view, it can be contrasted with the property of dispersion, which is the spacing of objects in relation to an enclosing shape, and can be contrasted to density, which is the property of dispersal relative to an area but is indefinite of the area shape or the dispersion of the objects within it (Unwin, 1981).

2.3 PATTERN RECOGNITION

'Pattern recognition' is regarded as a basic attribute of human beings as well as other living organisms. We are performing acts of recognition every instant of our lives. We recognize the objects around us, and we move and act in relation to them. We can spot a friend in a crowd and recognize what he says; we can recognize the voice of a known individual; we can read handwriting and analyze fingerprints; we can distinguish smiles from gestures of anger. A human being is a very sophisticated information system, partly because he possesses an advanced pattern recognition capability (Tou and Gonzalez, 1974).

According to the nature of the patterns to be recognized, we may divide our acts of recognition into two major types: the recognition of concrete items and the recognition of abstract items. We recognize characters, pictures, music, and the objects around us. This may be referred to as sensory recognition, which includes visual and aural pattern

recognition. This recognition process involves the identification and classification of spatial and temporal patterns. On the other hand, we can recognize an old argument, or a solution to a problem, with our eyes and ears closed. This process involves the recognition of abstract items and can be termed conceptual recognition, in contrast to visual or aural pattern recognition. Examples of spatial patterns are characters, fingerprints, weather maps, physical objects, and pictures. Temporal patterns include speech, waveforms, electrocardiograms, target signatures, and time series. In precise language, pattern recognition can be defined as the categorization of input data into identifiable classes via the extraction of significant features or attributes of the data from a background of irrelevant detail (Tou and Gonzalez. 1974).

Commercial pattern recognition systems are available for optical character recognition, speech recognition, speaker identification, fingerprint recognition, and automated cytology (Jain and Dubes, 1988).

In the field of image processing, classification of geographical features can be considered as (spectral) pattern recognition. Pattern (spectral) recognition systems are designed to classify an input pattern - an image or portion of an image - into one of several categories. The prime justification for this is that classification is often carried out on the basis of how far apart the individuals are in a 'property space', and that classification is the partitioning of this into discrete 'areas' or slices of space. A (spectral) pattern recognition classifier is designed by measuring features of representative image whose correct classification is known. This feature set, called prototype data, is then mapped in pattern space.

Figure 2.3 contains an example in which two features, for example average luminance and texture, are measured for each block. Hopefully, the prototype features will tend to cluster into groups according to desired classes. If this does occur, then decision boundaries are established to separate features of unknown data into proper classes.

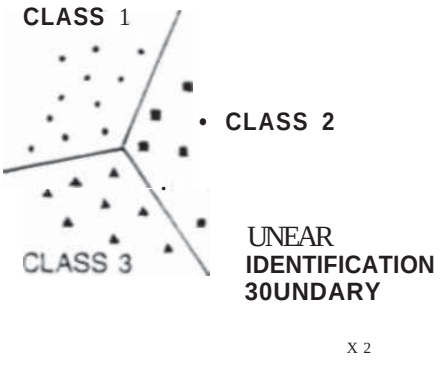

Fig. 2.3 **Example of Prototype Classification for Two Features** (after Pratt)
Source: Pratt, 1978, p.569

In its early days of development, (spectral) pattern recognition was viewed by many as a solution to almost all image analysis problems. This optimism was subsequently tempered by two limitations of the (spectral) pattern recognition approach. First, the inherent dimensionality of image is enormous, and in many cases the number of potential classifications is quite large. As a result the processing required by a (spectral) pattern recognizer is often prohibitive. A more fundamental limitation is that an image description by classification may not be appropriate. Although there are many applications in which classical (spectral) pattern recognition fails in an image analysis environment, the concept should not be dismissed entirely. There may be many sub-tasks that can be performed well by (spectral) pattern recognition (Pratt, 1978).

(Spectral) pattern recognition is a computer oriented methodology for extracting information based on 'salient patterns' in remotely sensed data. (Spectral) pattern recognition techniques convert raw satellite digital data into meaningful information useful for quantitative analysis of remote sensing data. (Spectral) pattern recognition techniques have been used for computer aided demarcation of land uses in an urban area (Subudhi *et al.*\ 1989). It is subsumed in pattern recognition not only the descriptive pattern in space but also the classification of geographical individuals into groups. In general data driven classification techniques use two types of information about the content of an image: spectral and spatial. Spatial information has been utilized much less frequently in a segmentation of satellite images (Michalak, 1993).

No satisfactory measures exist for the quantitative description of land use patterns. Pattern analysis carried out by eye on maps, aerial photographs or some other graphical image is the way most land use models that have been derived from remote sensing have been underpinned in the past. The value of a computer-based approach to pattern recognition has been advocated because of its speed, objectivity (i.e., the ability to repeat same process with the same procedures and data and to get the same answer), flexibility and because it produces quantitative results (Rhind and Hudson, 1980). The computer has a major role in storing, retrieving, summarizing and grouping data : at present, analysis of patterns in space is probably still best done by human means (Rhind and Hudson, 1980).

The techniques of pattern recognition and clustering are not widely used in the field of settlement pattern analysis. It may perhaps be possible to exploit the (spectral) pattern recognition technique(s) and the (spectral) clustering technique presently employed in the digital image processing/ GISs; for recognising, classifying and analyzing (spatial) settlement patterns based on satellite images, assuming that the concepts behind the spectral analysis and spatial analysis are similar. Two important facets of this are the decision making process consisting of human interpretation based on the knowledge and experience of the professionals working with the system; and information processing based on hardware and algorithms. However, experience indicates that the potential of fully automated pattern recognition has sometimes been overestimated (Voute, 1982).

2.3.1 Cluster Analysis

Another technique used parallel to pattern recognition is 'clustering'. Clustering techniques were first developed in biology and zoology to group similar animals and plants to construct taxonomies. The need to organize vast amounts of data into 'meaningful' groups, clusters,

categories, partitions, or classes in several scientific disciplines has made clustering a valuable tool in data analysis. A variety of entities or objects have been clustered, including mental diseases, land use patterns, rock samples, fingerprints, training methods, stars, consumers, prose, and images. In several of these applications it is not extremely important to identify the exact number of clusters or the correct membership of each pattern into a cluster. Often it is enough to group the objects in a reliable and parsimonious manner so that the underlying physical, biological, or evolutionary process(es) can be understood or learned. This does not mean that clustering can automatically be applied to data without human intervention. The choice of features or measurements, similarity measure, and grouping techniques requires familiarity with the subject area in which data arise. Most important, the clusters are best interpreted by an expert in the subject area. Naive users of clustering can often generate incorrect interpretation or description of data (Jain and Dubes, 1988).

The objective of cluster analysis is simply to find a convenient and valid organization of the data, not to establish rules for separating future data into categories. A cluster is comprised of a number of similar objects collected or grouped together. Some of the definitions of a cluster are:

i. a cluster is a set of entities which are alike, and entities from different clusters are not alike;

ii. a cluster is an aggregation of points in the test space such that the distance between any two points in the cluster is less than the distance between any point in the cluster and any point not in it; and

iii. clusters may be described as connected regions of a multi-dimensional space containing a relatively high density of points, separated from other such regions by a region containing a relatively low density of points.

The last two definitions assume that the objects to be clustered are represented as points in the measurement space. We recognize a cluster when we see it in the plane, although it is not clear how do we do it. While it is easy to give a functional definition of a cluster, it is very difficult to give an operational definition. This is due to the fact that objects can be grouped into clusters with different purposes in mind. Data can reveal clusters of differing shapes and sizes. To compound the problem further, cluster membership can change over time, as is the case with star clusters. Figure 2.4 illustrates some of these concepts for two-dimensional point clusters. At the global or higher level of similarity, we perceive four clusters in these data but at the local level or a lower similarity threshold, we perceive twelve[9] clusters. Looking at the data at multiple scales may actually help in analyzing its structure (Jain and Dubes, 1988).

Clustering techniques offer several advantages over a manual grouping process. First, a clustering programme can apply a specified objective criterion consistently to form the groups. Human beings are excellent cluster seekers in two and often in three dimensions but different individuals do not always identify the same clusters in data. Thus it is quite

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9 **Jain and Dubes (1988) identified nine clusters at the local level.**

common for different human subjects to form different groups in the same data, especially when the groups are not well separated. Second, a clustering algorithm can form the groups in a fraction of time required by a manual grouping, particulary if a long list of descriptors or features is associated with each object. A clustering algorithm relieves a scientist or data analyst of the treacherous job of looking at a pattern matrix or a similarity matrix to detect clusters. A data analyst's time is better spent in analyzing or interpreting the results provided by a clustering algorithm (Jain and Dubes, 1988).

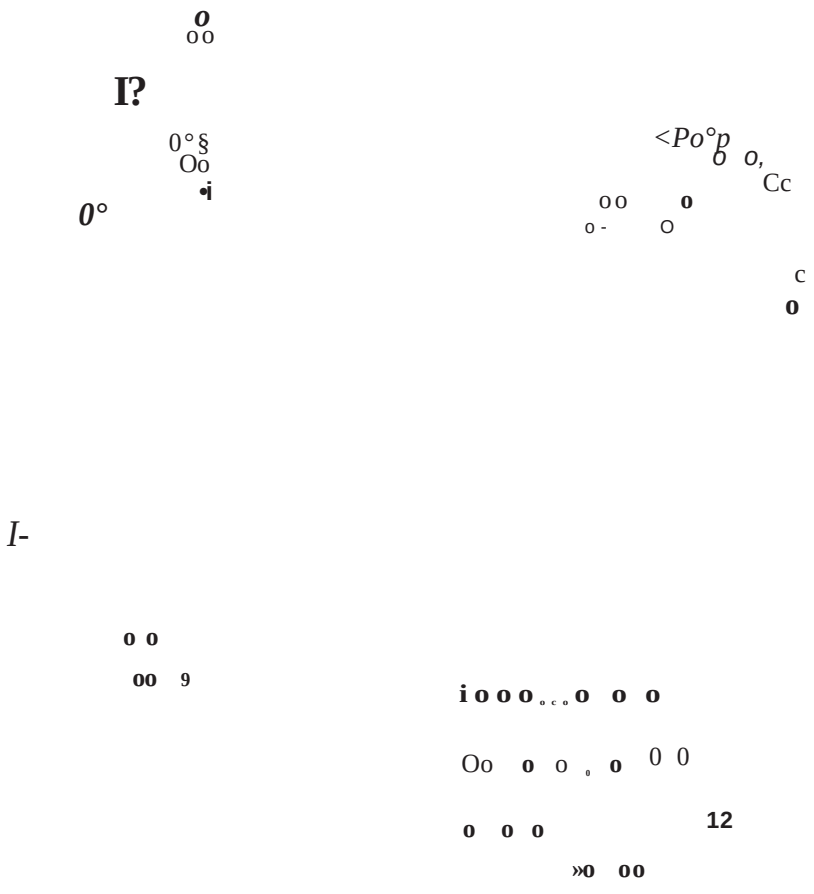

Fig. 2.4 **Clusters of Point Patterns in Two Dimensions**
(after Jain and Dubes)
Source: Jain and Dubes, 1988, p.2

Cluster analysis is one component of exploratory data analysis, which means sifting through data to make sense out of measurements by whatever means are available. The information gained about a set of data from a cluster analysis should prod one's creativity, suggest new experiments, and provide fresh insight into the subject matter. The modem digital computers make all this possible (Jain and Dubes, 1988). Yet, the main disadvantage of 'cluster analysis' is that it is not very specific towards 'spatial' clustering.

The main philosophical difference between 'pattern recognition' and 'cluster analysis' is the role of pattern class labels. These labels are crucial to the formation of decision rules in pattern recognition but are only used to verify the results of cluster analysis. In other words, pattern recognition requires extrinsic information, while cluster analysis uses only the data themselves (Jain and Dubes, 1988).

The recognition of different patterns of geographic variation is a necessary first step toward an analysis of the causes that lead to the establishment of the patterns. In data from diverse disciplines the patterns may be due to various forces: the internal dynamics of the system (i.e., interactions produced by the localities upon each other), external constraints due to peculiarities of the geographic area, and historical factors. Given a function describing a pattern over an area, this function can be used to predict the values of a variable at a location that has not yet been sampled. The ability to make successful predictions of this nature has obvious benefits in applied research. Such predictions are also necessary elements of proof in any system attempting to explain the causes of the patterns. The various techniques all assume the existence of a 'pattern' whether this be one of fairly uniform change or a patchy distribution of differing homogenous subsets. But a fundamental question to be answered first is whether there is any pattern at all to the distribution of the statistic over the area. If there are insufficient grounds for considering the observed spatial variation a significant departure from a random distribution of the statistics over the area, it would not seem worthwhile to analyse the data further.

In one study, (Royaltey *et al.,* 1975), tests were developed of whether observed patterns of geographic variation can be considered significant departures from the null hypothesis of random variation over an area. Localities are vertices in a graph whose edges are connections based on criteria of geographic contiguity and other criteria meaningful to any given scientific discipline. Ranked variables are assigned to each locality. Distributions of absolute differences in rank along edges between vertices yield various statistics of edge length that are compared with expectations developed. Several typical (spatial) patterns such as cline, depression, or a crazy quilt are generated and their behaviour characterized by this method. Computational and graphical methods allocate observed patterns to one of several types. It is a generalized method not dependent on sample size, type of character, or underlying statistical distribution and should be applicable to a wide range of data requiring only that variables for different localities can be ranked. The method is also not dependent upon the particular scheme for connecting localities. Any scientifically defensible way of drawing these connections is suitable as a basis upon which to compute expectations. The question of resolution of pattern structure depends ultimately on a general agreement on the number of types of distinct geographic variation patterns that exist and need to be recognized.

Patchiness of distribution is an important characteristic of a pattern in various disciplines. Several homogeneous but differing areas would respond similarly to intrusions, yet as the

number of homogeneous patches increases, their size will decrease proportionally to the entire area, and the pattern will assume the appearance of random variation. A possible drawback of this method is the ranking procedure employed. Since statistics for all localities must be ranked, trends may be imposed upon statistically nonsignificant, homogeneous subsets. Moreover, the form in which the study has been presented does not illustrate the application of such an analysis.

2.3.2 Point Pattern Analysis

Maps are spatial representations of information, and when that information can be characterized by a location on a map it becomes a spatial pattern. Although the real world objects themselves are not points, such a representation is possible because the physical sizes of the objects are very small relative to both the distances between them and the extent of the area in which they occur. Information gained from the analysis of point patterns may enable one to acquire initial insights into the phenomenon.

In general three distinct approaches seem to have been taken to characterize point patterns, one based on density considerations, another on distance measures and a third on inter-point distance and direction (Unwin, 1981). In the context of random pattern, it is the process which contains the random element, not the distribution. In no sense is it asserted that spatial patterns are ultimately chance affairs. In the real world, each point symbol on the map, be it a factory or an oak tree, has a good behavioral or environmental reason for its location. In aggregate these many individual histories and circumstances may best be described by regarding location processes as stochastic. In the real world events at one place and time are only seldom independent of events at another, so that as a general rule we expect point patterns to display spatial dependence.

2.3.3 Spatial Autocorrelation

When data are mapped, the map contains not only information about the values of variables but also information about how those values are arranged in space. Spatial interaction, which is the movement of goods, people, or information over space, means that events or circumstances at one place can effect conditions at other places if the places interact. Spatial autocorrelation exists whenever a variable exhibits a regular pattern over space in which its values at a set of locations depend on values of the same variable at other locations. A single event may effect several locations if the event involves an extended region. Interdependence among places lends pattern and structure to geographic data and autocorrelation statistics can be used to investigate hypotheses about how data for a particular variable are organized in space.

"...the often-quoted first law of geography that 'everything is related to everything **else,** but near things are more related than distant things'...is simply a statement that spatial autocorrelation exists." (Unwin, 1981, p. 134). Spatial autocorrelation may **be** positive or negative.

A clear, simple, and concise definition of spatial autocorrelation can not be found in most of the literature on the subject. It is inherently geographical. But its meaning is contextual, and multifaceted. It can be defined as (Griffith, 1992):

i. self-correlation attributable to the geographical ordering of data;
ii. a descriptor of the nature and degree of certain types of map pattern;
iii. an index of the information content latent in geo-referenced data, especially that information overlooked by classical statistical estimators when applied to spatial data series;
iv. a diagnostic tool for spatial model mis-specification;
v. a surrogate for unobserved geographic variables;
vi. a nuisance in applying conventional statistical methodology to spatial data series;
vii. an indicator of the appropriateness of, and possibly an artifact of, areal unit demarcation;
viii. a spatial process mechanism; and
ix. a spatial spillover effect.

2.3.4 Autocorrelation in Space and Time

Spatial patterns can change and develop over time. Many spatial patterns are the result of spatial-temporal processes in which spatial patterns change in some systematic way and the pattern at any time is related to earlier patterns. Spatial-temporal processes are processes that transform a map for an earlier time into the map for a later time and statistical models can be used to investigate hypotheses about these processes (Odland, 1988).

There is no one single optimal technique for all applications and the selection of a particular procedure is influenced by both practical and statistical concerns. Formal comparative studies are few. Some techniques are better than others in detecting clustering, whereas others are better in detecting regularity. In general, techniques that measure the dispersion characteristics of a point pattern appear better than those that measure its arrangement properties. However, when used in association with dispersion techniques, arrangement techniques can provide confirmation of results and sometimes also provide additional insight into the pattern (Boots and Getis, 1988).

Patterns which visually seem to **be** interpretable in the same way often turn out to have a spatial autocorrelation structure that is not significandy different from random, so that statistically there is no objective basis for the subsequent theorizing. There are firm grounds for suggesting that all spatial analysis should start with a test for spatial autocorrelation, simply in order to prevent this tendency to infer and interpret pattern where none exits (Unwin, 1981).

2.4 ILVVIS

A software, named the Integrated Land and Water Information System (ILWIS), version 1.4 (ITC, 1993; see Appendix I), provides for pattern analysis and spatial correlation analysis for a point data set. While the pattern analysis performs pattern analysis on a point file, the

spatial correlation calculates the spatial correlation for a point data set, i.e., the degree to which values at a certain set of locations depend on values of the same variable at other locations (TTC, 1993).

Point pattern analysis is a technique that is used to obtain information about the arrangement of point data in space, i.e., to be able to make a statement about the occurrence of certain patterns. Three fundamental patterns exist. In a situation of complete spatial randomness (CSR), no correlation exists between locations of points. In a clustered pattern, subgroups of points tend to be significantly closer to each other than to other subgroups of points. In a regular pattern, distances between adjacent points tend to be further apart than from CSR. If point items tend to attract each other, and there is environmental homogeneity, one can call the pattern grouped. On the other hand, if individual point items tend to repel each other, and points are more spread out than in CSR, one may call the pattern regular.

There are two basically different techniques: the location of points can be studied with respect to 'each other' (measures of arrangement), or with reference to the 'area' (measures of dispersion).

2.4.1 Measures of Arrangement

Measures of arrangement are techniques that examine characteristics of the locations of points relative to other points in the pattern.

The output of the pattern analysis lists a table in which measured frequencies of occurrences of reflexive nearest neighbours (RNN) are compared with expected frequencies of occurrences in a situation of CSR. The CSR is simulated for the same area and the same number of points. Two points are considered first order RNN if they are each other's nearest neighbour. This definition can be extended to higher orders; second order RNNs are points fat are each other's second-nearest neighbours, etc. The frequencies are calculated for RNNs of first to sixth order.

More higher order values in excess of CSR expectations indicate measure of regularity in arrangement of points, whereas lower empirical values imply elements of grouping in the pattern. If more (first order) RNNs occur than is expected in CSR, it can be concluded that isolated and relatively uniformly arranged couples exist.

2.4.2 Measures of Dispersion

Measures of dispersion are techniques that examine characteristics of the locations of points with respect to the area. The pattern is analyzed by calculating distances between individual points, and comparing these with the distances that would be found in a CSR.

The output of the pattern analysis lists a table in which the mean distance between RNNs are tested against the expected distances in a (simulated) CSR.

If the individual points are closer than they would be for CSR, this indicates a clustered pattern. If, on the other hand, individual points are further apart than they would be in CSR, a more regular pattern is assumed.

Both the techniques have their relative advantages over each other. The advantages of measures of arrangement are:

i. the technique is density free, i.e., no estimates have to be made, for example the expected number of points per quadrant; and

ii. the technique is free of edge effects, because one studies the arrangement of points with respect to each other rather than with respect to the area.

The advantages of the dispersion technique are:

i. it is more rigorous than the arrangement technique, because it is more sensitive to certain differences in some pattern characteristics. For arrangement, identical values may sometimes be expected for patterns that are different in some way; and

ii. the statistical theory for dispersion is more developed, hence this method is less subjective.

The higher order RNN analysis (refined analysis) might give more information than first order analysis alone; as in the case of couples on a dance floor, the distance to the first order RNN will be significantly less than in CSR, while higher order RNN distances will be higher.

When the pattern analysis is performed, two tables are generated (see Appendix IX). The first table lists the order of the reflexive nearest neighbour (nearest, second nearest, third nearest,...), the observed number of times such a pair is found in the dataset, and the number of times this would happen in the situation of CSR. If the number of pairs found is much larger than in CSR, this indicates that the points are not randomly distributed. Instead they cluster. If the number is smaller, the points are distributed regularly.

The second table lists the mean distance to the reflexive nearest neighbour for every order, and the mean distance in a CSR. If the mean distance for the data set is much smaller than the one for CSR, the points tend to cluster. If the distance is larger, the distribution is more regular.

2.4.3 Typical Pattern Curves

Pattern curves are generated for the three pattern types, i.e., the random, clustered and regular (see Appendix II for typical curves). Y-axis shows PI or PA11 as the case may be. PI is the probability (0.0 to 1.0) that within the specified distance (X-axis) of any point in the data set, another point will be found. Same way the probability is calculated for two other points (P2), three other points (P3) and so on. For a data set of n points PA11 is the summation of P1+P2+...+Pn-1, divided by (n-1).

2.4.4 Spatial Autocorrelation

Also provided for in ILWIS is 'spatial autocorrelation'. It measures dependence among nearby values in a spatial distribution. Variables may be correlated because they are affected by similar processes, or phenomena, that extend over a large region. Spatial correlation exists whenever a variable exhibits regular pattern over space in which values at a certain set of locations depend on values of the same variable at other locations.

For example, if the concentration of a certain pollutant is very high at a certain location, it will most likely also be high in the direct surroundings. In other words, the concentration is autocorrelated at small distances. At larger distances, it is less likely that the concentration will be equally high. The correlation will probably be lower, and the variance higher. The user is encouraged to compare his or her dataset with a dataset consisting of the same point locations, with a set of attribute values, approximately in the same range as the measured variable but created at random. If the graphs are very much the same for the measured data and the random data, no autocorrelation exists between the datapoints.

Results of some of these techniques, applied on the NCR of Delhi, India, have been presented in Chapter Seven.

2.5 SETTLEMENT PATTERNS

Since human settlements are spatially separated one from another, linkages between them are essential, and one framework for study is to view them as nodes or focal points in a transport network. If the location of cities, towns, and villages are marked on a map, the overall settlement pattern can be seen (Haggett[10], 1972). Earlier, Keeble (1969) conceived the pattern as primitive distribution of human settlements, which has, in areas of dense population, been overlaid and distorted by a series of subsequent events. The spatial distribution of centres of different grades tends to form a pattern the regularity of which is proportional to the simplicity and uniformity of the land area concerned.

Patterns may exist in their physical form or abstract form. In the physical form they may be observed in the spatial distribution of human settlements. In their abstract form, patterns are derived and deduced from the interpolation of data, its cartographic representation and analysis (Nangia, 1976). Settlement pattern is the distribution of population clusters of varying sizes (Johnston, 1981), or simply the nature of the distribution of human settlements (Mayhew and Penny, 1992). However, Goodall (1987) mentioned of spatial distribution.

With a particular reference to developing countries, these patterns are being transformed rapidly by:

i. growing population in the younger-age cohorts, which might well constitute a potential for future economic growth but which today creates an increasing surplus

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10 **In discussing the basic arrangement of nodal clusters, it is convenient to use as a substitute their morphological expression, the 'settlement pattern' (Haggett, 1965; Haggett *et al.*, 1977).**

of dependent, unemployed, and underemployed population, often migrating in search of economic opportunity;

ii. intensive rural-urban migration, often in sequential steps to the local centre, to the regional capital, and eventually to the primate city;

iii. a consequent urbanization which in many cases is not a result of either industrialization or economic development, as was the case in more industrialized countries. The result is a growth in urban population, without an equivalent increase in urban productivity, and an increasing polarization between urban and rural areas;

iv. nevertheless, a relative increase in industrialization has taken place. Generally this growth is due to intentional government economic incentives, or it is dependent on, controlled by, and subservient to, the demands of external capitalist or socialist economies. Each situation has its characteristic influences on the developing human settlement system; and

v. in most countries, an increasing amount of government control and regulation emphasizing economic growth and industrial development but in some cases also specifically oriented toward the planning of urban settlements.

The very recency and dynamism of the changes outlined here mean that their present and potential impact upon the human settlement system of both developed and developing countries are not adequately documented nor well understood. Certainly we are far from developing satisfactory theories for explaining their complex impacts (Bourne ***et al.,*** 1984). However, highly generalised theories of settlement patterns abound. The theory has developed over the last 150 years or so, mainly from the theoretical foundations laid down through the work concerned with understanding the forces affecting land use and location of human settlements, and their efforts to define the principles that generate these forces (Haywood, 1985). Such classical writings on the evolution of spatial patterns were characterised by an informal presentation. They were generalized theories or metaphors applied to very complex situations. Pregnant as such metaphors are, with concepts, ideas, and generalizations, there comes a time when the form in which such metaphors are cast seems to hinder objective judgement. The wish to be objective and scientific is somehow frustrated. Such studies demonstrated two things. Firstly that the simple schemes of spatial evolution put forward earlier in the century were far too crude and highly generalized to fit the real world. Reality was far more complicated than that. Second, that the actual form of presentation of their theories often lacked clarity (Harvey, 1968).

Settlement theory embodies the concept of a landscape filled with nesting human settlements, forming a hierarchy of dependency relationships, with each human settlement having its own productive hinterland and the whole being delicately maintained in a state of equilibrium by a network of interconnecting links. The neatness of this concept is based on a number of assumptions which are open to question when viewed from a developing country. The first assumption is that change is the product of outside factors and that the natural state of any given settlement pattern is equilibrium. In reality, human settlements are in a continuous state of change, and growth may not only affect the settlement pattern overall but may change the value of steps within the hierarchical structure to such an extent that a permanent situation

of imbalances occur. The belief that the suppliers and consumers of services will always arrive at an economic equilibrium ignores the very important influence of cultural, political and social factors on decision making. Like the definition of the human 'settlement' itself, settlement theories are too static in their approach; they can also be criticised for being too compartmentalised (Haywood, 1985).

History also plays a part in city-size distributions. It appears very likely, especially in underdeveloped countries, that external influences may have distorted the 'natural' rank-size relationships by inducing more-than-allometric growth for certain cities. These cities may be world cities or regional capitals, or the seats of colonial governments, or in entrepot situations to large, otherwise inaccessible hinterlands, or near to important mineral or other resources in world demand (Chadwick, 1987).

A further limitation is that settlement theory does not indicate either the process of evolution, which resulted in the particular settlement pattern, nor how specific situations may change in future. This emphasis on descriptive rather than prescriptive settlement theories is a particular limitation now that communications technology is tending to reduce the spatial component of urbanisation and replace it with a concept of urban life based on access to services. Only if a logical framework could be developed, would the testing, verification and modification of hypotheses regarding the evolution of settlement systems be possible. The most suitable way to develop such a logical framework is to develop some model construct of reality which expresses the notions contained in the theory (Harvey, 1968).

2.6 CONCLUSIONS

Rapid urban change requires constant monitoring, which is possible through remote sensing (see Chapter Four). It is proposed to use the concept of the CBA for the purpose of pursuing a tool, i.e., remote sensing. The concept of the CBA is useful and conveniently applied to remotely sensed data. It has fewer disadvantages than others for the purposes of this research. This and similar concepts not only allow for the element of spatial dynamism, they also enrich the temporal dynamism. Moreover, employing an all-inclusive definition and data source minimizes the possibility of excluding small and isolated human settlements by a traditional census survey. The concept has been further elaborated with the rules of operationalization as detailed out in Chapter Seven and Appendix III. The strength of the tool (i.e, the concept of CBA, applied to remotely sensed data) is that it might be calibrated to **any level** of generalisation (e.g., from 10m to 5km distance).

Not sufficiently comprehensive methods exist for defining and recognising spatial patterns. Cluster analysis techniques are also not suitable for spatial clusters. The methods available (e.g., the spatial autocorrelation) are generally for point patterns, which are best analyzed partly visually and partly manually. A comprehensive discussion on how these methods have been incorporated into various models available for settlement patterns is carried out in the following chapter.

3

MODELS FOR ANALYZING SETTLEMENT PATTERNS
A REVIEW

A number of theories and models have been put forth to describe and understand human settlement patterns. However, as discussed in Chapter Two, the limitations attached to the conventional definitions of the terms 'settlement' and 'settlement pattern' further limit their application towards modelling settlement patterns. Moreover, as in the case of these terms, the popularly used theories and models of analysing settlement patterns also have limitations, specially with reference to their applicability in developing countries. An attempt has been made in this chapter to investigate the applicability and adaptability of existing theories and models of settlement patterns analysis in the present day context, with specific reference to developing countries. While an attempt has been made to identify the limitations attached to these models, some factors beyond the scope of models, yet important in influencing the settlement patterns, have also been looked into. As was noted in Chapter Two, the major consideration in selecting the pieces of literature discussed here was that these have an interface with the existing spatial planning practices in India.

It was concluded in Chapter Two that the concept of CBA is useful and conveniently applied on remotely sensed data. Those elements of the theories and models being discussed in this chapter which support the concept of CBA, have been given special consideration for incorporation in the models that will be developed in Chapter Seven.

3.1 INTRODUCTION TO MODELS

The idea of using models in science is by no means new. There is a sense in which almost anything can be used as a model for almost anything else. But as in the use of analogies or metaphors, so models, to have predictive value, must bear some measure of similarity to the structure or process being modelled. Most used model types in spatial sciences may be regarded as the formal presentation of a theory using the tools of language, logic, set theory, and/or mathematics. Use of these tools allows to identify and eliminate inconsistencies within the theory. It also allows to use the powerful tool of algebraic analysis to make deductive statements as regards a particular system, and in some cases, to develop objective statistical tests of the relationship between the model being used and the real world. To make a model operational, therefore, one has to develop some simple system of model building. The term 'model' is conventionally employed in a number of different ways. It is used as a noun implying a representation, as an adjective implying a degree of perfection, or as a verb implying to demonstrate or to show what something is like. In fact models possess all of

these properties. Models are highly subjective approximations and abstractions in that they do not include all associated observations or measurements. Only the relevant properties of the real world are represented. But as such they are valuable in obscuring incidental detail and in allowing fundamental aspects of reality to appear. This selective attitude depends upon the intentions of the model maker. Models have varying degrees of probability and a limited range of conditions over which they apply. All models are constantly in need of improvements as new information or new vistas of reality (e.g., information available from satellite images) appear, and the more successfully the model was originally structured, the more likely it seems that such improvement must involve the construction of a different model. A successful model also contains suggestions for its own extension and generalization (Haggett and Chorley, 1968). A model of a situation is a simplified representation of a real world situation based on our understanding. It is systematic method, based on logical or mathematical relationships, for describing, simulating, and forecasting real life processes (Doxiadis, 1967).

3.1.1 Types of Models

The term 'model' has been used in such a wide variety of contexts that it is difficult to define even a broad type(s) of usages without ambiguity. One can classify models in various ways, into at least those which model structure, those which model function and those that model both. There are models which are obviously physical (e.g., an architectural building model) and those which are obviously conceptual (e.g., mathematical and statistical models for simulation), and so on (George, 1968). Though models can be conceptual, physical, or numerical, the process of abstraction is intended to reduce the complexity of the real world to a manageable level. Conceptual models diagram the relationships between those components of reality that impact the spatial system under study (Bennett *et al.*, 1993). With the physical model, the physical characteristics of reality are represented by the same or analogous characteristics in the model. Physical models can be divided into two categories. Ionic models represent the relevant properties of the real thing by those properties themselves, with only a transformation in scale. They are generally difficult to use for representing dynamic situations. In analogue models one property is used to represent another, and hence the necessity of a legend. In the conceptual models, the relevant characteristics are represented by concepts (language or symbols). This type of model can also be divided into two classes. Verbal models describe the reality in logical terms using spoken words. These models are of limited help in predicting or precisely specifying the state of a system. Symbolic models represent and express the properties of the real world system symbolically (Reif, 1973).

One division is between descriptive and the normative; the former concerned with some stylistic description of reality and the latter with what might be expected to occur under certain stated conditions. Descriptive models can be dominantly static, concentrating on equilibrium structural features, or dynamic, concentrating on processes and functions through time. Where the time element is particularly stressed historical models result. Descriptive models may be concerned with the organisation of empirical information, and may be termed data, classificatory (taxonomic), or experimental design models. Normative models often involve the use of a more familiar situation as a model for a less familiar one, either in a time (historical) or a spatial sense, and have a strongly predictive/ prescriptive connotation.

Models can also be classed according to the material from which they are made, into, firstly, hardware, physical or experimental constructions, and, secondly, into theoretical, symbolic, conceptual or mental models. The former can either be ionic, wherein the relevant properties of the real world are represented by the same properties with only a change in scale, or analogue (simulation) models, having real-world properties represented by different properties. The latter are concerned with symbolic or formal assertations of a verbal or mathematical kind in logical terms. Mathematical models can be further classed according to the degree of probability associated with their prediction into deterministic and stochastic.

Another view of models concentrates upon them as systems which can be defined on the basis of the relative interest of the model builder in the input/ output variables, as distinct from the internal status variables. In order of decreasing interest in the status variables, many models can be viewed as synthetic systems, partial systems and black boxes. The scale on which models are valuable and the standpoint from which they are constructed allow further distinctions, notably into internalized models which give a very parochial view of reality, and paradigms which are broadly significant models of value to a wide community of scholars (Haggett and Chorley, 1968). Self-evaluating models are not very common in the field of planning, though they do exist.

3.1.2 Models and Model Building in Planning

The choice of type of model depends upon the object of the planning exercise (Hall, 1992). It helps to have a check list of questions to help in the design of a model for spatial planning purposes. These are (Wilson, 1974):

What is the purpose behind the particular model building exercise? What should be represented as quantified variables within the model? Which of these variables are under the control (at least partially) of the planner? How aggregated a view can be taken, both for the sectoral aggregation and spatial aggregation? How should the concept of time be treated? How far ahead are we trying to look and can comparative static equilibrium techniques be used? What theories are we trying to represent in the model? What techniques are available for building the model? What relevant data are available? What methods can be used for the calibration and testing of the model?

The purpose could relate to a major exercise or something much more partial. The effort devoted to the model building exercise should be related to the importance of the purpose in hand. The choice of variables will be dependant on the availability of data and on the type of computer hardware and software available. It is often preferable to develop a fully dynamic model but very much difficult in terms of techniques and data requirements. Many disciplines contribute to theory building in urban and regional studies and model builder should be capable of utilizing this literature when appropriate. The use of remotely sensed data and computerised GISs has facilitated the obtaining, processing, storage and retrieval of information. As Forrester (1969, as quoted by Reif, 1973) comments, conventional forms of data-gathering will seldom produce new insights into the details of system structure. Calibration involves estimating any parameters of the model in such a way as to get the best fit between model prediction and the data representing the real world; testing involves deciding whether such fits are good ones (Wilson, 1974).

In the development of an urban and regional model system, three kinds of works may be identified (Wilson, 1974). The first is the empirical development for the study area of exiting models which had been tested elsewhere. Second work involves the empirical development of known but untested models. The third is the work on new theoretical problems leading to new models. These three obviously feed back on each other.

It is important to maintain a balance in an overall programme between these kinds of work. Hence, predictions of any new models can always be compared to those of existing models, and it also minimises risk for the whole programme, because if an element of theoretical work fails, there is always the existing work to fall back on (Wilson, 1977).

Like all models, spatial models are low-variety representations of high variety situations: variety is destroyed in the modelling process but can be re-invoked by retracing the path via models of sub-systematic aspects of the larger system which has been followed in the crystallisation of overall system modelling. In order to reduce the complexity of the system under study and consequently reduce the model to a manageable size, the researcher has to simplify the real world situation. The simplification can be obtained by omitting relevant variables, by changing the nature of variables, by changing the relationship between variables and by modifying constraints (Reif, 1973).

Once a simple model of one sector of reality has been constructed, one can, then, link together several such individual models into a model system. One may, for example, collect together the outputs of several models and treat these inputs to another model, identify feedback loops throughout the system, and so on. Given the complexity of real world phenomena, it would be meaningless to expect one simple model to have great explanatory power. Ultimately one must aim for a complex model system to represent an even more complex reality (Harvey, 1968).

However, the approach of fully integrated modelling has gradually been abandoned and a much more elastic/ partial approach is advocated (Lee, 1973). One of the main dangers of computer modelling is that unskilled users may uncritically accept the results and assume that complex models perform adequately. Even experts may accept simulated results without adequate validation. The mechanistic use of simulation models by non-specialists is a potential danger to rational decision making. Many models of environmental processes are complex and may require data at levels of spatial and temporal resolution that are too costly to collect (Burrough, 1993).

Models themselves, of course, do not generate the solutions. The inventiveness of the designer and the policy maker is a crucial component of model-based planning. The 'best' plan can only be chosen if it is one of the alternatives which had been investigated. But at the very least model outputs will supply much information which is relevant to planning decisions (Wilson, 1977).

3.2 MODELS FOR ANALYZING SETTLEMENT PATTERNS

At first glance a modem system of settlements, consisting of a set of settlements varying in size and economic functions and interconnected by a range of commodity, population and

information flows, presents a confusing picture to the analyst. Some settlements are major centres of political and corporate power, others are dynamic and prospective metropolises. Some others are stagnating manufacturing cities in declining industrial regions. Despite this functional complexity, researchers have developed a general theoretical understanding of the distribution of settlements as service, manufacturing and management centres. When integrated and combined in an historical context these identify and account for a high level of locational and organisational order in the settlement system (Clark, 1982). Although the main contributions to the analysis of urban location and hierarchies of function do not provide all-inclusive, ready formulas for general application, they do offer powerful theoretical as well as empirical foundations for local analyses to be undertaken in developing countries (Stanford Research Institute ***et ai,*** 1968).

Virtually all models of settlement patterns have one thing in common; they assume a measurable degree of order in their spatial and functional properties. This seems to be founded on the following parameters which form the basis of, or are implied in, most models (Garner, 1968):

i. The spatial distribution of human activity reflects an ordered adjustment to the factor of distance;

ii. locational decisions are taken, in general, so as to minimise the frictional effects of distance;

iii. all locations are endowed with a degree of accessibility but some locations are more accessible than others;

iv. there is a tendency for human activities to agglomerate to take advantage of scale economies;

v. the organisation of human activity is essentially hierarchical in character; and

vi. human occupance is focal in character.

A simple classification for the models of settlement patterns can be applied: uniform, random, competitive and contagious. If one is studying change(s) over a relatively small area the effects of physical and human change may frequently be regarded as being uniform over the study area. If one is considering population growth within a country, one might find thai the population growth is distributed randomly over the study area. Certain kinds of events compete for space and one may employ a relevant spatial theory to describe how such events are likely to be distributed over space. The occurrence of a particular event as the result of a time process may increase the probability of a similar event occurring close by, or contagious, in space. This simple classification is only relative to the size of the study area. Events which may be contiguous on a world-wide scale may be treated as random or competitive within a very small area and vice versa. Bearing in mind this problem of scale, the above classification may still prove useful in formulating a model system (Harvey, 1968). A fundamental consideration, when examining the relevance of models of settlement patterns to the problems of developing countries, is the fact that most of the theoretical work has been generated by research in the developed world. The work which has been undertaken in the

developing world is generally small in extent and poorly disseminated. As a result theories and resulting models in general circulation have been based on a series of preconditions and assumptions that clearly do not match the conditions of most developing countries. In particular, assumptions concerning stability, constant growth, and the implication that decisions will always be arrived at in a logical manner, are not always relevant (Haywood, 1985).

With the inclusion of some of the models generated in the developing countries, some of popularly known models of analysing and measuring (Hagget, 1972) settlement patterns have been reviewed below, in order to gain an insight and to learn from their capabilities and limitations.

3.2.1 Gravity Model and the Rank Size Rule

'Gravity model' and the 'rank size rule' are the two basic models which help in understanding the relationship of one settlement to other and between city population and its rank order in a set of cities, respectively. These models are based primarily on the distance of one settlement to other and population size of the settlements.

However, in reality, distance is a relative measure. Not only may the nature of the distance function change over time but it may also vary a great deal from place to place. Distance could be replaced by travel time or cost or effort. Travel time is of special significance, as the amount of time in a day is both fixed and equally distributed over all persons. This is not the case with other factors (e.g., travel cost or effort). It, thus, becomes a vital constant in a sea of variables. In today's context, with increasing dependency on modern means of communications and information transfer, distance (or travel time, cost, effort) alone seems to be a limited determinant. Flow of data and information plays and will continue to play a larger role than the flow of goods and capital (Blakely, 1991).

Similarly, the rank size rule is a special case of the allometric growth formula (Nordbeck, 1971). The rule may be regarded as an empirical finding rather than a theoretical or logical necessity (Haggett *et al.,* 1977). It is a statistical regularity which appears when large numbers of cases are considered. It must be emphasized that the method is suggestive, not definitive (Harris, 1970).

Contrasting patterns in rank-size relationships may be in part explained by the fact that the resident population size of various cities is determined by a number of parameters, including the availability of urban(isable) land and the increasing demand, and therefore, the value of the urban land (Haggett, 1972). As opposed to the assumption behind the urban growth indices generally made, one can postulate that the dynamics of development in the towns/ cities operate not only through the population but also through their area base. It is important that our consciousness of urban growth takes due cognizance of the space problem - the problem of congestion on urban land (Kundu, 1982).

It will, perhaps, be interesting to know the results when the population sizes in the rank size formulae is replaced by (or added to) the 'continuously built-up', municipal, urbanised, residential and commercial areas that different settlements under examination have.

Moreover, if the understanding of the distribution and scenario building is area based, satellite images will help performing analytical exercises not every decade (repeat cycle of the census) but as often as once a month, if desired.

Moreover, both the models are non-spatial in nature and are generally not used for analysing settlement patterns. An important kind of information not contained in both the models is the geographical distribution of settlements. This kind of information is presented by a map, for which there is no substitute (Erickson and Young, 1992).

3.2.2 Central Place Theory

City size distribution theory, or the theory of the urban hierarchy, is non-spatial in nature. There is also a spatial hierarchy, an arrangement of cities and settlements in spatial relationship to one another, and there is no necessary symmetry between the two aspects of urban hierarchy. It is the intention of central place theory to attempt an explanation of both aspects of hierarchic structure of settlement patterns (Chadwick, 1987).

In 1933, Walter Christaller proposed that, given an isotropic landscape (one which is physically uniform and has an even distribution of resources, population, wealth and the like), settlements would be evenly distributed in order to render most efficient the supplying of goods and services by people living in central settlements (central places) to people living in surrounding communities. The central places and surrounding consumer communities are linked by flows of money and goods which result from the demand of consumers being met by the supply of producers in the central places. In a market situation of perfect competition, prices reflect the balance between demand and supply. However, an economic environment of perfect competition is unlikely to prevail in the real world. As the population grows, the market areas of central places touch and eventually overlap to produce hexagonal (the most efficient[11] arrangement) units. The network of central places is known as a K-value network. The K-value is determined by the number of communities of low-order places served by a central place or a higher-order place, in addition to its own population. The K=3 network is geared to efficient marketing; the K=4 network is the most economical arrangement for traffic flow; and the K=7 network is economically most efficient to run for the purpose of administration.

Higher K-value systems can be derived from these basic networks to give K-values as 9, 12, 13, 16, 19, 21, 27 and so on. Christaller argued that, once established, the K-system remains fixed. Even though the high-order centres contain all the functions of the smaller centres, this produces a very marked hierarchy of functions and regular distribution of centres of the same order (Meyer and Huggett, 1981). In 1941, Christaller also put forward what was known as 'Mixed Marketing and Administrative Model'. He believed that the hierarchical structure and boundaries of planning, economic, and administrative regions at the national, regional and

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11 **However, as Isard (1956) put in the Location and Space Economy : A General Theory RelatinE to Industrial Location, Market Areas. Landuses. Trades and Urban Structure (M.I.T. Press, Cambridge, p.274), the hexagon "...loses its significance as a spatial form once the inevitable agglomeration forces... are allowed to operate.".**

local levels should be as similar as possible, that the overall framework should consist of urban-centred regions, and that the allocation of public goods should play a crucial role in hierarchical definition and integration.

He demonstrated his mixed principle by a three step model that utilized all the three pure principles. He started with a marketing landscape (step 1). Next, he combined his administrative and marketing models in a manner in which urban development in the centre of the triangles formed by the second order centres was suppressed. This could be achieved by regional planning measures. The result was a marketing-principle based central place system that met the undivided complementary area requirement of his administrative principle (step 2). He then suggested a traffic network that reinforced the theoretical settlement system arrived at in step 2, one that ensured that the areas with suppressed development in the triangle centres were not crossed by long-distance transportation routes (Figure **3.1;** Preston, 1992).

However, polarized development and diffusion of development impulses and innovations in developing countries, where the transportation and communication system is generally very weak, will be clearer if considered within a spatial system having a hierarchical distribution of settlements classified on the basis of the functional specialisation of activities and population size (Kulshrestha, 1980).

An important modification to Christaller's scheme was made by August Losch in 1939, who used all K networks together and varied their sizes. This resulted in an irregular distribution of centres of the same order. Losch oriented all these nets about a common centre to find the position in which the largest number of locations coincide and the distances between centres are minimal. This results in a pattern of sectors around a city - the 'city rich' and 'city poor' sectors (Figure 3.2).

However, the economic landscape described by the Loschian Model contains high-order centres which do not necessarily possess all the services in low-order centres. Also, the cities come in all sizes. Losch's model was criticised by Bouge (1949, as quoted by Meyer and Huggett, 1981) and Isard (1956, as quoted by Meyer and Huggett, 1981) for failing to take account of variations in population density. The economic landscape produced when variations in population density are considered presents a set of irregular-sized polygons, each containing the same number of people, smaller ones being found nearer city centres (Meyer and Huggett, 1981). Another problem of the Christaller and Losch models of settlement pattern is that they are essentially static (Haggett *et al.,* 1977).

Nevertheless, the simplified, abstract system of Christaller and Losch do help to explain the economic logic behind the size, spacing and number of settlements. A hierarchy of settlements can be developed where a higher order settlement will have high-order services. Both the higher order settlements and services will be found at just a few locations. Given a hierarchy of settlements, it is reasonable to suppose that the average spacing between centres of each order will become greater with increasing order of settlement. Present day service centres may have had their origin in the temporal and mobile arrangements, provided by itinerant tradesmen or pedlars and periodic markets or fairs.

Step 1	Step 2	Step 3
The Marketing Principle	The Marketing and Administrative Principles Combined	Transportation Model Reinforcing the Mixed Hierarchy

Fig. 3.1 Christaller's Mixed Marketing and Administrative Model (after Preston)
Source: Preston, 1992. p.532

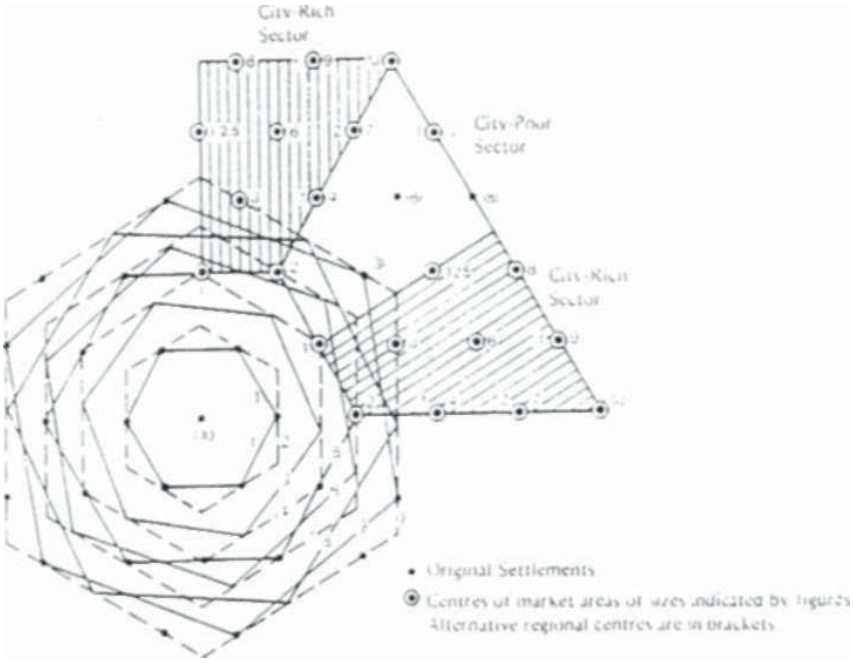

Fig. 3.2 Loschian Concept of City Rich and City Poor Sectors (after Meyer and Huggett)
Source: Meyer and Huggett, 1981, p. 19

Indeed, in many countries, this is still the case and weekly or twice-weekly markets are still to be found, not only for supply of perishable goods but for non-perishable goods too. However, with reference to metropolitan regions, the metropolis serves itself. Although retaining its central place functions for a wider area, the number of interactions and their density renders the simplicity of central place theory somewhat inadequate. Moreover, it is the quality, i.e., the variety and level, of services available in a given area which defines the degree of centrality of the place serving it, whilst the quantity of services is generally only a function of the number of people served (Chadwick, 1987). The techniques of institutional scalogram and sociogram (Roy and Paul, 1977), discussed later in this chapter, are interesting development of this concept.

3.2.3 Growth Pole Concept

Growth poles are centres or focii in abstract economic space "...from which the centrifugal forces emanate and to which centripetal forces are attracted." (Perroux, 1950, p.95).

The concept envisages that the development does not appear everywhere and all at once. It appears in points or growth poles with variable intensities; it spreads along diverse channels and has varying terminal effects for whole of the economy (Perroux, 1955). In other words, "...through concentrating investment capacity in a centre expansionary momentum can be generated in the economy of its region." (Mabogunje, 1971, p.3). This is extensively used as a planning strategy.

The growth poles according to the basic concept, generate two effects - the 'spread' and the 'back-wash' or the 'trickle down' and 'polarisation' respectively. Market forces lead to the clustering of increasing returns activities in certain areas of the economy. Regardless of the initial locational advantage, this build-up becomes self-sustaining because of increasing internal and external economies at these centres of agglomeration. The limited advantages of backward regions, such as cheap labour, are insufficient to offset these agglomeration advantages. The main influence on the rate of growth of lagging regions is the induced effects of growth in the prosperous areas. These are the 'centrifugal' and 'centripetal' forces which emanate from and are attracted to the growth pole respectively. The former include markets for the typically primary products of the lagging regions and diffusion of innovation. Normally, however, these are outweighed by backwash effects - particularly by creating a disequilibrium in the flows of labour, capital, goods and services from poor to rich regions (Richardson, 1973).

Among several theories of regional development, Growth Pole Concept provides an efficient tool if applied deliberately. However, "., it is full of confusion covering its nomenclature, definition, spatial aspects, nature, basic characteristics, type of activity concentration, regional impact and temporal aspects." (Kulshrestha, 1980, p. 167). Its application in practice with or without modification to cover a wider scope with special reference to spatial incidence of development further adds to the confusion.

3.2.4 Service Centre Hierarchy

The concept of 'service centre hierarchy' (Roy and Patil, 1977) draws from various theories on the formation and spatial growth of economic development poles, size, location, distribution and clustering of economic activities, the geographical incidence and spread of economic growth, discussed earlier. The concept is based on following assumptions:

i. people are distributed in various size settlements in space;

ii. they have bio-physical as well as socio-economic needs;

iii. they utilize physical and human resources, i.e., goods and services to satisfy their needs;

iv. they form settlements in space in the form of homesteads, hamlets, villages, towns or cities and continue to stay together as long as resources are adequate enough to meet their need;

v. they utilize resources for basic needs which are limited or wants which are unlimited; and

vi. they migrate to other places in a continuous search of goods and services that are not (or can not be) available in their own settlements.

In the process of this continuous search, central places emerge to provide essential goods and services to people within their spatial reach. As the range of goods and services on the one hand and the threshold of population and their resources on the other hand increases, service centres at different levels in the hierarchy become manifest. The lower level service centres provide certain basic goods and services that are limited in number and kind by the limited population and resources within the daily travel distance or radius of the centre. The next higher level service centres provide goods and services that are provided by the lower level service centres plus some other goods and services which require a larger 'threshold' of population and resources within the larger radius of centre. When people and resources are distributed in space in a uniform manner, the service centres develop in a progressive manner in time ideally to form a pattern of hexagons within hexagons. Planning for service centres, therefore, is a deliberate attempt to impose or superimpose this ideal pattern on the historically developed and geographically constrained pattern of service centres.

Isard (1956; as quoted by Chadwick, 1987), classified location factors as belonging to three, possibly overlapping groups. The first group included transport costs and certain transfer costs which tend to vary regularly with distance from given reference points. The second group of factors included the several costs associated with labour, power, water, taxes, insurance, interest (as payment for the services of capital), climate, topography, social and political milieu. The costs of these factors may be seen as varying independently of both distance and direction. The third group comprised those factors giving rise to agglomeration and deglomeration economies. In the former economies might be included those of scale,

localization and urbanization; in the latter diseconomies, those within a firm going beyond its natural scale of operating rises in rents and service costs associated with congestion, and food supply costs as urban size makes adverse location changes in contributory agricultural areas. Losch's homogeneous hexagonal system of nets of market areas oriented toward the common centre (the metropolis) was graphically interpreted by Isard with six centre-oriented sectors which concentrate production, thus reducing the costs of distance to the central market (Stanford Research Institute *et al.,* 1968).

Berry (1961) put forth a set of relationships to explain central place systems: the trade area served by a central city is a function of the density of the population in the trade area and the population of the central city; and the population of the central city is a function of the number of central functions performed by that city. Two kinds of city size distributions are recognized. First, rank size or lognormal distribution in which urban centres are of regular graduated sizes, and second, primate distribution in which there are one or more dominant centres and a deficiency of intermediate size centres. There is a scale from primate to lognormal distributions which is somehow tied to the number and complexity of forces affecting the urban structure of countries, such that when few strong forces obtain primacy results, and when many forces act in many ways with none predominant a lognormal city size distribution is found (Berry, 1961).

However, the resulting conglomerate structure from the theoretical strands in growth-pole analysis still leaves many points unanswered. "The meaning of a growth pole or a growth centre is still debatable. Does it mean a functional pole or a geographical pole or a combination of the two? The structure outline appears neat but the details are very fuzzy. What are the elements or the combination of elements which go to make a growth pole? Can the same type and size of growth pole or growth centre be successfully planned and developed in all situations? Is there a dynamic model of growth pole applicable to all situations? Do we really have dependable empirical data from the developed and developing countries passing through different stages of economic development to support the current concept of growth pole and related hypotheses? The answers to the these questions are largely negative." (Misra, 1970; as quoted by Richardson, 1973, pp.85-86).

Moreover, "Nodal models attempt to describe the macrostructure of human populations as it is arranged in sets of settlements. ...our understanding of human settlements - even in the broad terms of size and spacing - is still superficial and incomplete." (Haggett *et al.,* 1977, p. 138).

There are many methods of identifying service centres and service areas using various criteria. Methods based on distance criterion alone ignore the distribution of people and their resources in space. Methods based on the population criterion alone ignore distance and resource factors. Methods based on infrastructural criterion alone tend to emphasize the irrational nature of the past and consequently may inhibit the ideal nature of future development. Methods based on the criterion of movements alone manifest the factors of space preferences or alternatives and opportunities available in the past. Therefore use of more than one method based on multiple criteria is considered more reliable than the use of any single method based on a single criterion.

Roy and Paul (1977), recommended three methods (a) a scalogram method based on the number and types of infrastructural facilities; (b) a sociogram method based on preferences of people for different service centres; and (c) a bisectional method of dividing space based on purely geometric logic of allocating areas to lower level service centres from higher level ones on maps. They suggested to adopt most rational solution using all three methods, and to adjust the results to the existing revenue and/or administrative boundaries of spatial units. These and some of the following methods are particulary suited to developing countries, where they have been developed and applied.

3.2.4.1 Scalogram Method

The scalogram method ranks the settlements or places, in terms of importance, on the one hand and the institutions or infrastructural facilities on the other. Firstly, the settlements are arrayed in descending order of population size and the total number and types of facilities[12] located in each settlement are noted. Secondly, the facilities are arranged in descending order in terms of total number and types of facilities located in all settlements. And thirdly, the institutional hierarchy of settlements is demarcated by a bold line running diagonally so as to divide the services and facilities into ubiquitous and non-ubiquitous. A typical scalogram has been illustrated in Figure 3.3 (see also Saini and Sinha, 1985).

3.2.4.2 Sociogram Method

The sociogram method shows graphically the pattern of interaction or interdependence by the movement of people between settlements for selected facilities. This pattern can be prepared on maps on the basis of the preference for service centres, indicated by arrows showing which settlements go where for what. Superimposed layers are prepared to see the correspondence between various service centres and service areas and to identify the spatial gaps suggesting the possibility of locating new service centres. Summing up the number of arrow destinations on each layer for each service centre and then summing the figures of all three layers generates a fourth layer illustrating the relative importance by size of total destination score. Each arrow can be weighed by settlement population to give a more sophisticated destination score. A typical sociogram has been illustrated in Figure 3.4.

3.2.4.3 Bisection Method

The bisection method is designed to identify on a map, the high level, middle level or lower level service centres, by geometrically dividing space on the basis of some knowledge of the ranking of service centres, following the principles of spatial efficiency using a series in

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12 **There is no rigid list of facilities. It can be different from area to area depending upon the level of settlements being scanned and the emphasis on a group of facilities. The list used by Roy and Paul (1977) in the illustration includes hospital, arts college, medical college, engineering college, polytechnic, typing college, higher secondary school, junior school, primary school, stadium, cinema, drama Hall, public library, bank, agriculture credit society, dispensary, T.B. clinic, health centre, science college, commerce college, maternity and child welfare centre, family planning clinic and nursing home.**

graphic progression. It is based on the assumption that the lower level service centres are expected to develop in the middle of higher level service centres. In other words, if one or two of the most important centres of the specific area and in the neighbouring area are known, it is possible logically to expect lower level service centres around the bisection line. Bisection method for identifying service centre hierarchy is illustrated in Figure 3.5.

Although the three methods suggested by Roy and Patil (1977) can be applied to any region in principle, it should be noted that the methods were developed specifically for 'block[13] level planning'. Their adaptation for metropolitan regional planning will require an upgrading of the list of facilities as more and more facilities will tend to become 'ubiquitous' at the town level.

3.2.5 Composite Functionality Index

Developing further on the methods suggested by Roy and Patil (1977), a project for demonstrating and implementing an information system for regional planning (SAC-TCPO, 1992) for the district of Bharatpur in India used a Composite Functionality Index (CFI), based on the number of services that a settlement has. The CFI is based upon four other indices (see footnote 4). In general, each index is based upon a Functional Weightage ***(FW)*** derived for each function under consideration. ***FW = N I Fi,*** where ***Ft*** is the number of settlements where the function is available and ***N*** is the total number of settlements under study.

About 40 different functions[14] were considered under various sub heads.

Having worked out the weightage for each function, the facility indices are calculated based on the number of each type of facility available in a settlement multiplied by the assigned weightage. The four facility indices are then added to get a Composite Functionality Index for each settlement. However, like in the case of institutional scalogram, the decisions are non-spatial in nature. Also, the level of details required for information on many functions is changing frequendy and difficult to update on a regular basis.

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13 **A 'block', in Indian context, is an administrative unit below the sub-district level. It usually comprises of a number of villages and may or may not include a town.**

14 **Educational facilities: primary school, middle school, high school, pre-university college, college, adult literacy centre, training school, others.**

Medical facilities: hospital, maternity and child welfare centre, health centre, primary health centre, primary health sub-centre, dispensary, family planning centre, T.B. centre, registered private practitioner, nursing home, subsidised medical practitioner, community heath worker, others.

Transport and communication facilities: post office, telegraph office, post and telegraph office, telephone connections, bus stands, railway station, *kulcha* (fair weather) road, *pucca* (all weather) road.

General facilities: tailors, artisans, blacksmith, mechanic, market, wholesale market, fair price shop (government controlled shops providing essential food-grains, etc. at subsidised prices), bank, petrol station, cooperative society, street lamp.

Fig. 3.3 A Typical Institutional Scalogram
(after Roy and Patil)
Source: Roy and Patil, 1977, pp.32-33.

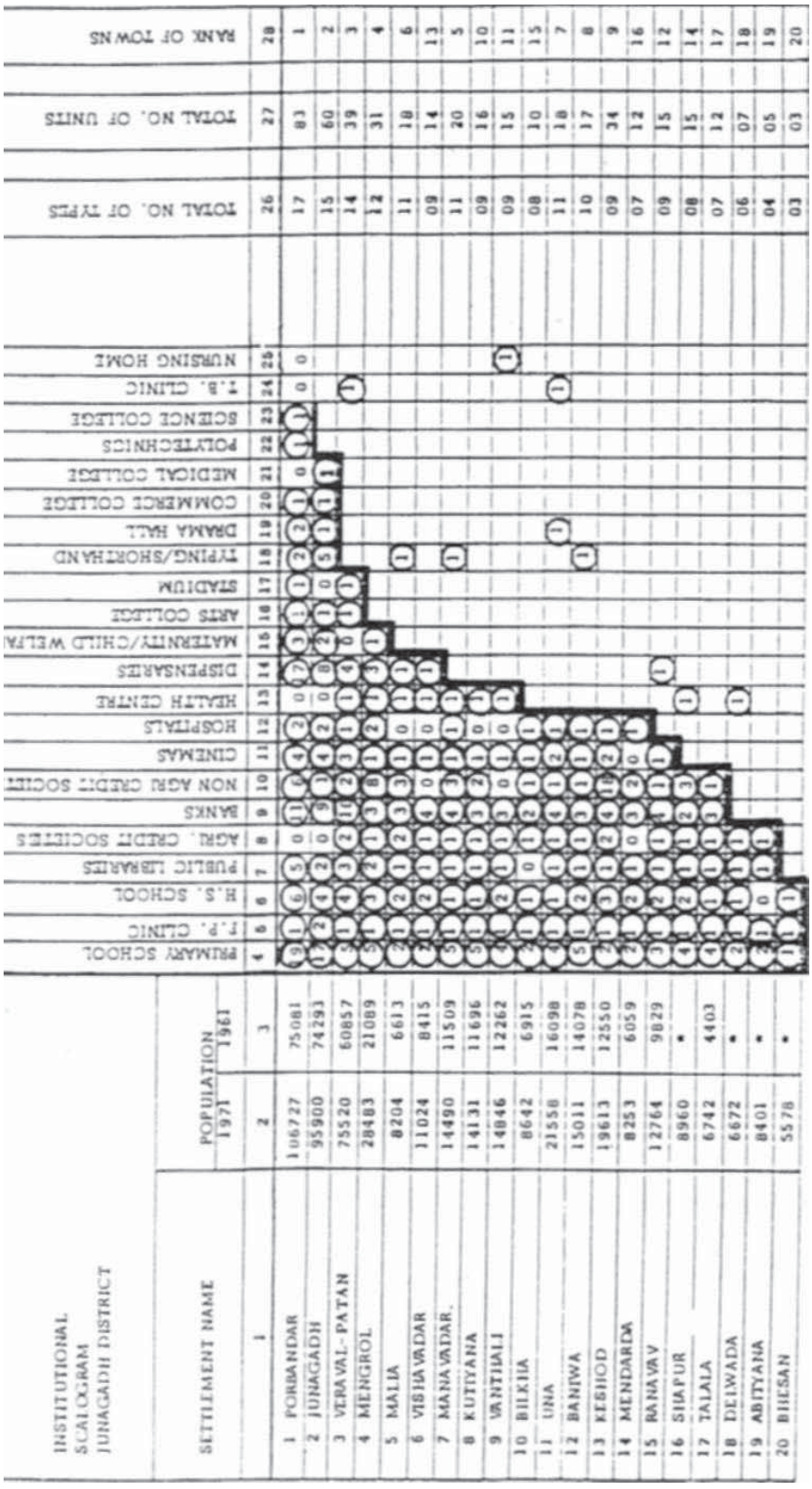

Fig. 3.4 A Typical Institutional Sociogram
(after Roy and Patil)
Source: Roy and Patil, 1977, pp.28-29.

REFERENCES

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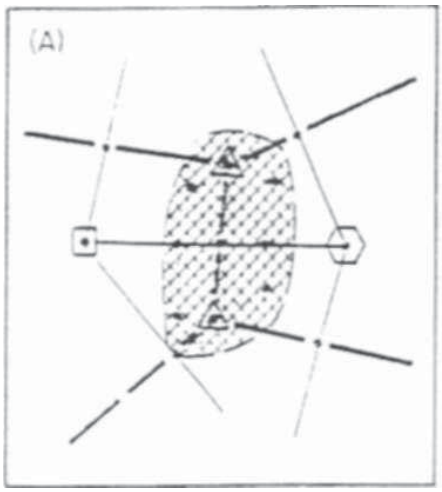
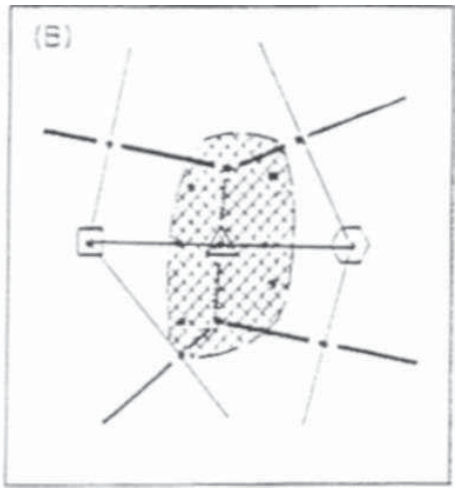
Fig. 3.5 Bisection Method for Identifying Service Centre Hierarchy
(after Roy and Patil)
Source: Roy and Patil, 1977, pp.28-29.

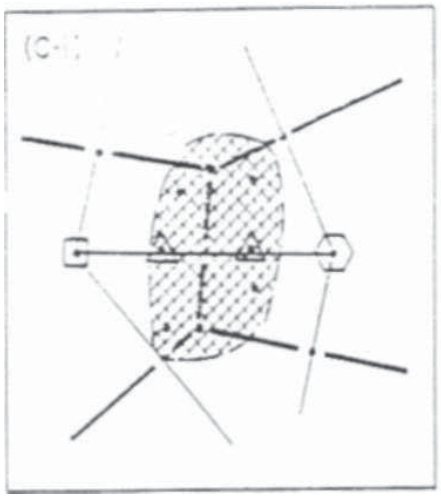
Sub-Centres at (about) Meeting Points of Bisection Lines



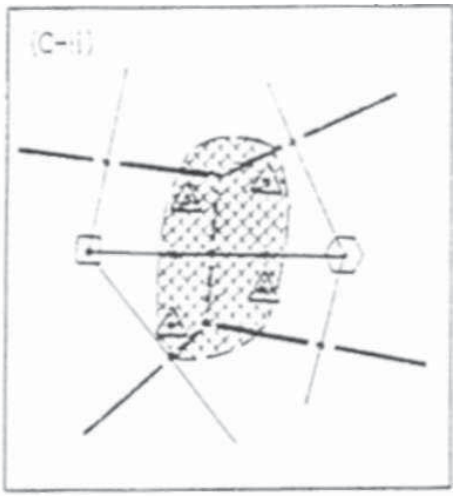
Sub-centres at (about) Bisection Points



Sub-Centres Towards Fixed Centres on Each Side of Bisection Line



Sub-centres Towards Fixed Centres on Each Side of Bisection Line



* Settlements — —— Bisection Line

Top Service Centre——————Line Joining Given Service Centre

— Intermediate Service Centre ***V///sYA*** Area Around Bisection Line

Lowest Primary Service Centre————Line Showing Area Around Bisection

3.2.6 Spatial Model for Spatio-Economic Development

Being inspired by the models relating to location of activities, centrality of places and diffusion of innovations, Kulshrestha (1980, 1991) developed a 'spatial model' for spatio-economic development of polarised regions (Figure 3.6). The model uses a square lattice instead of a conventional hexagonal. Interestingly, Losch, already in 1954, suggested that the square lattice might be adopted where new areas of settlements are being planned as squares are only moderately less efficient than hexagons and form a very useful substitute (Haggett ***etal.,*** 1977).

A metro-region, where all settlements depend upon and interact with the metropolis more than any other city of the same size, is a perfect example of polarised region and hence the spatial model is applicable to these regions. The model incorporates the following hierarchy of settlements.

	No. of Places
Dominant Polarised Activity Centre (metropolis; population 1 million and more)	**1**
Polarised Activity Centre (PAQ (large city/ medium town; population 20,000 to 1 million)	**8**
Rural Polarised Activity Centre (small town/ large village; population 5,000 to 20,000)	**64**
Rural Settlements (villages; population less than 5,000 persons)	**648**

The model follows a geometric progression for assigning the number of settlements as shown below.

Basic Spatial Unit	**9**
Sub-periphery	**81 (9x9)**
Metro-region	**729 (9 x9 x 9)**

For identification of the 'basic spatial unit' of the PAC, several alternative arrangements of the field of influence around a PAC are attempted, by changing the orientation and the size of the field. The model highlights the following (Kulshrestha, 1980):

a. smaller settlements are closely spaced and the distance between two similar order neighbouring settlements increases with the increase in their regional hierarchy;

b. towns and cities have two zones of influence, namely the immediate influence area and wider influence area;

c. the rural settlements do not rigidly follow the 'hierarchical dependency rule', i.e., a lower order settlement depends more on the immediate higher order settlements;

d. the spatial spread of an urban area obviously at higher order of hierarchy is larger than those on a lower one; and

e. the model suggests the distribution of the number of settlements at different hierarchy in the polarised region, which follows a geometric progression with 9 settlements in the basic spatial unit. But the actual number of settlements may be less due to the merger of rural settlements in urban texture.

Due to physical, administrative, historical or political constraints, the spatial pattern may not be as symmetrical as suggested in the model. Yet, the model ensures one town for a group of 8-10 villages, located at a distance of less than 11.3 km. It also ensures a balanced spread of various order of settlements in the region. Depending upon its hierarchy and function within the system of settlements in the metro-region, the local conditions and the policy of development, a variety of economic, socio-cultural, administrative and political activities polarise at a settlement. Moreover a continuous change in the hierarchy of settlements adds dynamism to the model whereas there is no rigidity in the size and function of a PAC.

The spatial model designed by Kulshrestha (1980) can serve as an effective tool for spatial distribution of settlements in a hierarchical order in a metro-region, assignment of functional specialisation and nature of activity polarisation.

3.2.7 Topodynamic Model

There is yet another topodynamic model given by Tellier (1992). The model is based on the concept of successive location decisions that are a function of what already exists, that is, of the existing spatial distribution of activities. Following ten indices play an important role in the topodynamic approach.

1. The parameter of the 'rank size rule' corresponding to the distribution obtained from the ranking of centres of activity concentration.

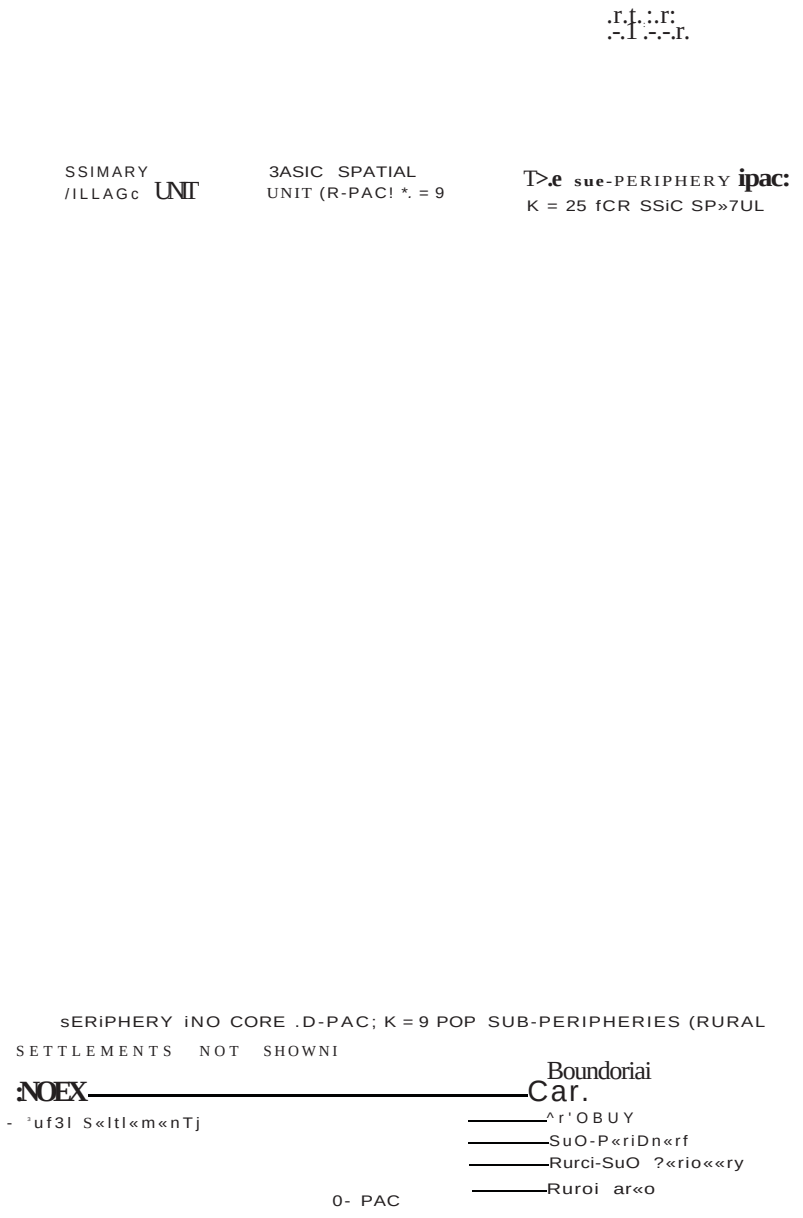
2. The ratio between the size of the second-rank centre and the size of the first-rank centre.

3. The distance between the centre of gravity location at time / and the corresponding location at time (/ + /).

4. The angle of gravity centre shifting - this angle is measured from north to the east.

5. The distance between the gravity centre and the geometric centre of the considered space.

Fig. 3.6 Spatial Model for Spatio-Fxonomic Development of Metro-Regions
(after Kulshrestha)
Source: Kulshrestha, 1991, p.6.



6. A deconcentration index related to the geometric centre. This index takes on values between 0 and 1; more the activities that are on average located far from the geometric centre, the closer is the value of this index to 1.

7. A concentration index taking on values between 0 and 1; the value 1 corresponds to the case where all activities are concentrated in a single location.

8. A scattering index varying between 0 and 1, value 1 corresponding to the case where all activities are grouped together in only two locations separated by the maximum distance possible in the studied space.

9. An index reflecting the distribution of activities (or population) between large, medium, and small activity centres.

10. A dispersal index, where increase in index indicates an increase in the relative dispersal of activities in the considered space.

As the model includes no growth rates, it is not really 'temporal'; it is, rather, dynamic in the sense that it simulates the evolution of urban population distributions when the total urban population increases and/or is reallocated in space. The order of successive decisions does matter but the period of time spent between any two successive decisions is neglected. In fact, the timing of the predicted evolution is a matter of exogenous interpretation.

The model was applied to the situation of Cameroon. The results obtained indicated that the ranking of cities tended to stabilize in the long run. A similar observation, though obtained through different analysis, was made by Das (1993) for three regional level primate cities of India.

3.2.8 Inter-Settlement Distances

An analysis of inter-settlement distances also helps to achieve a better understanding of the hierarchical system of settlements (Nangia, 1976). In a well developed and functionally-integrated hierarchy of settlements the number of settlements increases and inter-settlement distances tend to decline regularly from the higher to the lower levels of hierarchy. It may be observed, however, that in a dynamic system of settlements the inter-settlement distances within the same size range do not remain constant. Moreover, any significant diversion would mean distortion in the systems of settlements.

3.3 DISTORTION IN SETTLEMENT SYSTEMS

A settlement system is deemed to be distorted if (i) the distribution is marked by a significant clustering of large-sized settlements in pockets or corridors of development, (ii) such settlements are disproportionately more numerous, and (iii) the inter-settlement distance range of such settlements is much less when compared to the settlements in the lower size range. These are symptomatic of weaknesses in the linkages among the middle and lower orders of the urban settlements implying thereby a breakdown of the information system. Therefore,

they cease to function as effective links in the chain of settlement systems and tend to become ineffective centres of urban activities (Alam, 1984). In the Indian context, a number of factors have tended to disrupt and distort the evolution of settlement system. These factors could include the economic structure of the country, the break in the historical continuity of its evolving settlement system due to political factors, wide inter-regional disparity in levels of development, the inadequacy of linkages between urban centres and their surrounding rural areas and consequent malfunctioning of the supply and distribution system, the dysfunctional development of urban settlements, the haphazard development of services in the urban and rural settlements, and misconceived development strategies and policies of the private and public sectors.

3.4 BEYOND MODELS

Most quantitative models of settlement patterns have been developed within the 'spatial analysis' tradition in urban geography. This approach relies heavily on assumptions like isotropic planes and rational economic behaviour.

In a 'urban managerialist' thesis (Pahl, 1970; as quoted by Paris, 1982), the town planner would be the master-allocator of the scarcest urban resources. However, it would be unwise to expect that local government bureaucracies, of which the town planner is a part, would operate very differently from other types of bureaucracies (Pahl, 1982). Use and misuse of rules, the internal struggles, the confusions, decisions and non-decisions are all useful accounts of the workings of large-scale organizations and, in particular, of their relationships with those outside the organization. Similarly, the relationship between planning and 'political climate' (Chapin, 1965) is a crucial one. An effective decision process almost always involves both experts and politicians (or policy-makers) simultaneously in close interdependency. Failure to achieve a synthesis between the two will mean that the plans are not carried out or that policies adopted, being exclusively political, will be inadequate or inappropriate (Friedmann, 1973). Forms of planning are often historical precipitates of **Utopian** and ideological thought. Indian planning, for example, still reflects the influence of the social philosophy of *Mahatma* Gandhi. Recent amendments in the Constitution of India (Government of India, 1993), strengthening the local bodies at the village and municipal level, for example, have their roots in the *Panchayati Raj* philosophy of Gandhi. The complexity of most development problems is such that a full, integrated policy package will be required: one which tackles economic, social, political, ideological and cultural issues, and which may have both spatial and aspatial aspects to it. The often limited role of settlement planning in these packages must be recognized (Dewar *et al.*, 1986).

Besides the influence of a planning behaviour described above, quantitative models of settlement patterns require accurate, sophisticated and timely availability of data on a variety of subjects. While a large variety of data can be made available through a regular census, some other require extensive field surveys. Specially in the Indian context, the census data itself, though very accurate and detailed, is not available timely. On the quality side, the census, in India, is conducted on a 100 per cent sample basis, preceded by exhaustive pilot

surveys and the outcome is available in a convenient, ready to use digital format[15]. The temporal resolution of the census is 10 years. It usually takes 4-5 years before the detailed tables on various aspects covered in the census are made available. Thus, a village becoming eligible to be notified as a town in 1982 (one year after the previous census) will have to wait for an estimated 13-14 years before details of this town could be made available. This makes a very accurate data very old, and thus very inaccurate. Similarly, there are no elaborate supporting maps to clearly indicate the spatial extent of the various units and sub-units of information collection. Maps available from other sources (e.g., Survey of India) have the same problem. They are excellent maps for their accuracy (at the time the area is surveyed) but the updating seems to be neglected. For example, the latest authentic topographic maps, that this author could gain access to, were based on surveys carried out in late 1960's. A number of models discussed in the preceding pages will loose their sophistication if these outdated data were fed into them.

3.4.1 Shapes and Size of Urban Settlements

Besides the other criticism associated with them, the models discussed earlier invariably consider settiements as point locations when analysing their spatial distribution. Size of the settlement not in terms of the population it holds but in terms of the area it covers on ground, or its shape, is hardly ever considered. Although some attempt to define the idea of shape seems necessary, in practice most attempts to do this have been less than satisfactory (Unwin, 1981). It is apparent that a great many visually quite different shapes could give the same numerical indices. Reliability and the usefulness of these indices will depend largely on the objective of the measuring the shape. Scholars in other disciplines of learning (e.g., in the field of biology) have also found it necessary to devise adequate means of describing shapes (Thompson, 1952).

Since the English language has a limited 'shape' vocabulary it is necessary to develop quantitative means of describing the shapes of urban settlements. It is more necessary with the advancements in computers and automatization in image processing and interpretation. Shape is already an important parameter in unsupervised classification on satellite images. Some of the commonly used shape indices are elongation ratio, form ratio, circularity ratio, compactness ratio, ellipticity index and radial shape index (Haggett *et ai,* 1977). However, their application in urban planning is generally limited to work on morphological evolutions, or finding shape efficiency, of administrative areas. These have rarely been used for inter settlement comparisons or for predicting the shape and size of urban settlements. A recent study (Rao, 1995) used three basic shapes, i.e., circle, square and rectangle for estimating built up areas of urban settlements.

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15 **The Census of India started disseminating census data on floppy disks, for the census conducted in 1991. The floppy disks are easily available for sale from authorized government agencies. Moreover, the data can be reached through various networking facilities provided by the National Informatics Centre (NIC) of the Planning Commission, Government of India.**

3.4.2 Fractal Analysis

Another promising field where shape indices may prove very useful is 'fractal analysis', through which it may be possible not only to predict the shape, size and therefore area of urban settlements but also the pattern that they make in their regional setting. First attempts to give the study of shapes and sizes a scientific base were made by Mandelbrot (1983), which subsequently developed into a full field of fractal geometry. A fractal, as defined by him, is a pattern made of parts similar to the whole in some way. Phenomena displaying apparent self-similarity are abundant in the real world. In addition to self-similarity, another important characteristics of fractal phenomena is scaling. Length of a coastline as estimated by a map increases logarithmically with increase in the map scale. In the limit, the length of a coastline is infinite, "...boundaries can not be regarded as absolute; they are artefacts or compromises, and their statistics (length, breadth) are a complex function of the variation of the property being mapped and of the scale and mapping method." (Burrough, 1993a, p. 128).

Fractal geometry provides an appropriate means of measuring many types of irregular form that had previously resisted scientific classification (Whitehand, 1992). In the context of classifying a satellite image, each region (polygon) is described in terms of locational, spectral and spatial characteristics (e.g., size and perimeter). This helps in labelling a polygon as belonging to a particular land use class based on shape and size related factors. In general it is used to (de Cola, 1989):

i. improve the spatial analysis, spectral analysis, spectral classification, and functional labelling of remotely sensed data;

ii. address the task of making inferences about spatial processes from spatial pattern; and

iii. link remote sensing with GISs through regions with fractal perimeters imaged at a specific scale.

Its application in the field of urban and regional planning was with considerable uncertainty about the processes in operation, until the recently published works by Batty and Longley (1994). As they put it, extending fractal geometry to system of cities is comparatively straight forward. But a thorough analysis is yet to be attempted, which must therefore be high on any research agenda. Strangely, though they began this work by examining visual perceptions of urban form, they do not make much use of remotely sensed images, except for a remark in the passing, "...and we could complement this display of data with that taken from remotely sensed imagery... But our concern here is with measurement and simulation which requires a somewhat more abstracted picture of urban development..." (Batty and Longley, 1994, p.235, emphasis added).

3.4.3 Individual Decisions - Overall Effects

There are millions upon millions of individual choices and not a single choice of a combination of all locations, i.e., no person, body or authority who can make an overall, comprehensive choice. In many urban and regional systems it is important to ascertain an

overall situation. But the information we usually have, or likely to have, relates, by and large, to individual decisions (Chadwick, 1987).

With very high capabilities of providing synoptic views over large areas, satellite images can be useful base for carrying such macro-analyses of settlement patterns. It not only provides a great deal of information more efficiently than field surveys; it also offers a perception of human settlements that is truly new. It literally provides humankind with a new point of view, and therefore a new understanding of its habitat (Bolt, 1993). In perceptual terms, travelling by air, similarly, is an opportunity to see a metropolitan area almost at a glance (Lynch, 1960).

Using satellite remote sensing data, for example, is quite useful to establish the inherent relationships between urban and rural hinterlands of the city. Urban/ non-urban or built-up/ non-built-up boundary separation can be accurately delineated compared to conventional survey, where identifying and mapping is a difficult task (Subudhi *et al.*[7], 1989).

3.5 CONCLUSIONS

Techniques of pattern recognition and clustering are not widely used in the field of settlement pattern analysis. One reason may be that, often, the same procedures are developed in different disciplines but are so fragmented and departmentalized that cross fertilization is severely hindered (Jain and Dubes, 1988; McHarg, 1995). Research, undertaken jointly by a digital image analyst (specialist in spectral pattern recognition and spectral clustering techniques) and a spatial planner (specialist in analysing settlement patterns) may be fruitful.

The gravity model and the rank size rule are primarily based on the inter-settlement distances and the population size. However, in reality, distance is a relative measure. The distance could be replaced by travel time, cost or effort. Moreover, in the present day context of information super highways, physical distance seems to be a limited determinant. Similarly, one can postulate that the dynamics of development in the towns/ cities operate not only through the population but also through their area base. It will be interesting to know the results when the population size is replaced by (or added to) the CBA that different settlements under examination have. Moreover, if understanding of the distribution and scenario building is area based, satellite images will help to perform analytical exercises more often than at present. The gravity model and the rank size rule are essentially non-spatial in nature, and are generally not used for analysing settlement patterns.

A hierarchy of settlements can be developed using the central place theory and the spatial model for spatio-economic development. However, with reference to metropolitan regions, although retaining its (metropolis's) central functions for a wider area, the number of interactions and their density renders these models inadequate. Though the spatio-economic model uses a square lattice instead of a hexagonal one as in the case of central place theory, both are essentially geometrically oriented. Both assume a flat, uniform area and take the existing pattern and order in the settlements not sufficiently into consideration.

The growth pole concept offers an extensively used planning strategy. It provides an efficient tool when applied conscientiously. At the same time, there remain some ambiguities

concerning its spatial aspects, basic characteristics, regional impact and temporal aspects. The concept of service centre hierarchies draws from various other theories. It is more systematically applied, yet it is too much dependent on data on a number of facilities, as in the case of the Composite Functionality Index.

One important conclusion that can be drawn from a review of the above mentioned models is that they all help in analysing the existing patterns. Most of them help, in a limited way, in predicting settlement patterns and, rarely, in planning settlement pattern changes. Moreover, the prevalent models consider setUements as point locations when analysing their spatial distribution. The size of the seUlement, not in terms of the population it holds but in terms of the area it covers on ground, or its shape, is hardly ever considered. Although some attempt to define the idea of shape seems necessary, in practice most attempts to do this have been less than satisfactory. 'Fractal analysis' brings some hopes, however, the concept is still very new and its usefulness in modelling settlement patterns is premature.

Another conclusion drawn is that most quantitative models of settlement patterns rely heavily on assumptions like isotropic planes and rational economic behaviour. The geometrically and statistically guided models do not really work in the light of 'urban managerialism', political climate and planning behaviour. A system of service centres, for example, may provide access to a range of services but it will not necessarily spark economic development, since other factors outside the realm of settiement planning *per se* may prevent this.

Thus, methods will have to be developed which are flexible not only in the conceptual context (e.g., CBA) but also in their application to model settlement pattern in a region. Satisfactory techniques are not available for performing a 'formal' spatial pattern analysis exercise. The methods developed have to be based on a partial visual/ manual analysis. Similarly, since the techniques of spatial autocorrelation and point pattern analysis are essentially 'point' location based, their application into an area (e.g., the CBA) based approach is not possible in a strict sense. Existing settlement patterns that have emerged as result of the history of social, economic and political forces, and of technological advance, have to be respected.

Methods based on traditional concepts require accurate, sophisticated and timely availability of data, both spatial and attribute, on a variety of subjects. The level of detail required for information on many functions changes frequently and is difficult to update on a regular basis, more so in developing countries. Models loose their sophistication when outdated data are fed into them. Further, in many urban and regional systems it is important to ascertain the overall situation. But the information we usually have, or are likely to have, relates, by and large, to individual decisions.

With the capability of providing synoptic views over large areas, remotely sensed data (e.g., satellite images) can be a useful base for carrying macro-analyses of settlement patterns, at frequent intervals. It not only provides information more efficiently than field surveys; it also offers a new perception and a new understanding of human settlements. Some of the aspects involved, and limitations in using such data, are discussed in the following chapter.

4

MODELLING SETTLEMENT PATTERNS
INPUTS FROM REMOTE SENSING

the urban settlement - the town, the city, the metropolitan area - is a physically separate unit that is visually identifiable from the air." (Webber, 1964, p.81). It was concluded in the previous chapters that the concept of CBA has fewer disadvantages than others for the purposes of this research. This and similar concepts not only allow for the element of spatial dynamism, they also enrich the temporal dynamism. It is useful and conveniently applied on remotely sensed data. With very high capabilities of providing synoptic views over large areas, remotely sensed data (e.g., satellite images) can be useful base for carrying macro-analyses of settlement patterns, on frequent intervals. It not only provides a great deal of information more efficiently than field surveys, it also offers a perception of human settlements as painted by Isard as back as in 1956.

"Imagine our observer in space pilots his platform to a position fairly close to the earth's surface, and yet not so close that he fails to see the forest for the trees...In approaching the earth's surface, he might have already been forcefully struck by the spatial density configurations formed by the loci of population and by the physical structures and facilities constructed by man. Upon retreating into space, he might curiously regard these broad density configurations a second time, and perceive certain unchanging characteristics." (Isard, 1956, p. 18). Today, images provided by remote sensing satellites provide an opportunity to observe what was dreamed by Isard in the 1950's, as often as every 16, 26 or 22 days (i.e., the repeat cycle) respectively through Landsat 4 and 5, SPOT and IRS satellites.

This chapter appraises the technology of remote sensing for a general understanding, its application usefulness and limitations in the field of spatial planning, specifically towards modelling settlement patterns. As the models developed (see Chapter Seven) are intended to be applied in a developing country (i.e., India) situation, a scenario describing the status of the remote sensing technology in India has also been presented. The chapter concludes with the details of processing and interpretation of the data from the Indian Remote Sensing Satellite (IRS) for the NCR, India, case study area for this research.

4.1 CONVENTIONAL SOURCES OF DATA

Data are defined as measurements or observations of facts which, when processed/ interpreted/ organized, become information (Shelton and Estes, 1981). Data collection is an

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16 **Parts of this chapter have been prepared joinUy with Al-Amir (1996).**

essential part of any spatial planning exercise. Traditionally, data can be obtained from primary (e.g., surveys) and/or secondary (e.g., statistical) sources. These sources can be in the original format or processed.

Conventional primary surveys are carried out by actual physical measurement of various aspects of a settlement and its surroundings. These include physical surveys with the help of conventional instruments (e.g., dumpy level and theodolite) supported by other observations (e.g., of building height, material, condition and age); and density, land use, and traffic and transportation surveys. Physical surveys are supplemented by socio-economic surveys (e.g., population surveys relating to age, sex and income groups).

It is not always necessary to conduct a primary survey for each planning or planning-related exercise. A large amount of useful data can be obtained from secondary sources. Secondary sources include telephone directories, newspapers, time-tables, census data, annual reports and other published reports, tables and maps. More often, primary data, once published, become a secondary source for other users.

Both primary and secondary sources have disadvantages in their use. Primary surveys are often time consuming and costly. They require much manpower and are subject to human error (e.g., omissions, negligence and bias). Some times, the area to be surveyed may be inaccessible because of strategic or other reasons. Usually, the results of primary surveys are made available only after a time gap, rendering the data outdated. Temporal resolution of such surveys are either not fixed and/or too low (e.g., 10 years for a census survey, and more than 10 years for a land use survey in cities of developing countries). Time series are difficult because census authorities often change boundaries, especially at the lowest level. In developing countries, there is the additional problem of completeness, particularly with reference to informal settlements. Lack of continuity, and the absence of staff conversant with the data, or even with their location, usually mean that their secondary use is not practical (de Bruijn, 1991).

Perhaps the most difficult task for a planner is to have a sense of the whole area to which his plans will apply. Involved in the day-to-day tasks of a particular project, it is hard for him to maintain a perspective of a whole town, city or region. To maintain such a perspective would require an enormous investment of time - and quite a prodigious filing system.

4.2 REMOTE SENSING

No individual data source such as a census or survey can provide answers to the variety of problems addressed by planners. It is this problem that remote sensing is suited to handle. The images produced by remote sensor provide a record of the form of a place; this record can be interpreted to provide an inventory of the various functions that occur there; and when the records are made at intervals, they provide a history of the evolution of a place. The planner who uses remote sensing technology obtains a holistic sense of what his area looks like, what goes on there, and how it has changed (Bowden, 1979).

Remote sensing can be defined as science and art of acquiring information about the material objects from measurements made at a distance, without coming into physical contact with the materials of interest (Lindenlaub, 1976). It is considered the field to subsume all the disciplines of air photo interpretation, photogrammetry and the use of images from remote sensing satellites (Rhind and Hudson, 1980). Drawing, photography, and remote sensing are not only the sole substitutes for direct human viewing but they are the only way of picturing a large city. Superior to any maps, modern remote sensing image media are tools for informative communication amongst planners, with decision makers, and especially with the public. It is a way of bridging the gap between the planner's perceptions, information, analyses, intentions and the perceptions of his citizen clients (Westerlund, 1979).

4.3 AERIAL PHOTOGRAPHY

Aerial photography provides a complete and useful visual simulation of a city. Besides the information which it presents, photography can act as a trigger to recall pictures of parts of the city. Aerial photography provides a substitute for site visits, which are always desirable but often impractical. Also, without aerial photographs, the three-dimensional reality may not be fully appreciated because it may be too difficult and time-consuming to accumulate a reasonably complete mental picture of an entire area by inspection on ground. Photographs taken on the ground are no substitute for aerial photographs, since structures and differences in terrain restrict what can be seen, as compared with the information revealed in overhead pictures of the area. It is surprising how often this important use of air photo, to 'see' the city, is forgotten or ignored in urban planning (Branch, 1971).

The value of air photos in the presentation of planning to the public is evident, since the average citizen may have difficulty in fully understanding maps and plans, in visualizing the three-dimensional reality they represent, and in obtaining from them the information they contain. Sketches and drawings are not as realistic and actual, and they are subject to criticism in that they exaggerate or otherwise alter the true situation. Stereoscopic view further increases the range and reliability of photo interpretation.

4.3.1 Aerial Photographs for Urban Planning

A combination of low altitude, larger-scale vertical photographs with oblique views taken to each side at the same time makes possible the most complete and reliable interpretation of land use from aerial photographs for urban planning purposes. In comparative city planning research, urban studies, and environmental investigations, oblique photographs are adequate for many purposes. For example, if taken at high altitudes in clear weather or with filters reducing obscuration caused by haze, they may show urbanization, the relationship of communities to their metropolitan and regional surroundings, the extent of vertical development, circulatory patterns, or perhaps indications of air or water pollution. In essence, they represent the best descriptive, informational basis for many research investigations concerning the physical city. In a surprising number of cases, research can be conducted and conclusions reached from study of the photographs alone. When derived data and conclusions are superimposed on the photographs or closely associated with them, the reality of the pictures reinforces the reality of the quantitative abstractions. A typical aerial

photograph is shown in Figure 4.1.

A survey can be made on the ground to check information from aerial photography, or to develop reliable indicators of conditions not shown directly in overhead pictures. As a basic rule, photo interpretation must be checked with the 'ground truth'. Only in specific cases (e.g., when corroborative data are not available or time is very limited), can photo interpretation without checking the 'ground truth' be acceptable (Wogayehu, 1993). The greater the familiarity of the user with the general nature and many components of the urban scene, the more vivid the mental picture of these features and activities as they appear from above, the greater the awareness of indirect indicators of socio-economic information not directly shown in aerial photographs. Similarly, detailed interpretation depends on precise knowledge of the special category of information. Therefore, the more those concerned with city planning and related municipal activities know about their subject 'on the ground', the greater the information derived from aerial photography and the easier and more effective its use (Branch, 1971).

4.3.2 Constraints and Limitations

A number of important problems remain to be faced by all users of aerial photographs. One of these is the restraints imposed by the general scale of photograph. Another problem is the assumption of a constant relationship between form and function. Changes in the form/ function relationship may be very significant where some other variable is being inferred from land use. It is also obvious that multi-level urban land use data are difficult and frequently impossible to acquire from aerial photographs. There is a problem related to the question of form and function and to characteristics of the survey - the accuracy and consistency of the results (Rhind and Hudson, 1980). In many countries where the capacity to produce and regularly up-date maps has been found insufficient, and procedures of map production are costly and time consuming, the role of aerial photography is likely to increase. The increase is also likely to be supported by the increased use of computers (e.g., for the storage, retrieval and analysis of data). In turn, maintaining the data in up-to-date condition, through the use of aerial photography, is essential to the efficient use of the computer (e.g., in modelling). Moreover, in many (specially developing) countries the use of aerial photography is limited, or even restricted. Therefore, civilian decision makers must often use very inappropriate material to generate the type of data which would technically be readily obtainable from aerial photography. On the other hand, the civilian bureaucracy often blames its shortcomings on restriction which may not in fact exist (Thung, 1985).

4.3.3 The Policy of Restriction

In India, for example, aerial photography is governed by the policy of restriction. All the aerial photography is classified as 'secret'. It is laid down that the permission of the Ministry of Defence has to be obtained at the time of flying, after completion of photography, and before release of photographs (or maps) to the user. Topographic maps falling under restricted zones are also not available easily. The steps in filling up the forms to receive photographs or restricted maps and their cumbersome follow-up have made many organisations and individuals give up the technology of aerial photography altogether. As a

Fig. 4.1 **Vertical Aerial Photograph of the City Centre, Enschede The Netherlands; 1972**
Scale 1:5,000 (here reduced 75%)
Courtesy: ITC, Division of Urban Planning and Management

result, orthophotomapping has died its own death and there is hardly any production of orthophotomaps (Misra, 1989, 1993), in spite of the fact that base maps are required for about 500 important towns on priority[17]. The policy of restriction, and other disadvantages associated with the aerial photographs, are encouraging more and more professionals to use satellite data products, as they are not subject to the same restriction (Mahavir and Galema, 1991).

4.4 SATELLITE IMAGERY

Basically, two types of sensor systems are used in the field of remote sensing, photographic and non-photographic. In the photographic systems, wavelengths in the visible and near-infrared portions of spectrum are detected using photographic films. In the non-photographic systems, the image is created by light sensitive detectors that produce electrical signals proportional to the brightness of the light energy. A single detector views a strip of terrain by using a rotating mirror to direct its 'field of view' across the landscape below. This process is known as scanning. An image analysis system is then used to reconstruct and display the signals obtained by the detector as a picture-like image. This reconstructed image is composed of a large number of picture elements, termed 'pixels', each of which is assigned a colour, or shade of grey, according to the received light energy (Aronoff, 1993).

Remote sensing refers to the measurement from a distance of electro-magnetic radiation emitted by, or reflected from, the earth's surface. Information related to the earth's natural and human processes, their management and monitoring may be obtained by interpreting spectral, spatial and temporal variations in these measurements. Remote sensing instruments may be mounted on platforms such as aircraft or orbiting satellites. These instruments offer an opportunities for recording information in synoptic, repetitive and timely manner. Recording devices are based on scanners which operate in different modes (e.g., MS of 20m x 20m or PAN of 10m x 10m pixel size in SPOT satellite).

The earth orbiting spacecraft permit regular observation of urban locations around the world and provide an opportunity to discover if there are comparable trends or patterns of urban growth. Satellite surveys taken at five to ten year intervals could show patterns of urban growth, such as the rate of urban spread at the periphery, or the tendency of communities to grow together or coalesce to form large cities and huge megalopolis (Branch, 1971). It is too powerful a tool to be ignored in terms of its information potential, its technological spin-offs, and the logic systems implicit in the reasoning process employed to analyze the data produced by remote sensor systems (Estes and Holz, 1985).

Remote sensing from a platform high above the earth, such as a satellite, can provide regional views not readily gained by ground observations or observations from lower altitudes. It can provide repetitive looks - daily, weekly, monthly or yearly - at the same area

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17 **India has about 4,700 towns and cities as per 1991 census. Of these, 317 are class I cities, i.e., population more than 100,000 or more. There are 23 metropolitan cities, i.e., population 1 million and above. Formally produced base maps and guide maps at scales ranging between 1:10,000 and 1:20,000 are available for only about 60 cities (Misra, 1993).**

or target. As remote sensing images generated today are in an electronic format, they can be processed electronically. This makes possible the use of modern, high speed computers that can store, quantitatively analyze, and display remotely sensed data (Estes and Holz, 1985). Where remote sensing adds to the knowledge of a field related to city planning, this advance may be incorporated into the body of knowledge employed in studying and guiding the development of cities. Thought and imagination will indicate other possibilities of how remote sensing may serve city planning in important new ways at some future time. While remote sensing is not capable of producing a complete inventory for all land use studies, it is probably the single most important tool and labour saving device for land use mapping and functional class identification (Bowden, 1979). Such mapping is often inexpensive and useful; because of the altitude at which images are taken, the images are almost distortion-free and, in some parts of the world, are often more accurate than the best topographic maps (Rhind and Hudson, 1980; Paulsson, 1992).

4.4.1 Information Extraction

At no time in history has a technology moved and expanded as rapidly as remote sensing, perhaps excepting computer development which gave remote sensing and the resulting geographic data handling (GIS) the impetus for its rapid growth (Thung, 1985). While remote sensing is sometimes the only source of data, more often it complements and supplements other data sources and helps create an accurate data base for decision-making (Henderson, 1979). Combination of existing data sets such as zoning specifications and newly obtained remote sensing products often provide a tolerably reliable survey at a reasonable price. Combination with information from sources other than remote sensing occurs for two main purposes: i. to corroborate or compliment one type of information with the other, assuming some common substantive content, and ii. to perform an analytical function that relates two different types of information. Neither type of combination (corroboratory and analytical) necessarily demands that remote sensing derived information be fully integrated with an existing data base. In any case, existing material which may have been generated earlier by central agencies must be made use of; duplication is expensive (Thung, 1985). However, there must be ways of relating the information (Westerlund, 1979).

A noteworthy aspect of the present day use of satellite remote sensing is the fact that image analysis and information extraction are carried out using a variety of techniques. These range from simple interpretation methods - similar to those applied in many instances with aerial photography - to complex automatic, semi-automatic and interactive digital processing, optionally coupled with sophisticated information management sub-systems. Choice of methods and techniques depends upon the problems to be solved, scope of work and available resources, equipment and expertise. The resulting flexibility contributes significantly to the applicability of the data and the functioning of the sub-systems (Voute, 1982).

Satellite images for land surfaces are acquired by the American Landsat series, the French SPOT (Systeme Pour rObservation de la Terre), the Indian IRS-1 and the Japanese MOS series. For a long time, images with a low spatial resolution (e.g., 80m of MSS) only could be ordered. A considerable improvement of resolution arrived in the market in 1986 with the 10m spatial resolution Panchromatic SPOT (Figure 4.3). SPOT images provide a synoptic view on areas as big as 60 km x 60 km. On such an image not only a (big) city can be seen

but also a large part of its environment in which it might expand. Attempts are being made to define the building heights using SPOT Panchromatic images (Cheng and Thiel, 1995; Hard and Cheng, 1995). However, while stereoscopy is useful with large scale aerial photographs, stereo images (which are possible with SPOT) do not make delineation of setUements easier **(P0II6,** 1988; 1993). The future of these remote sensing satellites will provide continuity of data supply by replication of existing sensors and evolutional enhancements to current sensor designs with addition of wavebands, or increases in spatial resolution. These advances will give scientists new types of data, and the challenge to use these data in order to derive anew and meaningful information about the earth's surface (Plummer *et al.,* 1995).

Global proliferation of new high-resolution imagery is only a few years away. Commercial remote sensing satellites, viz. EarlyBird, Quickbird, OrbView and Sis, planned for 1996-97, will have cameras with a Ground Sample Distance (GSD) of 1-5 meters, stereoviewing capability, and the data from these could be provided in real time on Internet (Gupta, 1995, 1994; Plummer *et al,* 1995; Henderson III, 1995).

4.4.2 Classification and Interpretation

The primary value of remotely sensed data lies in the information which they convey about the environment. Such information is obtained through interpretation, which is partly science and partly art (Shelton and Estes, 1981). While sensor technology has improved considerably over the last two decades, the techniques used to extract the desired information from the resultant images have not always developed accordingly (Barnsley *et al.,* 1993). In this connection, the advantages of visual and optical interpretation techniques have to be stressed. They make use of the unique capabilities of the human eye and human mind to recognize features and patterns and to deduce the presence of objects, facts and processes (Voute, 1982). The human brain automatically takes into account texture, structure, context, experience, and 'common sense' in the analysis of the reflectance data. In visual/ optical interpretation, good use is made of synoptic overviews over very large areas for broad classifications so as to recognize and identify regionally important features, which may remain unnoticed in more local and detailed studies. The advantages of stimulating the creativity of the individual to understand and solve local problems, using both local knowledge and knowledge of the discipline involved, are often underestimated. This is of importance, irrespective of whether professional or non-professional utilization is considered (Voute, 1982). Despite advances in automated and machine-assisted interpretation, human interpreters will be always essential - identification and validation require human judgement (Shelton and Estes, 1981). For urban applications, in most cases, visual interpretation of satellite images is better than computer-based processing (Paulsson, 1992).

4.4.3 Digital Image Processing

Data originate from measurements made by instruments carried on earth orbiting spacecraft, they flow through a reception facility as a set of raw data. The raw data are then processed and geo-coded to perform the required measurements. Several established techniques of image enhancement (such as linear contrast stretch, density slicing, edge enhancement,

contrast enhancement, and spatial filtering) can be applied for achieving optimum results.

Digital image processing and information extraction techniques offer entirely different possibilities through the use of a man-machine interaction based on combining specific capabilities of the human being, on one hand, and the computer and peripherals, on the other. Advantages are a higher level of information extraction, a potential of combining digitally image obtained at different times or with different sensor systems, and integrating these with digitized data from other sources of information (Voute, 1982). At the simplest level, an image understanding system may provide a cue that an image contains a specific object or perhaps an unexpected object. At the other extreme, the system may generate a very general verbalized description of a scene in the sense that a human viewer would write a paragraph about the contents of a particular picture (Pratt, 1978).

In essence there are two different ways of classifying digital remotely sensed data - i.e., unsupervised and supervised. In the first, a computer programme carries out (spectral) cluster analysis in which the individual pixels are grouped on the basis of the similarity of the amount of radiation measured in each waveband. The results tend to be labelled as groups A,B, etc., i.e., at the analysis stage there is no knowledge of what, if any, (land use) classes these constitute. The alternative approach is to utilize *a priori* knowledge, derived from the facts on the ground, what is known in technical terms as 'ground truth'. Accuracies of between 80% and 85% have been recorded for simple division of pixels on spectral grounds into urban or rural areas (Rhind and Hudson, 1980).

Three obvious approaches exist to improve the level of success. First, to take into account not only the spectral signature but also the texture in each image taken at different seasons (or time coinciding with related events). Most automated classifications are one shot - all classes are regarded as being distinct. The second improved approach being utilized is to use layered classifications, i.e., to make decisions within a hierarchical classification framework, since most Oand use) classifications are hierarchical. A complication of this is the need for the input of thematic information in deciding the layers to be used and how this is to be linked to the remotely sensed data; an advantage is that errors may be restricted to much less significant ones. The third improvement is not within the control of the analyst - it is the improvement in the spatial resolution of the sensor and hence the reduction in the mixing of different land uses within each pixel (Rhind and Hudson, 1980).

4.4.4 Cost Effectiveness

Mapping at medium scales based on satellite data is normally less expensive and faster than conventional mapping using aerial photographs. A comparison must take into account the factors that cause considerable variation in costs for photo coverage, such as scale, size of the area, aircraft operating and staffing costs, field logistics, and climatic restrictions (Paulsson, 1992). In practice, it is remarkably difficult to assess how cost effective satellite remote sensing has been in comparison with that from aircraft or, indeed, from ground survey. In urban situations, the benefits are often even more difficult to assess. For example, counting losses which might occur in the absence of a survey is tricky in the extreme (Rhind and Hudson, 1980).

4.5 SATELLITE REMOTE SENSING FOR SPATIAL PLANNING

Images obtained through remote sensing satellites have been used in a variety of applications, including earth resources and population studies. A number of applications have been found in the area of spatial planning, some of which are discussed in the following paragraphs.

4.5.1 Population Estimation

Estimating population or population density is a complex problem. Estimates of population cannot be obtained directly from remote sensing images. However, simple models employing visible physical characteristics can be designed that infer population densities by surrogate. These models use remote sensing images to define an area according to land use types or the number of housing units. This is combined with such data as previous population counts, selected census data, and other variables associated with population, and the result is a rather precise population estimate. Work in the Sahel area of Africa, and in Brazil, concluded that, except in the largest cities, there was a linear relationship between population and area of cities as defined on satellite images (Henderson, 1979). In the case of Sokoto city in Nigeria, where a census was not held for decades and field checks could not be conducted due to political disturbances, Wogayehu (1993) demonstrated that reasonable estimates of population and housing densities could be made based on aerial photographs and SPOT images. Accuracy of each method is dependent upon local land use practices and settlement patterns. While most of the methods contain some inaccuracies, they are or can be comparable to results obtained by standard population estimating techniques. This is particularly true when time and/or data availability are factors. With perseverance, useful data can be derived economically but limitations must be recognized.

4.5.2 Change Detection

Change detection is fairly straightforward task for photo-interpreters evaluating large-scale aerial photography; but visual comparison of photos is slow, it is a tiring task, and it is subject to numerous errors of omission. These are some of the reasons why methods are used that automatically correlate and compare two sets of image and indicate changes. A change detection method should be based on a sensor system that: i. has a systematic period between overflights; ii. records image of the same geographic area at the same time of day to minimize diurnal sun angle effects; iii. maintains the same scale and look angle geometry; iv. reduces relief displacement as much as possible; and v. records reflected radiant flux in consistent and useful spectral regions.

If these conditions are satisfied, then it may be possible to analyze the spatial, spectral and temporal characteristics of the data to produce land use change statistics (Estes and Holz, 1985). Unlike administrative records such as files of plots or building permits, remote sensing surveillance picks up all actual occurrences of urban development within technical detection capabilities, whether or not they are officially recorded. The technical challenge lies in perfecting methods that replicate earlier classification with such consistency that the resulting information records may be compared for change with confidence that differences represent real change and not 'noise' or variability in the interpretation method (Westerlund,

1979).

Digital change detection is a difficult task to perform accurately, using satellite data. The results will not be as accurate as those produced by a photo-interpreter analyzing large scale aerial photography. Nevertheless, because manual change detection is exhaustive, difficult to replicate, that is, different interpreters produce different results, and incurs substantial data acquisition costs, researchers continue to seek improved digital change detection algorithms. Spatial, spectral and temporal constraints affect digital change detection. Assuming the image can be placed in a configuration that allows digital analysis, the selection of an appropriate change detection algorithm takes no significance. Image differencing or ratioing of spectral data are practical but may be too simple to identify the variety of change in a scene. Their utility may be enhanced by incorporating other processed data such as texture in the analysis. Classification comparison methods are useful only if accurate land use classification(s) can be obtained. Several processing operations, such as low and high pass filtering and principal component analysis (PCA), are also available as potential aids in change detection but these have not provided consistent change detection results. Moreover, persons conducting digital change detection must be intimately familiar with the environment under study, the quality of data set, and the characteristics of change detection algorithms (Jensen, 1985).

Updating of a topographical map of the urban fringe areas for planning purposes is quite feasible. This method of map updating could rapidly develop into a useful tool for planners, especially as the geometry of the SPOT images, for all practical purposes, is as good as that of a topographical map. This implies that measuring the growth of a settlement, in area measures, can be done with reasonable accuracy **(P0II6,** 1992). SPOT images are particularly useful for analyzing the growth and size of human settlements. Even a few general land use classes can be studied with sufficient accuracy for most general planning purposes (Mahavir and Galema, 1991). Moreover, SPOT imagery has a very high revisit capability, any area in the world can be observed every 3 days (Maurel, 1993).

Eurostat (Statistical office of the European Communities) recently launched a pilot project entitled, 'Remote Sensing and Urban Statistics' to monitor both the extent of urban areas and their composition in terms of land use. Largely based on SPOT-HRV data, different stages of the project will include producing an accurate map of land use within and around the urban area; producing a map delineating the urban morphological zone; and finally producing an 'urban agglomeration map' (Barnsley, 1993).

If remote sensing can provide one set of information that is frequently updated, and in which change is identified, this may effect the use, interpretation, or credibility of other information that can not be updated as frequently. Change detection may trigger the collection of new information of other kinds. An information set created by remote sensing can thus provide a standard by which other information is judged for consistency (Westerlund, 1979).

4.5.3 Settlement Patterns

Providing synoptic view over a large area , in a very short time, is probably the most important use of remote sensing in planning (Jensen, 1979; Thung, 1985). Since settlement patterns are composed largely of visible, spatially arranged inhabitation, more can be learned

of them from remote sensing image than any other single source. Images have the potential for providing information concerning the contemporary elements and type of settiement. They often reveal the detailed physical condition and areal patterns involved in the process of original setdement and subsequent occupancy (Bowden, 1979). The information that satellite images might reasonably be expected to provide about urban areas includes data on their physical extent, i.e., their location and perimeter (Barnsley ***et al.,*** 1993). A study concerned with the detection at a regional scale of areas where changes have occurred does not require the high spatial resolution. The relatively low spatial resolution of 72.5m meets the spatial characteristics required for the detection of landuse changes at a regional scale (Charbonneau ***etal.,*** 1993).

The advantages of satellites as sensing platforms is the frequency and repetitiveness of image provided, the consistency of recording and (if automated procedures are used) of interpretation, the low cost per unit area which may accrue from many users, and the lack of any problems from other air traffic. If detection of change rather than the provision of a base line-survey is considered, the relative utility of image and aerial photography are, as ever, entirely dependent on the detailed needs of the user. Also, all forms of remote sensing are liable to lead to errors where land use based on function is being sought (Rhind and Hudson, 1980).

4.5.4 Constraints and Limitations

In general, there is a lack of awareness of the technical possibilities and limitations of remote sensing technology, and its potential benefits. Remote sensing should be seen as a method for acquiring data, and not as a tool to solve development problems. The proliferation of remote sensing centres may become expensive unless it is coordinated so that data gathering can be conducted with minimum overlap (Thung, 1985).

Voute (1982) grouped the constraints in applying remote sensing in developing countries into three categories. These are the system limitations of the satellite missions, which only partly meet the needs of developing countries, the lack of facilities and manpower, and insufficient preparedness for remote sensing application and their operational use. Furthermore, the lack of awareness of those in power about the usefulness of remote sensing data gathering techniques is coupled with a lack of willingness to accept new technology, due to consequences as to infrastructural adjustment. This may result in frustration of those who have mastered the technique and, therefore, have become isolated.

Though used in a variety of applications (e.g., in the fields of natural resource management and environmental protection) the use of satellite remote sensing in urban planning is not as widely spread, both in developed and developing countries. Although relatively cheap desk-top and window versions of image processing packages (together with Geographic Information Systems) are now available, hardware and software are expensive and require expertise.

Overcoming the lack of facilities and qualified personnel in developing countries requires investment of considerable resources, in the case of development assistance, by both donors and recipients. The investment includes the design of appropriate education and training

methodologies, and the production of relevant educational material. Reducing the gap in the availability of facilities between developed and developing countries is not only a matter of funding, equally important is a selection of suitable subsystems and components. There should be a proper assessment of the new technology by the national governments concerned and by national user communities. This, in turn, requires a science and technology policy based on national economic and cultural development policies. Such assessment should be based on efficiency, cost effectiveness of operations, types and volume of work to be performed, plans for consolidation or adjustment of infrastructure required for surveying, monitoring and use of information, and economic and social benefits to be derived therefrom (Voute, 1982).

The operationalization of remote sensing involves moving from a study of remote sensing principles and technology to an analysis of how remote sensing can be used to solve practical problems. The operational use of remote sensing faces obstacles. These include the under-estimation of the complexity and size of the impact that remote sensing has on existing institutions, and under-estimation of costs associated with the introduction of this technology, such as daily running costs, system maintenance and staff development (Genderen, 1993).

There is another view on the research and development needs of remote sensing, which is based on experiences of the remote sensing market. In this view, to develop routine applications, remote sensing research has limited value if it does not pave the way of real use in any field (e.g., scientific community, operational public benefit, commercial users). "We must develop systems, not just methods. End-to-end systems that solves the whole problem at affordable cost, that fits into established structures, and that makes use of available techniques and other scientific fields as well... Remote sensing is bridging the gap between technology, science and application, and culture." (Borg, 1995, p. 16).

4.6 STATUS OF (Satellite) REMOTE SENSING IN INDIA

The major focus of the Indian space programme has been on strengthening and accelerating the pace of development in the country through significant enhancement of her capabilities in communication, broadcasting, weather forecasting, education, disaster warning and optimal management of land and water resources. Indian Remote Sensing Satellite IRS-1A was the first operational earth resources satellite in the country, followed by IRS-IB. Both had two payloads each employing Linear Image Self-Scanning Sensors (LISS), which operate in a push-broom scanning mode using Charge Couple Devices (CCD) linear arrays. LISS-1 provides a resolution of 72.5m, whereas LISS-2 provides a resolution of 36.25m. The choice of the payloads has been made on the basis of application needs of the users. The operationalisation of various application projects using remote sensing techniques has been conceived and enhanced through the successful launch and commissioning of both IRS-1A in 1988 and IRS-IB in 1991 which are the indigenous, state of art satellites[18]. Both the satellites operate under four spectral bands, as detailed further (ISRO, 1989, pp.2.6, 6.1):

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18 See ISRO, 1989, for detailed technical specifications of these remote sensing satellites.

BAND/ SPECTRAL RANGE (in microns)	SALIENT CHARACTERISTICS	PRINCIPAL APPLICATIONS
1 (Blue) 0.45-0.52^	Sensitivity to sedimentation; deciduous/ coniferous forest cover discrimination.	Coastal environment studies; Soil/ Vegetation differentiation; Coniferous/ Deciduous vegetation discrimination.
2 (Green) 0.52-€.59$_{M}$	Green reflectance of healthy vegetation.	Vegetation vigour; Rock/ Soil discrimination; Turbidity and bathymetry in shallow waters.
3 (Red) 0.62-O.68$_{M}$	Sensitivity to chlorophyll absorption by vegetation; differentiation of soil and geological boundaries.	Strong chlorophyll absorption leading to discrimination of plant species.
4 (near IR) 0.77-0.86/1	Sensitivity to green biomass and moisture in vegetation.	Delineation of water features; Landform/ geomorphic studies.

Based upon the experience of various user communities of satellite data in India, it was observed that LISS-1 data is compatible with that of Landsat MSS data. Linear features like rail/ road and a few wasteland categories are better detected in LISS-1 data. On the other hand, the LISS-2 data which has a spatial resolution almost similar to Landsat TM could provide for better discrimination of vegetated and non-vegetated areas (ISRO, 1989, p.6.2).

The mean equatorial time of passing the satellite is 10.25 hrs. during every descending (north-south) pass. The satellite completes one coverage cycle in 22 days. The nominal scene size of LISS-1 is 148.48 km x 174 km with an along track overlap of 25.52 km. Similarly, the nominal scene size of LISS-2 is 74.24 km x 87 km with an along track overlap of 12.76 km (ISRO, 1989).

A ground segment has been established to operate the satellites, receive the remotely sensed data, generate data products and disseminate to the users. It receives data from[19] Landsat MSS/TM, NOAA AVHRR 9 and 11, IRS-1 series and from ERS-1 (Deekshatulu, 1993).

Considering the technology development scenario and user requirements during the nineties, a series of second generation remote sensing satellites has been planned. Taking into account the increased use of space image for different applications and the requirement of higher spatial resolution for specific applications, the second generation satellites will have more revisit capabilities (5 days), stereo-viewing, and on-board data recording facilities. First such satellite, IRS-1C, was launched in December, 1995 (The Times of India, December 29, 1995, New Delhi). It incorporates sensors with resolutions of 23.5 metres in multispectral bands; and 5.8 metres, with stereo capability, in the panchromatic band. The spectral resolution ranges from 0.5/x to 0.75/*. A band in Short Wave Infra-Red (SWIR) is added with a spatial resolution of 70 metres. Also a Wide Field Sensor (WIFS) with spatial resolution of 189 metres and larger swath of around 810 km is provided for viewing in red and near-IR bands (Remote Sensing nieuwsbrief, 1996). IRS-ID is planned to be launched during 1996-97

19 Receipt of SPOT data has been discontinued since January, 1992.

(Kalyanaraman ***et al,*** 1995), while four more are planned to be launched, one every year, until end of the century (The Times of India, December 29, 1995, New Delhi). Following the deployment of a 5.8 meter resolution sensor, India could possibly develop a higher resolution sensor for follow-on IRS systems (Gupta, 1994).

The Department of Space in the Ministry of Science and Technology, the Indian Space Research Organisation, the Space Application Centre, the National Remote Sensing Agency and the Indian Institute of Remote Sensing are amongst the various agencies engaged in the research, planning, design, data receiving, dissemination and training activities related to remote sensing. Besides these, a number of universities and institutes of higher learning offer academic programmes leading to the award of a degree of M.Sc. and Ph.D.

Large scale operational demonstrations have been carried out in the selected theme areas under the programme of Remote Sensing Application Missions. Amongst these themes are Crop Acreage and Production Estimation, Soil Resources and Soil Salinity/ Alkalinity Mapping, Agricultural Drought Assessment and Forecasting, Land Use/ Land Cover Mapping, Wasteland Mapping, Urban Sprawl Mapping, Ground Water Potential Mapping, Mineral Survey, Geo-environmental Surveys, Underground Coal Fire Mapping, Surface Water Mapping and Monitoring of Major Reservoirs and Command Areas, Flood Mapping and Damage Assessment, Snow-Melt Runoff Estimates, Marine Fishery Potential Zone Mapping, Forest Cover Mapping, Integrated Land and Water Resources Mapping, Monitoring and Assessment of Volcanic Eruption, and Forest Fires Monitoring. The noteworthy aspect of these projects is that many user departments have accepted the utility of remote sensing for implementing their management plans (Deekshatulu, 1993). In the field of human settlements, a number of significant research studies and other projects have been successfully conducted by the Human Settlements Analysis Group of the Indian Institute of Remote Sensing[20] (IIRS).

Unfortunately, not many studies have been reported in the literature, on the application of IRS data in human settlements planning and monitoring, other than those conducted at the IIRS. A few studies available (e.g., Venugopal ***et al.,*** 1993; Pathan ***et al.,*** 1993) generally revolve around a mix of using aerial photographs, satellite images including those obtained from foreign agencies and GIS for monitoring of urban areas. Some studies do attempt various image enhancement and interpretation techniques but on the whole fail to recommend any generalized procedures which could later be automatized. Moreover, there seems to be a general reluctancy in using IRS data (for example, see Sokhi and Sharma, 1989; Sokhi ***et al.,*** 1989).

Lack of publicity, both for the availability of data and for reporting the results of studies conducted based on such data, may be the principal reasons for comparatively low use of IRS data internationally. Most recent books and papers on the subject do not list IRS as one of the satellite data sources. Other than the publication and distribution of the Journal of Indian Society of Remote Sensing (a non-governmental organisation), and publication of papers in individual capacity of authors, there is no evident official attempt for the same.

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20 **See Photonirvaehak; Journal of Indian Society of Remote Sensing, Vol.17, No.3 (Special Issue on Human Settlement Analysis), 1989, Dehradun, for a sample of such studies.**

Though the IRS data, in principle, is available both to domestic and international users without any restriction, there is a general tendency to treat it as 'secret', a culture influenced by a similar official policy in case of aerial photographs. With the appointment of the EOSAT for distribution of IRS data outside India, it is hoped the IRS data will be more widely used.

4.7 DATA USED FOR THIS RESEARCH

Out of the popularly used satellite images (e.g., those from Landsat, SPOT, IRS), the use of the data from IRS was preferred. This decision was prompted due to following reasons:

1. Ready availability of the data in the desired format and medium;

2. optimum resolution with respect to the objectives of this research. Whereas better resolution, say 10m of SPOT Pan would have taken huge storing space and processing time, at the same time it would have increased the burden of 'aggregating' and generalizing the pixels of individual elements into one representing a CBA (see Chapter Two);

3. much lower costs of procuring the data, compared to other satellites; and

4. opportunity for conducting a pioneering study using IRS data. As stated earlier, not very many studies have been reported in the field of human settiements using IRS data, and certainly none at a regional level.

IRS-1A and IRS-IB data was procured from the National Remote Sensing Agency (NRSA), India. The data was obtained for the periods around 1st January, 1991 and 1st January, 1994. These dates were chosen respectively to coincide with the availability of latest census data (i.e., of 1991) and the most recent available images at the time of ordering. These dates also avoid large flooded areas during the rains/ very green city surroundings/ and hot-dry land that can cause a very high reflectance. The exact dates of the data were determined based on two factors, i. the nearest date to the target date, on which the satellite passed over the area; and ii. near zero cloud cover in the scene.

The scenes finally selected ranged from those acquired between December 23, 1990 to March 20, 1991 (to represent 1st January, 1991); and between December 16, 1993 to January 7, 1994 (to represent 1st January, 1994). The scenes were selected so as to cover the entire study area at a resolution of 72.5m for both the time periods, i.e., 1991 and 1994. Two sub-scenes, for each time period, were also obtained at a resolution of 36.25m for parts of the study area. All the scenes were obtained in CCT, 6250 BPI, BSQ format, Standard data products with polyconic projection and cubic convolution resampling. A complete specification of the products used is provided in Appendix IV.

All the data from CCTs was copied on 60 or 250 Mbytes Cartridge Tapes for use on PC based ILWTS software package for image processing (ITC, 1993, 1994; Gorte, 1994). See para 5.3.3 for the choice of software.

4.7.1 Image Processing

The first step in using the data was preparation of False Colour Composites (FCCs) of the various scenes and sub-scene. After various trials, it was observed that the combination of Bands 1, 2 and 4, i.e., Blue, Green and near IR respectively, provided the most sharp images (see also Subudhi[1] *et al.,* 1989 and ISRO, 1989 for the choice of bands).

Several established techniques of image enhancement were applied for achieving a best visual delineation of the CBAs. These techniques ranged from linear contrast stretch, density slicing, edge enhancement and contrast enhancement to spatial filtering. These techniques were applied separately on each band of a multispectral image. Besides, Band Ratioing and Principal Component Analysis (PCA) were also applied. Ratioing B1/B4 and B2/B4; and PCA of Bands 1, 2 and 4 yielded good results. Standard procedures (e.g., those developed by Hofstee and Budde, 1994, Ex. 9.2) for 'linear stretching' and making FCCs were adopted. Pixel values with a cumulative frequency between 5% and 95% were used as lower and upper boundaries respectively. This resulted in a better (sharp) image compared to a usual 1% and 99% choice. Standard Colour Lookup Table was used for assigning colour to various pixels. Various filtering techniques were also applied to the images.

In spite of the use of various established techniques of image enhancement, no 'universal' technique(s) could be identified that could be applied uniformly to all the scenes. Different scenes and sub-scenes required different treatment to obtain the most optimum image. In many cases, the simple FCC of linearly stretched bands provided good results. In many other cases the enhancement techniques did not bring fruitful results. This is due to the fact that not all the settlement have similar density/ texture/ and the general pattern of growth. Different (areal) size of settlements also required a different treatment. Moreover, surroundings of each settlement played a very important role in identifying, delineating and interpreting the settlement. The general surroundings in the study area varied from a rich fertile agricultural land in the state of Uttar Pradesh to dry, desert like surroundings in the state of Rajasthan (see Chapter Six for details of the study area). This failure to pin-point a specific technique(s) capable of being applied uniformly to the entire study area lead to further limitation, that of non-automatization of the image processing. Each scene had to be processed individually and independent of other scenes.

It was also observed that instead of processing the whole scene at a time, breaking the scene (150 km x 150 km approx.) into several sub-scenes (usually 20 with a little overlap to ensure continuity), and then applying the various techniques mentioned above gave better results. The images, thus produced, were more sharp and had better contrast. This also facilitated in comparatively easy distinguishing the settlements from their surroundings. The same process was further extended to enhance the image of settlements. In this case, after having a settlement identified on the image, a sub-scene covering the 'search area' (i.e., a rectangular area covering roughly three times the diameter of the settlement seen visually in the first instance) for the settlement was carved out for further processing. This helped in better delineation of the 'settlement', i.e., in better operationalization of the concept of CBA.

The final FCCs, thus created, were saved in digital format for further use. Also, the FCCs were printed on an /ipPaintJet printer at a (print) scale of 1:250,000. This scale was chosen to match the scale of topo-sheets of the Survey of India, for ease of comparison, updating,

identification and delineation of setUements on both the mediums. These hard copy FCCs were joined together to form a mosaic covering the entire study area.

4.7.2 Image Interpretation

Results obtained from digital image processing with supervised landuse classification of medium and low spatial resolution data are generally not encouraging for studies related to human settlements **(P0II6,** 1988; Subudhi[1] *et al.,* 1989; Paulsson, 1992). The spectral signature of this theme (pixel) is a combination of the elements of asphalt, concrete, different roof types, lawns, trees and bare soil (Charbonneau *et al.,* 1993).

The application of the term CBA, on an image is based on mixed spectral signatures of distinct ground elements having specific physical properties. Visual image interpretation was carried out mainly on the hard copy prints. Interpretation was carried for identification of settlements satisfying the criteria of CBA (see Appendix III for the operational definition), delimitation of the CBAs, predominant natural features (e.g., forests and rivers) and predominant linear features (e.g., railway lines, road and canals). It was sometimes easier to interpret the image (visually) on the computer monitor rather than on the print. While it was possible to broadly differentiate between the densely built and sparsely built areas within a settlement, it was not possible to put a dividing line between the two. Delineation of the CBAs was governed by the operational definition (see Appendix III). It was not possible to determine the urban/ rural status of the settlement, nor the function of the settlement, based only on the image interpretation.

The various steps involved in processing the raw data into image processing and interpretation have been summarized in Figure 4.2.

FCCs of the images taken in 1994 were compared with the images taken in 1991. While it was possible to find appreciable changes (in the CBA) in some newly emerging settlements, most of the settlements did not show any significant change. On the contrary, a few settlements suggested even a reduction in the CBA, which is unlikely. Moreover, the overall quality of the images for 1991 (i.e., from IRS-1A) was found to be inferior than that of 1994 (i.e., from IRS-IB). This could be one of the reasons for poor comparison between the two time periods.

As mentioned earlier, two sub-scenes, for each time period, were also obtained at a resolution of 36.25m for parts of the study area. The improvement of this resolution in relation to a resolution of 72.5m provided better images and the delineation of the CBAs, and its change over 1991-94, was significandy better. Use of this resolution data also enabled in printing the FCCs at a scale of 1:50,000 - the scale next to 1:250,000 of the topo-sheets from the Survey of India. However, use of this resolution data was made only for sample settlements due to constraints of processing time, storage facilities and the cost of obtaining raw data.

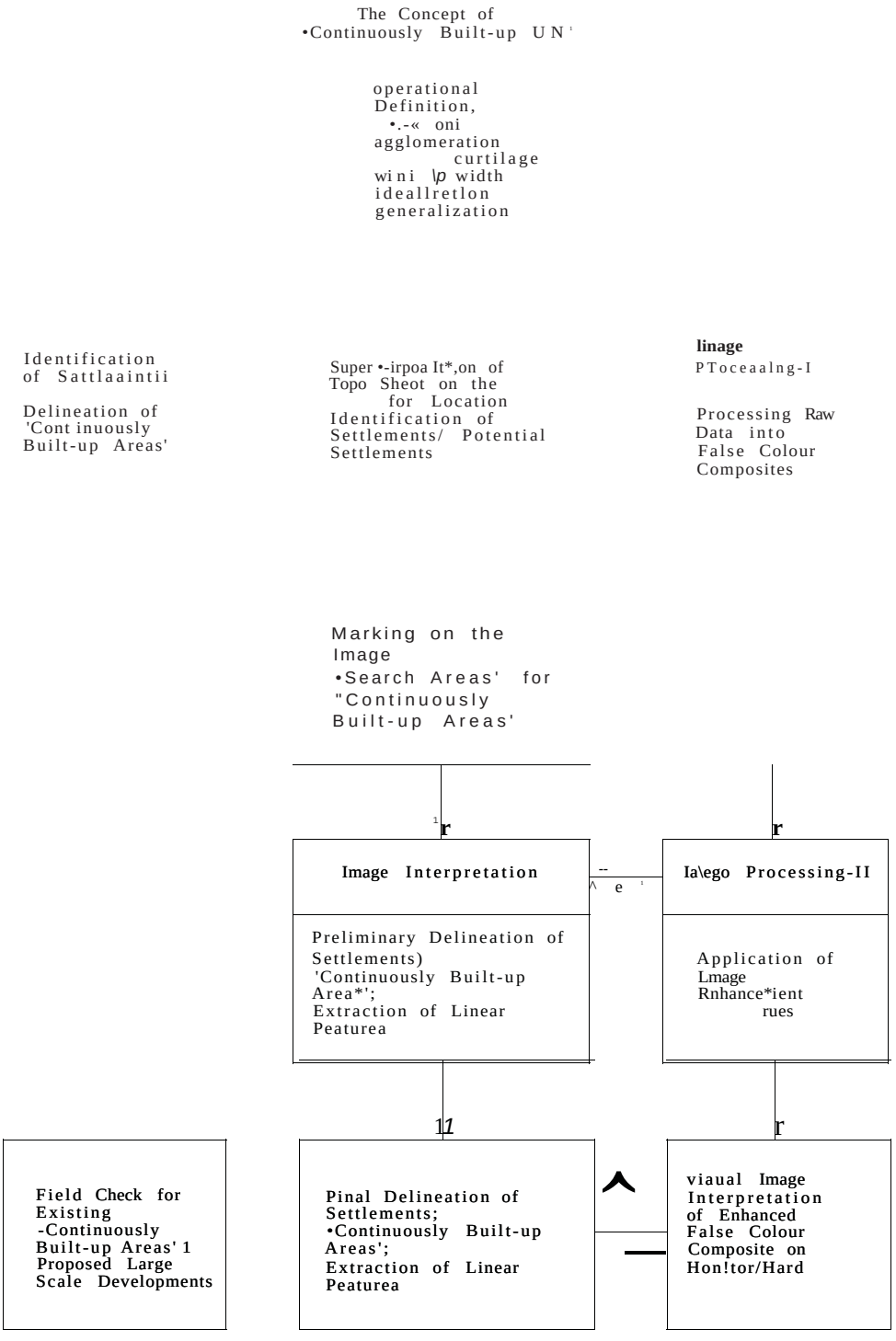


Fig. 4.2

Flow Diagram for Image Processing and Interpretation of IRS Data for the Purpose of Identifying and Delineating the *Continuously Built-up Areas*

A sub-scene of the SPOT 10m Panchromatic image, obtained in 1987, was also available in hard copy format (see Figure 4.3). This sub-scene covered mainly the city of Delhi and surrounding areas. However, it did not prove very useful except to reconfirm the conclusions of an earlier study for monitoring the growth of urban settlements (Mahavir and Galema, 1991).

Some of the results of final FCCs prepared by various techniques have been illustrated in Figures 4.4-4.7.

4.7.3 Field Check

A field check was conducted to verify the delineation of CBA for a few sample settlements. It was found difficult to validate the delineated CBAs because of the following reasons.

1. Images at a scale of 1:250,000 are too small for orientation in the field. Orientation with the images at a scale of 1:50,000 was relatively easier, yet difficult to precisely locate a given landmark on the image because of low (72.5m or 36.25m) resolution.

2. The distinction between the 'built-up' and 'not-built-up' is not so very easy even on the ground in the absence of large scale updated maps or aerial photographs and difficulty in comprehension when encountered with individual buildings or other elements of the landscape (Poll6, 1993).

   However, the limitation (1) worked like a solution for overcoming the limitation (2). The image provides an updated synoptic view and an 'pre-aggregated' comprehension at the pixel level, thereby doing away with the necessity of dealing with individual elements of the built landscape.

3. The areas earmarked for large scale development but not yet developed were not possible to be interpreted on satellite images. For this, there is no substitute for the respective master plans, regional plans and other official documents.

4.8 CONCLUSIONS

The need for data obtained through remote sensing techniques arises for a variety of reasons, important ones being the inadequacy and untimely availability of conventional sources of data. Also, remotely sensed data provides a synoptic view of human settlements, as was imagined by Isard (1956) and Webber (1964).

The use of aerial remote sensing (photographs) for the purpose of the study area must be discounted because of the attitude of some agencies involved, and the lack of adequately trained manpower required for their day-to-day handling and interpretation. High resolution (10m or better), stereo images obtained from satellites are also not feasible because of relatively high cost, huge data storing space and processing time constraints.

The remotely sensed data with spatial resolution of 72.5m is appropriate for the purpose of this task (e.g., modelling settiement patterns), providing a synoptic view of the entire region under study. Specifically, its comparatively low resolution performs the otherwise difficult task of determining the 'built-up' pixel out of a mix of 64 pixels (of 10m resolution compared to ±80m) in reality.

Application of various image processing, enhancement and interpretation techniques revealed that while the CBA of settiements could be delineated with reasonable accuracy (relative to their use in the model proposed later, in Chapter Seven), this is not the case for delimitation of urban or rural boundaries. Indication of density (built-up/ non-built-up) patterns, structure and function of large settiements may be possible but useful conclusions are not possible at this resolution (72.5m) under present technology.

Modelling settlement patterns involves use of data, information, concepts, theories and policies from a variety of sources and formats. Remote sensing covers only part of this. Means have to be found, still, to achieve desired objectives. One such mean is the use of GISs, which is discussed in the following chapter.

ig. 4.3 SPOT Image of a part of Delhi, India, 1987
PAN, Spatial Resolution 10m; Print Scale 1:50,000 (here reduced 75%)
Courtesy: ITC, Division of Urban Planning and Management

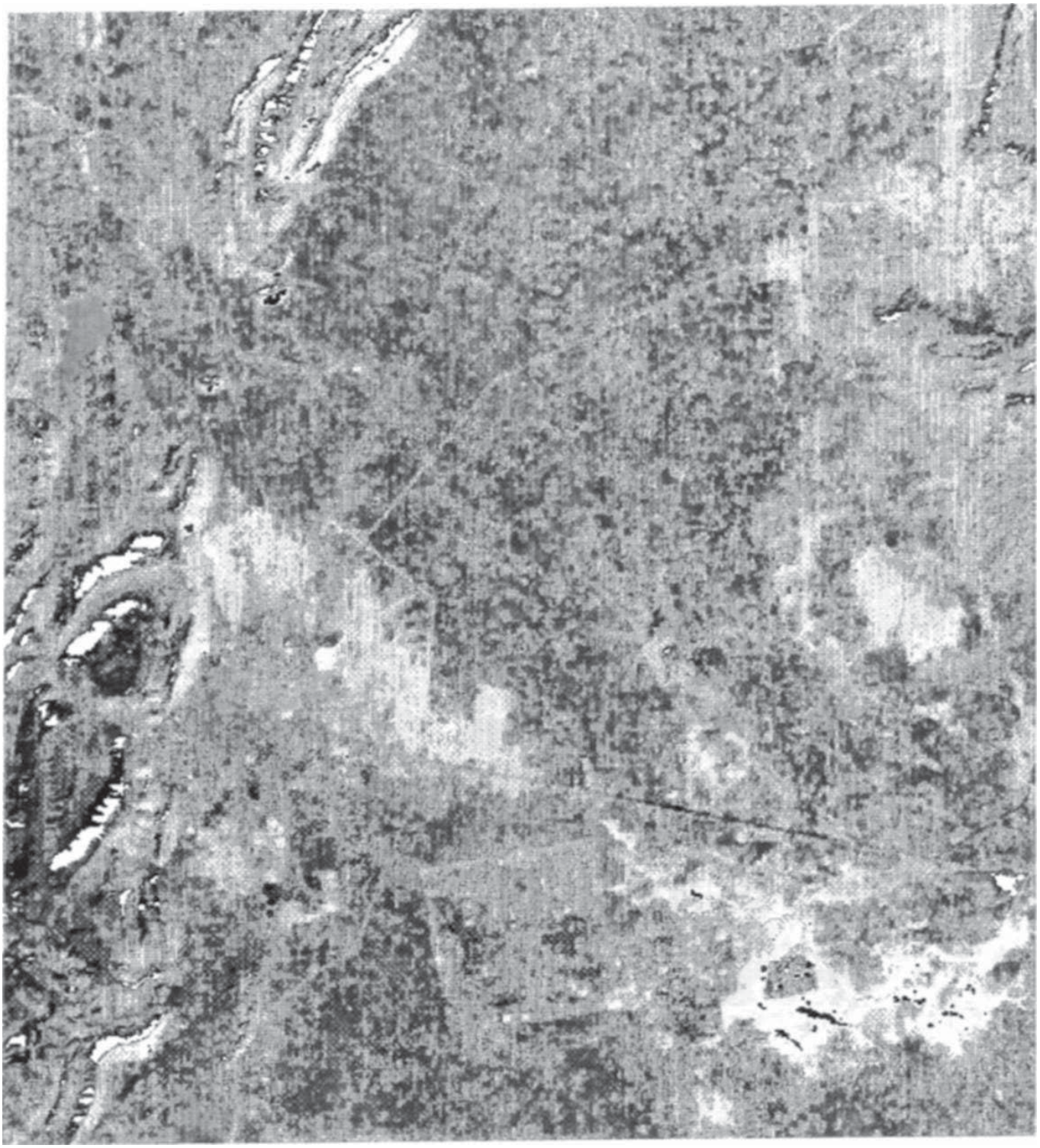
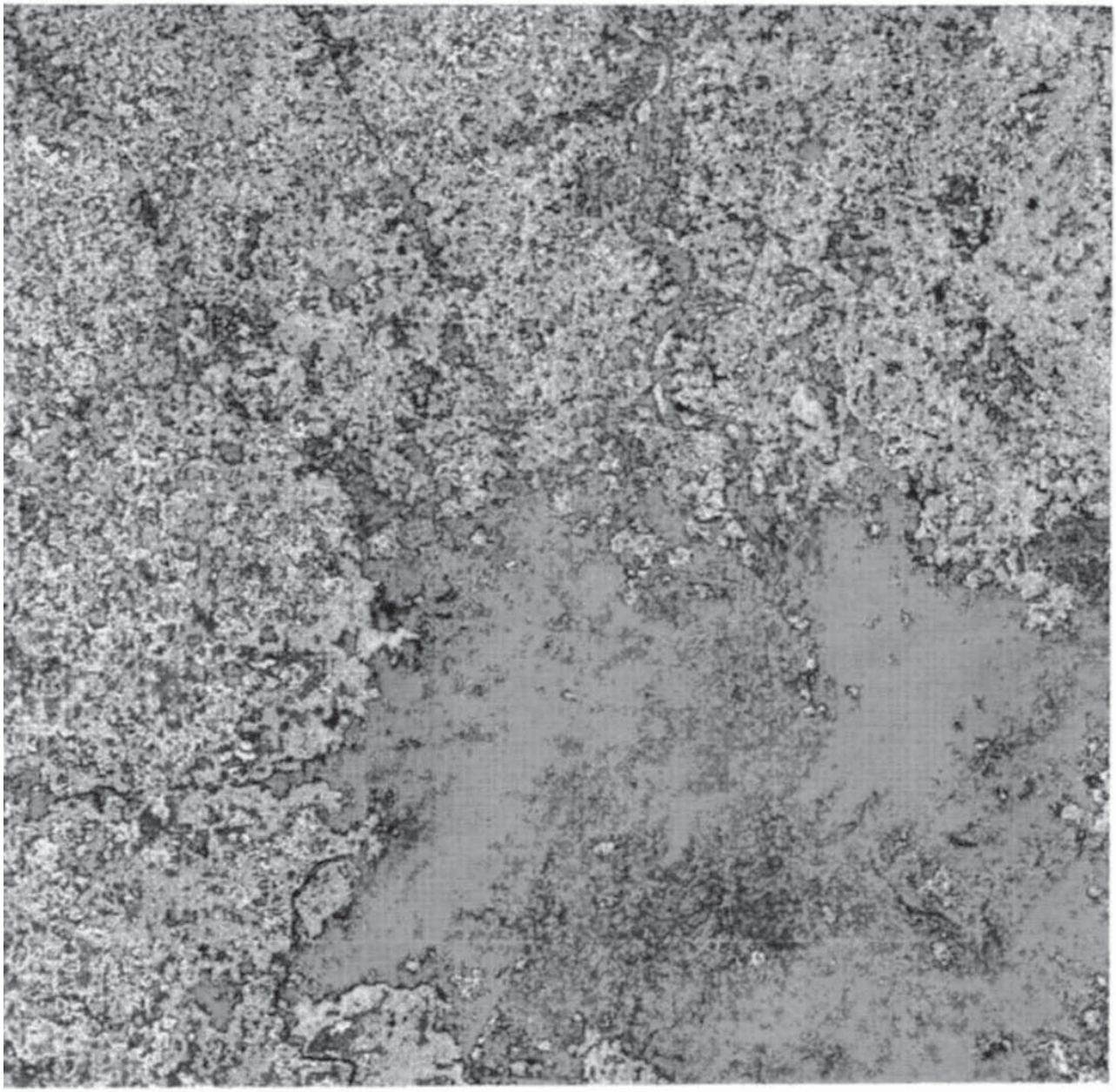


Fig. 4.4 **False Colour Composite (FCC) of the City of Alwar and surroundings, India**

IRS-IB, Path 29, Row 48, LISS-II, A2; Spatial Resolution 36.25m; December 16, 1993

Bands 1,2,4; Linear Stretch applied on part scene, Lower and Upper Bounds 5% and 95% respectively; Print Scale 1:62,500 (here reduced 75%)



ig. 4.5 False Colour Composite (FCC) of the National Capital Territory of Delhi and surroundings, India

IRS-1B, Path 29, Row 47, LISS-I; Spatial Resolution 72.5m; January 7, 1994 Bands 1,2,4; Linear Stretch applied on part scene, Lower and Upper Bounds 5% and 95% respectively; Edge Enhancement Filter applied on part scene; Colorlut rrgggbbb;

Print Scale 1:250,000 (here reduced 75%)

Fig. 4.6 False Colour Composite (FCC) of the National Capital Territory of Delhi and surroundings, India

IRS-1B, Path 29, Row 47, LISS-I; Spatial Resolution 72.5m; January 7, 1994
Bands 1,2,4; Linear Stretch applied on part scene, Lower and Upper Bounds 5% and 95% respectively; Standard Colorlut
Print Scale 1:250,000 (here reduced 75%)

Fig. 4.7 **False Colour Composite (FCC) of part of the National Capital Region of Delhi, India**

IRS-1B, Path 29, Row 47, LISS-I; Spatial Resolution 72.5m; January 7, 1994
Bands 1,2,4; Linear Stretch applied on full scene, Lower and Upper Bounds 5% and 95% respectively; Standard Colorlut
Print Scale 1:825,000 (here reduced 75%)

5

MODELLING SETTLEMENT PATTERNS
ROLE OF GEOGRAPHIC INFORMATION SYSTEMS[2]

It was concluded in Chapter Four that remotely sensed data provides a synoptic view of the human settlements, and that remotely sensed data with spatial resolution of 72.5m is appropriate for the purpose of modelling settlement patterns. The concept of CBA, to represent 'settlements', was found, in Chapter Two, to be useful and conveniently applied on remotely sensed data.

Data, information, concepts, theories and policies from a variety of sources and formats are required for modelling settlement patterns. Means are required to be found to be able to complete the chain in a sufficiently (for the purpose) integrated manner so as to achieve desired objectives. Use of GISs, holds promise in this direction. Point Pattern Analysis and Spatial autocorrelation are two of the techniques that were identified, earlier, to be widely used in modelling settlement patterns. Some of these techniques, now available in GISs for 'point' based approach might be developed for an 'area' based approach being pursued in this research. Further, the images obtained through remote sensing satellites are required to be processed and enhanced for obtaining useful information from them. Image processing and enhancement techniques also require the use of a GIS or a similar software.

An attempt has been made in this chapter to appraise the technology of GISs for a general understanding, its application usefulness and limitations in the field of spatial planning, and more specifically its usefulness and limitations towards modelling settlement patterns. As the models developed is intended to be applied in a developing country (i.e., India) situation, a scenario describing the status of GISs in India has also been presented.

5.1 GEOGRAPHIC INFORMATION SYSTEMS

A system can be defined as a set of components that work together towards the overall objective of the whole. It is a collection or combination of different elements or sub-systems working together towards achieving the same objective. Systems can be simple or complex, with relatively weak or stronger relationships between the elements.

Data are defined as measurements or observations of facts which, when processed, interpreted and organized, become information (Shelton and Estes, 1981). Thus, information

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21 **Parts of this chapter have been prepared jointly with Al-Amir (1996).**

is processed data, capable of enhancing the knowledge of the person receiving it. In practice, quite often the choice is between a package of information or no information at all (de Man, 1989).

Theoretically, "An information system is a system for transmitting and receiving messages. It defines, formally and informally, and often by default, when and where messages are sent, who receives them and what makes them comprehensible." (Farbey, as quoted by Backhouse *et al.,* 1991, p.23). Practically, it is a chain of operations starting from observation and collection of data, to storage and analysis of data, to the use of derived information for decision making. As is in the case of information, it is meaningless to try to design an information system without reference to the context in which it is going to be used, i.e., who will use it, how it will be used and what it will be used for. Information systems imply information processing and the capacity to manipulate data in ways that are useful to their users (Cartwright, 1987). Such information systems can be manual or computer-based. Manual techniques can produce the same information as computer-aided techniques, and the same general sequence of operations may occur (e.g., data storage and data manipulation) (Shelton and Estes, 1981; McHarg, 1995).

Data collection of world features dates back to the earliest times. These features have spatial and non-spatial descriptors. The most common medium of storing such coordinate-based geographical information has traditionally been paper (e.g., a map document). The use of such geographical information by different users normally involves visual inspection of the map document and using simple measurement tools. The information stored on analogue maps is not easy to be retrieved or updated. The advent of digital computer as a data handling device also raises the question of its applicability to the storage and manipulation of spatial data.

Initial attempts to apply computer technology for the storing, displaying and retrieval of spatial data concerned the reduction of data handling problems encountered with spatial data. The improvement of computer systems has made it easier to apply this technology to the problem of storing, manipulating, and analyzing large amount of spatial data. This allows dynamic and flexible handling of spatial information. Among the various systems used for these activities, one is GIS.

"A geographic information system is a system for collecting, inputting, checking, processing, integrating, analyzing, modelling, and reporting information relating to a land surface." (Paulsson, 1992, p.58). It is a key technology for the automated capture, structure, management, analysis and presentation of location-referenced data all over the world (Ottens, 1992). It also allows for visualization - the user-controlled display of information helpful to animate, change perspective views, rotate, zoom in and out of the images on the screen (Fung and Lasserre, 1993). Visualization in itself is a unique contribution of GISs as a means of understanding the process and arriving at conclusions. De Bruijn (1992) stated that the GIS concept comprises a database with a variety of spatial data, and suitable software to access the database and to perform logical, statistical and cartographic operations with the data.

In a nutshell, a GIS is a system to store, retrieve, manipulate, analyze, visualize and present geographical data. It is moulded from a blend of dataware, hardware, software, humanware and orgware. These terms are described as follows.

1. A GIS database includes data about the position and attributes of geographical features that have been coded as points, lines, polygons, pixels or gridcells (Burrough, 1993). Different data sets can be integrated into a central geographical data base that enables the linked manipulation of all the different spatial objects and their attributes.

2. Hardware is the physical component of a GIS (e.g., the computer, plotter, printer and digitizer). There is a wide range of devices that can be used to fill the hardware requirements (Burrough, 1993).

3. Software is the general name of programs and programming language. In general, five basic modules exist in a software package, i.e., data input and verification, data storage and database management, data output and presentation, and interaction with the user (Burrough, 1993).

4. Humanware, i.e., the trained and motivated staff responsible for use, operation and maintenance of GISs. It also requires its users to have awareness and understanding of the various components of the system.

5. Orgware, i.e., the computer technology which has been designed to fit into existing organizational structure. Computer applications have to take place in the context of existing administrative and policy-making procedures. In this way, a better fit between the organization needs and the facilities offered by this technology can be achieved (Jong, 1990).

5.**1.1** Users of GISs

Users of GISs can be classified in term of its applicability (e.g., business, public information, research, operations, management). Muller (1993) grouped the users according to the specific tasks that they have to perform (i.e., integration of spatial information, integration of expert knowledge and collaboration of a variety of scientific and professional disciplines). Within the field of spatial planning, Burrough (1993) identified users in categories according to the task defined (e.g., a mapping agency), partly defined (e.g., central town and country planning organisations), or not defined (e.g., teaching and research institutions).

5.**1**.2 Information Types

The information or knowledge used in planning is of four different kinds (Harris, 1990). First, general knowledge which needs be collected usually once, updates are not so frequent. It includes standards, laws, rules, costs, knowledge of the behaviour of people, households and enterprises under various conditions. Maps are a part of this one-time knowledge. The second type of knowledge is a description of the state of the system, with respect to all the attributes of the city or region which are relevant to judging the progress of plans and predicting the effects of future changes and needs. The third type of knowledge consists of the scenarios about the future environment of planning and of the proposed changes which will be made by planned action. A fourth type of knowledge is the implicit structure which is defined for relations and processes in the region by the planning system itself.

GISs must satisfy several criteria, including data reliability, periodicity, portability and flexibility (Michalak, 1993). The design of database requires to be worked out carefully at the stage of system planning. Urban and regional-planners in particular require to have a good understanding of the principles and techniques of spatial database design. This enables them to play a more active role in the development of information systems that fulfil their needs more efficientiy (Yeung and Hall, 1989).

Information regarding the current data processing practices is also important **(P0II6** and Sliuzas, 1987). This and projection of future data requirements, can be obtained by a carefully planned user requirements study. Such an exercise involves visits and interviews aiming at the collection of the following kinds of information: basic institutional organization and responsibilities of information users; procedures and equipment used to carry out the responsibilities; inventory and description of geographical information used or generated by the users; existing resources and estimation of the potential for the use of the new technology in the future (Yeung and Hall, 1989).

5.1.3 Geo-data Sources

Different users' requirements derive information from different geo-data sources. These sources are speech, texts, lists and tables, existing analogue maps, remotely sensed data (aerial photographs, satellite images) and field surveys. Geo-data sources for GISs include digitized maps, photographs and satellite images, Global Positioning Systems (GPSs) and related tables. Data input covers all aspects of transforming spatial and non-spatial (textural or feature attributes) information from both printing and digit files into GIS data base. Data entry into GIS is made through digitizing, satellite images, scanning and the keyboard.

Spatial data bases are made increasingly more available through modem data-capture technology, including field computers and, possibly in the near future, digital cameras. What is increasingly seen today is an integration of GPSs, remotely sensed images (from aerial photographs to satellite images) and GISs processing, providing 'seamless' views covering large areas on work stations and PC platforms (Muller, 1993).

GISs have the capabilities of integrating variety of spatial scales and levels of resolutions of geo-data from different sources. Besides, GISs have the advantages of easy exchange of information between different actors, as well as the continuous updating of such information in the GIS environment.

5.2 ANALYTICAL PLANNING METHODS, MODELS, PROCESSES AND GISs

Different analytical planning methods and tools (primarily quantitative) are used by planners. However, they also attempt to devise policies which can influence development, so as to move in a desired direction. In order to influence the development of the spatial system in a desired direction, major variations in the system can be analyzed and evaluated with the help of models (Krueckeberg, 1982). However, incorporation of such models into GISs is a difficult task because these models are mathematical abstractions and do not deal with the spatial dimension in an explicit manner (UNCRD, 1991).

It is essentia] to define the domain of interest with respect to planning and the nature of GISs. Batty (1991) raised concern for three sets of objectives: information systems, planning models, and the planning process. In fact, the sorts of functions which are required in urban and spatial policy analysis are usually absent from the archetypal GISs whose functionality embodying spatial analysis and modelling is weak (Newton *et al.*, 1988, as quoted by Batty, 1991). However, many GISs have emerged from areas of concern involving sub-systems of the urban and regional system.

Spatial planning activities, at all levels, are based on geo-data acquisition, manipulation and analysis. The earth's surface data can be accessed, transformed and manipulated interactively in GISs, consequently they can provide the basis for studying and analyzing the end result of planning decisions. Theoretically, by using GISs, planners and decision makers can explore a range of possible scenarios and obtain an idea of the consequences (What-if?) of a course of action before mistakes are made in reality. GIS software allows for the analysis of planning problems, model forecasts, monitoring and evaluating the effects of their policies (de Meyere, 1992). GISs have frequently been used in planning for a host of applications (e.g., urban and regional planning, resource inventory, resource management, land capability evaluation, inventory of housing, service facilities location and management, infrastructure planning and Environmental Impact Assessment). More recent applications have been in the fields of fighting fires, assessing damages caused by naturally occurring disasters, identifying high risk areas and the coordinating of reconstruction efforts. A GIS is, for the most part, used as a geographical, operations and legal tool (Muller, 1993).

Planning is a heavily politicized activity and GISs cannot be divorced from the socio-economic-political environment in which it is used for policy formulation, resource allocation and decision making. Yet, it is apparent that GISs are revolutionizing the traditional methods of handling spatial data in planning. GISs confront well-established, politically favourable, non-automated procedures that are able to obfuscate the decision making process through inefficiency and lack of documentation. In enforcing rigorous methods of evaluation, GISs challenge existing institutional organization and power structures (Harris and Elmes, 1993). Moreover, in the case of spatial data handling and GISs, the development of analytical and modelling techniques is lagging behind developments in database design and handling (de Man, 1989).

5.2.1 Types and Functions of GISs

Batty (1993) considered a GIS as a system in which data has some spatial or geographical referent, this data being ordered according to this referent, and displayed by software in such a way that spatial analysis is possible. This distinguishes GIS from computer mapping software and other forms of geo-processing. However, despite the fact that a GIS must have some functionality relating to analysis, many applications to date have emphasized their use for elaborate computer mapping, storage, retrieval of spatial data rather than the analytical purposes for which they are ultimately intended.

Typical functions of a GIS involve the following operations on spatial data: topological operation which transforms and generalizes two-dimensional spatial data, thus producing maps at various levels of aggregation; analysis functions (e.g., characterizing neighbourhood,

measuring distance, map classification, cartographic modelling); overlay analysis which combines maps as layers and enable various visual, statistical and logical operations on resulting coverage; buffering and related spatial subdivision methods which identify areas conforming to various criteria; elementary statistical operations involved in describing, smoothing and developing methods of removing errors and bias in data.

In considering the comments by the various authors, it becomes apparent that there is not yet a well-developed classification of GISs in practice, and it is clear that single systems are being used in a fairly blunt manner for many different applications. One single GIS is not likely to be applicable to all problems in the context of spatial planning. Different problem contexts may require their own purpose-built (customized) systems. In a sense, this is happening in the development of computer-based infrastructure in spatial planning, in that the most appropriate modules for the task in hand are assembled by planners and users. Consequently, the development of GISs by various vendors is beginning to take focus on modular units that can be assembled to the requirements of the users.

5.3 CHOOSING A GIS

5.3.1 Data Structures

There are basically two types of data structures for storing spatial information in digital format: 'raster' and 'vector'. In the raster, the whole terrain is treated as a matrix of small grid squares (tessellation/ field approach), known as pixels. Each pixel is given a value based on the type, quality or quantity of the information contained in it. The resolution and hence the quality of the resulting image depend on the size of the pixels used: the smaller the pixel, the higher the resolution but the greater the volumes of data that must be stored.

The alternative to raster is vector, where the terrain is treated as consisting of features (object approach). Here a cursor is placed at the beginning, turning points and at the end of each line allowing the coordinates of each point to be measured and recorded. The map is built up as a series of straight line sections between these coordinated points.

There is yet another storage method, named 'quadtree', which is a special type of raster data structure. In this method, the data are stored in grid cells of variable size. Within larger homogeneous area, a large cell size is used whereas towards the edges of the area, the cell size diminishes to form a more precise picture. An area is therefore covered by considerably fewer quadtree cells of varying size than is the case in the regular grid storage method. The speed with which analyses can be carried out with a quadtree structure is high, whilst the original precision of the data is retained rather well (Scholten and Still well, 1990). However, there is a disadvantage in the sense that overlaying of different themes requires special care as the polygon sizes and shapes, and therefore the structure of quadtree in the different layers, will be different.

With both raster and vector data there is need to classify the features so that points, lines or polygons can be given meaning with respect to typology of the area. The addition of a feature classification is the most expensive part of spatial data capture because, although some development has taken place in automatic feature recognition, much of the required

work is still undertaken by human intervention. In consequence, the time and cost involved in capturing both graphic and alphanumeric data is still high (Dale, 1991).

Both the vector and raster methods of representing the spatial extent of geographical entities could be incorporated in the same database. There exist methods for converting vector format images to raster and vice-versa, though the latter are much more complex and less satisfactory than the former (Burrough, 1993). There could be still a basic difference between structured raster data and unstructured pixel data. Line segment structures (e.g., DIME and TIGER) are also available as a special type of vector data.

The advantages of vector data structures are that greater precision can be maintained, that the resulting graphic output can be of high quality, that the volumes of data held are small and that linear network analysis is more straight forward. With raster data structures the volumes of data to be held are much higher but conversely, since the scanning process is automatic, the capture of raster data is much quicker. Raster data structures are relatively easy to handle by making the use of the computer, and are particularly useful where areas are to be analyzed by overlaying polygons on the graphic screen.

According to Maurel (1993), the question of choice between raster and vector data structures may now have been made irrelevant through technological change. Today, raster and vector systems are increasingly compatible, with most major systems capable of handling both. Yet, it is a fact that certain tasks can be done better in the one mode than in the other, either because the current state of the development of algorithms, because of hardware capabilities, or because of storage requirements. "The two modes should now be seen as complementary in any GIS, but the accent on a dominantly vector-based approach or a dominantly raster-based approach should depend on the type of GIS application under consideration." (Burrough, 1993a, p. 169).

5.3.2 With or Without Image Processing ?

Remote sensing data usually have been interpreted visually or manually, converted to thematic map form, and then digitized for input into a GIS. Simultaneous to the development of GISs, digital image processing packages have also been developed for image restoration, enhancement, quality improvement, and a number of other statistical techniques for information extraction. Since most of the information extracted is ultimately used in a geographical context, and related to geographical information, it is logical to have a linking of image processing with the GIS.

As a general rule, when the majority of geo-data for a GIS is being derived from a satellite image, it is easier to work with a system having both the image processing and GIS (in the raster method). However, if the major source of data is from conventional sources, a standard GIS without image processing (in the vector method) may suffice.

It is probably better to acquire a number of specialized modules that do a limited number of tasks well (e.g., vector mapping, raster overlay analysis, interpolation and image analysis) and link them together so that they make use of common data sources, than to attempt to find a single universal system that can do everything (Burrough, 1993). Also, the experience from

developing countries with information systems in general highlights the importance of taking an incremental approach to acquiring a system. Even the best designed systems are going to change over time as the role and priorities of planners change - and as planners gain experience with the system. It is more feasible to identify a specific need, and for an information system to meet that need, rather than to try to choose or design a system to meet all possible needs. The design of the system is important, both to meet identified needs of users, and to allow for modification as those needs change (Cartwright, 1987). There is a tendency to prefer a customized GIS for specific jobs instead of depending upon standard GIS.

It was argued in Chapter Two that the concept of the CBA is useful and conveniently applied on remotely sensed data. It has fewer disadvantages than others for the purposes of this research. It was also concluded in Chapter Four that the remotely sensed data with spatial resolution of 72.5m is appropriate for the purpose of modelling settlement patterns, providing a synoptic view of the entire region under study. Besides the concept of CBA, the use of remotely sensed data in the form of satellite images, digital image processing, techniques of (spatial) pattern recognition and analysis are some of the essential elements identified earlier for use in modelling settlement patterns. GISs, with digital image processing capabilities, offer the possibility of delineating the CBAs and performing some other tasks required for modelling (spatial) settlement patterns.

5.3.3 ILWIS

The Integrated Land and Water Information System (ILWIS) was chosen for use in this research for its capabilities to integrate image processing and spatial analysis, tabular databases and conventional GIS features. Data acquisition from aerospace images forms an integral part of the system, enabling effective monitoring. This feature is particularly important in regions in which data are scarce or difficult to gather (ITC, 1993; see Appendix I for a brief introduction to ILWTS). Moreover, the system, developed and produced by the ITC, Enschede, was comparatively more accessible, and better input was available for 'on-line' help. Further, it is backed by vast experience of users including students, teachers and researchers at ***YTC.***

5.4 INTEGRATING GISs AND REMOTE SENSING

As described in Chapter Four, image resolution represents the ground area in terms of pixels, which are a function of the sensor, scene characteristics and data pre-processing. Data obtained through satellite images differ from other geographic data in their consistency, positional accuracy, spatial and temporal resolution, and levels of human abstraction or interpretation. To be able to process such data, GISs require raster capabilities to store and analyze large volumes of these data with minimum loss of resolution or radiometric precision. To make use of relevant map data (e.g., polygons, lines and points), GISs require vector capabilities. Therefore, the integration of GISs with remote sensing requires multiple data structures, and software that supports a range of spatial queries (Davis and Simonett, 1991).

Though both remote sensing and GISs involve manipulation of spatial data in digital form, remote sensing allows the measurement and examination of variation of surface electromagnetic radiation whereas GISs, in principle, enable the organization and analysis of these measurements and attribute data to improve the mathematical and statistical modelling of the patterns and processes on the surface of the earth using either spectral and/or choropleth information (Michalak, 1993).

In practice, the integration of GISs and remote sensing is a product of the users' willingness to adapt the use of the two technologies to the broadest possible application. The potential of information systems and remote sensing is exercised when the synergism created by the two technologies can be used to provide data and analysis that were never before possible (Shelton and Estes, 1981). A truly applied GIS will require integration and automation of at least some routine procedures in both approaches. One of the objectives of integration is simplification of the tasks of converting digital images and associated attribute data into a map through user interface and built-in expert rules, as is the case in the expert-system approach (Michalak, 1993). Satellite imagery represents a means of decreasing data-acquisition costs and delivery time and improving the frequency of updates. Besides many other useful features, it offers the possibility of being integrated with GISs. Satellite imagery can be used in GISs as a visual background, as a cartographic reference for the whole database (especially when basic geographical data are poor or not accurate enough), as a document to update information already available in a GIS, and as a source of new geographical information such as land uses and road networks (Maurel, 1993).

A fully integrated GIS would contain remote sensing systems designed to provide an efficient and effective flow of data to meet specific information system data requirements. Not only would the data in the system be used to develop interpretation and classification of remote sensing data but the resulting interpretation could efficiently flow through the system to some end decision. Conceptually, remote sensing is readily integrated into the structure of a GIS as a component of data acquisition, or as a subsystem providing input to the information system (or data processing subsystem). There could be systems which only utilize the products of remote sensing and those in which remote sensing operations are designed - integrated - into the entire information system (Shelton and Estes, 1981). At present, technical integration is limited to the provision of a common data exchange, and conversion capabilities between remote sensing and GIS environments. Operational integration is most likely to involve three development steps: data exchange automation, transparent conversion of data structure, and integration of analytical procedures capable of processing data stored in various formats. An expert-system approach would require prior integration of raster-based remote sensing images, vector-based GIS attribute information and rules of expert data (Michalak, 1993).

Incorporation of GISs in remote sensing also improves classificatory and change detection accuracies using the attributes derived from ancillary data sources. A significant limitation of using these approaches emanate from the limited quality of the data itself (Michalak, 1993).

In short, remote sensing can provide information on current and changed land use cover for a GIS, and a GIS can provide an essential expert knowledge base to help automate the technically demanding aspects of remote sensing change detection analysis (Newkirk and

Wang, 1989). GISs data can be used to enhance standard image processing functions like geometric correction, image classification and masking operations. Remotely sensed imagery can be used for image-map backdrop and database update (Gugan, 1993). Although remote sensing is an important source of data for planning use (e.g., monitoring and mapping), it needs to be linked to other data sets. What is needed is the best of both worlds: an integrated GIS that can store, manipulate and display both raster and vector data without losing the benefits of either format (Hinton, 1994). Many users feel that the full potential of both techniques can not be achieved until they are integrated, and some go even further and see the success of remote sensing firmly linked to its ability to service geographic information systems (Curran, 1985).

In considering the comments by Curran (1985) and others, it becomes evident that integration of remote sensing and GISs would be mutually beneficial to both technologies. However, there are barriers. The terms used by each speciality have reflected some of them. While the remote sensing community speak of 'orbital paths', 'rows and columns', and 'pixels', GISs users speak of 'map frames', 'data-bases', 'points', 'lines' and 'polygons'. There is another reason for the lack of integration between the two technologies. Remote sensing as a method of data collection is unspecific in terms of what it collects. It records everything to which a sensor responds under given conditions. The result is an abundance of information which needs to be sorted out (Shelton and Estes, 1981).

Whereas, in a GIS, data can be fed selectively. Measurement and representation of land use change, incompatibility of data formats, generalization and accuracy of digital information are some other difficulties associated with the integration of the two techniques (Michalak, 1993).

In spite of these barriers, the two technologies have been converging for the past few years.

Geo-visualization and digital orthophotos are two of the recendy developed concepts in relation to the integration of GISs and remote sensing. Geo-visualization is a sub-discipline of visualization associated with cartographic presentation and GISs. Since remote sensing is one of the significant data source into GISs, and the collection and updating of data is the lifeblood of GISs, geo-visualization can be a powerful tool for integration of GISs and remote sensing (Bin and Muller, 1993).

Airborne remote sensing, using high resolution film, provides the most detailed information in the visible and near infrared wavelengths. It allows the user to prepare and select optimal conditions for data acquisition. After scanning, this data is ready for processing as any other comparable remote sensing data set. High resolution scanning converts the photographic document in a digital raster file for digital orthophoto production. Coupling digital orthophotodata with GISs offers new perspectives for automatic raster, line and Digital Elevation Model (DEM) information extraction, especially for softcopy purposes. Digital orthophoto is not just a new GIS layer but a GIS partner. With this coupling, data coherence is preserved at all stages (Loodts and Steenmans, 1993). Another example of integration of GISs and (small format) aerial photography can be found in a mapping and analysis system, MASMAP (Bruijn and Ruotsalainen, 1987).

Based on successful research developments, SPOT Image announced the launch of the new Geospot product line dedicated to GIS (Maurel, 1993). A Geospot is a precision-processed satellite image that looks like and can be used as a map and exactly matches a specified map frame. It is in fact a map on a satellite-image underlay. Labels, place names and other information may be attached. Three main products of the Geospot range launched are SPOTMap[22], SPOTView Basic[23] and SPOTView Plus[24].

The integration of the two technologies is dependent on realization that the potential of each technology can not be achieved until they are integrated (Shelton and Estes, 1981). The dangers and potentials of integration can be summarized as follows: "At its worst, IGIS (Integrated GIS) is a powerful technology that can be used to answer poorly posed questions by running misspecified models on improperly extrapolated data to generate output whose validity can never be tested. At best, the coupling of satellite measurements with other spatial data has tremendous potential for describing Earth surfaces, [and] predicting future conditions..." (Davis *et al.,* 1991, as quoted by Michalak, 1993, p.39, explanation of IGIS added).

Although remote sensing is an important source of data for planning use (e.g., monitoring and mapping), it needs to be linked to other data sets. Other significant developments with regard to the utilization of image in a digital format concern the establishment of GISs, for which satellite images with geometrical properties approaching orthophotography can serve as a digitized spatial data base. Satellite images serve a dual purpose in this case. They can constitute the main geographical reference base by providing grid-like formatted planimetric data suited for all map scales or substitutes. Further, they can serve as an additional source of thematic information (Voute, 1982).

For more than a century, science has been dominated by the concept of the microscope. Scientists have sought more and more detail about everything, and integration has suffered through neglect. Now with the remote sensing and GISs, we have for the first time in history, a rudimentary 'macroscope' (Dobson, 1993).

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22 **A made-to-order analogical-image map. It precisely matches a standard map frame (at scales from 1:25,000 to 1:250,000) and comes complete with annotations and auxiliary information for cartographic use. It is especially effective when basic geographical data are poor.**

23 **Designed for easy loading into a GIS, available only in digital form.**

24 **Available both in digital or analog form, SPOTView Plus precisely matches standard map frames. The data can be loaded direcdy into a GIS without special processing or enhancement. It is intended primarily for GIS users, giving them direct access to SPOT but it can also be used for giving a cartographic reference for all other geographical information to guarantee the geometric coherence of the GIS, updating existing geographical information in the GIS and extracting new information direcdy from the image maps using GIS drawing functionalities.**

5.5 DYNAMIC GISs

For many years, the focus of using a GIS was on the ability to answer 'what if questions accurately. It was a powerful but primarily static model, dynamism was introduced by the user, manually. However, in many situations, the information stored in a GIS is changing very quickly and these changes need to be factored into the system without delay. Traditional GISs remain static, even though most geographical phenomena are dynamic. However, analysing and displaying dynamic events often requires a multi-step process relying on a number of batch processes and lengthy compilations. Another disadvantage of this approach is that the user must use a modular approach instead of just focusing on the final objective.

Dynamic GISs would skip these intermediate steps by processing the operations in a real-time fashion and by displaying the result of the operation automatically. The user would be able to visualize the result without the necessary interaction between each step. The incorporation of changing factors, such as modified attribute values, would automatically change the result without any user's intervention. It would offer an environment for automatic attribute computations, based on spatial phenomena, while minimizing the need for user intervention.

As accurate decision making can be achieved only when the result of the analysis is visible, the display and symbolization of data become important factors. In a dynamic GIS, this symbolization is performed automatically, through the use of expert knowledge. Dynamic GISs do not require the user to decide when the data should be symbolized. Instead, symbolization becomes transparent to the user.

A traditional GIS does not explicitly include time as an element in spatial reference, the time dimension is generally omitted. Such omissions would be minimized in Dynamic GISs. It will, in principle, still answer 'what-if questions, however providing dynamic user-interaction, incorporating geo-mobility and change processes.

Dynamic GISs could be implemented in a number of ways, and the characteristics described above are but some of the features expected to be seen in the next generation of GISs. Dynamic GISs may be expected to behave much like a spreadsheet, in which most operations and data structures are transparent to the user. As it would be more accessible than traditional GISs, it would be more suitable to the casual user. The ability to obtain real-time analysis and faster answers would make it applicable to the modern needs of the GISs users (Albaredes, 1993). It would open the conventional static abstraction of a map to the virtual realities possible through video presentations, and the realization of a viable archive for historic data (Fung and Lasserre, 1993). Updates could be performed regularly and outdated information treated as a valuable resource, not as a waste product (Langran, 1993).

However, in spite of its promise, it is a new concept and useful applications are yet to be identified. The latest developments in the areas of Object Oriented GISs, Feature Oriented GISs, Intelligent GISs and Expert Systems are also expected to bring changes in the application of GISs.

5.6 STATUS OF GISs IN INDIA

5.6.1 Availability of GISs

Software, for most GISs, is written and developed with the likely requirements of potential users in mind. However, what lacks in a majority of software that is internationally available, is flexibility in the use of data types - of varying periodicity, reliability and inconsistency, as is especially the case in most developing countries. Added to that, exorbitant costs (partly due to import duties and involvement of foreign exchange) of the licensed copies make them unaffordable for most of the users in these countries. Yet, despite difficulties, many organisations and institutions in developing countries have managed somehow to start using GISs.

Attempts have been made in India to make available indigenously designed and produced, affordable GIS packages. These range from the Desk Top Mapping package THEMAPS (together with DIGITIZ) to the more sophisticated ISROVISION, combined with its image processing capabilities. However, some of these packages are duplications and overlap efforts between various government and semi-govemment departments. An overview of some of these packages is provided in Appendix V. Another package, named INGIS, has been developed jointly by the Department of Space and the Department of Mines. This raster-based package has been developed around the VAX 11/780 workstation, with associated PERICOLOR display monitor (Masthan *et al,* 1990).

Many large planning agencies **(e**.g., the Hyderabad Urban Development Authority, the Bombay Metropolitan Region Development Authority and the central Town and Country Planning Organisation) have GIS packages, and have used them in a variety of applications. More agencies are in the process of acquiring GIS packages.

5.6.2 Personnel

In India, no formal introduction of GISs technology to planning graduates existed 10 years ago. Only 3 out of 10 schools of planning in the country introduced it as a part of their courses during the last 6-7 years. These schools now have GIS packages, sometimes as part of remote sensing laboratories.

Efforts have been made to create awareness amongst senior planners by organising seminars and workshops - a landmark being one organised by the School of Planning and Architecture (SPA), New Delhi in 1985 (Saini, 1987). This workshop, co-sponsored by the ITC, the Netherlands; the Indian Institute of Remote Sensing (IIRS), Dehradun; the Town and Country Planning Organisation (TCPO) of the Ministry of Urban Development[25] of the Government of India, and the Institute of Town Planners, India (IIPI), created awareness not only amongst the planning community but also amongst political and administrative decision makers responsible for the planned development of human settlements in India.

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25 **Since renamed as the Ministry of Urban Affairs and Employment.**

In India, training with GISs for in-service spatial planners has been rather restricted. An institution which has contributed significantiy is the IIRS. This training is a part of a 10 months Post Graduate Diploma programme in the Human Settlements Analysis Group of the IIRS. Of late, there have been a number of 'crash training' programmes of 1-3 weeks duration organised by the SPA, theTCPO, the ITPI and the IIRS, either singularly or jointly. Another kind of training is being offered by the producers of various GIS packages - both to sell their product and as part of sold packages, like the training being provided by the Systems Research Institute, Pune, for their Desk Top Mapping package THEMAPS.

Appreciation courses, like the one proposed as part of the Urbwatch and Urbserve projects ***(YTC,*** 1993) could be specially useful for policy makers and technical personnel, especially personnel from the local government and non-governmental organisations.

5.6.3 Working Environment

In the present day context, all GISs are using a PC or work station. Difficulties that arise in developing countries with GISs have little to do with the choice of hardware, as they often occur at another level (e.g., the lack of reliable power supply). Load shedding or the planned (though at times unannounced) interruption of power pose a threat, not just of interrupting the work of computers but of losing a large part of the work in progress. In addition, power failures can damage computer equipment. Uninterrupted Power Supply (UPS) equipment has begun to find its place along side basic computer hardware but it is not yet always dependable.

Compatibility among different kinds of hardware equipment is problem. It is not uncommon to find one item in the chain of hardware equipment not compatible with the rest of the chain. Moreover, software vendors tend to patronize particular makes of hardware equipment, instead of offering flexibility in the use of hardware options. However, the THEMAPS package developed in India (see Appendix V), is an example of flexibility. This user friendly package supports various kinds of digitizers, graphic cards, display monitors and printers/ plotters that are available in the market.

5.6.4 Organisational Issues

Information systems can help to shape public administration. They can alter the roles of individual and change institutional responsibilities, they can affect the balance of bureaucratic power. Accordingly, it is important to look beyond the technical aspects and to try to assess the organizational implications of improved information flows (Cartwright, 1987). The challenge of GISs is not so much technical but more so in the organizational ability to utilize the potential of GISs through management and planning. One difficulty faced by developing countries may lie in the disparity in levels of development among national agencies. Sometimes, high technology is available in only a few departments, with no foreseeable integration at the national level (Muller, 1993). The problem is both intra-organisation and inter-organisation.

In the case of the principal mapping organisation of the country, Survey of India, the organisation introduced the concept of GISs and modern cartographic techniques in their work about a decade ago. However, about 80 percent of the organisation, however, is still untouched by this introduction (Misra, 1993). One reason is that the data collected from various sources do not adhere to a standard format. The standardisation of data has not yet crystallized. While the National Data Centre (NDC) of the NRSA has started supplying remote sensing data (satellite images) on floppy disks, CCTs or cartridge tapes and the Census of India has started supplying the demographic and socio-economic data on floppy disks, it is not yet possible to obtain mapping data on the same mediums.

5.6.5 Efforts of the TCPO

In the early '80s, the central TCPO of the then Ministry of Urban Development (subsequently renamed as the Ministry of Urban Affairs and Employment) was entrusted with the responsibility of establishing an information system for human settlements planning in India (Kishore and Singh, 1987). Over the years, TCPO has developed, and is now in the final stages of development, 'prototype' information systems like the Urban and Regional Document Information System (URDIS); the Monitoring Information System (MONIS) for the national programme of Integrated Development of Small and Medium Towns; the Information System for the programme of Environmental Improvement of Urban Slums; the Organization and Manpower Information System (OMIS) and the Land Use Information System (LUIS). All of these form part of overall efforts in developing an Urban and Regional Planning Information System (URIS) in India.

The Space Application Centre (SAC), Ahemedabad and the TCPO recently concluded a collaborative pilot project (SAC-TCPO, 1992) on development of a GIS based data for the district of Bharatpur in the province of Rajasthan. The exercise formed a part of the above mentioned Urban and Regional Planning Information System (URIS) and is one of the major nodes of a three-tiered National Natural Resource Management System (NNRMS). These tiers are at the strategic, tactical and technical levels. To test the potential efficacy of an information system, this exercise was taken up as a case study for development of a GIS and for use as an automated system for the preparation of the Integrated District Development Plan for Bharatpur (Dhinwa ***et al,*** 1992).

This and other pilot studies reveal various application barriers (e.g., non-standard locational encoding, non-standard data structuring and temporal resolution, varying classifications and definitions and invalidated data). The case of the information system for human settlements, as was initiated by the TCPO, highlights the importance of taking an incremental approach to design, an approach which also reflects the dynamics of the organization (Masser and Campbell, 1989).

A detailed account of other GISs application experiences in the field of spatial planning in India is available in Saini (1987) and in Photonirvachak. Journal of the Indian Society for Remote Sensing, Special Issue on Human Settlement Analysis, Vol.17, No.3, September, 1989, Dehradun. No more recent comprehensive accounts are available to date.

5.7 OTHER APPLICATION POSSIBILITIES AND CONSTRAINTS

An international expert group concluded that GISs technology had great potential for supporting, and being integrated into, the planning process in the developing world (UNCRD, 1991). GISs have the potential to play a major role in research and planning in developing countries. However, it should be recognized that the number of successful and long-lived GISs applications remains remarkably limited. Despite the diversity of GISs applications, three main constraints clearly imped the effective development of GISs applications in developing countries. These constraints are related to finance, data availability and accessibility, and human resources and institutional issues (Teeffelen *et al.,* 1991).

Ottens (1992) recommended that, in developing countries, priority should be given to applications that have proven to be efficient and to entail low risks. He further stated that cautious system planning, customized systems and implementation strategies and methodologies are required in adopting an appropriate approach to the application of GISs. Developing countries can benefit from some experiences in the developed world, and from new hardware and software capabilities.

The constraints in the use of GISs (expertise and capital) faced by local organizations in developing countries make it necessary to take a closer look at the low-end GIS tools. Several standard PC based packages can be used in developing countries for prototype purposes in the early phase of the introduction of larger systems (Meijer and Kuipers, 1992).

As in most of the technological advancements, there is a danger involved in too much dependency on GISs also. For instance, at ITC, M.Sc. research studies in GISs related fields are focused around data manipulation, data structure and data management. There is tendency to overlook the objectives of using a GIS. It may be useful to remind ourselves that the use of GISs, or any information system, is to derive useful knowledge from it.

"Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?" (Eliot, 1935).
Where is the information we have lost in data!

There is another danger. The use of GISs can actively stimulate the emergence of a data rich but theory poor environment (Openshaw, 1993).

5.8 CONCLUSIONS

GISs have the capabilities of dealing in an integrated manner with a host of data, information, concepts, theories and policies from a variety of sources and formats, so as to be able to model settlement patterns. Within the possibilities and constraints identified in the chapter, GIS software ILWIS is selected for use in this research for its ability to handle image processing, and because it has standard functions of a typical GIS both in vector and raster format.

However, a number of functions can still not be performed in a GIS and have to be performed outside the GIS - or make use only of the statistical part of the GIS. As an example, in the field of spatial planning, image interpretation can not yet be fully automated and made part of a GIS.

Incorporation of various government policies and programs in a GIS is complex. It is not yet clear whether the strategy should be to incorporate GIS in a model, to incorporate a model in a customized GIS, or to build a hierarchy of GISs using various models as buttresses and filters between their use in real world planning processes (Batty, 1993).

The models for understanding, monitoring and describing; and for predicting and recommending settlement patterns, as proposed later in this book, will be developed outside the GIS. However, GIS will be used, as a tool, in dealing with various parts of the models.

An effective account of the policies and programs of governmental agencies, which form an essential element of any model dealing with settlement patterns, can not be given unless their context is comprehended. The following chapter describes this context. It details the NCR, India, which provides the geographical basis for the development of the models referred to above.

6

NATIONAL CAPITAL REGION (NCR) OF DELHI, INDIA

AN INTRODUCTION TO THE REGION AND IT's PLANNING

Delhi, the focus of the socio-economic and political life of India, a symbol of ancient values and present aspirations, is assuming increasing importance among the great cities of the world. It has a distinct personality embedded in it, in the history of centuries (DDA, 1991). In its parts it has throbbing lanes of Shahjahanabad - the capital of Emperor Shahjahan, and the grand vistas of New Delhi - the capital of British India, designed by Sir Edwin Lutyens.

Delhi's beginning can be traced back to the fierce war fought nearly 3,500 years ago, between estranged cousins, the *Kauravas* and *Pandavas,* for the city of Indraprastha, as related in the epic, the *Mahabharaia* (Goyel, 1993). Several other cities have been built and housed from time to time at the present site of Delhi. Built not layer upon layer but contiguously, these total up to seven, major cities. Some landmarks of these cities are still visible in the form of Old Fort, Qutab Minar, Siri Fort, Tughlaqabad, Kotla Ferozeshah and Shahjahanabad, popularly known as *Purani Dilli* (Old Delhi).

6.1 DELHI - THE HISTORIC WALLED CITY

The city of Shahjahanabad was built in 1638 A.D. by Shahjahan who, incidentally, also built the world famous Taj Mahal. It is now a parallel and thriving city, with the magnificent Jama Masjid, the bustling markets of Chandni Chowk and the impressive *Lai Quila,* or Red Fort. This magnificent city was built with wide streets and paths. Apart from the main streets, the roads were narrow and labyrinthine. A wall having a circumference of about six kilometres was built around it, which served both as a protection and city boundary (Figure 6.1). The scale and speed of this endeavour were such that estimates of the population of Shahjahanabad by the year 1659 ranged from 150,000 to 500,000 (Noe, 1993). Yet, it had a human scale, and was well adapted to movement by foot and face-to-face social interaction (Nath, 1993). The city thrived until 1739 A.D. when Nadir Shah, the Emperor of Persia, wrecked the empire of then weak emperor, massacred thousands of local inhabitants and carried away large amounts of gold, jewels and skilled craftsmen. SubsequenUy, Delhi set into a rapid decline, Delhi territory was placed by the British (East India Company) under the charge of a Resident and Chief Commissioner of Delhi, and the last Moghul ruler, Bahadur Shah Zafar, was exiled to Burma when the power was transferred from the East India Company to the British Crown. The walled city was officially designated as a slum in the first Master Plan of Delhi (Datta and Jha, 1984, as quoted by Noe, 1993; Nath, 1993), and subsequently declared as 'special area', together with Karol Bagh (DDA, 1990). Today, Shahjahanabad can be viewed as a city within a city (Saha, 1992). It now functions as a highly specialized component of the immense metropolis (Noe, 1993) and the region.

6.2 NEW DELHI - THE NATIONAL CAPITAL

For a major part of British rule, Calcutta, not Delhi, was the capital of India. At the historic Delhi *durbar* in 1911, King George V announced the decision of transferring the capital from Calcutta to Delhi (Nath, 1993). Following this announcement a secretariat, now known as Old Secretariat, was built. It was also announced that an entirely new city would be built to serve as the capital of British India. A committee of architects, headed by Sir Edwin Lutyens, was appointed to select a site and to plan the new capital. A site south of Shahjahanabad was chosen for the capital city, which was subsequently named as the Imperial Capital or New Delhi. This city was dominated by wide vistas, enormous buildings and large gardens. The *Rashtrapati Bhawan* with its Moghul Gardens, the India Gate, the North and South Blocks, Parliament House, Connaught Place, North and the South Avenues, Jan Path and the Raj Path are some of the landmarks from this city. Connaught Place became New Delhi's commercial centre, almost as busy as Shahjahanabad's Chandni Chowk. New Delhi railway station also possessed a counterpart in Old Delhi. The old and the new cities were placed side by side as two separate systems. The links between them were decidedly of an abstract nature (Figures 4.3 and 6.2). Between the old and New Delhi were created the railway station and a stretch of grassland (now known as *Ramlila Maidan)* - a clear line of demarcation between Indian and English (Nilsson, 1973).

New Delhi continued to grow through the war and soon turned into the nerve centre of India's political life. When British rule ended with India's independence in 1947, New Delhi continued to serve as the capital of the Republic of India. A general understanding of present day use of the name 'Delhi' includes Shahjahanabad, the Imperial Capital, post-independence developments and rural Delhi.

The crux of Delhi's post-independence growth lies in its rapid urbanisation and its ability to offer wide opportunities for large scale employment through specialisation and increased productivity in manufacturing and supporting services (DDA, 1990). Till 1941, Delhi was essentially an administrative centre with a population of 0.7 million. Partition of India, in 1947, brought an influx of refugees, doubling its population to 1.44 million in 1951 (Nath, 1993). Gradually, expansion of industry and trade and commerce began to transform its character from an administrative city to a multi-functional city in 1981, when its population size became 5.7 million as against 4.6 million provided for in the Master Plan (DDA, 1990). Moreover, Delhi acts as a powerful job magnet at the national level. It draws job aspirants particularly from the neighbouring states (provinces). About 150 thousand people were migrating into Delhi annually between 1971-81. The population of Delhi stood at 9.3 million in 1991. Included in this is the population living in Delhi Urban Area (8.4 million), Alipur, Bawana, Bijwasan, Pehladpur Banger and Pooth Khurd - each identified as individual census town within Delhi in 1991, and the rural areas (Map 7.1).

Moreover, various national and international economic forces have led to concentrations of urbanization in the advantageously placed metropolitan cities, including Delhi[26] (Gnaneshwar, 1995).

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26 **See Nath (1993) for an overview of planning for Delhi and the National Capital Region.**

Fig. 6.1 Shahjahanabad
Delhi, India
Source: Breese, 1966, p.57

Fig. 6.2 Shahjahanabad - New Delhi
India
Source: Buch, 1987, p.48

6.3 DELHI - THE STATE

Until very recently, the administrative set up of Delhi was unique, administered as it was through a multiplicity of authorities. It was governed vertically by the central government through an administrator designated as Lt. Governor. The implication of this provision was that unless otherwise provided by parliament, the President of India functioned as the executive head of Delhi and the Lt. Governor as his agent. Under this provision, the constitutional status of Delhi was that of a Union Territory.

The Union Territory had a Metropolitan Council (of 56 elected and 5 nominated members) which had no legislative powers but was empowered to discuss and make recommendations in respect of legislative and budget proposals, development schemes and other matters referred to it by the Lt. Governor. The Union Territory also had an Executive Council (of 4 councillors appointed by the president of the Union) which was meant to deliberate and thus assist the Lt. Governor in the exercise of his functions in all matters except in respect of certain reserved subjects such as law and order, services, police, and land and buildings. The executive council was not directly responsible to the Metropolitan Council.

The office of the Lt. Governor was named as the Delhi Administration. The Union Territory of Delhi had a number of local bodies also. The Municipal Corporation of Delhi (MCD), New Delhi Municipal Committee (NDMC) and Delhi Cantonment Board were the three key bodies for all municipal services. A number of services were also provided by various institutions/ organisations which were not under the direct control of the Delhi Administration (e.g., the Delhi Development Authority (DDA), Delhi Transport Corporation, Delhi Milk Scheme, Mother Dairy, Super Bazar and Delhi Urban Arts Commission). This system remained in operation for about two and a half decades (Goyel, 1993).

The system, however, found itself always struggling between the two conflicting requirements of satisfying the democratic aspirations of the citizens to govern themselves in accordance with the spirit of the Constitution, and the need for sufficient control by the central government over the capital city and its administration. Out of the various options the Government had, the two prime options were to grant full-fledged statehood to Delhi and the continuance of Delhi as a Union territory.

The Government of National Capital Territory of Delhi Act, 1991, became effective on January 2, 1992. As per the provisions of the act, Delhi did not become a state at par with other states of the country but gained a special status among the union territories. Delhi now has a 70-member legislative assembly and a seven-member council of ministers with restricted powers. The Council of Ministers is headed by a Chief Minister who is appointed by the President (Goyel, 1993).

Subject to the provisions of the Constitution, the Legislative Assembly has powers like a state legislature to make laws for the whole or any part of the National Capital Territory of Delhi with respect to any of the matters in the State List or the Concurrent List of the Constitution of India. The Act specifically provides that the Legislative Assembly will have no powers to legislate on matters relating to public order, police and land which all remain under the direct control of the Central Government.

The act stipulates that the Union Territory shall be called the National Capital Territory (NCT) of Delhi[27].

6.4 NATIONAL CAPITAL REGION

The genesis of the NCR of Delhi can be traced back to the Draft Master Plan of Delhi, 1959. Thereafter, the Master Plan of Delhi, 1962, recommended a larger region comprising of several districts contiguous to Delhi to be planned as a composite unit.

Broadly, this Master Plan for Delhi (DDA, 1962) was a united regional, urban and rural master plan. Seven 'ring towns' at an average distance of about 25 km from Delhi (viz. Loni, Ghaziabad, Faridabad, Ballabgarh, Gurgaon and Narela) were selected for priority development within the metropolitan region (Map 7.1). These were called 'first tier ring towns'. Their role was to absorb a portion of the population expected to join Delhi. The Master Plan also delineated 'second tier ring towns'. This zone of moderate influence of Delhi was called the National Capital Region encompassing about 110 km radius from Delhi (Pandey, 1992). This plan also recommended that a statutory National Capital Region Planning Board should be set up for ensuring balanced and harmonised development of the region.

Taking cognizance of these recommendations, the Government of India set up a high power board to co-ordinate the development of the National Capital Region within the framework of a comprehensive regional plan to be formulated by the board. The central TCPO functioned as the technical secretariat for drawing up a regional plan in collaboration with the concerned State Governments. It also undertook to delineate the region based on various indices[28] under three broad categories, i.e., demographic characteristics of the region; inter-action between Delhi and the surrounding areas; and an efficient framework for urbanisation and the provision of infrastructure (TCPO, 1974). Administrative convenience and contiguity were also considered while delineating the region.

Today, the NCR covers an area of 30,242 sq. km, lying between 27°18'N and 29°29'N latitudes and 76°09'E and 78°29'E longitudes (NCR Planning Board, 1988). The region surrounds and includes the NCT of Delhi. It also covers the parts of the states (provinces) of Haryana, Rajasthan and Uttar Pradesh (Figure 6.3 and Table 6.1).

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27 **'Delhi', in the rest of this dissertation, refers to the National Capital Territory (NCT) of Delhi, unless otherwise specified.**

28 **These indices were the population growth rate; migration; density of population; economic activity; supply zones of milk, vegetables and fruits; communication; physiography; and passenger traffic by rail and buses (TCPO, 1974, p. 14).**

Fig. 6.3 National Capital Region of Delhi India
Source: NCR Planning Board, 1988

Table 6.1 POPULATION DISTRIBUTION OF THE NCR OF DELHI, 1991

Constituent	Area (sq. km)	Percentage of Population of the NCR (1991)		Density of Population (p.p.sq.km)
NCT of Delhi	1,483	35	(9.3 million)	6,351
Haryana	13,413	25	(6.6 million)	495
Rajasthan	4,493	6	(1.6 million)	352
Uttar Pradesh	10,853	34	(8.9 million)	B07
NCR of Delhi	30,242	100	(26.4 million)	573

Source: Break-up of population for 1991 from SPA, 1994, p. 15.
Area from NCR Planning Board, 1988, p.l.

It is the biggest and generally accepted to be the best-defined metro region in India (Ribeiro, 1993). The region accommodated a population of more than 26 million people in 1991, spread over about 100 towns and cities and 6,700 villages. The urban component is about 52% of the total population. Density of population of the region was close to 873 persons per sq. km., against an all India average of 240 in the year 1991. Of the four constituents, National Capital Territory of Delhi has the highest concentration of about 6,350 persons per sq. km., with about 9.3 million people in 1991.

6.5 THE FIRST PLAN

The basic concept of the first plan, prepared under the technical secretariat of the Town and Country Planning Organisation (TCPO, 1974), was the progressive deconcentration of population and economic activities that had developed in the Delhi Urban Area during the previous three decades and their dispersal to the various parts of the National Capital Region in a manner that would satisfy the demands of the population and the economic activities and, at the same time, achieve a balanced growth in the entire region.

This plan projected that Delhi, as the National Capital, would continue to attract population and activities (e.g., related to industry, commerce and culture). The plan recognised that it would not be possible for Delhi to grow interminably, both on account of the limitation in providing the necessary basic infrastructure as well as the complex physical, socio-economic and political problems that would result from concentration of the large magnitude of population and its activities. At the same time, it was recognised that not only Delhi but its entire hinterland should benefit from development. The plan, therefore, provided for a slow rate of growth of Delhi and a simultaneous rapid growth of other urban areas within the region.

6.5.1 Development Strategy

A two-pronged development strategy was envisaged. Firstly, there had to be some disincentives, which would direct the industrial and commercial activities to seek locations near and not within Delhi, both for expansions and for new establishments. Secondly, the regional towns in the NCR were to be made sufficiently attractive for industry, trade, government offices, etc. This development of regional towns was envisaged not as dormitory towns but as self-contained, liveable urban centres equipped with an acceptable level of educational, health and recreational facilities, including good housing at reasonable costs.

The pre-requisites, necessary for the strategy to be put into effect were identified and grouped under the following heads (Qaiyum, 1982; NCR Planning Board, 1987):

i. development of an adequate physical and economic infrastructure base at the regional level so as to make possible the dispersal of economic activities and population to the region;

ii. the provision of an acceptable level of services, amenities and facilities for growth of activities in various urban centres within the NCR, as quickly as possible so as to make them receptive to the activities flowing into them from Delhi or from outside the region; and

iii. policies and programmes in Delhi territory that will discourage excessive growth and concentration and also promote shifting of the non-conforming activities from Delhi into the regional centres.

The Plan favoured a 'radial corridor pattern' and a 'multi-town pattern' on the grounds of social, economic and technological considerations (TCPO, 1974, pp.29-30).

6.5.2 A Non-Starter

Due to various political and administrative reasons, the first plan never obtained statutory status, and in the meanwhile Delhi and the region continued to grow with profound changes in the land use, ecology and economy of the areas. There were no legal provisions to bind various state governments to abide by the plan, or to enforce various policies of the plan concerned with the private sector. This recommendatory plan remained a non-starter also because of differences in legislation, land policies and taxation and lack of inter-governmental responses, with inner-city and ring town lands being favoured locations for employment generating activities, even to the extent where new urban growth emerged in this inner belt (Ribeiro, 1993).

A statutory board could not be constituted due to opposition to it of the state governments of Uttar Pradesh and Haryana, which were afraid that it would interfere with their powers of planning and development in their areas included within the region. The governments of the two states encouraged and supported the expansion by providing liberal incentives for location of industries and other economic activities in them. The incentives and investments were concentrated in satellite towns like Ghaziabad, Loni and the New Okhla Industrial

Development Area (NOIDA) in Uttar Pradesh; and Faridabad, Rallabgarh and Gurgaon in Haryana, which have been developed as residential-cum-industrial centres (Nath, 1993; Map 7.1). As an example, the development of Greater NOIDA has been in gross violation of the objectives of the NCR (SPA, 1994, p.50). NOIDA too, as per the approved NCR Plan, is to have not more than that of 0.7 million population by the year 2001 and yet, the plan being prepared for the city is for about twice that population. Something similar is happening with other ring towns too (Ribeiro, 1993). These developments, though they sometimes correspond to the NCR Plan proposals, were primarily dictated towards the respective city master plans (and state level regional plans, where available). Some of these developments are also rooted in the centrally sponsored scheme for Integrated Development of Small and Medium Towns (IDSMT), initiated for encouraging planned development of less populated towns (Government of India, 1977).

However, the Delhi government took little or no action to slow down new major employment activities. In fact, in partnership with several economic ministries, employment generating and foreign exchange earning activities were encouraged in Delhi (Ribeiro, 1993).

Table 6.2 indicates that the overall urban population of the region, in 1981, was less than the one proposed in the first plan. Similarly, the population of Delhi Urban also did not deviate very much from the proposal. However, most of other urban centres were far behind their assigned population figures. The urban population that remained unaccounted for is the one in new towns like NOIDA, which were never planned for in the first plan.

Table 6.2 PLANNED VERSUS REAL URBAN DEVELOPMENT IN THE NCR, 1981

Urban Centre/ Unit	Population (million persons) Proposed* for 1981	Reality** in 1981	% Achievement
Delhi Urban	5.30	5.72	108%
Faridabad	0.35	0.33	94%
Alwar	0.15	0.14	93%
Rohtak	0.20	0.16	80%
Ghaziabad	0.40	0.28	70%
Meerut	0.80	0.53	66%
Panipat	0.20	0.13	65%
Modinagar	0.15	0.08	53%
Sonipat	0.20	0.10	50%
NCR Urban	9.30	9.10	98%
Total NCR	21.10	19.19	91%

Source: * TCPO, 1974.
** NCR Planning Board, 1988.

6.6 THE SECOND PLAN

The enactment of the National Capital Region Planning Board Act, 1985; the setting up of the National Capital Region Planning Board in 1985; and the consequent preparation and approval of the Regional Plan 2001 in 1988 (effective as on January 23, 1989) marked the beginning of a new phase in planned development of the region. The Regional Plan 2001 (in fact the 'first statutory' plan for the NCR) suggested policies and measures which would help in achieving the objective of the planned development of Delhi in its regional context aiming to:

" - relieve the Capital city from additional pressures,
- avoid adding new pressures on to the Capital and
- remodel the pattern of settlements in the National Capital Region to enable them to play their assigned role." (NCR Planning Board, 1988, p.ix).

6.6.1 Policies and Strategies

The Regional Plan 2001 contains broad policy framework, strategies and guidelines for development of the region together with broad land uses at the regional scale. The plan has provisions for the preparation of functional (action) plans for various sectors of development. These plans will suggest measures:

i. to contain the population of Delhi through decelerated growth;

ii. to achieve moderate growth of Delhi Metropolitan Area excluding Delhi;

iii. to include growth in the towns/ complexes identified for priority development by enhancing the momentum of economic expansion and technological development and, also adopting effective promotional measures to create employment opportunities to attract the Delhi bound potential migrants and, creating a physically efficient pattern and socially desirable environment with effective participation of the (constituent) States, that will sustain dynamic growth in keeping with objectives and goals of the Regional Plan 2001; and

iv. for action to expand and to effect qualitative and quantitative improvement in physical and social infrastructure in towns identified for priority development.

The plan also envisages the sub-regional plans indicating:

i. reservation of areas for specific land uses which are of regional or sub-regional importance;

ii. future urban and major rural settlements indicating their areas, projected population, predominant economic functions, approximate site and locations;

iii. road network connecting sub-regional centres, service centres and basic villages;

iv. proposals for the coordination of traffic and transportation, including terminal facilities;

v. priority areas at sub-regional level for which immediate plans are necessary;

vi. proposals for the supply of drinking water and sanitation and drainage; and

vii. any other matter which is necessary for the development of the sub-regions.

However, the preparation of sub-regional plans by the respective state governments could start very late in the planning process. All the sub-regional plans were approved by their respective authorities in or after 1994 (see Deptt. of T&CP, Govt, of Haryana, undated; Rajasthan, 1992; Uttar Pradesh, undated; and DDA, 1994). These plans vary in the levels of detailing corresponding to the planning culture prevalent in each of the departments of town and country planning of the various states.

The regional plan envisages development of economic activities over a wider area in the towns/ complexes that are identified for this purpose. These priority towns need to be planned as self-contained units and action taken for their coordinated and synchronised development. In view of greater concentration of population in the capital, the need for flow of migrants to be re-directed to priority towns is greater. This requires well identified projects to gradually increase the migration share to the priority towns by improving their economic base. For effectuation of such a programme of projects, the institutional framework both at the State and local levels needs to be strengthened and action taken to improve the resource mobilisation at the local level (NCR Planning Board, 1988).

6.6.2 Policy Zones

The plan divides the region into three policy zones for effective application of the policies and implementation of proposals with a view to achieve a manageable Delhi and an harmoniously developed region. These policy zones are termed as Delhi Union Territory (since redesignated as National Capital Territory of Delhi); Delhi Metropolitan Area (excluding Delhi); and beyond Delhi Metropolitan Area (Rest of the NCR; Figure 6.4).

National Capital Territory (NCT) of Delhi

Earlier known as Union Territory of Delhi, it covers a total area of about 1,500 sq.km., of which about 40% is urbanised. The urban area is spread over 6 towns, including Delhi Urban Agglomeration. The rural area comprises over 200 villages.

Delhi Metropolitan Area

Delhi Metropolitan Area (DMA) excluding Delhi, comprises the controlled areas of the contiguous towns of Ghaziabad including Loni and NOIDA in the province of Uttar Pradesh; and the Faridabad-Ballabgarh Complex, Gurgaon, Bahadurgarh, Kundli and the extension of Delhi ridge in Haryana. This area also includes about 450 villages. The total area of DMA (excluding Delhi) is about 1,700 sq.km.

Fig. **6.4** Policy Zones of the National Capital Region of Delhi (after Nagpaul)
Source: Nagpaul, 1988, p.206

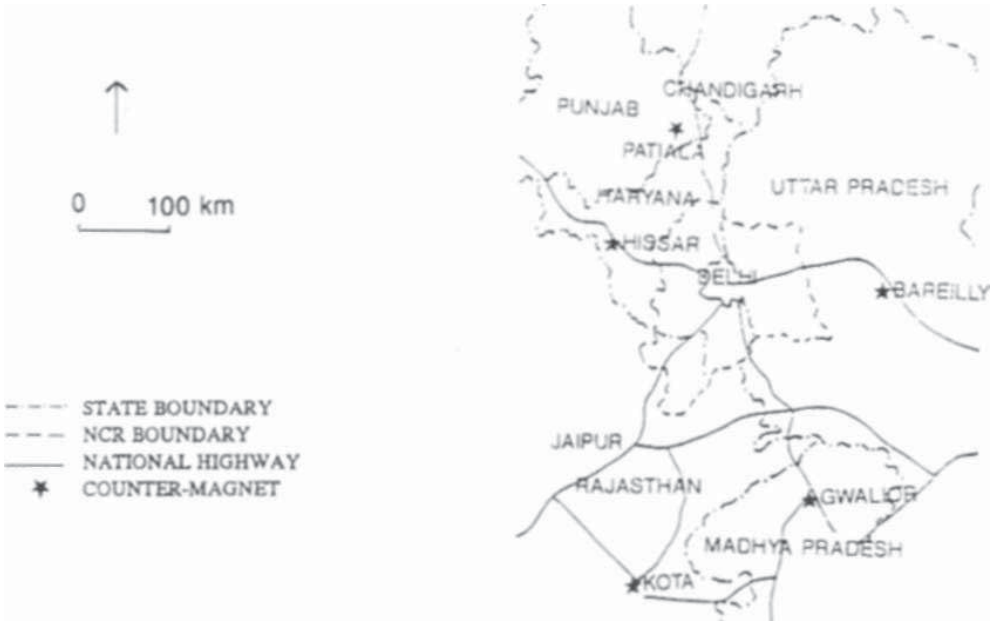

Fig. **6**.5 Counter-magnets to the National Capital Region of Delhi
Source: NCR Planning Board. 1988

Rest of the NCR

Rest of the NCR, i.e., beyond the DMA, comprises an area of about 27,000 sq. km. It contains 83 towns and some 6,050 villages.

Counter-magnets

Besides above mentioned areas, the NCR Plan has also identified[29] five 'counter-magnet' towns for development, located outside the NCR (Figure 6.5). These towns viz. Hissar in Haryana, Gwalior in Madhya Pradesh, Patiala in Punjab, Kota in Rajasthan and Bareilly in Uttar Pradesh are expected to maintain a certain amount of complementarity in respect to metropolitan functions with Delhi and the region. A range of 250-300 km from the NCR boundary or about 350-400 km from Delhi, representing 6 hours journey time by road, from Delhi, should enable interaction between chosen counter-magnet and the metropolitan core without impairing its development autonomy and functional identity as a regional growth centre. The plan expects that these towns will act as future interceptors of migratory flow to NCR, and will play the role as regional growth centres in the regions of their setting.

6.6.3 Sectoral Policies

The Regional Plan 2001 envisages detailed sectoral policies regarding the matters of population, settlement systems, land use, transportation, telecommunication, industrial location, trade and commerce, office location and improvement of environment. These policies have been summarized in Appendix VI. These policies are envisaged to create a new development momentum in the regional urban centres as a result of which their population is bound to increase manifold in the decades to come. The spread-effects of such massive development programme are difficult to visualise. A series of studies (e.g., SPA, 1994) have been initiated by the NCR Planning Board to review the policies and priorities as part of mid-term assessment.

6.7 DEVELOPMENT DYNAMICS

6.7.1 Population

The first plan for the region projected and proposed a population of 21.1 million in the region for the year 1981 (TCPO, 1974, p.32, p.68). However, the actual population of the region, in 1981, was only 19.1 million (NCR Planning Board, 1988, p. 138). The Regional

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29 **These counter-magnets were recommended by the consultants to the Regional Plan 2001. However, the counter-magnets were to be finally identified by the NCR Planning Board in consultation with the concerned state governments (NCR Planning Board, 1988, p. 124).**

30 **Extensive use of the Census of India, 1991 and SPA, 1994 has been made while compiling various figures for this part.**

Plan 2001 projected a population of 25.4 million people in the year 1991, which rose to 26.4 million (SPA, 1994).

Almost 52 per cent of this population lived in urban areas indicating a high rate of urbanisation compared to the rest of India (26 per cent) and other urban regions. 35 per cent of the total population of the NCR resides in Delhi, whereas 34 per cent resides in Uttar Pradesh, 25 per cent in Haryana and 6 per cent in Rajasthan. The distribution of population showed only a marginal variation between 1981 and 1991. The share of Delhi showed an upward trend by 4 per cent while Uttar Pradesh showed an upward trend of 3 per cent (SPA, 1994).

Out of the total population of the region, 73 percent live in the DMA towns including Delhi, 15 percent in priority towns and 12 percent in the sub-regional centres and other urban centres. Within the DMA, Delhi has the highest urban population (85 per cent) followed by Faridabad and Ghaziabad (about 6 per cent each). Amongst the priority towns, Meerut is the most populated urban centre accommodating 43 per cent of the population living in priority-towns, followed by Rohtak, Alwar and Panipat (about 10 per cent each).

The rate of growth of population between 1981-91 was 65 per cent for the DMA towns while it was 46 per cent for priority towns. Within the DMA, Loni and NOIDA showed highest growth rates (256 per cent and 249 per cent) followed by Ghaziabad (93 per cent), Faridabad (87 per cent) and Delhi (61 percent). Amongst the priority towns, Meerut has highest growth rate of population (58 per cent) followed by Rewari (46 per cent), Alwar (44 per cent) and Hapur (42 per cent). Bhiwadi registered the highest rate of growth of population (784 per cent) between 1981-91. 14 human settlements were classified as urban in 1991, whereas two were declassified from urban to non-urban. An overview of all the towns in the region is provided in Appendix VII and Map 7.2.

Apart from the towns, the NCR has more than 6,500 villages. These are predominantly medium sized with populations between 500 and 2,000 persons, constituting more than 55 per cent of the total villages. 20 per cent of the villages have population between 2,000 and 5,000 persons. Less than 5 per cent of the villages had population more than 5,000 persons.

Though no detailed studies are available to indicate the level of in-migration to the region as a whole, Delhi takes the major burden including migration from within the region. 57 per cent of the total population increase in Delhi, in the decade 1971-81, was due to immigration (NCR Planning Board, 1988, p. 137). The major reason for migration has been the employment, followed by family movement (NCR Planning Board, 1987, p. 16).

6.7.2 Literacy

52 per cent of the total population of the region is literate. Literacy rate is highest in the NCT of Delhi (62%) followed by Haryana (48%), Uttar Pradesh (40%) and Rajasthan (36%) sub-regions.

6.7.3 Employment

The workforce participation rate in the region, in 1991, was 30 per cent, both for the urban and rural population. 34 percent of the total workforce is engaged in the primary sector. While in the urban areas 68 percent of the workforce is engaged in tertiary sector activities, only 25 percent of the workforce in rural areas in engaged in the same.

Among the sub-regions, participation rate varies from 34 per cent in the NCT of Delhi to 28 per cent in Uttar Pradesh. Delhi has a very low (3 per cent) proportion of workers in the primary sector. Other sub-regions have considerably larger proportions of their working population engaged in primary sector - Haryana 52 per cent, Uttar Pradesh 54 per cent and Rajasthan 68 per cent.

6.7.4 Industry

The region had over 900 large and medium scale industrial units, spread in the sub-regions of Haryana (38 per cent), Uttar Pradesh (35 per cent), NCT of Delhi (19 per cent) and Rajasthan (8 per cent). The region also has over 100,000 small scale industrial units, a large proportion of them in the urban areas. In the NCT of Delhi, 95 per cent of the small scale units were in the urban area. Corresponding figures for Uttar Pradesh, Rajasthan and Haryana sub-regions stood at 85 per cent, 76 per cent and 60 per cent respectively (SPA, 1994).

6.7.5 Traffic and Transportation

The National Capital Region of Delhi is served by road-based and rail-based transportation systems. The only located airport in the region serves as a major port both for international and national travel beyond the region. The road network comprises of nine major corridors together with seven orbitals providing linkages with the various urban centres within and beyond the region. Similarly, the rail network comprises of eight corridors with a mix of broad and meter gauge railway lines.

Roads and railways carry the gross annual freight traffic to and from Delhi in a proportion of 80:20 (SPA, 1994). Similarly, the total daily passenger movement in the region is in the proportion of 44:32:24 by private vehicles, public vehicles and rails respectively (NCR Planning Board, 1988).

Delhi has about 22 million motor vehicles. About 390 new vehicles were being registered every day during the years 1991-92. These vehicles emit about 872 tonnes of vehicular pollutant daily, contributing more than 60 per cent of the total air pollution levels in Delhi (SPA, 1994).

6.8 TOWN PROFILE

Towns in the region vary in nature and extent. Other than the city of Delhi, the towns range from a population size of less than 4,000 to close to a million people. They also range from historical towns to new industrial estates in the process of development.

The general level of the environment in these towns is very low. In a study (SPA, 1994) conducted on DMA and priority towns, 10 out of 18 towns were considered to be environmentally critical, based upon 28 parameters. 6 out of 18 towns were considered partially critical, whereas only 2 towns were considered not critical. Towns identified as critical werePanipat, Palwal, Gurgaon, Faridabad-Ballabgarh, Bahadurgarh, Meerut, Hapur, Ghaziabad, Bulandshahr and Bhiwadi. Towns identified as partially critical were Rohtak, Rewari, Kundli, Khurja, Loni and Alwar. Dharuhera and NOIDA were identified as not critical.

A brief profile of some of the towns (arranged alphabetically, compiled from various sources[31]) is provided in the following sections to have an overview. These towns have been selected to cover a representation based upon the variety in their population size, functional and environmental characteristics and location in the region. Some of these towns also served as case studies during the field work phase of the research.

6.8.1 Bahadurgarh (Haryana)

Designated as a DMA town, this class III town (population 57,235 persons in 1991) lies in the immediate vicinity of Delhi. The town is generally functioning as a trade and commerce centre. It is known as a centre of local trade in millet, gram, salt and wheat. The majority of shops are dealing in sanitary, hardware and building materials. It has an extensive area for industries. The informal commercial sector is proportionately less than other NCR towns. Inner city roads are subject to congestion and traffic delays, due to lack of parking facilities. Domestic and commercial waste is dumped on the roadside, creating unhealthy conditions. Unorganised sewage and waste disposal is a major environmental concern. Water logged low lying areas are a source of concern.

6.8.2 Bhiwadi-Dharuhera-Rewari Complex (Rajasthan/ Haryana)

This industrial complex comprises of three towns: Bhiwadi from Rajasthan and Dharuhera and Rewari from Haryana (population 15,285; 10,848; and 75,342 persons respectively, in 1991). Out of the three, Rewari is comparatively old and is known for glue, copper and brass utensils, handicrafts, hand loom and fibre products. Except for parts of Rewari, this complex, planned primarily for heavy and medium industries, could be termed as a new town. The towns have industrial and commercial activities along the highways. A distinct buffer on either side of the highways adds to the vegetative cover of the area. However, the presence of open spaces is inadequate. Though the parking is generally on the street, traffic

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31 NCR Planning Board, 1988; Sharma, 1972; and SPA, 1994.

congestion is, as yet, not as serious a problem as in other towns of the region. Considerable inrormal commercial activity has also established in the area. Low lying pockets of residential areas are often water logged. The complex is partially sewered, with partially open drains. Major polluting industries have their own treatment plants, though the capacity is generally less than the discharge they generate.

The paper mills in Dharuhera emit untreated liquid and gaseous wastes, which has damaged agricultural crops as well as trees in the area.

6.8.3 Bulandshahr (Uttar Pradesh)

A class I city, Bulandshahr (population 127,201 persons in 1991) has developed into a centre of trade and commerce mainly because of its connectivity. This has also encouraged ribbon commercial development, particularly on the Bulandshahr-Khurja corridor. The city is served by water supply drawn form underground sources, while caters for upto 50 per cent of the total demand. The city has no sewerage system and septic tank effluent is channelled through unlined drains. The effluent is ultimately discharged into *Kali Nodi,* untreated. There is garbage collection system but the disposal is unorganised.

6.8.4 Faridabad (Haryana)

Contiguous to Delhi, this class I city (population 617,717 persons in 1991) is very well connected. Both the southern and western railway lines pass through the city. Agra canal also passes near the city making its hinterland very fertile. However, the economic base of the town is industry, which arose through the advantage of proximity to Delhi. The area is badly effected by polluting industries, especially those dealing in electro-plating. It has pools of eutrophied water, liquid industrial wastes are disposed untreated into open drains, causing a foul smell, and solid wastes are dumped on the road side. Traces of zinc have been found in the water drawn from borewells.

This linear city has a high concentration of slums and squatter settlements along the railway tracks, highways and low lying areas. Together with Ballabgarh, the whole city is termed as the Faridabad-Ballabgarh Complex, which is poised for vast residential expansion over the next decade.

6.8.5 Khurja (Uttar Pradesh)

A class II town, Khurja (population 80,305 persons in 1991) is known for its pottery products. Nearly 20 per cent of its population is engaged in industrial activities. It's more than 500 pottery industries employ about 13,000 persons. Since these industries depend on the use of coal-fired furnaces for their production, the level of the particulate matter in the air is very high. As there is no sewerage system for the town, it is dependent on septic tanks and unlined drains for sewage disposal. There is no organised garbage collection and disposal in the town.

6.8.6 Meerut (Uttar Pradesh)

Meerut is the most populous (849,799 persons in 1991) class I city in the region, after Delhi. It is an historical city, reference to it are found in the 12th Century. It is a major agricultural market and mills flour and vegetable oil. Based on the current growth rates of population, Meerut is considered to have already become a metropolitan city. It is also the most developed, with a complex system of networks. Industry, trade and commerce and administration are the three key functions this city performs. The city has three major industrial areas at Partapur, Modipuram and at Daurala. The city has had a master plan for a few decades, which is now under revision to accommodate NCR Plan postulates. Although the old city core is congested, the newly developed areas of the city are well planned. Yet the level of infrastructure, amenities and urban form presents a very gloomy picture. The drainage in the city is generally poor, and the sewage is disposed off untreated. The solid wastes are collected manually on bullock carts, and dumped along trunk roads outside the city.

6.8.7 Naraura (Uttar Pradesh)

A class V town, Naraura (15,652 persons in 1991) is located on the river Ganga, at the south-eastern tip of the region. The town is the location for the Naraura atomic power plant. A new township has been developed to accommodate the employees of the plant. This township has all modern environment and health infrastructure. However, the old town is a typical NCR town. Untreated sewage is directly discharged into the river Ganga, and garbage collection and disposal are hardly evident.

6.8.8 Palwal (Haryana)

Abutting the boundary of proposed Faridabad Complex, this class II town (population 59,168 persons in 1991) is well connected by rail and road. The town started on a higher land, and is now expanding on the lower plain, where it is surrounded by agricultural fields. Trade and commerce are the main activity of the town, repairs, restaurants, building materials, agriculture implements and tools are prominent. Inner parts of the town have narrow roads, which are congested. The environmental condition of the town is deteriorating owing to the informal sector, and on-street disposal of waste. Recent extensions of the town are subject to local flooding. Solid waste is now used as a landfill. The town is partially serviced by sewer lines.

6.8.9 Panipat (Haryana)

A site of historic battles, this class I city (191,212 persons in 1991) is, today, known for its textile, hand loom and power loom industries. It is also well known for its brass utensils, pottery and cane products. The city is served by the Western Yamuna Canal and is bisected by the Delhi-Kalka railway line. The city is surrounded by rich agricultural land. Linear development of the city has lead to major traffic congestion. Although two fly-overs are under construction, the general condition of roads is very poor. Water logged areas and

garbage dumps is a common sight. Both solid and liquid wastes from industries are discharged into open drains. Extensive garbage dump sites are located very near to residential areas. The city is partially served by a sewer line. A large and polluted surface drain, running through the middle of the city, discharges into the Yamuna, polluting it dangerously.

6.8.10 Rohtak (Haryana)

Located on the western fringe of the region, this class I city (population 216,096 persons in 1991) is well connected both by rail and road. The Western Yamuna Canal also passes through the city. The city has well maintained and organised open spaces. It also has a lake, which is developed as a tourist spot, serving as a regional recreation facility. The overall environmental condition of the city is fairly good. The sewer system consists of partially open, and partially closed drains. Both solid and liquid wastes are disposed off into open fields outside the city. The city serves as a trading, commercial and educational centre. There are a few industries, including the manufacture of muslin used for turbans.

6.8.11 Sikandrabad (Uttar Pradesh)

Sikandrabad is a class II town (60,992 persons in 1991), connecting Bulandshahr and Khurja. Industry, trade and commerce, and primary activities are the main functions of the town. The town has a water supply system covering about 65 per cent of the population. Although there is no sewerage system, the drains are cemented. Untreated sewage is discharged into natural streams. While the municipality collects and disposes domestic garbage, industrial waste is dumped along highways, causing hazardous conditions.

6.8.12 Sonipat (Haryana)

This class I city (143,922 persons in 1991) is known for its small and medium industries. The city is surrounded by rich agricultural land, which is now under threat from urban sprawl. Major expansions are along the road to Kharkhoda. The city is partially served by a sewer system. Surface storm water drains also carry effluent from septic tanks. Garbage is dumped on the road side, and is collected once a day. Disposal of the garbage is not organised and is dumped in open fields. Large scale pollution of land and water from the effluent of large industries is prevalent. The Haryana Urban Development Authority (HUDA) is developing some new areas.

6.9 PLANNING PROCESS

As is mentioned earlier in the chapter, the first plan for the region was prepared, as far back as in 1974, by the TCPO. However, due to various reasons, no statutory body could be set up to carry out the overall objectives and effectuate the proposals of this plan. The process of preparing a plan with adequate statutory backing started with the setting up of the National Capital Region Planning Board, in 1985.

For the purpose of preparing a plan for the region, a planning committee was constituted under the chairmanship of a Member-Secretary. The planning committee drew members representing the top administrators and planning professionals working at the central government and various constituent states of the region. The planning committee was further supported by various study groups comprising of experts in the field of demography, settlement pattern, transport, communications, water supply, sewerage, power and industries.

6.9.1 Interim Development Plan

Based upon the extensive studies carried out by various study groups, the Board came up with an Interim Development Plan 2001 (NCR Planning Board, 1987). This plan, by and large, was a policy document. Part I of the plan listed a package of policy measures and proposals in respect of different sectors of development. Part II of the plan dealt in detail with aspects such as demography, settlement system, economic activities, transport and communications, energy, water supply, sewerage and sanitation, land use, the environment and ecology, and the financial implications of the plan proposals. Whereas it is conventional to supplement a plan with relevant 'work studies' (e.g., DDA, 1962), reports of the study groups were not made public in the case of Interim Development Plan 2001. Objections and suggestions on the interim plan were invited from the members of the public, central and state governments, local bodies and non-governmental organisations (NGOs).

6.9.2 Regional Plan 2001

After considering the objections and suggestions received, the Regional Plan 2001 was prepared and approved (NCR Planning Board, 1988). Besides drawing upon the findings of the study groups, the Board also consulted professional as well as institutional consultants in respect of certain specific aspects of the plan. Like in the case of study groups, reports from these consultants were also not made public.

Studies on the settlement system for the region were undertaken by the Physical Research Laboratory (PRL), Ahmedabad. These studies (PRL, undated), conducted separately for the constituent states of the NCR, in principle adopted a Composite Functionality Index method (see 3.2.6). Indicators ranging between 30 to 40 in number were used in these studies to arrive at recommending the selection of regional, sub-regional and service centres, and basic villages. The studies did not look into the growth potential of various settlements under consideration. No attempt was made to define what made a regional, sub-regional or a service centre. Further, no attempt was made to study in which direction the development is to be made in order to restrict migration to Delhi. These are some of the limitations reported in the studies (e.g., PRL, undated, Uttar Pradesh, pp.27-28).

6.9.3 Use of Remote Sensing and GISs

As is explained in Chapters Four and Five, the use of remote sensing and GISs is rather new in the filed of spatial planning in India. Apparently, no use of either technique was made in preparing the interim development plan. This plan provides a table showing land utilisation

in NCR by constituents: 1981-82 (NCR Planning Board, 1987, pp.42-43). Statistical abstracts of the respective districts and states were used as a basis for preparing this table. The second plan (NCR Planning Board, 1988), however, made use of Landsat satellite images and aerial photographs in preparing a land use (1986-87) map for the region (NCR Planning Board, 1988, map 3). Services of the Terrain Research Laboratory (TRL) of the Ministry of Defence, Government of India, were used for this purpose. TRL obtained, processed and analyzed these images on behalf of the Board. Though there are no image processing and/or GIS facilities available within the Board, it is aware of the usefulness of these techniques in monitoring the land use and related aspects over the region. The plan recognises the need for developing a scientific system, "Through sequential/periodical aerial photographs/satellite imageries to evaluate persistent trend of landuse over a period of time and monitor unauthorised developments and to detect growth trend of urban areas..." (NCR Planning Board, 1988, p. 119). Findings of this research are directed at contributing to developing such a system. The Board is in the process of acquiring and establishing a GIS.

6.10 A SCENARIO FOR THE PLANNING OF SETTLEMENT PATTERN IN THE REGION

The National Commission on Urbanisation (NCU) are of the view that a decadal growth rate of over 30 per cent in any human settiement is beyond the maintenance capacity of local government (Government of India, 1988). However, as revealed by Appendix VII, more than 45 towns in the NCR, in the decade 1981-91, experienced a population growth rate higher than the 'limit' identified by the NCU. Some of the towns experienced growth rates of the order of 80, 90 and even over 250 per cent. Appendix VII also reveals that most of the large towns and cities are becoming multi-functional. Administration, business, the distributive trade, industries, education and culture are amongst their intrinsic functions.

Delhi and its immediate surroundings attract population from all over the country due to a favourable investment climate and due to employment opportunity, both in the formal and informal sectors. This is partly countered by disadvantages arising from centralised licensing and other functions arising from the role of Delhi as the national capital (Ribeiro, 1993).

The National Capital Region Planning Board Act, 1985 (NCR Act) leans heavily on a partnership for integrated growth of the region between the central, state, and local governments and also, hopefully, on private entrepreneurs and citizens in what has already emerged as a complex exercise in trade-offs to determine best locations for statutory integrated growth. Many towns in the region do not have a master plan. In others, master plans were prepared long before the enactment of the NCR Act. The National Capital Region Planning Board is only a coordinating and monitoring body. The responsibility of executing the schemes remains with the participating states (NCR Planning Board, 1987). Urban development, as per the Constitution of India, is a state (and not a central) subject. With the 74th Amendment to the Constitution (Govt, of India, 1993), providing more responsibilities and powers to the local government, ensuring that urban development will be within the overall framework of the NCR Plan will be a complex task. There are already several court cases pending, involving the private developers, state governments and the central government.

The complexities are such that doubts are raised if there are any implementable solutions in a situation where uncoordinated political interventions persist. There are, already, scenarios for unified authorities for the NCR for power supply, telecommunications and transport (Ribeiro, 1993). These scenarios may, ultimately, broaden the scope of government of the NCT of Delhi so as to cover the entire region, leading to the formation of a government of the National Capital Region of Delhi. However, this is speculative and development along these lines may take several decades to materialise.

6.11 CONCLUSIONS

The NCR has evolved into a complex planning and administrative system. Planning for the region involves coordination among more than half a dozen ministries of the central government, senior decision makers and administrators of half a dozen state governments (including those of Madhya Pradesh and Punjab), planning professionals from the central and state governments, and a large number of urban local bodies. More complex is the planning for settlement pattern for the region, with human settlements in population sizes ranging from less than 500 persons to over 9 million people. The planning board does not have the methods and tools to comprehend settlement pattern over an area of the vastness of NCR. It also does not have the methods and tools to monitor settlement patterns at intervals appropriate to rapidly growing human settlements. The concept of CBA, supported with tools such as remote sensing and GISs, enables planners, administrators and decision makers in gaining better understanding of this complexity, in a way that can be impartially, and with consistency, executed by technicians (Mahavir and Al-Amir, 1996). An attempt is made in the following chapter to develop this concept and the tools in the form of models for understanding, monitoring and describing, and for predicting and recommending settlement patterns in metropolitan regions such as the NCR.

7

MODELS
FOR UNDERSTANDING, MONITORING AND DESCRIBING AND FOR PREDICTING AND RECOMMENDING SETTLEMENT PATTERNS

It was concluded in Chapter Six that the NCR Planning Board does not have adequate methods and tools to comprehend settlement pattern over an area of the vastness of NCR. The Board also does not have the methods and tools to monitor settlement patterns at an interval corresponding to rapidly growing human settiements and, therefore, rapidly changing settlement patterns. With the 74th Amendment Act, an effort is being made to strengthen the role of urban local bodies, without defining 'local'.

The concept of CBA, as described in Chapter Two, was found to be useful and conveniently applied on remotely sensed data. It not only allows for inclusion of the elements of spatial dynamism of human settlements, it provides a tool for defining the term 'local', in the context of the 74th Amendment Act.

An extensive review of some of the popularly used models for analyzing human settlement patterns was carried out in Chapter Three. Though all the models discussed there are landmark developments in their own context, they are usually associated with limitations of various kinds. The concept of 'service centre hierarchy' draws from various other theories. It is more systematically applied, yet it is too much dependent on data on a number of facilities. Moreover, this and other prevalent models invariably consider settlements as point locations. They also rely heavily on assumptions like rational economic and planning behaviour. Thus, other methods will have to be developed which are more flexible and capable of adjustment, and therefore, partially visual and manual.

An attempt is made in this chapter to evolve models, prototype in the context of urbanisation in India, for understanding, monitoring and describing; and for predicting and recommending settlement patterns in metropolitan regions, such as the NCR. The chapter also sets out the advantages and limitations of the proposed models, and appraises the models with respect to the plan for the NCR. The chapter goes on to identify areas in which the research might be developed further.

7.1 EXPLANATION OF TERMS

In Chapter Two, the term CBA was defined. In this sub-chapter, some other terms used in describing the model presented in this chapter will be discussed. The terms will be used to express the dimensions of volume and time, as well as location and other characteristics of human settlements.

Locations are point locations with X, Y and Z coordinates, as expressed in geography by the terms longitude, latitude and altitude. Accordingly, in referring to the location of human settlements, reference is made to point locations. Human settlements may be shown on maps as points. In updating such maps, remote sensing might play a role in identifying new human settlements, or identifying shifts relevant to human settlements (e.g., a shift of the business area) leading to a new location of the point representing the settlement.

Location is a principal characteristic of human settlements. Other characteristics (e.g., population characteristics) are deemed to be concentrated at the location of human settlements. Some characteristics allow a degree of visualisation. For example, population figures may be represented by proportional circles, or other scalable shapes, centred on locations. However, such cartographic representations do not represent spatial arrangements.

Arrangements of volumes are spatial arrangements. Where the volumes of human settlements are to be shown on maps, they are represented by their projections, here named areas. The patterns formed by areas and changes in these patterns observed at intervals, permit study of the behaviour of human settlements.

Here, areas of human settlements are defined by CBA method set out in Chapter Two. The method includes a series of operational definitions of the CBA which is related to the scales of the relevant remote sensing data [e.g., at a scale of 1:250,000, a minimum curtilage of 4mm x 4mm (representing one square kilometre) and a minimum width of 2mm (representing 500 metres) is used]. The CBA method is demonstrated in Appendix III, in which the CBAs in the NCR of Delhi are delineated.

One behaviour that can be observed in this way is the merging of two or more human settlements. Where their areas were previously in different locations they will, upon having become one area, be in one location. Therefore, on a map showing point locations, the number of points will be reduced. Conversely, it is conceivable that a human settlement develops two or more nodes, ultimately leading to spatial segregation and hence more point locations.

Once a change in the number of locations has been determined, analyses that were made of previous situations should be reapplied, leading to new results, just as changes in other variables (e.g., population numbers) will lead to new results. The insight gained from the study of the behaviour in human settlements can assist planners in undertaking the task of predicting future changes in these results (e.g., by projecting trends in changes of CBAs, and hence trends towards new characteristics, including new locations). In addressing this task, the planner is supported by remote sensing, which enables him(her) to delineate CBAs at frequent intervals, thus providing indication of possible future change (e.g., the forming of agglomerations of human settlements).

Here, the term 'settlement pattern' especially refers to the pattern of human settlement in the NCR of Delhi, India (the region). The region was delineated by the TCPO in 1974 and, after minor amendments, adopted by the NCR Planning Board in 1988. A detailed description of the region is provided in Chapter Six.

In 1991, the Census of India determined that the number of villages and other human settlements in the region amounted to 6,700. This number has remained more or less constant over a long period of time, except for changes due to settlements that were engulfed by urban growth. Excepting these cases, the pattern made by the human settlements in the region evolved over so many years that it is virtually permanent in terms of the life span of individuals of the humankind. The exceptions confirm the apparent rule that changes in the pattern of human settlements in the region are due to changes in their areas.

The rule represents a model. The model permits the observation that changes in areas can be monitored through remote sensing, thus reducing the need of existing models for a frequent supply of detailed data (e.g., census data). Existing models have the further disadvantage that they, in general, are models for understanding existing patterns, rather than models for making predictions concerning the development of future patterns if no interventions were made to interfere. Time series studies suggest that such interventions (e.g., natural calamities or human interventions such as the construction of new towns) are so rare in the region that they have little impact on the development of changes in pattern, thus the measurement of changes in area provides a potentially important technique for predicting future change.

As the CBA method plays a key role in this technique it may be presented as the CBA technique, and the model to which the technique is applied as the CBA model. Potential applications of this model are further discussed in the following sub-chapter.

7.2 A MODEL FOR UNDERSTANDING, MONITORING AND DESCRIBING SETTLEMENT PATTERNS

One of the principal objectives of this research was to evolve a model for understanding, monitoring and describing settlement patterns in metropolitan regions, such as the NCR. An attempt is been made in this section to detail such a model, which is summarized in Figure 7.1. Some of the elements of this model are as follows.

The model draws from the concept of CBA to represent 'settlements'. Spatial planning at the regional level is traditionally perceived in terms of territorial units of government. As the use of CBAs is likely to take time to be accepted by decision makers and administrators, an attempt has been made in the model to start the process of adoption by using conventional 'point locations' of settlements (e.g., census towns). This is then supported by using the concept of CBA (as detailed in section 7.2.1.2 and Appendix III). Use of images obtained through remote sensing satellites (such as IRS) is made at this stage, supporting the monitoring aspect of the model. The model also makes use of existing knowledge and tools available for performing 'point' based analysis of settlement patterns. This stage of the model dwells upon socio-economic data for the settlements, as obtained through the census. Whereas in conventional approaches (e.g., the scalogram method) facilities are assumed to

be concentrated at the centre of the settlement, in the proposed model facilities are assumed to be uniformly distributed throughout the CBA. The output from the model for understanding, monitoring and describing settlement patterns is then used as an input for the model for predicting and recommending settlement patterns, detailed later in this chapter.

A number of steps incorporated in the model have been dealt with elsewhere in the book. The model is suggested to be recalibrated when the results of a new census become available, or when a new plan for the region is prepared. The parts of the model that are dependant on remotely sensed data are suggested to be adjusted more frequently.

7.2.1 Application of the Model on the NCR

7.2.1.1 Point Patterns

Techniques for the point pattern analysis and spatial autocorrelation, as provided in ILWIS, were discussed in Chapter Two.

A map on a scale of 1:530,000, showing census towns in the region (NCR Planning Board, 1988; additional towns declared in 1991 were added by the author) was digitized and stored in ILWIS in the form of point locations. The national highways, railways, rivers and canals were digitized in the form of line segments, and the external boundary of the region in the form of a closed polygon. Point locations of the towns were also simulated for regular distribution in the region and for distribution in CSR.

The region has rich fertile land with rivers and canals and a good network of rails and roads, which influences the distribution of census towns in the east of the river Yamuna. Point neighbour analysis was performed on three sets of locations. The results are presented in Appendix IX. First order RNNs in existing locations suggest regular distribution in both tests, for dispersion and arrangement. However, the first order RNNs in the situations simulated for CSR and regular distribution suggest regular distribution in both tests, whereas they suggest towards clustering even for the situation simulated for regular distribution in the test for dispersion. These conflicting outcomes suggest a need for other techniques of testing.

Typical Pattern Curves

Pattern curves were generated for the three pattern types discussed above, i.e., the existing, simulated regular and simulated CSR. When compared to standard curves (Appendix II), the existing situation seems closer to random distribution.

Spatial Autocorrelation

Four variables, viz. population in 1991, population growth rate 1981-91, *%* literacy in 1991 and % work force in 1991, were tested for autocorrelation in the existing point locations of the towns. The process was repeated for the same set of locations but for variables generated at random. It is interesting to note that graphs for the existing situation and that created for non-autocorrelation were alike for the variables population growth rate and work force, suggesting non-autocorrelation. The graph showing variance for variable populations showed

Fig. 7.1 A Model for Understanding, Monitoring and Describing Settlement Patterns

a little correlation. Graphs showing both correlation and variance for variable literacy suggested autocorrelation.

In a separate exercise performed by the author, the number of national highways, railways, state highways and the district roads passing through every census town in the region were recorded. With respective weights of 3, 3, 2 and 1, a connectivity index (CI) was arrived at for each town. Also, the distance of each town from Delhi (point locations in each case) was determined. A proximity index (PI) was determined for each town as PI=CI/Distance.

Only very weak correlations were found between any of these indices and various characteristics of the towns. For example, the correlation between CI and the population growth rate (1981-91) was only 0.071. The correlation between CI and the work force participation rate was found to be only 0.170, and that between CI and the literacy rate was found to be 0.529.

Using equal weights for all the major transportation mediums did not make the correlations stronger.

Point Neighbours

Using a facility provided by the software ISNAP[32], the number of neighbours that each census town has was determined. The number of neighbours ranged from 4 to 9. Various combinations of this number with those of the above mentioned indices also did not yield any significant correlations.

Visualising the 'point pattern' through ISNAP provides improved pattern recognition, specially in detecting clusters and linear patterns. Testing the location of census towns in the region through this facility further strengthened the identification of a pattern corresponding to that of transportation corridors in the region (see also para 6 below). It also helped identify a few more clusters than were identified before.

7.2.7.2 *Area Patterns*

1. Human settlements in the NCR that do not satisfy the CBA operational definition are considered only in the dimensions of location and other characteristics, and time. Human settlements that do satisfy the CBA operational definition but stand in isolation, are also considered only in the dimensions of location and other characteristics, and time. Interaction among human settlements in these categories depends on the existence of transport and communication facilities.

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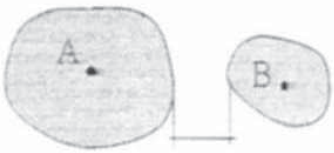
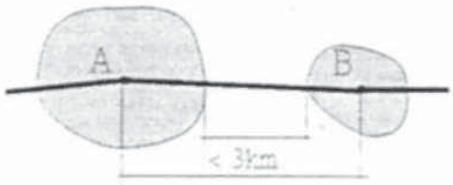
32 **Peng, Wanning and Pilouk, Marakot; ISNAP 1.0 (Simplical Network Application Package), August, 1995, ITC, Enschede.**

The package was developed by its authors for its use in their research, and is not available commercially. The package is vector based and runs on Windows.



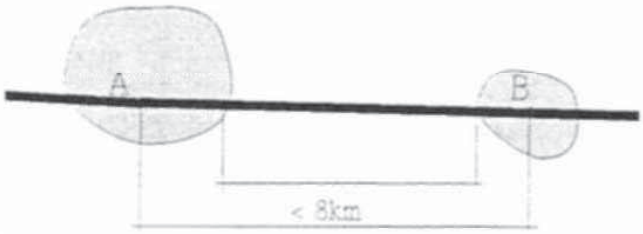
< 2.5 km

POTENTIAL 'ASSEMBLAGE'



< 8km

POTENTIAL 'COUPLE'



< 13 km

POTENTIAL 'FUNCTIONAL COUPLE'

SETTLEMENTS SERVED BY A CORRIDOR

Fig. 7.2 Rules for Potential 'Assemblage', 'Couples' and 'Functional Couples'

For the purpose of identification, these human settlements have been named as 'insular' human settlements.

2. Some human settlements reflect the existence of (or a potential for) corridor development (e.g., due to transportation, proximity and need for a socio-economic interaction). These human settlements are considered in the dimensions of location and characteristics, and time, collectively for all the human settlements forming the corridor development.

   For the purpose of identification, these human settlements have been named as 'couples' or 'functional couples', as in the rules illustrated in Figure 7.2.

3. The city of Delhi, together with some other (census) towns forms an agglomeration[33], satisfying the CBA operational definition. Some of these towns are located within the National Capital Territory of Delhi.

   Some other towns reflect an apparent potential for forming an agglomeration.

   These human settlements are considered in the dimensions of location and other characteristics, as well as volume and time, collectively for all the human settlements forming a potential agglomeration.

   For the purpose of identification, these human settlements have been named as 'assemblage'.

4. The city of Delhi forms an urban agglomeration with 23 other (census) towns. Six other towns are also located within the National Capital Territory of Delhi (see Table 7.1 and Map 7.1).

5. The NCR had 49, 53, 94 and 106 (census) towns respectively in the years 1961, 1971, 1981 and 1991 (see Table 7.2 and Map 7.2).

6. These (census) towns form a pattern that corresponds to the pattern of major transport corridors in the region. Based on Table 7.3 and recommendations of the NCR Planning Board (1988), nine major corridors were identified in the region. Towns

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33 **As per the Census of India, an 'urban agglomeration' constitutes (Census of India, 1981, Series 1, India, Part X-A(i), Town Directory, 1988, New Delhi):**

i. a city or town within a continuous outgrowth, the outgrowth being outside the statutory limits but falling within the boundaries of the adjoining village or villages; or

ii. two or more adjoining towns with their outgrowth as in (i) above; or

iii. a city and one or more adjoining towns with their outgrowths all of which form a continuous spread.

However, the decision of whether the outgrowth is continuous or not is not based upon an elaborate set of rules.

located directly on these corridors represented a major share in the region both in terms of numbers and resident population (see Table 7.4 and Map 7.3). The corridor towns accommodate 81 percent of the total population of the region, excluding Delhi. Including Delhi, the percentage rises to 93 percent. The situation has remained the same for last three decades.

The corridors towns (excluding Delhi) were growing at a rate of 57% between 1981-91, whereas other towns were growing at a rate of 55% during the same period (Table 7.4).

7. When delineated on the topo-sheets of the Survey of India, scale 1:250,000, covering the period 1965-70, only 17 human settlements satisfied the CBA operational definition. These were the (census) towns of Alwar, Bahadurgarh, Bulandshahr, Delhi, Faridabad, Ghaziabad, Gurgaon, Hapur, Khurja, Meerut, Palwal, Panipat, Rewari, Rohtak, Sikandrabad, Sohna and Sonipat. However, there existed 53 (census) towns in the region in 1971 (TCPO, 1974).

The first NCR Plan (TCPO, 1974, p.25) noted a few corridor towns in the region. However, these were only the towns served by major transportation corridors and not the towns or pair of towns showing corridor/ ribbon development, as revealed by the topo-sheets.

8. During the period 1971-81, the number of (census) towns in the region rose to 94, adding 41 towns over 1971. Most of these towns were insular human settlements.

However, the following assemblage human settlements were observed on the landuse map (NCR Planning Board, 1988) and satellite images of 1990-91 (see section 4.7.2):

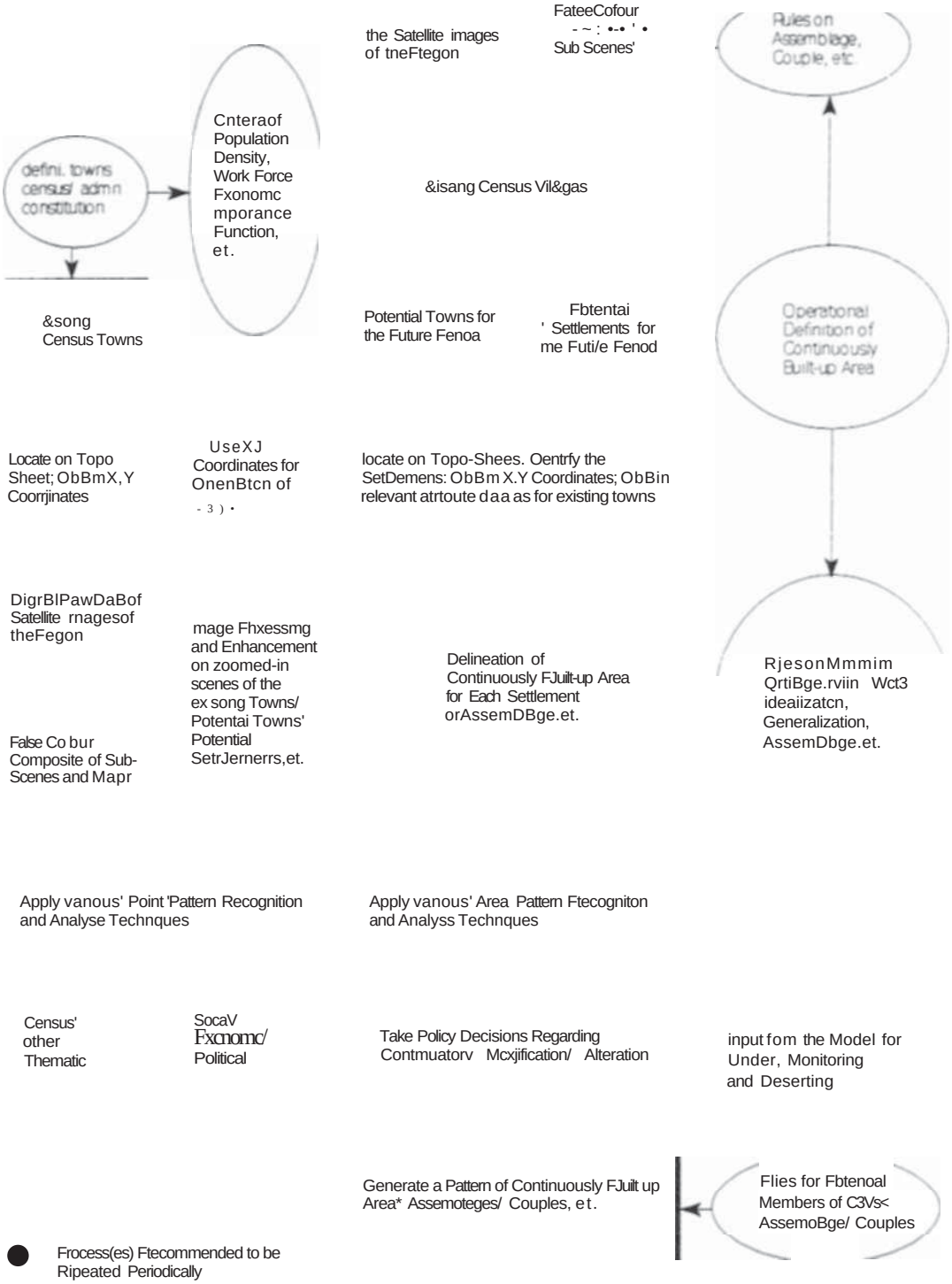
Delhi, Loni, Ghaziabad, NOIDA and Faridabad-Ballabgarh Complex;
Meerut and Abdullapur;
Muradnagar and O.F.Muradnagar.

A number of (census) towns showed potential for growing into couple human settlements. These couples included Hapur-Babugarh, Gurgaon-Jharsa, Kundli-Alipur, Hailey Mandi-Pataudi and Tikri-Doghat.

The settlement pattern for the region, in the period 1961-91, is illustrated in Map 7.4.

7.3 A MODEL FOR PREDICTING AND RECOMMENDING SETTLEMENT PATTERNS

One of the principal objectives of this research is to evolve a model for predicting and recommending settlement patterns in metropolitan regions, such as the NCR. An attempt is made in this section to explain the model, shown in Figure 7.3. The elements of this model are as follows.



7.3 A Model for Predicting and Recommending Settlement Patterns

The model is a follow-up of the model for understanding, monitoring and describing settlement patterns explained in the previous section. One of the important elements of this model is that it takes into account existing rural settlements (e.g., villages, as identified by the census) that have a potential to become urban in the subsequent census (or by the end of the plan period). To achieve this, the model uses criteria for a settlement to be declared a census town and growth rates relevant to such criteria. On the other hand, the model uses the CBA approach to identify and locate on satellite images the potential settlements. The steps of the model for understanding, monitoring and describing settlement patterns are followed in this model too.

For the purposes of making recommendations, the model uses conventional concepts and definitions of settlements (e.g., census towns), so as to facilitate implementation by decision makers and administrators. Accordingly, the relevant attribute data pertaining to the constituent settlements of the CBA is re-aggregated to represent uniform distribution over the entire CBA. A settlement hierarchy based on population, functions and services can then be made using techniques such as scalogram and the composite functionality index.

As stated earlier in this chapter, the model addresses a situation where human settlements are fixed in their location. Hence, the model treats the regional human settlement pattern as constant at the regional scale, allowing areas and characteristics of individual settlements to change. Over time, these changes may cause local variations in the regional pattern.

As a result, there is no distinct division between 'prediction' and 'recommendation' parts of the model. Whereas identifying the existing villages having a potential to become census towns in 2001 (see section 7.3.1, step 1) may be named prediction, conceiving such settlements as CBAs (e.g., assemblage, couple, insular) may be named recommendation. An important aspect of a recommendation is that while it has to draw from planning goals and policies that might be specified for the region, it does recognize the local evolution of the settlement pattern. In the case of the NCR, assignment of populations to various census towns by the Regional Plan 2001 has been taken into account while recommending the formation of assemblage, couple, and insular settlements.

As in the case of the model for understanding, monitoring and describing, a number of steps incorporated in this model have not been illustrated in this chapter as they been dealt with elsewhere in the book. As before, the model is suggested to be recalibrated each time the results of a new census become available, or when a new plan for the region is prepared. However, parts of the model that are dependant on remotely sensed data are suggested to be adjusted more frequently.

7.3.**1** Application of the Model on the NCR of Delhi

The proposed sequence of steps for application of the model to the NCR is as follows.

1. As defined by the Census of India, towns are places with a municipal corporation, a municipal area committee, a town committee, a notified area committee or a cantonment board. Also, all places having 5,000 or more inhabitants, a density of not less than 400 persons per sq. km, pronounced urban characteristics and at least three-

fourth of its adult working male population employed in pursuits other than agriculture (Census of India, 1981). In marginal cases the discretion of the Director of Census is also applied to categorise the area as urban or rural.

To generate a list of existing villages (in 1991) having a potential to become (census) towns in 2001, the following steps[34] were followed:

i. all villages with a population of 4,000 and more persons were identified. This resulted in a count of 656 villages out of a total of 6,677 villages in the region (NCR Planning Board, 1988, p.28);

ii. from these, villages with a population density of 341 persons or more per sq. km were selected. 565 villages passed this test;

iii. next, villages with more than 70 percent of male working population in non agricultural sector were selected. This gave a list of 73 villages, of which 48 are located with in the NCT of Delhi and the rest elsewhere in the region (see Table 7.5a);

iv. in addition, all existing *Tehsil* (sub-district) Headquarters are likely to become towns in the light of the Constitution (Seventy-fourth Amendment) Act, 1992, providing greater powers and responsibility to the local governments (see Appendix XI);

v. further, some villages were selected because they satisfied the CBA criteria on the satellite image, even though they did not qualify in the steps i., ii. and iii. above (see Table 7.5b).

Thus, the total number of villages (as existing in 1991) identified as having a potential to become (census) towns in 2001 comes to 19 excluding the villages located in the NCT.

2. The satellite images of 1990-91 and 1993-94 were examined for:

i. existing 'assemblage' of human settlements;

ii. existing 'couples' or 'functional couples';

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34 **Based upon the assumption that all the existing villages are moving towards becoming (census) towns in the year 2001.**

The criteria of 4,000 persons (as against 5,000), 341 persons per sq. km (as against 400) and 70% male working population (as against 75%) were chosen here keeping in mind the rate of growth of rural population in the region (30% per decade), and that most of these villages have already met at least one of the criteria.

iii. 'insular' human settlements having a potential to join an already existing 'assemblage', to form a new 'assemblage' or 'couple', including the existing villages with a potential to become (census) towns in 2001; and

iv. existing and potential towns that are likely to stay as 'insular' human settlements, based on the rate of growth of their CBA.

The potential of remaining 'insular', or becoming 'assemblage' or 'couple', will depend upon the existence of a strong transportation corridor, distance between the edge(s) of the towns, connectivity and interaction between the towns and their functional[35] characteristics. However, as revealed by Table 7.2, more and more towns were multi-functional in 1981 (see Figure 7.2 for the rules of determining the potential).

7.3.2 A Scenario for 2001

The application of the criteria adopted in the model leads to a scenario for the year 2001. In this scenario, there will be 4 'assemblage' human settlements, 11 'couple' human settlements, 3 'functional couple' human settlements and 65 'insular' human settlements. These 83 human settlements (against 191 census towns projected for the year 2001) are as listed in following sections.

7.3.2. J 'Assemblage' Settlements

i. The NCT of Delhi together with Loni, Dharoti Khurd, Beta Hazipur; Western Ghaziabad[36]; NOIDA; Tilpat, Faridabad Complex; Gurgaon, Dunda Hera, Khandsa; Bahadurgarh, Ladrawan, Sahoti; Kondli and Nahri.

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35 **As per the Census of India, nine categories of workers are regrouped into five broad functional classes of i. primary or agriculture, ii. industry, iii. trade and commerce, iv. transport and communications, and v. services.**

If workers under one of the occupations form 40 per cent or more of their total number, it is considered as a mono-functional town. If however, such percentage is less than 40 percent, the next predominant occupation is taken into account so that the total of the two may come up to 60 per cent or above and such town is considered bi-functional. In spite of this, if the total does not come up to 60 per cent, the third occupation is taken into account and such a town is treated as multi-functional.

(Source: Census of India, 1981 - A Portrait of Population - Rajasthan; Directorate of Census Operations, Rajasthan, 1991, p.63)

36 **The total population of Ghaziabad U.A. assumed to be equally divided between Eastern and Western Ghaziabad, as divided by the river Hindon.**

These human settlements, together, may be included in the Delhi Metropolitan Area, representing a combined projected[37] population of 15.5 million (in 2001) including the population of existing villages identified as having a potential to become (census) towns in 2001. However, keeping the assigned[38] population for some of the (census) towns listed above, the assigned population for this 'assemblage' is estimated to be 14.5 million people in 2001.

ii. Eastern Ghaziabad[39], Dasna and Dunda Heda, representing a combined projected[40] population of 0.55 million in 2001. However, keeping the assigned[41] population of Ghaziabad for the year 2001, the assigned population for this 'assemblage' is estimated to be 0.43 million people in 2001.

iii. Modinagar, Muradnagar, O.F. Muradnagar, Begum Budhana, Kalchhina, Sewalkhas, Patala, Niwadi, Faridnagar, Mohiuddinpur and Ron representing a combined projected[42] population of 0.32 million in 2001. However, keeping the population for some of these (census) towns, the assigned[43] population for this 'assemblage' is estimated to be 0.45 million people in 2001.

iv. Dharuhera, Bhiwadi and Sidhrawali, representing a combined assigned (NCR Planning Board, 1988, p.26) population of 0.19 million people in 2001.

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37 Using rate of growth of population between 1981-91 for existing towns; using rate of growth of population of the NCT of Delhi between 1981-91, i.e. 42.5% for other settlements.

38 See NCR Planning Board, 1988, p.26 and p. 139, for population assigned to various towns for the year 2001. For rest of the towns, population projected as above was used as assigned population.

39 The total population of Ghaziabad U.A. assumed to be equally divided between Eastern and Western Ghaziabad, as divided by the river Hindon.

40 Using rate of growth of population between 1981-91 for Ghaziabad U.A., i.e. 93%; using the same rate of growth of population for Dunda Heda.

41 See NCR Planning Board, 1988, p. 139. Population of Loni subtracted from the assigned population of Ghaziabad + Loni.

42 Using rate of growth of population between 1981-91 for existing towns; using rate of growth of population of the largest town, i.e., 29% in this case, for other settlements.

43 See Deptt. of T&CP, U.P. pp.79-84.

7.3.2.2 'Couple' Settlements

Combined Projected[44] Population in 2001 ('000 persons)
Figures in brackets refer to the assigned[45] population

v.	Alwar - Ramgarh	314 (515)
vi.	Hapur - Babugarh	213 (500)
vii.	Surajpur - Kasna[46]	(300)
viii.	Sonipat - Bahalgarh	199 (200)
IX.	Baghpat - Agarwal Mandi	48 (113)
X.	Kithor - Shahjahanpur	44 (75)
xi.	Khairthal - Kishangarh	42 (40)
xii.	Hailey Mandi - Pataudi	32 (28)
xiii.	Tikri - Doghat	29 (41)
xiv.	Daurala - La war	29 (45)
XV.	Bahsuma - Hastinapur	29 (36)

7.3.2.3 'Functional Couple' Settlements

Combined Projected[47] Population in 2001 ('000 persons)
Figures shown in brackets refer to assigned population

xvi.	Modinagar - Mohiuddinpur/Rori - Meerut U.A.[48]	1500 (1550)
xvii.	Sikandrabad - Bulandshahr - Khurja[49]	336 (800)
xviii.	Rewari - Dharu Hera/Bhiwadi[50]	165 (300)

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44 **Using rate of growth of population between 1981-91 for existing towns; using rate of growth of population of the larger town in the pair for other settlements.**

45 **See NCR Planning Board, 1988, p.26; Deptt. of T&CP, Haryana, pp. 7.8-7.9; Deptt. of T&CP, U.P. pp.79-84.**

46 **This is already being developed as one urban complex for a population of 0.3 million in the year 2001 (see Deptt. of Town and Country Planning, U.P., pp.48).**

47 **Using rate of growth of population between 1981-91 for existing towns; using rate of growth of population of the larger town in the pair for other settlements.**

48 **See NCR Planning Board, 1988, p.26, for population assigned to Meerut.**

48 **Bulandshahr and Khurja were conceived as corridor towns in both the first and the second plan for the region (see TCPO, 1971 and NCR Planning Board, 1988). This complex is being designed for a total population of 0.8 million in the year 2001 (see NCR Planning Board, 1988, pp. 26). It is proposed to add Sikandrabad in this corridor.**

50 **This is already being developed as one complex for a target population of 0.3 million in the year 2001 (see NCR Planning Board, 1988, pp.26). Town of Sidhrawali is expected to join this complex.**

7.3.2.4 'Insular' Settlements

All other (census) towns and potential (census) towns from tables 7.2, 7.5a and 7.5b, not covered above. Figures in '000 persons, projected[51] for the year 2001. Figures shown in brackets refer to the assigned[52] population for the year 2001.

SETTLEMENT	POPULATION (2001)
ROHTAK	271 (500)
PANIPAT	264 (500)
PALWAL	"4 (300)
BARAUT	99 (100)
MAWANA	71 (100)
P1LKHUA	66 (150)
SARDHANA	61 (100)
DADRI	54 (50)
JAHANGIRABAD	49 (75)
KHEKRA	49 (50)
GULAOTHI	47 (50)
GO HAN A	40 (50)
SIANA	39 (75)
SHUCARPUR	39 (75)
HODAL	35 (30)
GARHMUKTESHWAR	35 (100)
DEBAL	34 (50)
JHAJJAR	3; (32)
JEWAR	29 (75)
GANAUR	26 (25)
ANUPSHAHR	25 (100)
SAMALKHA	25 (22)
NARAURA	25 (75)
ATSENI+BAIT+BIH UNI	24
BEHROR	22 (25)
TAORU	22 (16)
AURANGABAD	20 (25)
TUARA	19 (25)
MAHAM	19 (20)
UCHAGAON + AMARGARH	-.9
PAHASU	19 (25)
CHHAPRAULI	19 (25)
PHALAUDA	18(25)
SOHNA	18 (20)
KALANAUR	17(17)
PASAUNDA	17
SALARPUR KHADAR	17
PARIKSHITGARH	16(25)
FEROZEPUR JHIRKA	16 (20)
BERI	15
KHANPUR	15
BAHIN+KOT	14
BUGRASI	14 (18)
KARNAWAL	12(25)
RABUPURA	12 (20)
B"BAHADUR NAGAR	12 (20)
PUNAHNA	12 (12)
KHARKHODA	12 (20)
CHHATARI	11 (12)
DANKAUR	11 (50)
BAWAL	10 (20)
AMINAGAR SARAI	10 (20)
JAHANGIRPUR	10
FARRUKH NAGAR	10 (10)
KHERI SAMPLA	10 (10)
DUJANA	10
HASSANPUR	10 (10)
HATHIN	9 (10)
NUH	9
SHAHAJAHANPUR	9(20)
BILASPUR	8
AS AN KHURD	8
KAKOD	8 (6)
PINAGWAN	7 (8)
TAPOOKRA	6

51 Rate of growth of population between 1981-91 for existing towns; and rate of growth of population of the NCR between 1981-91, i.e., 38%, for other settlements used.

52 See NCR Planning Board, 1988, p.26; Deptt. ofT&CP, Haryana, pp.7.8-7.9; Rajasthan, pp.52-53; U.P. pp.79-84.

Settlement pattern for the region, as predicted[53] (by application of conventional methods) for the year 2001 and as recommended (by application of methods developed in this research) for the same year is illustrated in Maps 7.5 and 7.6 respectively.

It may be noted (Map 7.6) that the river Hindon and vast marshy land separate the 'assemblages' (i) and (ii). It should also be noted that Meerut U.A. forms a 'functional couple' (xvi) with the 'assemblage' (iii) and the 'couple' (xiv). Similarly, Rewari forms a 'functional couple' (xviii) with the 'assemblage' (iv).

7.4 OUTCOME OF THE MODELS

The proposed models provide a basis for political decisions based on social, economic and environmental considerations. The models do so not only by providing numbers of scenarios like the scenario developed in section 7.3.2 but also by focusing the attention of decision makers on physical reality rather than administrative (e.g., municipal) boundaries. By doing so, use of the models may be expected to lead to two general advantages:

i. increased awareness of the need for coincidence between physical and administrative boundaries; and

ii. increased awareness of the need for coincidence between physical boundaries and the survey plan for the census.

7.4.1 Advantages

Planning, by nature, is a formal activity influenced by formal instruments (e.g., legislation). This shapes the way the citizens, their political representatives and governments perceive human settiements. This perception is evident in the form of 'municipality', 'census town', 'revenue village', etc. There is evidence that this perception, when translated into planning, does not work as intended. Instead, a reality takes place on the ground. New means are, therefore, required so that the reality can be translated into a formal perception and be incorporated into the legislative structure in a standard format.

That means is available through this model, whereby various agencies can come to the same formal and standard realisation of the reality. It, then, becomes capable to be integrated as a system of measurement in the legislation. As a result, reality rather than administrative abstraction can become the basis for planning and management of human settiements.

Specifically, the models have the following advantages.

1. The models do not rely on 'point location' based aggregate data, and therefore on 'point patterns', for analyzing settlement patterns. In stead, they take into account

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53 **Census villages (in 1991) located in the NCT of Delhi, identified to become census towns (in 2001) excluded from this illustration.**

existing or potential 'assemblage' human settlements. This ensures that area is considered in analyzing settiement patterns.

2. The models look beyond administrative boundaries, treating human settlements as communities.

3. The models provide a framework for understanding, monitoring and describing existing patterns, and for making predictions and recommendations.

   The models take into account not only existing (census) towns but also the villages having a potential to become (census) towns within the planning period. This corrects a lacuna hitherto present in plans for the region (e.g., TCPO, 1974). Regional Plan 2001 leaves this task for the sub-regional plans (NCR Planning Board, 1988, p. 129). However, the sub-regional plans have not referred to the issue (see DDA, 1994; Deptt. of T&CP, Govt, of Haryana; Deptt. of T&CP, Govt, of Rajasthan, 1992; Deptt. of T&CP, Govt, of U.P.).

4. The models provide for periodic revision and updates corresponding to availability of two major sources of data (i.e., the census and satellite images).

5. The models utilize satellite images, which provide a comprehensive rendering of physical urban development. This enables the decision makers to take more realistic decisions.

6. To strengthen the decision making process, the models provide for generating alternatives. This is achieved by calibrating the operational definition of CBAs to different levels of generalisation and by using alternative set of rules for identification of 'assemblage' and 'coupled' settlements.

7. By adopting the method of identifying 'assemblage' and 'couple' human settlements, the models reduce the number of human 'settlements' to a more manageable number (from 191 projected census towns to 83 human settiements, in the case of the NCR). This removes some of the burden of the central planning agency (i.e., the NCR Planning Board), whilst it provides flexibility to local government in planning the human settiements under their jurisdiction, within the overall framework provided by the central planning agency. This has two positive implications:

   i. improved opportunity for local government to exercise the powers and responsibilities entrusted upon them by the recent enactment of the Constitution (Seventy-fourth Amendment) Act, 1992 (Government of India, 1993); and

   ii. improved utilization of resources (e.g., planning and managerial skills) of local government.

   Thus, the models provides a tool for decision makers, administrators and planners to re-define 'local' according to the spirit of the Constitution (Seventy-fourth Amendment) Act.

8. The models make use of IRS-1A and IRS-1B data with spatial resolution of 72.5m and 36.25m, which has been found to be apt for this purpose. It is noted that planning at the human settlement level requires higher spatial resolution (e.g., 5.8m of IRS-1C), and that these should be more accessible to local government.

9. Through a flexible approach in defining the human settlements and use of images from satellite, the models are readily applied in 'data-poor' situations, as is the case in many developing countries.

7.4.2 Limitations

The models have five limitations, which are discussed below.

1. The models make the assumption that villages tend to become urban. Whereas the assumption is true for many villages in the region, there are cases where villages are not growing because of emigration. To establish the number of these cases requires migration and growth data for each village.

   However, the focus of developing these models was on urban and urbanising settlements; therefore, some important villages were incorporated even if they did not show signs of becoming urban in the near future. Although there may be exceptions to the urbanisation rule, these exceptions were not deemed to significantly affect the overall validity of the model.

2. As mentioned above, the focus of developing these models was on urban settlements. In principle, the focus can be extended to include rural settlements, due to the availability of higher resolution data (e.g., from IRS-1C). However, use of the extended models should only be made at the sub-regional level because of the need for access to ground truth and related data.

3. Functional characteristics of different human settlements and interaction between them plays an important role in understanding the settlement pattern in a region. However, in practical terms, these cannot be deduced from satellite images under present sensor technology and interpretation techniques. The models, therefore, are limited to measuring the physical extent of human settlements, as visible on satellite images.

4. The models should not be seen as a replacement of traditional models drawing upon socio-economic and other relevant data. The models should be viewed as complimentary to existing models, and a means to bridge gaps created by the non-timely availability of census and other data.

5. Application of 'area patterns', though found more useful than 'point patterns' (see section 7.2.1), is liable to inconsistency, error and bias in the absence of full automatization in its present state.

7.5 APPRAISAL OF THE MODELS WITH RESPECT TO THE REGIONAL PLAN 2001

The regional plan for the NCR became effective on November 3, 1988 (NCR Planning Board, 1988). Two developments, significant to the planned development of the region, have occurred since. One, conferring the status of a State to Delhi (The Government of National Capital Territory of Delhi Act, 1991[54]) and two, the enactment of the Constitution (Seventy-fourth Amendment) Act, 1992 (Government of India, 1993). These developments will make their own contributions to shaping the development of the region. These contributions are not discussed here. Various national policies[55] have also influenced in shaping the region and will continue to do so.

Aims, goals, objectives and tasks specified in the regional plan include the following:

1. "The two important goals to be achieved by the Regional Plan are a balanced and harmoniously developed region, leading to dispersal of economic activities and inmigrants to Delhi, thereby leading to a manageable Delhi." (Foreword to the Regional Plan by the Minister of Urban Development, Government of India; p.iv.);

2. "We need,..development policies, programmes and plans aiming to:...remodel the pattern of settiements in the National Capital Region to enable them to play their assigned role." (p.ix);

3. "The prime objective of the Regional Plan is to contain Delhi's population size within manageable limits.., it is necessary to moderate the growth in the areas around it." (p. 10);

4. "A spatially and functionally articulated settlement system has to be evolved with purposive development of urban areas of the Region beyond DMA to meet the objective of controlling the growth of Delhi and achieving balanced development of the Region." (p.23);

5. "...to integrate them (the regional urban centres) in a well-knit system of settiements with specific functions to encourage an orderly development of economic activities and increase their complementarity." (p.23);

6. "...the development of small urban centres and villages should be integrated in relation to priority towns[56] to achieve the objective of balanced development of the Region. These could be achieved by developing a four tier hierarchical system of settlements..." (pp.23-24, footnote added);

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54 **Effective as on January 2, 1992 (Goyel, 1993).**

55 **See Gnaneshwar (1995) for a comprehensive review of various urban and urbanisation policies in India.**

56 **Meerut, Hapur, Bulandshahr-Khurja, Palwal, Panipat, Rohtak, Rewari-Dharuhera-Bhiwadi and Alwar (NCR Planning Board, 1988, p.26).**

7. "The main issue to be resolved is about dovetailing the planning and development in the rural areas along with urban areas. The concept of the development of the NCR...has to integrate and harmonize the development of the rural areas also." (p.117); and

8. "future urban and major rural settlements indicating their areas, projected population, predominant economic functions, approximate site and location;" (p. 129).

Concerning the Regional Plan 2001, it is important to understand that the National Capital Region is a nodal region. It has been conceived, delineated and planned as a region with Delhi as its node. By virtue of its nature, as a capital region, it will continue to be a nodal region. Therefore the term 'balanced and harmonious development' should not be misinterpreted.

The functional classification of the (census) towns based on the 1981 census (see Table 7.2) shows that more and more towns are assuming diverse functions and being labelled as 'others'. Therefore, the identification of a system of human settlements with specific functions seems to be a rather difficult task. Moreover, the present system of allocating functions to individual towns is not in conformity with the objective of 'integration', which is discussed below.

Integration of the development of small urban centres and villages in relation to priority towns is a recognised objective. However, this objective is defeated by adopting a hierarchical system of settlements, thereby dealing with a service centre as being distinct and separate from a regional centre. Adopting the concept of CBAs, delineated on the basis of satellite images regardless of settlement's urban/ rural character, promotes the desired integration.

In this context, an important statement from the regional plan deserves mention here. "In our democratic system, migrants do not feel bound by physical boundaries of the States while our administrative, development planning and resource allocation systems operate within the limits of territorial boundaries. The operation of this system...has acted as an obstacle in the integrated and balanced development of the Region..." (NCR Planning Board, 1988, p.vii). The proposed models address this obstacle by adopting a real world definition of human settlements, providing periodic revisions (through satellite images), and by recommending formation of couple human settlements where this is relevant. By adopting reality-based definitions of human 'settlements', the models take into account informal and fringe area developments, which are generally overlooked by adhering to the administrative boundaries.

Conferring the status of a State to Delhi (The Government of National Capital Territory of Delhi Act, 1991) and the enactment of the Constitution (Seventy-fourth Amendment) Act, 1992 (Government of India, 1993) will not only play a role in shaping the future development of the region but also effect its management structure. Although it is beyond the scope of this research to develop management aspects of the proposed models, it is important to quote a statement from the regional plan in this context. "A review of the existing planning and implementation arrangements shows a varied pattern in the three participating States and the Union Territory of Delhi (since renamed as the National Capital Territory of Delhi). However, none of the existing arrangements has been found to be fully compatible to fulfil

the needs of taking up the balanced and integrated development of the concerned Sub-regions at the field level, which could encompass both the rural and urban areas." (NCR Planning Board, 1988, p. 116).

7.6 FURTHER WORK

In research, the horizon recedes as one advances (Pattison, 1891). On the horizon of this research the following topics for further research have been identified.

1. Identification and/or development of standard techniques of image processing and enhancement that could be applied universally in the region, thereby promoting opportunities for automatization.

2. Automatization of the image interpretation and delineation of 'assemblage' and 'couple' human settiements to ensure consistency.

   Steps 1 and 2 above will reduce the time input, thereby freeing time for analysis.

3. Automatization of 'point' and 'area' pattern recognition techniques, based upon the proposed delineation, so that the entire process, from satellite raw data to the pattern recognition, can be automated.

   Exploitation of the techniques of (spectral) pattern recognition and (spectral) clustering presently used in the digital image processing; for recognizing, classifying and analyzing spatial settlement patterns might bring useful results.

4. Extension of the models to include other human settiements (i.e., villages) in the region and, ultimately, other regions.

   Steps 1-4 require the adoption of a set of rules, based on case studies. Sample surveys for establishing ground truth will be required. Automation of the balance of the process will enable scenarios to be generated more often, thus providing inputs, on a more frequent basis, for taking planning decisions.

5. Undertaking of research after a modification of existing concepts of density of population in urban areas, so as to be better prepared to address problems arising from potential increases in urban population densities in the region and beyond.

Table 7.1 POPULATION AND GROWTH RATE OF TOWNS IN THE NATIONAL CAPITAL TERRITORY (NCT) OF DELHI

S. NO.	NAME OF TOWN	POPULATION in 1991	GROWTH RATE 1981-91
1.	DELHI CITY	7.602,394	45
2.	SULTAN PUR MAJRA*	111,567	99
3.	PALAM*	98,975	187
4.	BHALSAWA JAHANGIRPUR*	95,065	35
5.	NASIR PUR*	81,366	235
6.	NANGLOI JAT*	76,063	102
7.	GOKAL PUR*	49,186	228
8.	BABAR PUR*	47,451	116
9.	BIND A PUR*	36,148	289
10.	TIGRI*	34,416	99
11.	DEOLI*	33,214	473
12.	PATPARGANJ (Gharonda Neem Ka)*	22,945	299
13.	MOLAR BUND*	19,629	268
14.	JAFFARABAD*	17,492	S
15.	MUNDKA*	17,380	;40
16.	PUL PEHLAD PUR*	14,343	63
17.	DICHON KHURD*	13,870	170
18.	RAJKORI*	11,766	104
19.	SULTAN PUR*	8,365	100
20.	NANGAL DEWAT*	7,657	-3
21.	GHITORNI*	6,254	33
22.	TAJ PUL*	5,882	19
23.	AYA NAGAR*	4,405	-7
24.	RANG PURI*	3,251	-23
TOTAL DELHI URBAN AGGLOMERATION		8,419,084	49
25.	BAWANA**	18,999	50
26.	ALIPUR**	9,256	37
27.	POOTH KHURD**	8,293	16
28.	KANJ HAWALA**	6,100	18
29.	ASOLA**	5,061	-2
30.	PEHLAD PUR BANGER**	4,832	-3
TOTAL NATIONAL CAPITAL TERRITORY OF DELHI (URBAN)		8,471,625	49

* Included in Delhi Urban Agglomeration. These towns experienced an average Growth Rate of 118% between 1981-91.

•* Not included in Delhi Urban Agglomeration but located within National Capital Territory of Delhi. These towns experienced an average Growth Rate of 25% between 1981-91.

Source(s):

for population and rate of growth - Census of India, 1991;
for location - DDA, 1994.

Table 7.2 POPULATION, GROWTH RATE AND FUNCTIONAL CLASSIFICATION OF TOWNS IN THE NATIONAL CAPITAL REGION (NCR) OF DELHI
(Arranged in descending order of population in 1991)

NAME OF TOWN	POPULATION in 1991®	GR.RT.Q 1981-91	FUNCTIONAL CLASSIFICATION-J (Based on 1971-81 Census*
DELHI U.A.****(61)	8,419,084	46	Others
MEERUT U.A.(61)	849,799	58	Others, Industry
FARIDABAD(61)	617,717	S6	Industry, Others
GHAZIABAD U.A.(61)	554,506	93	Others
ROHTAK(61)	216,096	29	Others, Trade, Commerce
ALWAR(61)	210,146	44	Others
PANIPAT(61)	191,212	3S	Industry, Trade, Commerce, Others
NOIDA(91)	146,514	-	Industry**
HAPUR(61)	146,262	4:	Trade, Commerce, Industry, Others
SONIPAT(61)	143,922	31	Industry, Trade, Commerce, Others
GURGAON(61)	135,884	34	Others
BULANDSHAHR (61)	127,201	22	Others, Trade, Commerce, Industry
MODINAGAR(61)	101,660	29	Industry, Others
KHURJA(61)	80,305	\9	Industry, Trade, Commerce, Others
REWARI(61)	75,342	46	Trade, Commerce, Others, Industry
BARAUT(61)	67,705	46	Trade, Commerce, Industry, Others
SIKANDRAB AD(61)	60,992	41	Industry, Primary, Trade, Commerce
PALWAL(61)	59,168	25	Others, Trade, Commerce, Industry
BAHADURGARH(61)	57,235	52	Others, Industry, Others
MAWANA(61)	51,701	37	Diversified
PILKHUA(61)	50,162	32	Industry, Others
MURADNAGAR(61)	44,395	~0	Industry, Trade, Commerce, Primary-
SARDHANA(61)	42,980	42	Industry, Primary, Trade, Commerce
JAHANGIRABAD(61)	37,981	29	Primary, Industry, Trade, Commerce
LONI(81)	36,561	256	Others
KHEKRA(81)	35,191	40	Others
GULAOTHK61)	33,982	39	Trade, Commerce, Others
DADRI(61)	32,883	66	Others, Trade, Commerce,Industry
GOHANA(61)	32,496	24	Trade, Commerce, Primary, Others
BETA HAZIPUR(91)	30,360	-	-
SIANA(61)	29,888	33	Primary, Trade, Commerce, Others
SHIKARPUR(61)	29,197	35	Primary, Industry, Others
DEBAL(61)	27,721	23	Industry, Trade, Commerce, Primary
JHAJJAR(61)	27,693	14	Primary, Trade, Commerce, Others
HODAL(61)	25,635	36	Diversified
GARHMUKTESHWAR(61)	25,241	40	Primary, Industry, Others
BAGHPAT(61)	24,939	45	Primary, Others
KHAIRTHAL(71)	22,741	42	Primary, Trade, Commerce, Others
JEWAR(81)	21,376	39	Others
GANAUR(71)	20,952	27	Industry, Trade, Commerce, Others
ANUPSHAHR(61)	19,684	29	Others, Industry, Primary
KITHOR(81)	19,270	39	Primary
BAWANA**«(81)	18,999	50	Others
SAMALKHA(81)	18,384	35	Others
DASNA(91)	16,963	-	-
SOHNA(61)	16,348	12	Trade, Commerce, Industry, Others

NAME OF TOWN	POPULATION in 1991®	GR.RT.0 1981-91	FUNCTIONAL CLASSIFICATION (Based on 1971-81 Census*)
BEHROR(91)	16,238		-
CHHAPRAULI(81)	16,008	15	Primary
NARAURA(81)	15,652	63	Others
AURANGABAD(81)	15,402	32	Others, Primary
TUARA(81)	15,399	26	Others
BHIWADI(91)	15,285	-	Industry**
MAHAM(61)	15,083	28	Primary, Trade, Commerce, Others
HASTINAPUR(71)	15,081	29	Industry, Others
KALANAUR(81)	14,524	17	Others
BERI(61)	14,508	7	Primary, Others
LAWAR(81)	14,471	25	Primary, Others
SEWALKHAS(81)	14,402	40	Primary
PHALAUDA(81)	13,970	34	Primary
PARIKSHrTGARH(81)	13,677	20	Others
BEGUM BUDHANA(91)	13,509	-	-
HAILEY MANDI(61)	13,263	30	Trade, Commerce, Others
PAHASU(61)	13,127	45	Others
O.F. MURADNAGAR(71)	12,792	-2	Others
TIKR1(81)	12,784	12	Primary
TAORU(81)	12,534	Bl	Primary, Industry, Others
SHAHJAHANPUR(61)	12,443	40	Primary, Industry
FEROZEPUR JfflRKA(61)	12,413	32	Primary, Trade, Commerce, Industry
PASAUNDA(81)	12,387	-	-
DOGHAT(81)	12,309	22	Primary
KHANPUR(81)	11,420	37	Primary
PATAUDI(61)	11,278	33	Primary, Others
BUGRASI(61)	11,093	33	Primary, Industry, Others
KARNAWAL(81)	11,047	11	Primary
FARIDNAGAR(61)	10,940	20	Industry, Primary, Others
AGARWAL MANDI(81)	10,871	'.6	Primary, Others
DHARUHERA(91)	10,848	-	Industry**
RABUPURA(81)	10,769	19	Primary, Others
KHARKHODA(81)	10,550	21	Primary, Others
KALCHHINA(91)	10,373	-	-
DAURALA(81)	10,025	9	Primary
DANKAUR(61)	9,531	20	Others, Trade, Commerce, Industry-
ALIPUR***(81)	9,256	37	Others
PATALAt(81)	9,181	17	Primary
B. BAHADUR NAGAR(81)	9,101	34	Others, Primary
BAHSUMA(81)	9,060	14	Primary
BAWAL(61)	9,010	16	Primary, Others
NIWADI(81)	8,841	24	Primary
PUNAHNA(91)	8,679	-	-
R0RI(91)	8,473	-	-
POOTH KHURD***(81)	8,293	16	Others
AMINAGAR SARAI(71)	8,274	21	Industry, Trade, Commerce, Others
JAHANGIRPUR(81)	8,206	27	Primary, Others
CHHATARJ(81)	8,202	39	Primary
FARRUKH NAGAR (61)	8,046	26	Primary, Trade, Commerce, Industry
HATHIN(81)	7,863	19	Primary, Others
KHERI SAMPLA(91)	7,838	-	-
NUH(61)	7,492	25	Trade, Commerce, Others
DUJANA(91)	7,313	-	-
HASSANPUR(81)	7,130	39	Primary, Others

NAME OF TOWN	POPULATION in 1991®	GR.RT.Q 1981-91	FUNCTIONAL CLASSIFICATION.J (Based on 1971-81 Census*)
DUND AHERA(91)	6,767	-	-
BILASPUR(81)	6,127	31	Others
KANJHAWALA***(91)	6,100	-	-
KAK0D(81)	5,838	35	Others, Primary
ASOLA***(91)	5,061	-	-
PEHLADPUR BANGER«**(81)	4,832	-3	Others
BABUGARH(81)	3,581	49	Others

Notes:

Assandh, Bisokhar and Razapur were also listed as towns in the Census of India, 1991. However, their location could not be confirmed from any official source(s) and therefore omitted from analysis.

In case of varying spellings of town names from different data sources, the spellings used by the Census of India, 1991, have been adopted here.

(61) Declared a town in 1961 or before.
(71) Declared a town in 1971.
(81) Declared a town in 1981.
(91) Declared a town in 1991.

• Named as 'Patla' in the Topo-Sheet (Survey of India, 1980) and 'Patiala' in the regional plan (NCR Planning Board, 1988)

• Functional classification for 1991 not yet available.
A newly added town. Classification based on local knowledge.
*** Within the National Capital Territory (NCT) of Delhi.
•*** Delhi U.A. includes 23 towns other than Delhi (see Table 7.1).

Source(s):

® Census of India, 1991.
NCR Planning Board, 1988, pp. 140-142.
(61) TCPO, 1974, p.34.
(71) NCR Planning Board, 1988, pp. 140-142.
(81) NCR Planning Board, 1988, pp. 140-142.
(91) Census of India, 1991.

Table *73* TRANSPORT DEMAND FORECAST* BETWEEN CITY PAIRS**, 2001, NATIONAL CAPITAL REGION OF DELHI

S.No.	CITY PAIRS	NUMBER OF PASSENGER	
		BUS	RAIL
1.	DELHI - FARIDABAD	58,662	16,149
2.	DELHI - PALWAL	11,101	2,232
3.	FARIDABAD - PALWAL	17,692	8,344
4.	DELHI - SONIPAT	5,150	25,484
5.	DELHI - PANIPAT	4,426	5,113
6.	PANTPAT - SONIPAT	18,405	6,329
7.	DELHI - BAHADURGARH	20,317	15,811
8.	DELHI - ROHTAK	8,442	5,942
9.	BAHADURGARH -ROHTAK	9,096	4,988
10.	HAPUR - BULANDSHAHR	19,985	1,676
;;.	DELHI - REWARI	3,539	7,415
12.	PANIPAT - ROHTAK	3,140	1,008
13.	MEERUT - HAPUR	31,629	2,214
14.	GHAZIABAD - HAPUR	49,463	1,568
15.	MEERUT - GHAZIABAD	23,286	3,978
16.	DELHI - MEERUT	17,240	11,508
17.	DELHI - GHAZIABAD	101,669	51,164
18.	DELHI - HAPUR	21,018	2,500
19.	MEERUT - BULANDSHAHR	13,771	2,145
20.	SONIPAT - ROHTAK	639	-
21.	FARIDABAD - ROHTAK	904	-
22.	BAHADURGARH - REWARI	212	-
23.	GHAZIABAD - BULANDSHAHR	28,672	-

* Based upon:

i. Demand for travel by bus and rail between the city pairs.

ii. Population and manufacturing employment in the cities under study.

iii. Travel time and travel cost by bus and rail, including access time, waiting time, access cost and fare of the travel.

** Out of the 64 possible city pairs in the region, only above mentioned city pairs were considered to be significant.

Source: Baig, 1991, pp.75-76.

Table 7.4 POPULATION AND RATE OF GROWTH OF CORRIDOR TOWNS (EXCLUDING DELHI) IN THE NATIONAL CAPITAL REGION OF DELHI

CORRIDOR NO.	TOWNS INCLUDED	POPULATION 1991	GR.RT. 1981-91
	Ghaziabad, O.F. Muradnagar, Muradnagar, Begum Budhana, Kalchhina, Modinagar, Rori, Meerut U.A., Daurala	1,605,712	6
II.	Ghaziabad, Dasna, Pilkhua, Hapur, Babugarh, Garhmukteshwar	796,715	77
III.	Ghaziabad, Dujana, Dadri, Sikandrabad, Bulandshahr, Khurja	863,150	65
IV.	Faridabad, Palwal, Hodal	702,520	77
V.	Gurgaon, Dundahera, Dharuhera, Bhiwadi, Bawal, Behror	351,631	224
VI.	Gurgaon, Sohna, Nuh, Ferozepur Jhirka, Alwar	382,283	39
vn.	Bahadurgarh, Kheri Sampla, Rohtak, Maham	296,252	37
vm.	Sonipat, Ganaur, Samalkha Panipat	374,470	35
IX.	Loni, Beta Hazipur, Khekra, Agarwal Mandi, Baghpat, Baraut	205,627	90
X.	Panipat, Gohana, Rohtak	439,804	33
XI.	Meerut U.A., Kharkhoda, Hapur, Gulaothi, Bulandshahr, Khurja	1,248,099	4S
All Corridor Towns (excluding Delhi and other towns in the National Capital Territory of Delhi)		4,241,915	S7
Rest of the Towns (excluding Delhi and other towns in the National Capital Territory of Delhi)		990,766	55

Source(s):

Corridors identification based on TCPO, 1974; NCR Planning Board, 1988 and Baig, 1991.
Population and growth rate compiled from Census of India, 1991.

Table 7.5a LIST OF VILLAGES (IN 1991) IDENTIFIED AS POTENTIAL* TOWNS (IN 2001)

NAME •	POPULATION* (1991)
DALLO PURA*	56,783
QARAWAL NAGAR*	47,455
IIASTSAL*	39,596
KIRARI SULEMAN NAGAR*	33,421
MUSTAFA BAD*	32,225
POOTH KALAN*	28,767
SAHIB ABAD-DAULATPUR*	27,343
NAWADA MAJRA HASTSAL*	18,100
BURARI*	17,587
CHILLA SARODA BANGAR*	16,460
DABRI*	16,405
KHAJOORI KHAS*	16,334
PANIPAT TARAF ANSAR®	14,953
SALWANV	14,803
BHATI*	14,326
MAT I ALA*	14,002
DHAROTI KHURD	13,324
KONDLI*	13,317
PALWAL (RURAL)®	12,469
SALARPUR KHADAR	12,338
PANIPAT TARAF MAKHDU®	12,078
CHATTAR PUR*	11,815
JHARODA KALAN*	11,685
MIRZAPUR*	11,577
GHAROLI*	11,187
MIR PUR TURK*	11,135
NAHRI	10,196
BANKNER*	10,152
SADATPUR GUJARAN*	9,967
BIJWASAN*	9,439
MITHEPUR*	9,212
LADRAWAN	9,108
QAMURUDDBS NAGAR*	8,356
KAKROLA*	8,284
SONIPAT (RURAL)®	8,193
RAMGARH	8,111
KAPAS HERA*	7,815
QUTAB GARH*	7,734
CHHAWLA*	7,521
SIRAS PUR*	7,441
DUNDA HEDA	7,357
LIBAS PUR*	7,313
KHERA KHURD*	7,182
REWARI (RURAL)®	7,111
KISHANGARH	6,801
DAYAL PUR*	6,607
ASAN KHURD	5,972
JIWAN (JOHART) PUR*	5,937

NAME •	POPULATION* (1991)
SUKHRALIV	5,538
SIKRI KHURDV	5,360
SHAHABAD MOHD. PUR*	5,206
P1NAGWAN	5,033
JONA PUR*	4,903
GHEORA*	4,883
ZIAUDDIN PUR*	4,830
SIDHRAWALI	4,760
SANOTH*	4,756
JHARODA MAJRA BURARI*	4,742
BEGUM PUR*	4,734
KHANDSA	4,634
DARYAPUR KALAN*	4,616
SAMBHALKA*	4,605
SAIDUL AJA1B*	4,488
TAPOOKRA	4,471
NANGAL THAKRAN*	4,447
GHOGHA*	4,357
PANIPAT TARAF RAJPUTAN®	4,355
SAHOTI	4,343
MOHIUDDINPUR	4,270
SANKHOLV	4,177
TILPAT	4,144
LAD PUR*	4,142
SAGAR PUR*	4,112
AMINAGAR urf BHUDBARAL V	4,022

Notes:

These villages, in 1991, had a population of more than 4,000 persons, a density of more than 340 persons per sq. km and more than 70 per cent of their male working population engaged in non-agricultural and allied activities.

* Within the National Capital Territory (NCT) of Delhi.

@ These are expected to merge with their urban counterpart and therefore not identified as separate potential villages.

V Location of these villages could not be confirmed from any official source and therefore omitted from analysis.

Source(s):

Potential identified by the author.

- Population, density and employment data obtained from Census of India, 1991. Industrial categories I, II and III were treated as agricultural and allied activities.
- Names for the villages located in the National Capital Territory of Delhi taken from (DDA, 1994, pp.74-78). Others from the Census of India, 1991.

Table 7.5b LIST OF ADDITIONAL VILLAGES (IN 1991) IDENTIFIED AS POTENTIAL* TOWNS (IN 2001)

NAME(S) OF VILLAGE(S)	POPULATION (1991)	DENSITY p/sq.km	% MALE WORKERS IN Non-Agriculture Sector
ATSENI V	7,656	*960*	36
BArr v	7,303	928	27
BIHUNI V	2,543	667	18
UCHAGAON •	8,755	1,314	39
AMARGARH •	5,023	826	23
BAH IN*	5,154	437	14
KOT +	5,475	30"	35
BAHALGARH *	1,911		83
RATHDHANA A	6,201	634	44
SHAHAJAHANPUR	6,713	365	46

Notes:

I These villages were selected because they satisfied the criteria of CBA and were found to be predominantly located while interpreting the satellite images.

V These villages are expected to form one town, under the name shown in bold letters.

• These villages are expected to form one town, under the name shown in bold letters.

• These villages are expected to form one town, under the name shown in bold letters.

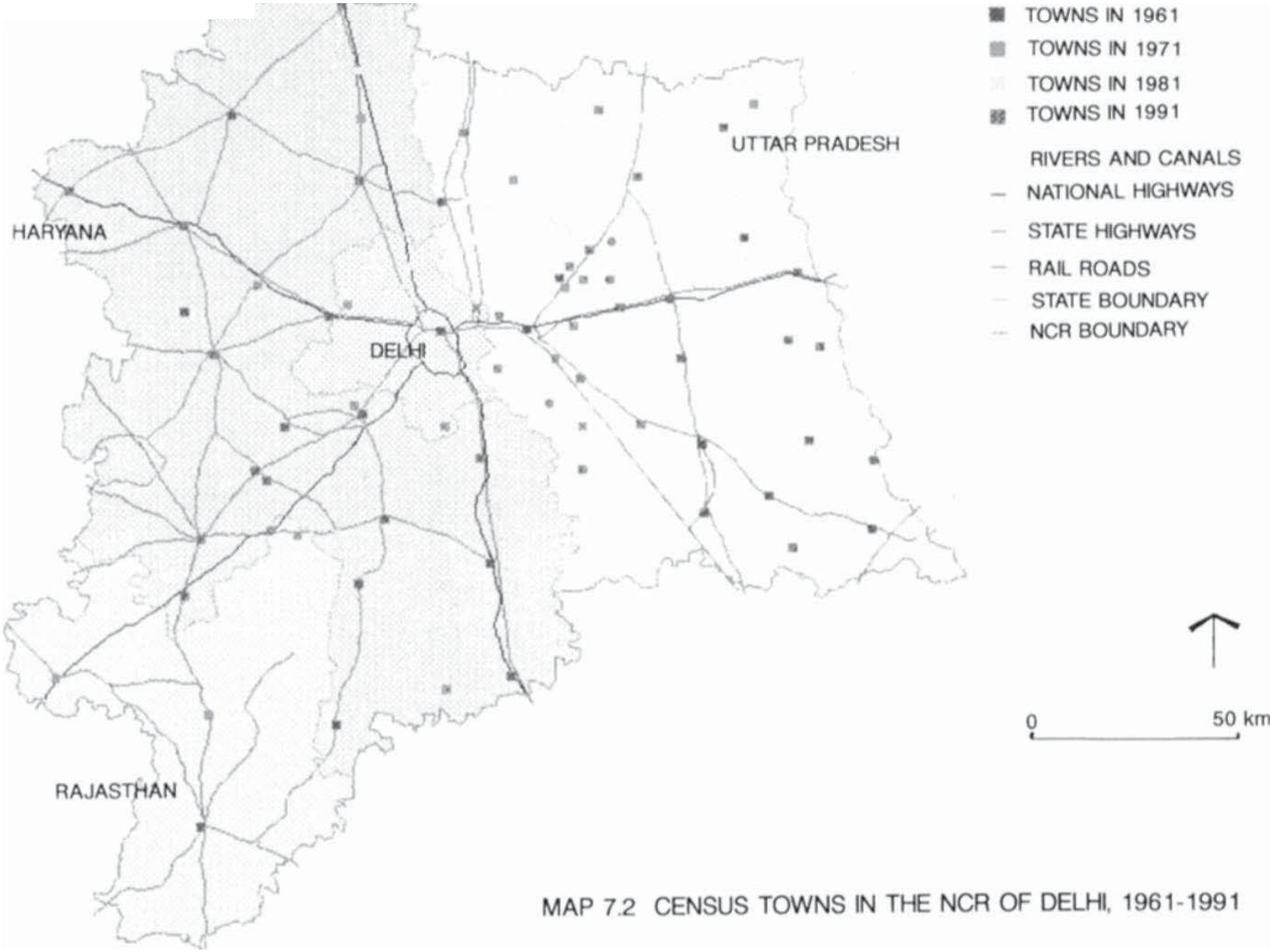
• These villages are expected to form one town, under the name shown in bold letters.

Source:

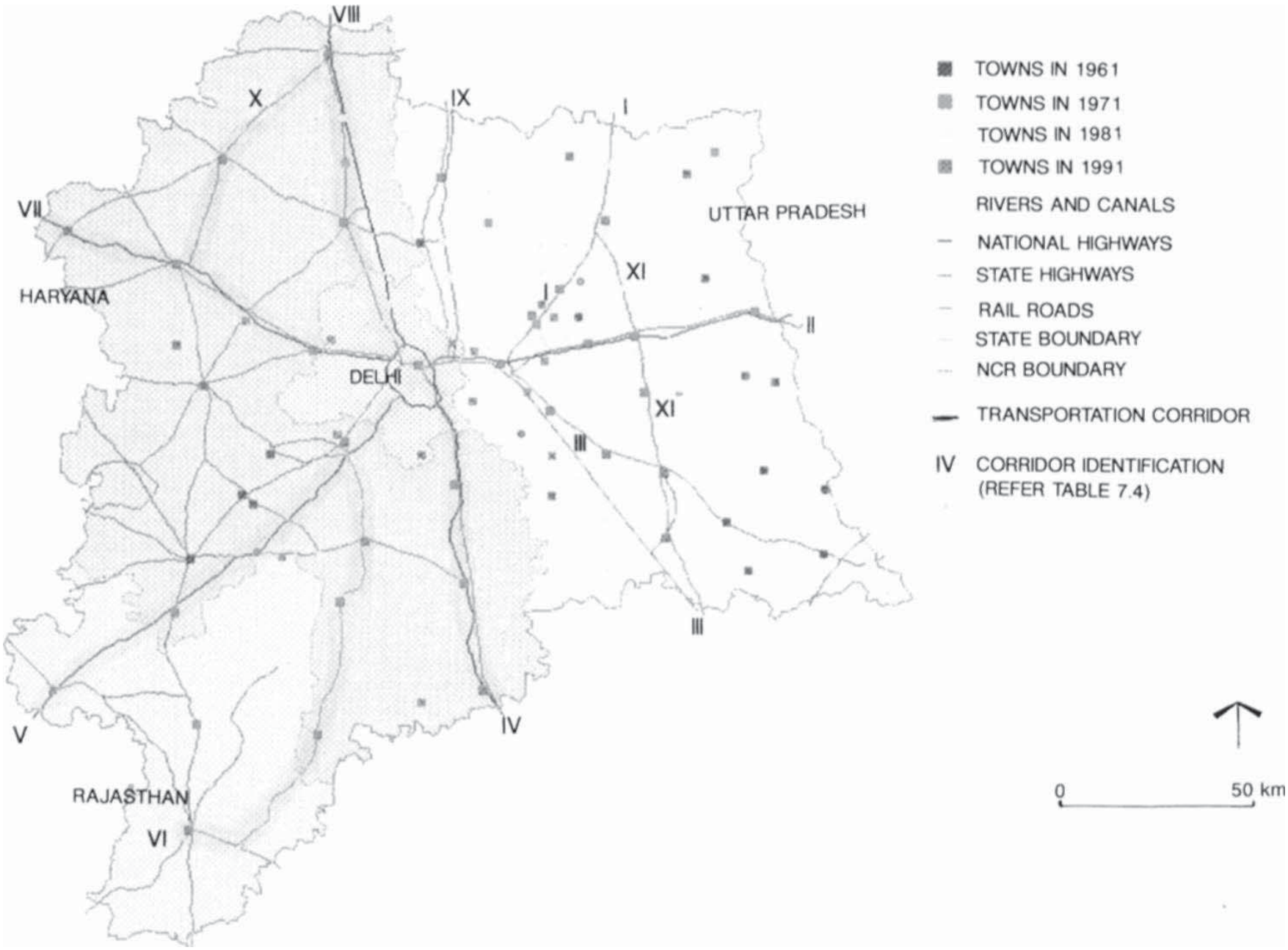
Potential identified by the author.

Population, density and employment data obtained from Census of India, 1991. Industrial categories I, II and HI were treated as agricultural and allied activities.

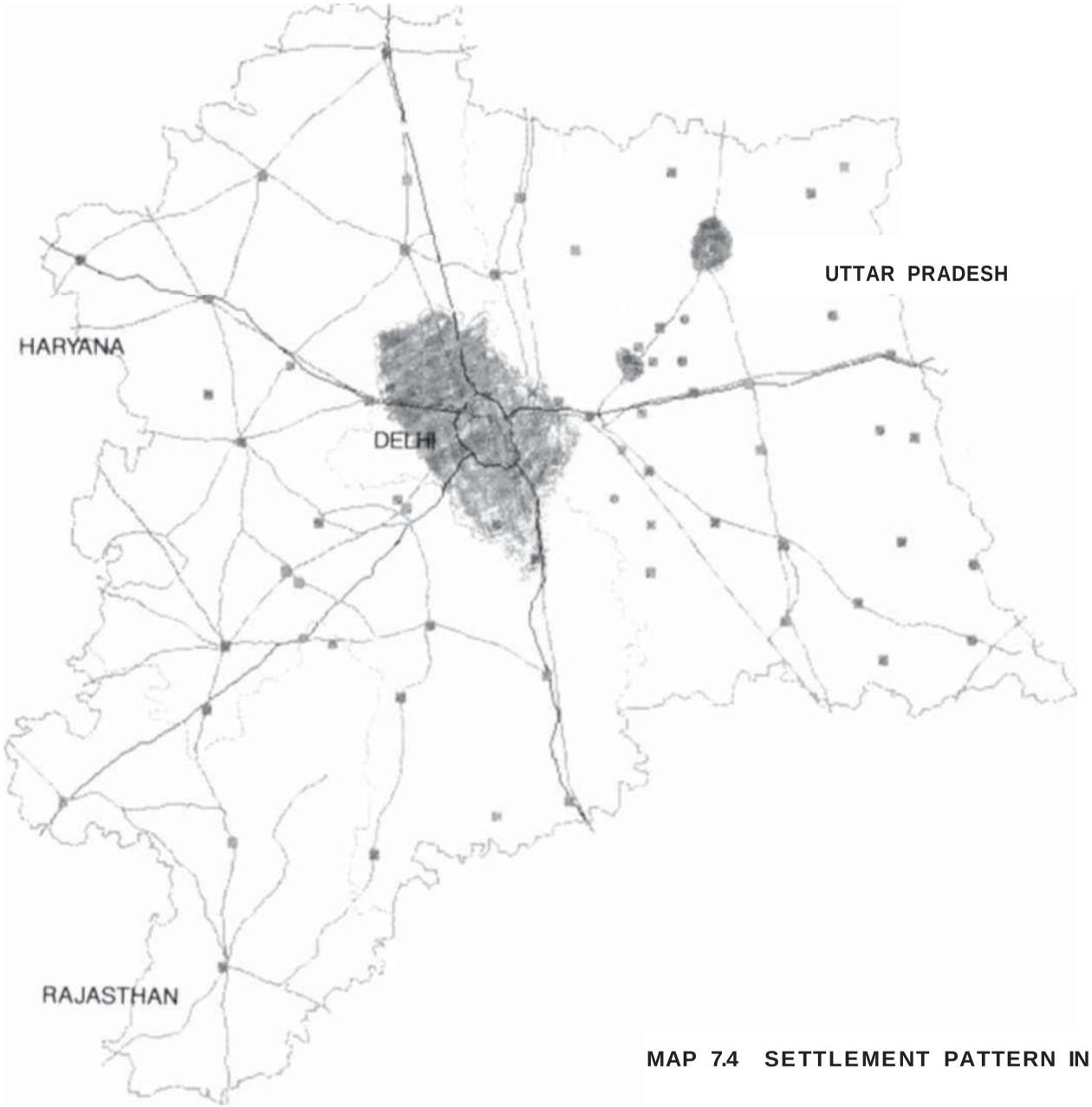
MAP 7.1 CENSUS TOWNS IN THE NCT OF DELHI, AND IN THE DMA, 1991-2001



MAP 7.2 CENSUS TOWNS IN THE NCR OF DELHI, 1961-1991



MAP 7.3 CENSUS TOWNS AND MAJOR TRANSPORTATION CORRIDORS IN THE NCR OF DELHI, 1991



tf TOWNS IN 1961

• TOWNS IN 1971

TOWNS IN 1981

• TOWNS IN 1991

RIVERS AND CANALS

- NATIONAL HIGHWAYS

STATE HIGHWAYS

RAIL ROADS

STATE BOUNDARY

NCR BOUNDARY

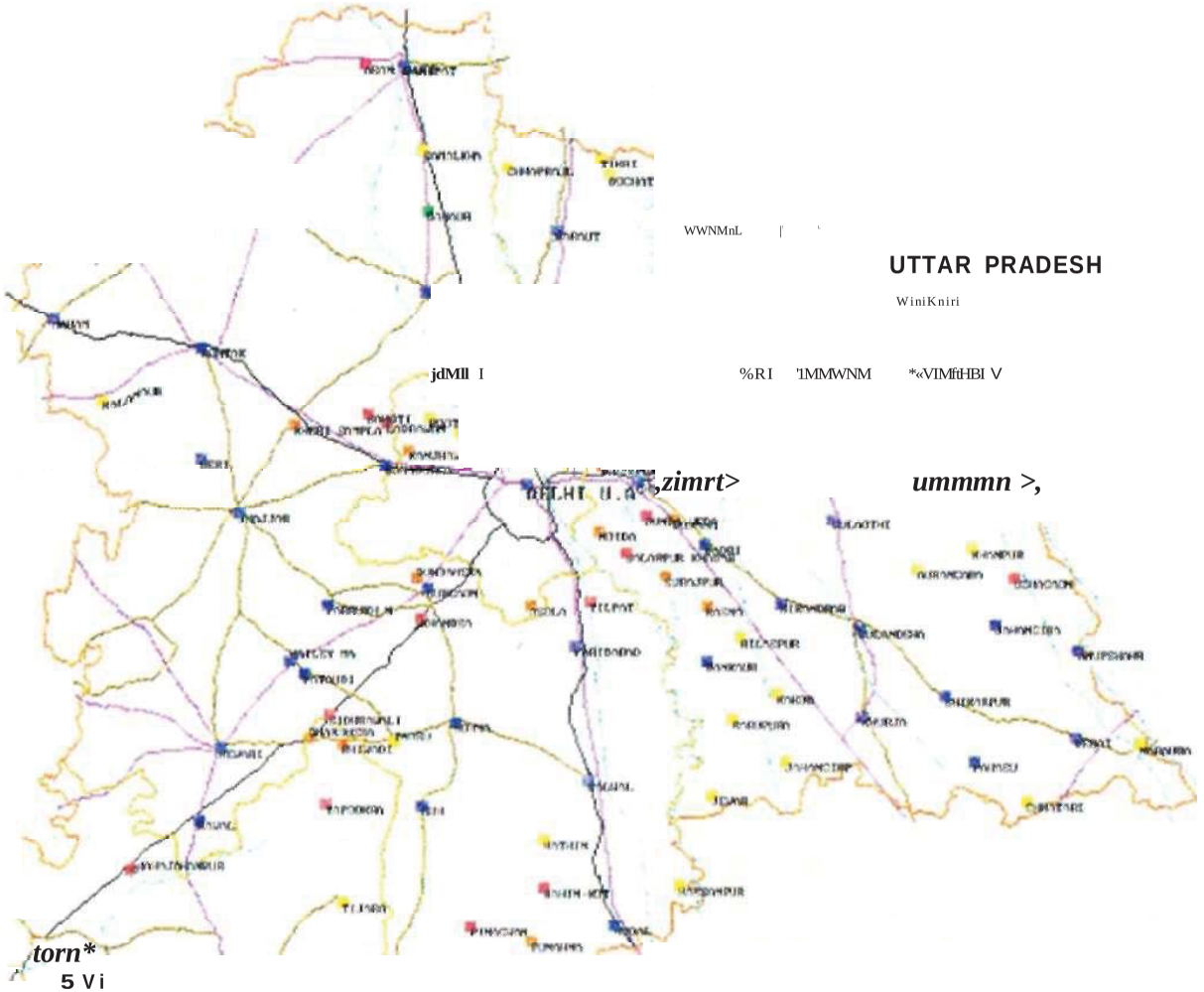
• 'ASSEMBLAGE' SETTLEMENTS

• 'COUPLE' SETTLEMENTS

T

50 km

MAP 7.4 SETTLEMENT PATTERN IN THE NCR OF DELHI, 1961-1991



W TOWNS IN 1961

• TOWNS IN 1971

TOWNS IN 1981

W TOWNS IN 1991

• TOWNS IN 2001 (PREDICTED)

RIVERS AND CANALS

- NATIONAL HIGHWAYS

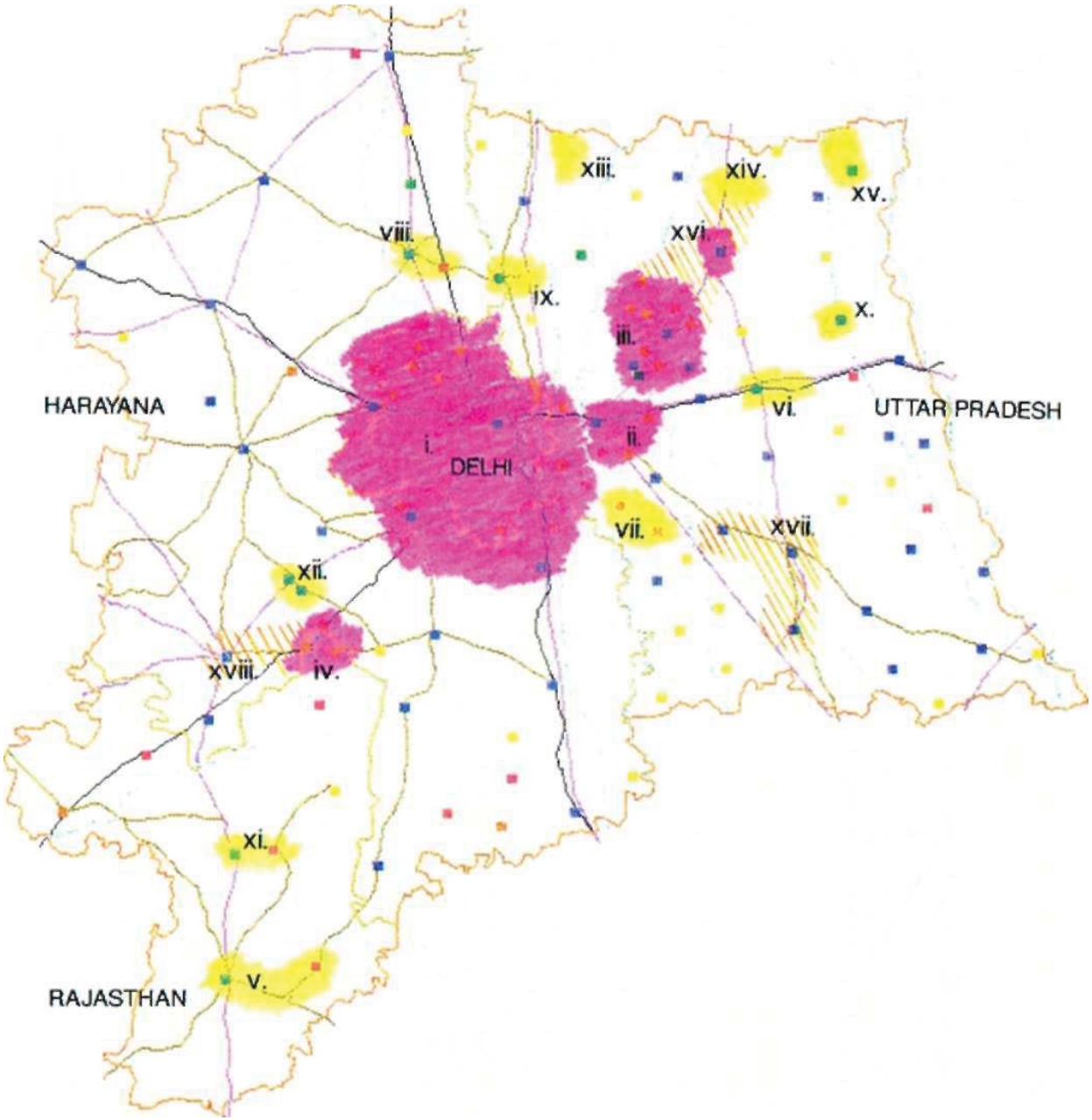
- STATE HIGHWAYS

RAIL ROADS

STATE BOUNDARY

NCR BOUNDARY

MAP 7.5 SETTLEMENT PATTERN FOR THE NCR OF DELHI, 1961-1991, 2001 (PREDICTED)



- TOWNS IN 1961
- TOWNS IN 1971

TOWNS IN 1981

TOWNS IN 1991

- TOWNS IN 2001 (PREDICTED)

RIVERS AND CANALS

- NATIONAL HIGHWAYS

STATE HIGHWAYS

- RAIL ROADS

STATE BOUNDARY

NCR BOUNDARY

'ASSEMBLAGE' SETTLEMENTS

- 'COUPLE' SETTLEMENTS
- 'FUNCTIONAL COUPLE' SETTLEMENTS

Xiv. SETTLEMENT IDENTIFICATION (SEE 7.3.2.1,2,3)

T

50 km

MAP 7.6 **RECOMMENDED SETTLEMENT PATTERN FOR THE NCR OF DELHI,** 2001

Appendix I

ILWIS CAPABILITIES[57]

1.1 User Interface

The design of the system takes into account that not all GISs users have a thorough knowledge of computers. All operations are therefore performed through a user-friendly menu, which allows the user to concentrate on application rather than on learning the intricacies of the system. Experienced users can, on the other hand, perform operations directly through commands and/or command files.

1.2 Data Input

A conversion program allows the import and export of remotely sensed data, tabular data, and raster maps and vector files from or to several other formats. Analogue data can be transformed into vector format by means of a user-friendly digitizing program, of which the 'on screen digitizing' (digitizing with any raster map or image as on-screen underlay) is one of the most important features.

1.3 Spatial Modelling

Complex modelling procedures can easily be executed by the 'MapCalculator'. The MapCalculator includes an easy-to-use modelling language and enables the use of mathematical functions and macros. It integrates spatial and tabular databases. Complex procedures can be executed rapidly on portions of study area on to video memory. After evaluation and assessment of the results, the procedures can be applied to the entire area. Tabular and spatial databases can be used both independently and on an integrated basis. Calculations, queries and simple statistical analysis can be performed by TableCalculator. Computational procedures and efficient use of the system are improved by the appropriate use of modelling processes. Not all analysis involves the use of spatial databases; whenever possible, knowledge-driven queries in the tabular database should take precedence over similar operations in the spatial database. Fast overlay procedures constitute one of the main characteristics of the system.

Extracted from ILWIS 1.4 User's Manual. ITC, 1993, Enschede, pp. 1.2-1.3. For more details refer to the Manual. See also ITC Journal. 1988-1; ITC, 1994; and ILWIS for Windows, March, 1996.

1.4 Image Processing

Image processing capabilities integrated with spatial modelling and tabular databases constitute a powerful tool. Together they enable analysis of data which has only recently been possible. ILWIS also incorporates conventional image processing capabilities such as filtering, geometric correction and classification procedures.

1.5 Special Features

For the interpolation of point data and contour lines, special programs are available to create DEMs (digital elevation models). Special filters and functions are available to produce slope and aspect maps. Functions and filters can also be defined by the user.

1.6 Data Output

The system supports black & white and colour hard copy output devices in either vector or raster format. It supports standard pen plotters, B&W and colour matrix printers and laser printers. Conversion routines from the ILWIS data formats to a number of other data formats (raster, vector, tabular) are provided.

1.7 ILWIS for Windows

ILWIS for Windows is an integrated object oriented geographical information and remote sensing system. It provides for display of raster, point, segment and polygon maps, as well as tables and graphs in zoomtable and scrollable windows. Display of multiple maps and annotation layers are provided in one map window. It also provides for simultaneous data retrieval of multiple maps and attribute tables.

Appendix II

PATTERN CURVES FOR FUNDAMENTAL PATTERN TYPES

Source: ITC, 1993, p.6.129.

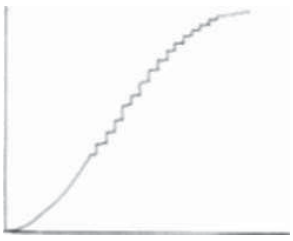
clustered

regular

I

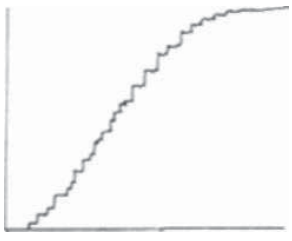
pAll

PATTERN CURVES FOR THE SETTLEMENT PATTERN IN THE NCR. 1991



Simulated CSR

As Existing



Simulated Regular

Appendix III

OPERATIONAL DEFINITION AND DELINEATION OF CONTINUOUSLY BUILT-UP AREAS IN THE NCR OF DELHI

HI.l THE RULES

m.1.1 Built-up Area

Topographical sheets from the Survey of India (see Appendix X) were available at a scale of 1:250,000, appropriate for the research objectives. These topo sheets show large built-up/ inhibited areas in red, in contrast to the general appearance of the topo sheets. All such filled areas were considered to be qualifying as 'Built-up Area' in the first instance. It was a class in dichotomy: built-up/ non built-up.

An 'exclusive' definition was applied: meaning that in case of doubts it was decided to be non built-up. As an example, an area showing urban road network - but not filled in red was assigned to be non built-up.

HI. 1.2 Minimum Curtilage

A minimum curtilage of 5mm x 5mm and a minimum width of 2.5mm was adopted to start with. However, subsequently the minimum curtilage adopted was 4mm x 4mm (terrain 1km x 1km or 100 ha) with a minimum width of 2mm (terrain 500m) (see III.2 also). Also the built-up areas along major roads (e.g., ribbon developments) were excluded if these were narrower than 2mm on the topo sheet. The application was carried out by preparing a template for the minimum curtilage and minimum width.

III. 1.3 Generalisation, Idealisation and Agglomeration

The minimum curtilage and the minimum width provide the standard for the minimum area to be delineated. The same standard was also followed for the generalization of the delineation. The line did not follow the outline of every small or narrow built-up parts but was generalized along important boundaries of built-up area or along the average boundary of built-up areas. The manual generalization process is though subjective, interactive and idiosyncratic, yet comprehensive in its perception and execution (Beissmann, 1993).

The technique of idealization was used to make a boundary between the two entities 'built-up' and 'non built-up', where in reality only a diminishing density of built-up area can be seen on the topo sheet. Here also the template of minimum curtilage and minimum width was used.

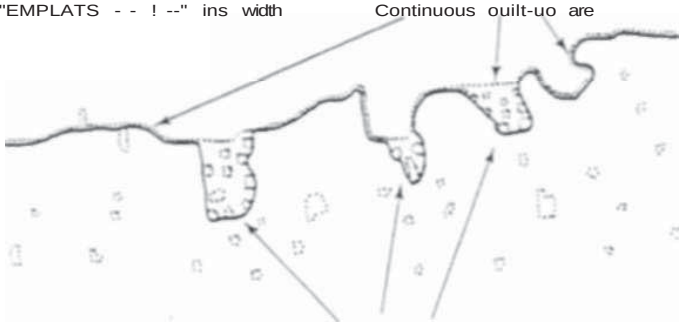
TEMPLATE minimum turtllaga and -rammum wBtn

A clot 2ig anougri :c -a csiireatBC

\ I I
Not -aaemng Tinimum width

Generalisation of the outline of the urban area.

"EMPLATS - - ! --" ins width Continuous ouilt-uo are



tee toe i/^n cc.-carv

Idealisation of the boundary of the ursac area.

TEMPLATE minimum curtllaga 5 mm x 5 mm minimum width 2.5 mm

n

Agglomeration' >'» Agglomeration? No
_arger than minimum curt I lags.) I Not reaching minimum width.

Agglomeration, ainiztua curtilage and ainunai width.

Source: **P0II6,** 1988, pp.**6-7**

A small built-up area (smaller than the minimum curtilage) is generally combined with a nearby built-up area, if the distance to that area is less than twice the diameter of the small built-up area (measured in the direction of that other built-up area). The process is repeated. The final delineation must fulfil the conditions of the minimum curtilage and the minimum width. The area delineated in this way should not contain non built-up areas larger than the minimum curtilage. However, no such agglomeration possibilities were encountered in the current exercise.

The above described rules were developed after Polle" (1988) and Mahavir and Galema (1991), with a possibility of being applied consistently while repeating the exercise on satellite images.

HI. 1.4 Other Rules

Two other situations were expected in the delineation of built-up areas. In the first situation, there are two distinct built-up areas, both separately satisfying the minimum curtilage but very close to each other. It was decided to combine them into one if the boundary to boundary distance between them was less than the minimum width criteria. As an illustration, eastern part of Delhi was separated from the main Delhi, because of the river Yamuna (wider than minimum width criteria). However, the same was combined with Ghaziabad, because the distance between the two was less than the minimum width criteria.

In the second situation, there is a distinct non built-up area, larger than the minimum curtilage criteria but surrounded by a built-up area also satisfying the minimum curtilage criteria. It was decided to ignore the inner non built-up area in this situation and take the boundary of surrounding built-up area. An illustration of this is central ridge area of Delhi surrounded by its main built-up areas.

There still could be a situation where a very large non built-up area is surrounded by a ring of built-up area. However, such a situation is neither present nor expected in the region under study.

Built-up areas thus obtained after application of all above mentioned rules were accepted as Continuously Built-up Areas (CBAs).

III. 1.5 Local Knowledge Biases

The author possesses considerably good local knowledge on the region. This may be viewed as a source of bias in application of above rules when the delineation is being done on topo sheets. The same can be eliminated by applying the rules very strictly and repeating the process by another qualified person not familiar with the region. The bias will be minimized, if not eliminated, during the computerized processing of satellite images. However, possession of local knowledge will be a valuable asset while interpreting the satellite images (Mahavir and Galema, 1991).

ni.2 DELINEATION

A minimum curtilage of 5mm x 5mm and a minimum width of 2.5mm was adopted to start with. Based upon the above rules, 17 CBAs were delineated[58] on the Survey of India topo sheets covering the region. While a few of the remaining human settiements were smaller than the minimum curtilage, a few others did not qualify the minimum width criteria.

It is interesting to note that the region had only 15 towns of population 20,000 and above in 1961 (TCPO, 1974). The figure stood at 19 and 30 in the years 1971 and 1981 respectively (NCR Planning Board, 1987). Survey of India topo sheets available are based on surveys carried out in the years 1965-75 (and printed in the years 1975-85). The time gap between surveying and printing ranged from 4 years to 20 years (see Appendix X). The results (on the number of delineated areas) obtained based on the operational definition of the CBAs are not far from the census definition of urban areas. The region had a total of 44, 48 and 94 towns in the years 1961, 71 and 81 respectively (TCPO, 1974; NCR Planning Board, 1987).

Based upon 1981 administrative boundaries, average area of a smallest category of town in the region was less than 3 sq.km (NCR Planning Board, 1987). This should, theoretically, enable delineation of all the towns on a topo sheet of 1:250,000 with the minimum curtilage criteria of 5mm x 5mm, i.e., 1.5625 sq.km. However, the actual inhibited area may be far less than the administrative boundary and not necessarily in a square shape. Moreover, area derived from the topo sheets of such a large scale will normally be less than the actual areas on ground due to the fractal effect.

The whole exercise when repeated with the minimum curtilage 4mm x 4mm, i.e., 1 sq.km, and minimum width 2mm, i.e., 500m, no additional CBA was possible to be delineated. Further reduction in minimum curtilage was difficult to handle both visually and physically.

Therefore, it can be concluded that from the point of view of Survey of India topo sheets at a scale of 1:250,000, operational definition of CBA is governed by a minimum curtilage of 4mm x 4mm, i.e., 1 sq.km, and minimum width 2mm, i.e., 500m. This curtilage was further used as training curtilage for the processing and interpretation of satellite images.

These were the areas representing the towns of Alwar, Bahadurgarh, Bulandshahr, Delhi, Faridabad, Ghaziabad, Gurgaon, Hapur, Khurja, Meerut, Palwal, Panipat, Rewari, Rohtak, Sikandrabad, Sohna and Sonipat.

Appendix IV

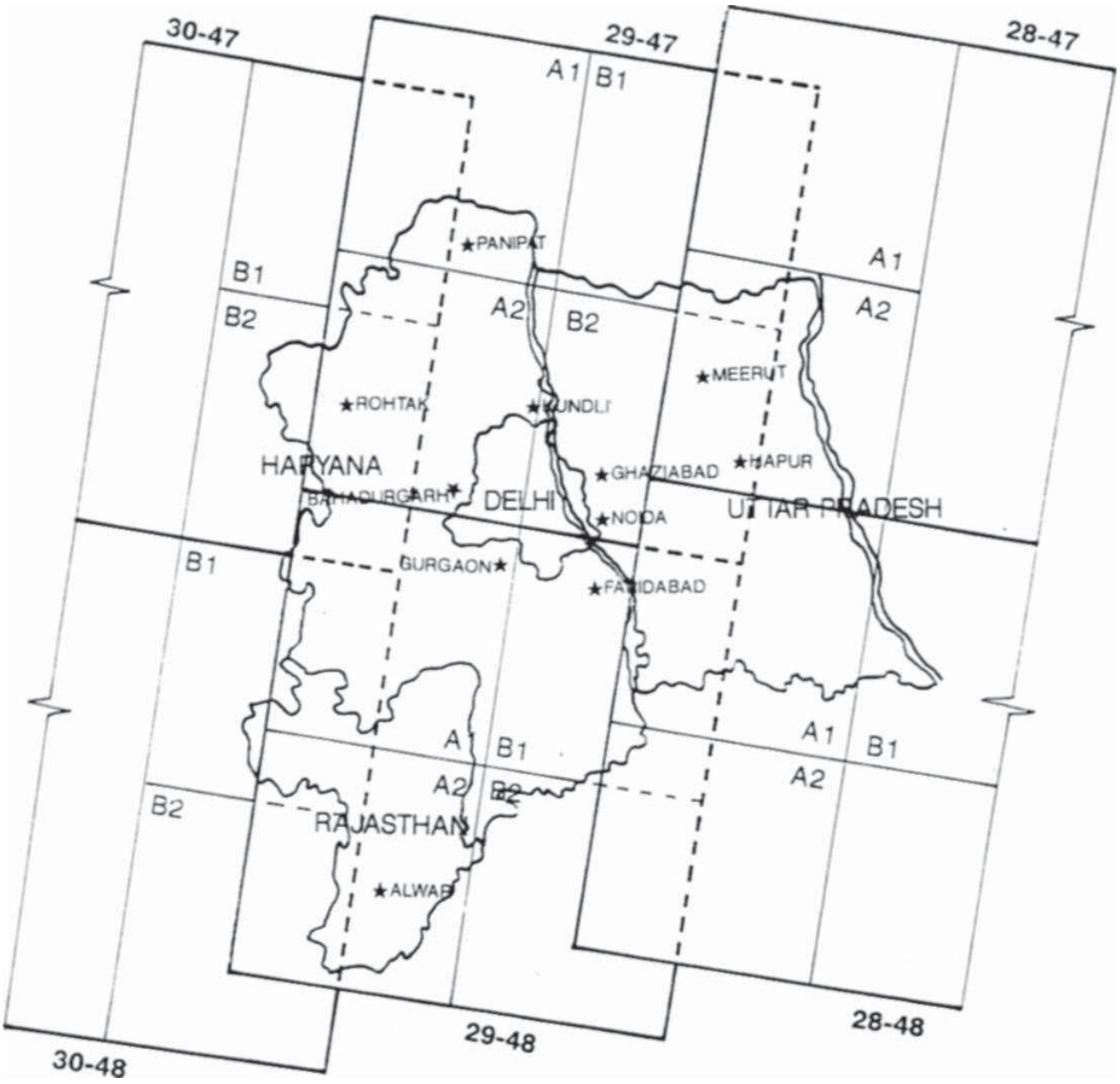
LIST OF SATELLITE DATA PRODUCTS USED L\ THE RESEARCH*

SI. No.	SATELLITE	SCENE PATH/ROW	SENSOR/ Sub-Scene	RESOLUTION	DATE	PRODUCT CODE**
1.	IRS-1A	2847	LISS-1	72.5m	04FEB91	STPC00277
2.	IRS-1A	28-48	LISS-1	72.5m	20MAR91	STPC00277
3.	IRS-1A	29^7	LISS-1	72.5m	23DEC90	STPC00277
4.	IRS-1A	29-48	LISS-1	72.5m	23DEC90	STPC00277
5.	1RS-1A	30-47	LISS-1	72.5m	28FEB91	STPC00277
6.	IRS-1A	30-48	LISS-1	72.5m	28FEB91	STPC00277
7.	IRS-1B	28-47	LISS-1	72.5m	06JAN94	STPC00277
8.	IRS-IB	28^8	LISS-1	72.5m	06JAN94	STPC00277
9.	IRS-1B	29^*7	LISS-1	72.5m	07JAN94	STPC00277
10.	IRS-IB	29-48	LISS-1	72.5m	16DEC93	STPC00277
11.	IRS-1B	30-47	LISS-1	72.5m	17DEC93	STPC00277
12.	IRS-1B	30-48	LISS-1	72.5m	17DEC93	STPC00277
13.	IRS-1A	28^*7	LISS-2/A2	36.25m	04FEB91	STPC00277
14.	IRS-1A	29^8	LLSS-2/A2	36.25m	23DEC90	STPC00277
15.	IRS-IB	28^7	LISS-2/A2	36.25m	06JAN94	STPC00277
16.	IRS-IB	29^*8	LISS-2/A2	36.25m	16DEC93	STPC00277

See also figure on next page for the coverage of each scene.

All products were Standard CCT, 6250 BPI, BSQ Format, 'Standard' data products with polyconic projection and cubic convolution resampling.

Coverage of the IRS 1-A and 1-B Scenes Used in the Study



———— Coverage of scenes with 72.5m resolution

Coverage of scenes with 36.25m resolution

28-47 Path/Row identification of the scene

B2 Quadrant identification of sub-scenes

Appendix V

COMPARATIVE FEATURES OF SOME OF THE GIS PACKAGES DEVELOPED AND PRODUCED IN INDIA*

PACKAGE	THEMAPS/ DIGITIZ	ISROGIS	NRDMS-LIS	GRAM	NIC-GIS
PACKAGE DEVELOPED BY	SRI, Pune ©	SAC, Ahemadabad •	NISTADS, New Delhi V	csre, rrr, Bombay •	NIC, New Delhi *
TYPE	Vector	Vector	Vector	Vector/ Raster	Vector
ENVIRON-MENT	MS-DOS	UNIX 5.3	MS-DOS	MS-DOS	Xenix/ SCO Unix
COMPUTER CONFI-GURATION	PC XT/AT 386	PC AT 386/ 486	PC XT/AT 386	PC XT/AT	PC AT 386
ESSENTIAL MEMORY	640 KB	8 MB	640 KB	640 KB	
ESSENTIAL MONITOR	CGA (VGA Desirable)	VGA	CGA (VGA Desirable)	EGA/ VGA	CGI
ESSENTIAL DISK SPACE	20/40 MB	155 MB HDD		40 MB HD	
MARKET PRICE (Rs) *	60,000, for 1 each of THEMAPS & DIGITIZ			50,000	Only on Turnkey Projects
SPECIAL PRICE (Rs) •	30,000, for 1 DIGrTIZ & 2 THEMAPS			50,000	

* Compiled by the author from various information brochures provided by the developers of the packages. Information updated till January, 1993.

<Q With image processing capabilities.

© Designed and marketed by Systems Research Institute, Pune, India.

© Designed by Space Application Centre, Ahemadabad for Indian Space Research Organisation, Bangalore; marketed by Era Software Systems Pvt. Ltd.

V National Institute for Science, Technology and Development Studies, Ministry of Science and Technology, Government of India.

• Designed by Centre for Studies in Resources Engineering, Indian Institute of Technology, Bombay; for Ministry of Science and Technology, Government of India.

\+ National Informatics Centre, Government of India.

4k Prices indicative, as in January, 1993. Indian Rs. 1,000. = US $30.
e.g., for educational and/or training institutions.

Appendix VI

SECTORAL POLICIES PROPOSED IN THE REGIONAL PLAN 2001

VI.1 POPULATION POLICIES:

1. to decelerate the population growth of Delhi so as to achieve a manageable Delhi (11.2 million people) by 2001;

2. to achieve a moderate growth of the Delhi Metropolitan Area (DMA), excluding Delhi, to hold a population of 3.7 million people by 2001, in Ghaziabad, Loni, NOIDA, Faridabad, Gurgaon, Bahadurgarh, and Kundli towns, and 0.1 million in rural areas; and

3. to induce the growth of urban population in the areas beyond the DMA in the NCR (assigned population 17.5 million people in 2001).

VI.2 POLICIES ON SETTLEMENT SYSTEMS:

1. to develop selected areas intensively on a priority basis; and

2. to evolve a four-tier hierarchical system of human settlements consisting of regional centres, sub-regional centres, service centres and basic villages for the judicious distribution of population.

VI.3 LANDUSE POLICIES:

1. the existing cultivated land of 2.4 million ha is to be reserved for intensive agriculture;

2. the existing forest area of 1.2 per cent is to be increased to at least 10 per cent of the total area through conversion of barren lands, cultivable wastes, etc.;

3. zoning regulations are proposed and permitted uses are specified in order to avoid haphazard development in the region; and

4. a control 'green belt' is proposed around the future urbanisation area to arrest any undesirable encroachment, and to ensure orderly and compact urban development. In addition, green buffers on either side of national highways and state highways are proposed to prevent ribbon development.

[59] **Extracted from NCR Planning Board, 15**

1. interconnection of regional centres and the National Capital, by efficient and effective network system allowing free movement;

2. provision of these networks to connect maximum traffic attracting and generating urban nodes in the region, and to diminish the centrality of Delhi;

3. decongestion of Delhi roads and terminals by diverting long distance through traffic; and

4. integration of road and rail networks in Delhi, DMA and the balance of the region with appropriate interfacing facilities.

VI.5 TELECOMMUNICATION POLICIES:

1. full automation of telephone services;

2. responding of telephone and telex facilities to demand;

3. extension of subscribers dialling facilities to all DMA and priority towns;

4. connection of priority and DMA towns with Delhi by reliable cable or radio media;

5. provision of reliable trunk services, either by direct dialling or through demand services among the priority towns and DMA towns;

6. extension of telegraph facilities where justified; and

7. replacement of manual exchanges in Delhi as well as other towns of the region by automated exchanges.

VI.6 INDUSTRIAL LOCATION POLICIES:

1. the present policy of not promoting location of large and medium scale industries within Delhi is to be continued;

2. large and medium scale industries are to be permitted to be located in the DMA towns for a period of 10 years; this policy to be reviewed thereafter; and

3. priority towns are to have a strong industrial content and incentives, as applicable to centrally backward areas, are to be given for the location of large, medium and small scale industries in priority towns.

VI.7 TRADE AND COMMERCE POLICIES:

1. there is not to be advantage in terms of preferential treatment of lower taxes by way of incentives to wholesale trade in Delhi vis-a-vis the adjoining states;

2. certain wholesale trades of hazardous nature, located in congested areas of Delhi and requiring bulk handling, are to be encouraged to develop in other DMA towns; and

3. incentives, concessions and infrastructure is to be made available in regional towns so as to encourage and accelerate the growth of trade.

VI.8 OFFICE LOCATION POLICIES:

1. there should be strict control on the location of new government and public sector offices. The main criteria of the control is to be that, if they are to be located in Delhi, they perform ministerial, protocol or liaison functions which, by their nature, can not be performed anywhere else. Existing offices which do not perform any such functions are to be identified, and shifted from Delhi;

2. a similar control on the opening of new central government and public sector offices in the DMA is to be exercised; and

3. central government offices, considered suitable for moving from Delhi and other DMA towns, should be located in other towns of the NCR, and incentives should be given for this.

VL9 POLICIES ON IMPROVEMENT OF ENVIRONMENT:

1. no industry should be permitted to discharge its affluent over land or into water bodies without treatment and bringing the affluent to recommended standards;

2. new industries should be developed only in identified and classified industrial areas/ estates which have proper treatment facilities;

3. urban wastes should be treated so as to meet prescribed standards before being discharged into rivers or other water bodies;

4. detailed schemes are to be prepared, at the local level, for sewage treatment for DMA, priority and other towns, so that the affluent can be used for irrigation and related purposes;

5. solid wastes are to be recycled for effective and valuable use as a nutrient and/or as energy; and afforestation programmes are to be undertaken on all barren and un-cultivable land.

Appendix VII POPULATION, GROWTH RATE AND FUNCTIONAL CLASSIFICATION OF TOWNS IN THE NCR OF DELHI, 1991

(Arranged alphabetically)

NAME OF TOWN	POPULATION in 1991©	GR.RT.tfJ 1981-91	FUNCTIONAL CLASSIFICATION (Based on 1971-81 Census')
AGARWAL MANDI(81)	10,871	16	Primary, Others
ALn>UR*"*(81)	9,256	37	Others
ALWAR(61)	210,146	44	Others
AMINAGAR SARAI(71)	8,274	21	Industry, Trade, Commerce, Others
ANUPSHAHR(61)	19,684	29	Others, Industry, Primary
ASOLA***(91)	5,061	-	-
AURANGABAD(81)	15,402	32	Others, Primary
BABUGARH(81)	3,581	49	Others
BAGHPAT(61)	24,939	45	Primary, Others
BAHADURGARH(61)	57,235	52	Others, Industry, Others
BAHSUMA(81)	9,060	14	Primary
BARAUT(61)	67,705	*46*	Trade, Commerce, Industry, Others
BAWAL<61)	9,010	16	Primary, Others
BAWANA***(81)	18,999	50	Others
BEGUM BUDHANA(91)	13,509	-	-
BEHROR(91)	16,238	-	-
BERI(61)	14,508	7	Primary, Others
BETA HAZIPUR (91)	30,360	-	-
B. BAHADUR NAGAR(81)	9,101	34	Others, Primary
BHIWADK91)	15,285	-	Industry**
BILASPUR(81)	6,127	31	Others
BUGRASI(61)	11,093	33	Primary, Industry, Others
BULANDSHAHR(61)	127,201	22	Others, Trade, Commerce, Industry
CHHAPRAULI(81)	16,008	15	Primary
CHHATARK81)	8,202	39	Primary
DADRI(61)	32,883	66	Others, Trade, Commerce, Industry
DANKAUR(61)	9,531	20	Others, Trade, Commerce, Industry
DASNA(91)	16,963	-	-
DAURALA(81)	10,025	9	Primary
DEBAL(61)	27,721	23	Industry, Trade, Commerce, Others
DELHI U.A.****(61)	8,419,084	46	Others
DHARUHERA(91)	10,848	-	Industry**
DOGHAT(81)	12.309	22	Primary
DUJANA(91)	7,313	-	-
DUNDAHERA(91)	6,767	-	-
FARIDAB AD(61)	617,717	B6	Industry, Others
FARIDNAGAR(61)	10,940	20	Industry, Primary, Others
FARRUKH NAGAR (61)	8,046	*2b*	Primary, Trade, Commerce, Industry
FEROZEPUR JHIRKA(61)	12,413	32	Primary, Trade, Commerce, Industry
GANAUR(71)	20,952	27	Industry, Trade, Commerce, Others
GARHMUKTESHWAR(61)	25,241	40	Primary, Industry, Others
GHAZIABAD U.A.(61)	554,506	93	Others
GOHANA(61)	32,496	24	Trade, Commerce, Primary, Others
GULAOTHI(61)	33,982	39	Trade, Commerce, Others
GURGAON(61)	135,884	34	Others

AME OF OWN	POPULATION in 19910	GR.RT.(S) 1981-91	FUNCTIONAL CLASSIFICATION^ (Based on 1971-81 Census*)
IAILEY MANDI(61)	13,263	30	Trade, Commerce, Others
IAPUR(61)	146,262	42	Trade, Commerce, Industry, Others
IASSANPUR(81)	7,130	39	Primary, Others
IASTINAPUR(71)	15,081	29	Industry, Others
IATHIN(81)	7,863	19	Primary, Others
IODAL(61)	25,635	36	Diversified
AHANGIRABAD(61)	37,981	29	Primary, Industry, Trade, Commerce
AHANGIRPUR(81)	8,206	27	Primary, Others
EWAR(81)	21,376	39	Others
HAJJAR(61)	27,693	14	Primary, Trade, Commerce, Others
KAKOD(81)	5,838	35	Others, Primary
KALANAUR(81)	14,524	17	Others
KALCHHTNA(91)	10,373	-	
KANJHAWALA***(91)	6,100	-	-
KARNAWAL(81)	11,047	11	Primary
KHAIRTHAL(71)	22,741	42	Primary, Trade, Commerce, Others
KHANPUR(81)	11,420	37	Primary
KHARKHODA(81)	10,550	21	Primary, Others
KHEKRA(81)	35,191	40	Others
KHERI SAMPLA(91)	7,838	-	
KHURJA(61)	80,305	19	Industry, Trade, Commerce, Others
KITHOR(81)	19,270	39	Primary
LAWAR(81)	14,471	25	Primary, Others
LONI(81)	36,561	256	Others
MAHAM(61)	15,083	28	Primary, Trade, Commerce, Others
MAWANA(61)	51,701	37	Diversified
MEERUT U.A.(61)	849,799	5S	Others, Industry
MODINAGAR(61)	101,660	29	Industry, Others
MURADNAGAR(61)	44,395	~0	Industry, Trade, Commerce, Primary
NARAURA(81)	15,652	63	Others
NIWADI(81)	8,841	24	Primary
NOIDA(91)	146,514	-	Industry**
NUH(61)	7,492	25	Trade, Commerce, Others
O.F. MURADNAGAR(71)	12,792	-2	Others
PAHASU(61)	13,127	45	Others
PALWAL<61)	59,168	25	Others, Trade, Commerce, Industry
PANIPAT(61)	191,212	33	Industry, Trade, Commerce, Others
PARIKSHITGARH(Sl)	13,677	20	Others
PASAUNDA(81)	12,387	-	–
PATALA*(81)	9,181	17	Primary
PATAUDI(61)	11,278	33	Primary, Others
PEHLADPUR BANGER***(81)	4,832	-3	Others
PHALAUDA(81)	13,970	34	Primary
PILKHUA(61)	50,162	32	Industry, Others
POOTH KHURD***(81)	8,293	16	Others
PUNAHNA(91)	8,679	-	-

NAME OF TOWN	POPULATION in 1991@	GR.RT.® 1981-91	FUNCTIONAL CLASSIFICATION> (Based on 1971-81 Census*)
RABUPURA(81)	10,769	19	Primary, Others
REWARI(61)	75,342	46	Trade, Commerce, Others, Industry
ROHTAK(61)	216,096	29	Others, Trade, Commerce
RORI(91)	8,473	-	-
SAMALKHA(81)	18,384	35	Others
SARDHANA(61)	42,980	42	Industry, Primary, Trade, Commerce
SEWALKHAS(81)	14,402	40	Primary
SHAHJ AHANPUR(61)	12,443	40	Primary, Industry
SHIKARPUR(61)	29,197	35	Primary, Industry, Others
SIANA(61)	29,888	33	Primary, Trade, Commerce, Others
SIXANDRABAD(61)	60,992	41	Industry, Primary, Trade, Commerce
SOHNA(61)	16,348	12	Trade, Commerce, Industry, Others
SONTPAT(61)	143,922	31	Industry, Trade, Commerce, Others
TAORU(81)	12,534	SI	Primary, Industry, Others
TUARA(81)	15,399	26	Others
TIKRI(81)	12,784	12	Primary

Notes:

Assandh, Bisokhar and Razapur were also listed as towns in the Census of India, 1991. However, their location could not be confirmed from any official source and therefore they are omitted from this analysis.

In case of varying spellings of town names from different data sources, the spellings used by the Census of India, 1991, have been adopted here.

(61) Declared a town in 1961 or before.
(71) Declared a town in 1971.
(81) Declared a town in 1981.
(91) Declared a town in 1991.

• Named as 'Patla' in the Topo-Sheet (Survey of India, 1980) and 'Patiala' in the Regional Plan 2001 (NCR Planning Board, 1988)

Functional classification for 1991 not yet available.
A newly added town. Classification based on local knowledge.
Within the National Capital Territory of Delhi.
Delhi U.A. includes 23 towns other than Delhi (see Appendix VTTT).

Source

@ Census of India, 1991.
4 NCR Planning Board, 1988, pp. 140-142.
(61) TCPO, 1974, p.34.
(71) NCR Planning Board, 1988, pp. 140-142.
(81) NCR Planning Board, 1988, pp.140-142.
(91) Census of India, 1991.

Appendix VIII

POPULATION AND GROWTH RATE OF TOWNS IN THE NCT OF DELHI, 1991

S. NO.	NAME OF TOWN	POPULATION in 1991	GROWTH RATE 1981-91 (
1.	DELHI CITY	7,602,394	45
2.	AYA NAGAR*	4.405	-7
3.	BABAR PUR*	47,451	116
4.	B HALS AW A JAHANGIRPUR*	95,065	35
5.	BINDA PUR*	36,148	2S9
6.	DEOLI*	33,214	473
7.	DICHON KHURD*	13,870	170
S.	GHTTORNI*	6,254	33
9.	GOKAL PUR*	49,186	22S
10.	JAFFARABAD*	17,492	S
11.	MOLAR BUND*	19,629	26S
12.	MUNDKA*	17,380	140
13.	NANGAL DEWAT*	7,657	73
14.	NANGLOI JAT*	76,063	102
L5.	NASIR PUR*	81,366	235
16.	PALAM*	98,975	117
L7.	PATPARGANJ (Gharonda Neem Ka)*	22,945	299
1 *i.*	PUL PEHLAD PUR*	14,343	63
19.	RAJKORI*	11,766	104
20.	RANG PURI*	3,251	-23
21.	SULTAN PUR*	8,365	100
22.	SULTAN PUR MAJRA*	111,567	99
23.	TAJ PUR*	5,882	19
24.	TIGRI*	34,416	99
	TOTAL DELHI URBAN AGGLOMERATION	8,419,084	49
25.	ALIPUR**	9,256	37
26.	ASOLA**	5,061	-2
27.	BAWANA**	18,999	50
28.	KANJHAWALA**	6,100	18
29.	PEHLAD PUR BANGER**	4,832	-3
30.	POOTH KHURD**	8,293	16
	TOTAL NATIONAL CAPITAL TERRITORY OF DELHI (URBAN)	8,471,625	49

Included in Delhi Urban Agglomeration. These towns experienced an average growth rate of 118% between 1981-91.

** Not included in Delhi Urban Agglomeration but located within the National Capital Territory of Delhi. These towns experienced an average growth rate of 25% between 1981-91.

Source:

Census of India, 1991;
Draft Sub Regional Plan - National Capital Territory of Delhi, NCR Planning Cell (Delhi Development Authority), Delhi Administration, 1994, Delhi.

Appendix IX

TABLE SHOWING POINT NEIGHBOUR ANALYSIS FOR THE EXISTING, SIMULATED CSR AND SIMULATED REGULAR POINT LOCATIONS OF (CENSUS) TOWNS IN THE NCR OF DELHI, 1991

Reflexive Nearest Neighbours			Mean Distance to Nearest Neighbour		
Order	Observed Value	Assumed with CSR	Order	Observed Value	Assumed with CSR
Existing Locations					
1	52	55.94	1	11566	10568
2	34	29.62	2	15774	15853
3	22	21.88	3	18482	19816
4	20	18.14		21186	23118
5	10	15.84	5	23939	26009
6	14	14.24	6	26564	28609
Locations Simulated for Complete Spatial Randomness (CSR)					
1	58	59.04		13323	12169
2	28	31.26	2	20189	18254
3	20	23.09	3	24995	22818
4	14	19.14	-	29047	26620
5	20	16.72	5	33334	29949
6	8	15.03	6	37038	32943
Locations Simulated for Regular Distribution					
1	64	57.18	:	17267	10494
2	36	30.28	2	17780	15741
3	20	22.37	3	19293	19676
4	36	18.54	4	21443	22954
5	28	16.19	5	26750	25825
6	16	14.55	6	28201	28407

Appendix X

SURVEY OF INDIA TOPO-SHEETS, SCALE 1:250,000, USED IN THE RESEARCH

Sheet Code	Longitude Coverage	Latitude Coverage	Year Surveyed	Year Printed
53C	76°-77°	29°-30°	1965-66	1975
53D	76°-77°	28°-29°	1968-70, 72-73	1977
53G	—	Not Available*	—	—
53H	77°-78°	28°-29°	1969-73, 75-76	1980
53K	78°-79°	29°-30°	1966-67	1986
53L	78°-79°	28°-29°	1969-70	1977
54A	76°-77°	27°-28°	1967-69	1976
54E	77°-78*	27°-28°	1968-70	1975
541	78°-79°	27°-28°	1970-74	1983

This sheet was not available from any source. However, it was compensated by the maps provided by the Deptt. of Town and Country Planning, Uttar Pradesh.

Appendix XI

EXTRACTS FROM THE CONSTITUTION (SEVENTY-FOURTH AMENDMENT) ACT, 1992

"243-Q. Constitution of Municipalities.-

(1) There shall be constituted in every state,-

(a) a Nagar Panchayat (by whatever name called) for a transitional area, that is to say, an area in transition from rural area to an urban area;

(b) a Municipal Council for a smaller urban area; and

(c) a Municipal Corporation for a larger urban area, in accordance with the provisions of this Part: ...

(2) In this article, "a transitional area", "a smaller urban area" or "a larger urban area" means such area as the Governor may, having regard to the population of the area, the density of the population therein, the revenue generated for local administration, the percentage of employment in non-agricultural activities, the economic importance or such other factors as he may deem fit, specify by public notification for the purposes of this Part." (Government of India, 1993, pp. 10-11).

Author's Note: The Census of India does not consider the aspects of revenue and economic importance while classifying a human settlement into an urban area. Moreover, it considers only the male employment and not the overall employment as is inferred from above article of the Constitution.

"243-W. Powers, authority and responsibilities of Municipalities, etc-

Subject to the provisions of this Constitution, the legislature of a State may, by law, endow-

(a) the Municipalities with such powers and authority as may be necessary to enable them to function as institutions of self-government and such law may contain provisions for the devolution of powers and responsibilities upon Municipalities, subject to such conditions as may be specified therein, with respect to-

(i) the preparation of plans for economic development and social justice;

(ii) the performance of functions and the implementation of schemes as may be entrusted to them including those in relation to the matters listed in the Twelfth Schedule;

(b) the Committees with such powers and authority as may be necessary to enable them to carry out the responsibilities conferred upon them including those in relation to the matters listed in the Twelfth Schedule." (Government of India, 1993, pp. 13-14).

TWELFTH SCHEDULE (Article 243-W)

1. Urban planning including town planning.
2. Regulation of land-use and construction of buildings.
3. Planning for economic and social development.
4. Roads and bridges.
5. Water supply for domestic, industrial and commercial purposes.
6. Public health, sanitation conservancy and solid waste management.
7. Fire services.
8. Urban forestry, protection of environment and promotion of ecological aspects.
9. Safeguarding the interests of weaker sections of society, including the handicapped and mentally retarded.
10. Slum improvement and upgradation.
11. Urban poverty alleviation.
12. Provision of urban amenities and facilities such as parks, gardens, playgrounds.
13. Promotion of cultural, educational and aesthetic aspects.
14. Burials and burial grounds; cremations, cremation grounds and electric crematoriums.
15. Cattle ponds; prevention of cruelty to animals.
16. Vital statistics including registration of births and deaths.
17. Public amenities including street lighting, parking lots, bus stops and public conveniences.
18. Regulation of slaughter houses and tanneries." (Government of India, 1993, pp. 18-19).

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This work is based on the research he pursued at the International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands in cooperation with the University of Utrecht, The Netherlands, during 1993-96. Mahavir is thankful to his employers, School of Planning and Architecture, New Delhi, India, for permitting him to pursue the research and to the Netherlands Ministry of Development Cooperation (DGIS) for providing the necessary financial support.