APPRAISALS OF NOISE POLLUTION, TRAFFIC AND LAND USE PATTERNS IN METROPOLITAN KARACHI THROUGH GIS AND *REMOTE SENSING TECHNIQUES*

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CERTIFICATE

This is to certify that Engr. Mohammed Raza Mehdi, has ably completed his dissertation for the degree of Doctor of Philosophy, under my supervision on

"Appraisals of Noise Pollution, Traffic and Land use Patterns in metropolitan Karachi through GIS and Remote Sensing Techniques."

The completed work is beneficial and distinct for different disciplines of engineering, applied and social sciences. It is hoped that in future, more analogous multi-disciplinary researches would be conducted on the cities of developing countries.
I wish him success in his future research endeavours.

Dr. S. Jamil H. Kazmi

DEDICATED TO

My Beloved Family Members

ABSTRACT

Karachi is one of the worst effected cities due to unchecked and uncontrolled noise pollution. Population growth rate of Karachi is about 3.0% per annum that depicts the annual growth of population at risk while pollution growth is also considerably high. The growing environmental degradation has exerted grave burden on resources, therefore, environmental monitoring has become indispensable. This neglected issue needs a serious attention and continuous surveillance to evaluate the quality regularly.

In this study, a hypothesis is formulated: "the high level of noise is associated with the geographical agglomeration of land use and traffic volume, which results in high incidence of noise related diseases and people working near those areas are on vulnerable risk." The prime goals of this study are to modulate the information pertains to noise pollution and its adverse effects on human health and find out their spatial patterns all over Karachi. The research has covered different parameters: assessment of land cover / land use, human settlement growth, temporal traffic patterns, population distributions, current levels of noise, health implications, physicians' and public perceptions.

Spatial variations within metropolis have been largely ignored mainly due to less comprehension, under estimation of spatial techniques as well as difficulties in collecting, processing and analysing the data at micro geographic scales. Remote Sensing technology has been providing multi-dimensional information, which is utilized in various environmental investigations while Geographical Information Systems (GIS) have been accepted as a turnkey solution for the complex world due to its magnanimous breath of functionalities and cost effectiveness. The developed GIS evaluation combined the data sets, various analyses and the resultant maps with the capability to integrate further parameters for future risk assessments. Multi-attribute decision analysis was successfully employed. Micro–geographic appraisals of the metropolis were performed by considering 58 zones outlined by the local development authority. Each regional assessment included area, population density, distribution of land cover, split of land use, and frequency of noise-induced diseases, their prevalence scenario and temporal variations in noise levels within the zone. Multiple regression models for predicting noise levels at the olden

regions of Karachi metropolis have been formulated in which traffic and land use parameters act as independent variables.

The most unique feature of this study is the unification of engineering techniques with that of human behavioural sciences to trace down the manifestations of noise pollution. It is hoped that in future, more analogous multi-disciplinary researches would be conducted on emerging mega cities of the third world.

تلخیص :

صوتی آلودگی کی بناء پر کراچی دنیا کے آلودہ ترین شہروں میں ایک نمایاں مقام کا حامل ہے۔ جہاں آبادی میں تین (۳) فیصد سالانہ سے زائد شرح نمو، مخاطرہ آبادی میں اضافہ کا مظہر ہے وہیں آلودگی میں غیر معمولی اضافہ بھی محل نظر ہے۔ یہاں ماحول کا بڑھتا ہوا تنزل وسائل پر بے پناہ بوجھ کا سبب بن رہا ہے لہٰذا مسلسل ماحولیاتی جانچ ایک لازمی امر بن چکی ہے۔ ہنوز، یہ نظر انداز مسئلہ ایک سنجیدہ توجہ اور ماحولیاتی معیار کی مستقل خبر گیری کا متقاضی ہے۔

اس مطالعہ کو یہ سمجھتے ہوئے کہ ''بلند صوتی آلودگی درحقیقت بری استعمال اور ٹریفک کے حجم کے مکانی اجتماع سے منسلک ہے۔ اور یہ صوتی آلودگی سے جنم لینے والے امراض کی صورت میں عیاں ہوتی ہے۔ اور ایسے علاقوں میں بسنے والے افراد احتمالاً خطرات کی زد میں ہیں''، ایک تحقیقی رنگ میں ڈھالا گیا ہے۔ زیرِ نظر مطالعہ کے بنیادی اغراض میں صوتی آلودگی، انسانی صحت پر اسکے مضر اثرات اور انکی شہر بھر میں نفوذ شدہ مکانی تراتیب کی جانچ شامل ہیں۔ یہ تحقیق مختلف موارد کا احاطہ کرتی ہے۔ بری سرپوش و بری استعمال کے درجے، انسانی بستیوں کی نمو، ٹریفک کے زمانی تغیرات، آبادی کی تقسیم، صوتی آلودگی کی موجودہ سطح، صحت پر مضر اثرات اور عوامی رجحانات شامل مطالعہ رہے ہیں۔

کم آگہی، غیر تسخیری اور بے قابو صوتی آلودگی کی وجہ سے شہر البلاد کراچی میں مکانی تغیرات کو اکثر نظر انداز کیا جاتا رہا ہے۔ جس کی نمایاں وجوہات میں نہ صرف مکانی تراتیب کی کم علمی و کم اہمیتی، جغرافیائی معلومات کی نچلی سطح تک جمع آوری بلکہ ترتیب و تجزیہ کی عملی مشکلات سرفہرست ہیں۔ دورحسیات تکنیک (ریموٹ سینسنگ) ایک کثیر جہتی معلومات کا منبع ہے جو بیشتر ماحولیاتی تحقیقات میں معاون جزو کی حیثیت رکھتا ہے۔ اسی طرح جغرافیائی معلوماتی نظام (GIS) ایک ایسا مسلّم حل ہے جو اپنی وسعت استعمال اور کم خرچ ہونے کی بناء پر دشوار اور پیچیدہ معاملات کو سہل بنانے میں سازگار ہے۔

محاصل GIS کے ذریعے تیار کردہ جانچ، معلومات، مختلف تجزیات اور منتج نقشہ جات پر مشتمل ہے۔ اس تحقیق میں کثیر الجہتی فیصل تجزیہ کامیابی سے استعمال کیا گیا۔ ادارہ ترقیات شہر البلاد کراچی کے متعین کردہ اٹھاون (۵۸) منطقوں کی جغرافیائی معلومات کے نچلی سطح تک تخمینے پیش کیے گئے جن میں منطقہ کا اندرونی رقبہ، آبادی کی کثافت، بری استعمال کے درجات کا تناسب، بری سرپوش کی تقسیم، صوتی آلودگی سے پیدا ہونے والے امراض کا تعدّد، انکے پھیلاؤ کی صورت حال اور صوتی آلودگی کے زمانی تغیرات کی کیفیات قابل ذکر ہیں۔ اس کے ساتھ ساتھ بری استعمال اور ٹریفک کے مختلف موارد کو آزاد متغیر عناصر تسلیم کرتے ہوئے کثیر مراجعتی نمونے وضع کیے گئے جو صوتی آلودگی کی پرانے شہر میں معیاری پیشگوئی کی صلاحیت رکھتے ہیں۔

اس مطالعہ کی نمایاں ترین خصوصیت صوتی آلودگی کے تناظر میں کی گئی تحقیق میں مہندسی تراکیب اور انسانی عمرانی علوم کی جمع آوری ہے۔ امید کی جاتی ہے کہ مستقبل قریب میں دنیا کے ابھرتے ہوئے بڑے شہروں کیلئے اختیار کردہ خطوط پر کثیر الشعبہ جاتی تحقیقات جاری رکھی جائیں گی۔

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BERG	Buildings Effects Review Group
CBD	Central Business District
dB(A)	Decibel (A-scale sound level)
DHA	Defence Housing Authority, Karachi – Pakistan
EC	European Commission
EPA	Environmental Protection Agency
EPW	Environment Protection Wing of PCYO
ESCAP	Economic and Social Commission for Asia and the Pacific
ESRI	Environmental Systems Research Institute, Inc.
GIS	Geographic Information Systems
GOP EUAD	Environment & Urban Affairs Division, Government of Pakistan
GOP	Government of Pakistan
GPS	Global Positioning System
HEI	Health Effect Institute, United States
HRV	High Resolution Visible scanner
ICA	Instituto Geografico Nacional, Spain
IEEE	Institute of Electrical and Electronics Engineers
IUCN	World Conservation Union
JPMC	Jinnah Post Graduate Medical Centre
KCHS	Karachi Cooperative Housing Society
KCR	Karachi Circular Railway
KDA	Karachi Development Authority
KESC	Karachi Electric Supply Corporation
KMC	Karachi Metropolitan Corporation
KMTP	Karachi Mass Transit Programme
KPT	Karachi Port Trust
LDCs	Less Develop Countries
LIDAR	Laser Radar
MAGIS	Metropolitan Area Geographic Information Systems
MBBS	Bachelor of Medicine / Bachelor of Surgery
MDCs	Most Develop Countries
MIC	MapInfo Corporation
MSS	Multi-Spectral Scanner
NAS	National Academy of Science
NASA	National Aeronautics and Space Administration, United States
NIPA	National Institute of Public Administration, Karachi – Pakistan
NOAA	National Oceanic and Atmospheric Administration, United States
NSIEM	National Swedish Institute of Environmental Medicine
OECD	Organization for Economic Co-operation and Development
PCI	PCI Geomatics Canada
PCSIR	Pakistan Council for Science and Industrial Research
PCYO	Pakistan Crescent Youth Organization
PECHS	Pakistan Employees Cooperative Housing Society
PEPA	Pakistan Environmental Protection Agency
PRB	Population Reference Bureau, United States

PSI	Pakistan Standards Institution
RCD	Regional Cooperation for Development
RS	Remote Sensing
SEPA	Sindh Environmental Protection Agency
SITE	Sindh Industrial Trade Estate
SPOT	Satellite Probattoire de l'Observation de la Terre (French Satellite)
SRS	Satellite Remote Sensing
SUPARCO	Pakistan Space and Upper Atmosphere Research Commission
TEB	Traffic Engineering Bureau, Karachi – Pakistan
TM	Thematic Mapper
UHI	Urban Heat Island
UNCHS	United Nations Centre for Human Settlements (Habitat)
UNDP	United Nation Development Programme
UNEP	United Nation Environment Programme
URC	Urban Resource Center, Karachi – Pakistan
USEPA	United States Environmental Protection Agency
WB	World Bank
WHO	World Health Organization
WRI	World Resources Institute, United States

LOCAL TERMS

Bagh	Garden
Bazaar	Market
Chawrangi	Roundabout
Chowk	Intersection
Chowki	Check Post
Dakkhana	Post Office
Dawakhana	Clinic
Deh	Rural administrative entity
Goth	Village
Gully	Minor Street
Hakim	Physician practicing with herbal medicines
Jhuggi	Temporary Settlement
Katchi Abadi	Squatter settlement
Mazar	Mausoleum
Morre	Intersections
Patharay walas	Temporary small cabins
Pul	Bridge
Purana	Old
Qabristan	Cemetery, Graveyard
Rickshaw	2-stroke, 3-wheeled para-transit vehicle
Sarafa Bazaar	Gold Market
Shahrah	Major Arterial
Subzi Mandi	Vegetable Market
Thana	Police Station

.... and the voices shall be low before the Beneficent God so that you shall not hear aught but a soft sound. ....

Verse 108: Chapter 20
The Quran

1. INTRODUCTION

1.1 BACKGROUND

Linkages amongst transport, environment and health across urban settings are crucial. Indiscriminate urbanization in the third world cities deteriorates the quality of environment besides many other sizable socio-economic problems. By all means, this degeneration of the environment is the product of human settlement patterns and their activities. Major portion of this phenomenal dilemma is associated with vehicular traffic. The enormous growth of traffic along with the distribution patterns of urban land use, emanate noise creating entirely different situations as compared with the developed world. The ever-increasing pollution, demand for the early and reliable detection of the adverse effects of this uncontrolled menace.

Most of the environmental problems are embedded in a spatial matrix. Such spatial differences in environmental quality resulting from patterns of transportation and land use are legitimate themes of transportation engineering, environmental management and geographic inquiry. In this context, the empirical data of mega cities of developing countries could help in tracing the relationships between relevant urban, environmental and transportation factors such as noise, traffic, population, incidence of diseases and land use. Environmental monitoring and modelling techniques enables us to identify pollution, its sources, nature, concentrations, patterns, trends and its effects.

The impact and importance of urban traffic pollution cannot be ignored. As the rate of urbanization increases, noise pollution levels are expected to increase significantly .The most obvious expected effects are those related to public health. According to ESCAP (1990) and UNEP (1999), urban noise and traffic congestion are emerging problems in many of the principal cities of Asia and the Pacific region. However, there is a general dearth of materials and data on urban environmental concerns in developing countries particularly in Pakistan.

Pakistan covers 0.7 percent of the world's land area (MS Encarta, 2002), but accounts for over 2 percent of the world's population (McDevitt, 1999). It is a country with per capita annual income of hardly US$ 450 (WB, 1998), a fast depleting natural resource base, inadequate social service, and an arid or semi-arid climate where health issues are a predominant concern. The country is particularly vulnerable to the negative impacts of environmental degradation.

Karachi is one of the worst effected cities due to unchecked and uncontrolled noise pollution. Population growth rate of Karachi is about 3.0% per annum (GOP, 2000_b) that depicts the annual growth of population at risk while pollution growth is also considerably high.

1.2 SPATIAL CANVAS

In the eighteenth century, *Kalachi-Jo-Goth* or *Kalachi-Jo-Kuh* (*i.e.* Village of *Kalachi*) was founded by some businessmen and fishermen along the Arabian Sea (GOP, 1984). Small village of the past has now become the largest city of Pakistan; chief financial, commercial, manufacturing centre; port and hence hub of transportation. It is situated in between 24° 45' N to 25° 37' N and 66° 42' E to 67° 34' E. Administratively it is divided into five districts, namely, Karachi East, Karachi West, Karachi South, Karachi Central and Malir Figure 1.1.

In August 2001, the 'Sindh Local Government Ordinance' was promulgated and accordingly Karachi City Government was established to look after the whole Karachi Division under the single administrative authority. Instead of former five districts Karachi Division was divided into eighteen towns (Mahmood *et al.*, 2001). It lies in Sindh Province and surrounded by Lasbela District in the West (Baluchistan Province), Dadu District in the North and North East, Thatta District in the East and Arabian Sea in South (Figure 1.2). The whole administrative area occupies about 1400 square miles in which a major portion is under urban land use.

Karachi has grown nearly 25 times since 1947 and is growing at the rate of about 5.4 % per annum (KDA, 1991), making it one of the fastest growing cities in the world. This situation is mainly due to the rapid industrialization process, which has caused continues influx of people from up-country areas to Karachi. Manufacturing includes steel, textiles, chemicals, cement, refined petroleum, and processed food. It is an important banking centre and has a stock exchange. Most of the international trade of Pakistan and

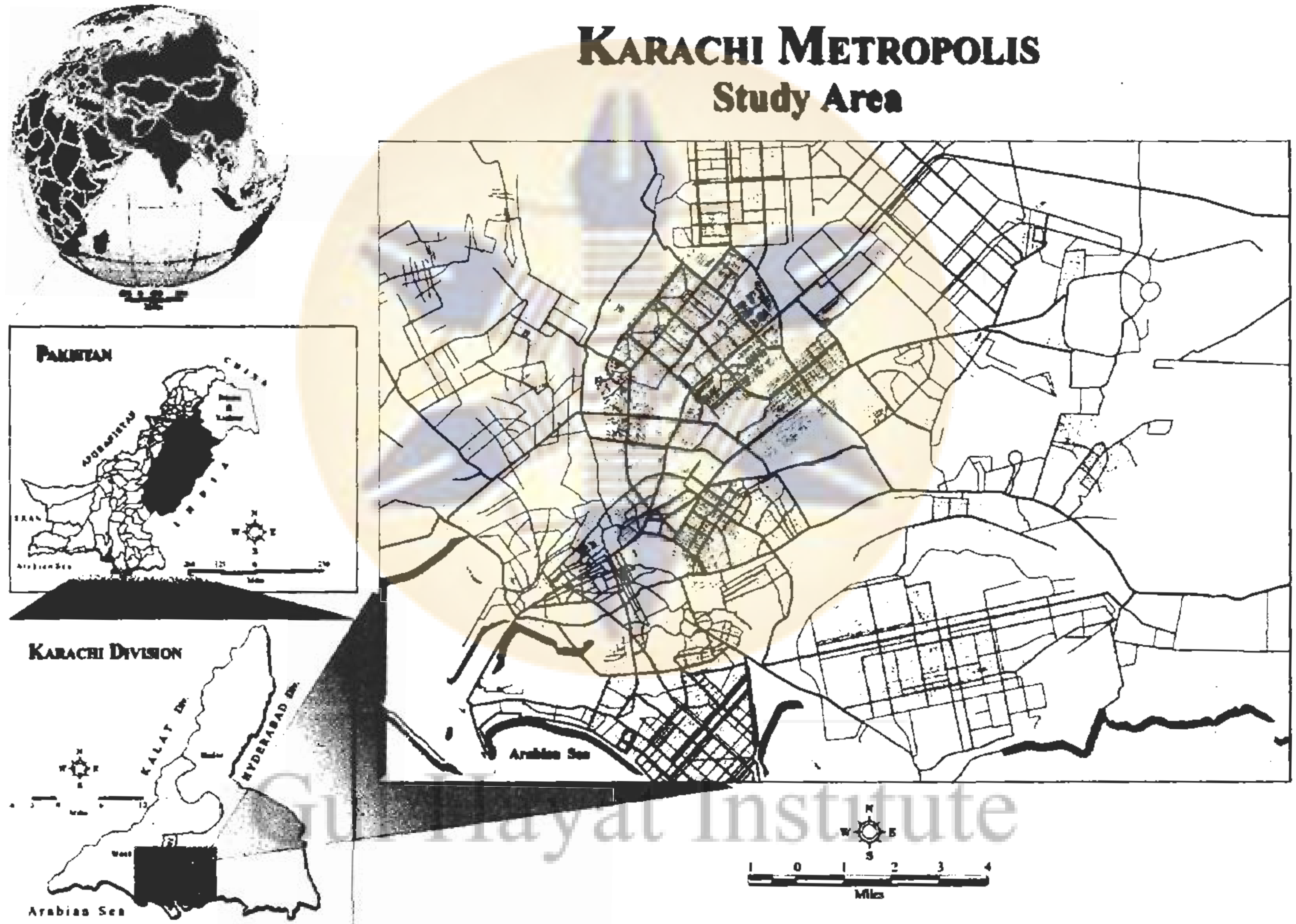
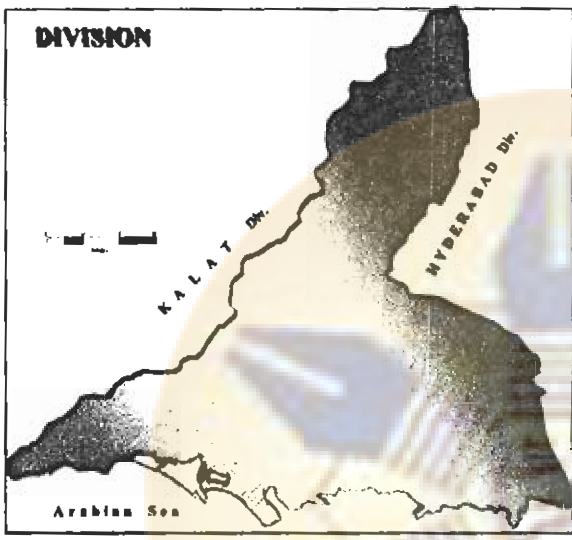
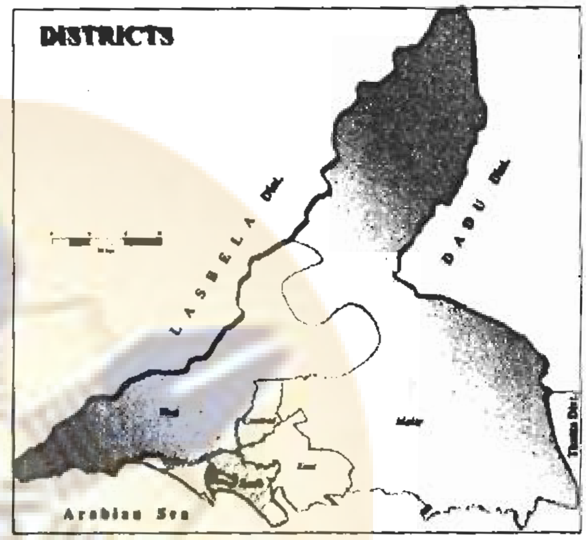

KARACHI METROPOLIS
Study Area
PAKISTAN
CHINA
AFGHANISTAN
INDIA
IRAN
KARACHI DIVISION
KALAT Div.
HYDERABAD Div.
Arabian Sea
Arabian Sea
Miles

Figure 1.1

KARACHI METROPOLIS
Administrative





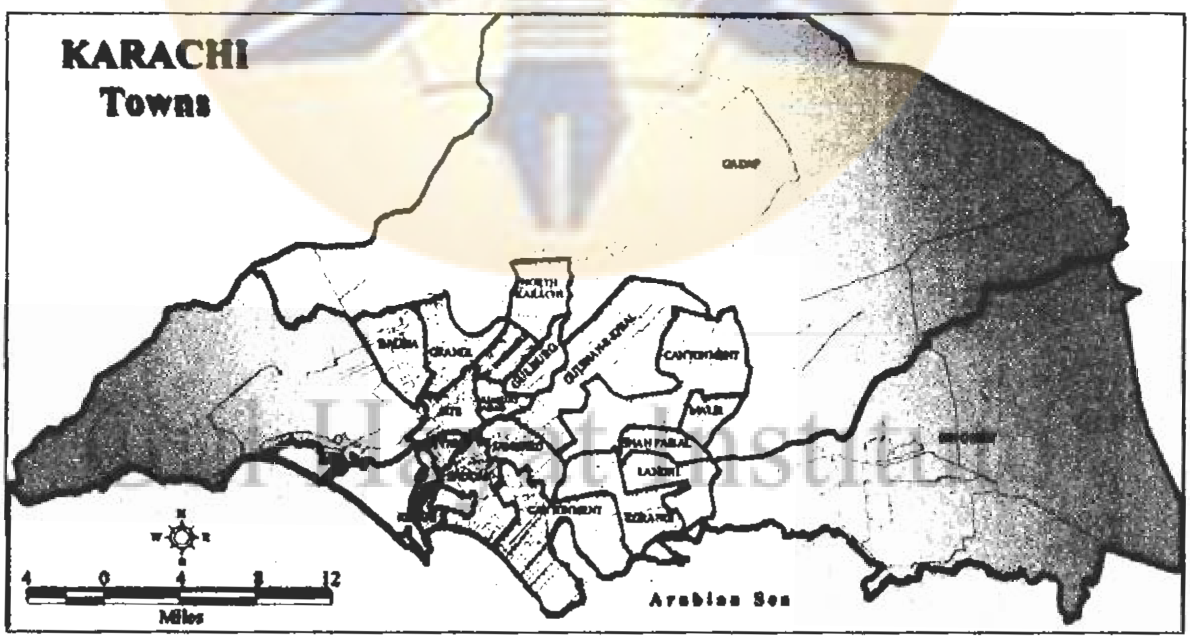


Figure 1.2

landlocked Afghanistan passes through the city's busy modern ports, centred on the Kiamari and Bin Qasim. It is the terminus of major road and rail networks, which link it to the interior of the country. This transport infrastructure has transformed it into a cardinal national and international commerce and banking centre and thus serves as lifeline for the whole country.

Analyses of past growth trends in Karachi suggest that the city has expanded primarily along growth corridors to the South, North, East and Northwest (KDA, 1991, Afsar 2001). The 'urban' Karachi of today is presented in Figure 1.3, *densely built-up land cover* being the prominent feature.

1.2.1 Historical Sprawl

Karachi has been one of the world's fastest growing cities since the creation of Pakistan in 1947 when the population of Karachi was 450,000 (GOP, 1951). By 1951, Karachi's population had increased to 1.137 million because of the influx of 600,000 refugees from India and it became a high-density city. The major problem that Karachi faced after the refugee influx was of housing the migrants, developing infrastructure for transportation, water and sewage, and creating space for the further development of the then capital city.

The administration encouraged cooperative housing societies around the then city and itself developed two satellite towns, Landhi,-Korangi to the east and New Karachi to the north of the city. These satellite towns were to be about 25 km from the city centre. Industrial estate was developed as part of the satellite town plans (Hasan *et al.*, 1999). The unmet demand for housing resulted in the creation of squatter settlements on the roads that connected the city with these planned satellite towns, which caused Karachi's lasting transports problems. Between 1951 and 1972, the population of Karachi increased by 217 percent (GOP, 1984). Road transport for cargo movement between Karachi Port and the rest of the country took over from rail transport, adding to Karachi's transport and traffic problems.

In early 1970s, townships like Orangi and Baldia at some distance from the city were developed, which had insufficient infrastructure. These settlements were to the north and west of the city. Squatter settlements started to develop, making use of the facilities that

Urban Land Cover of
KARACHI

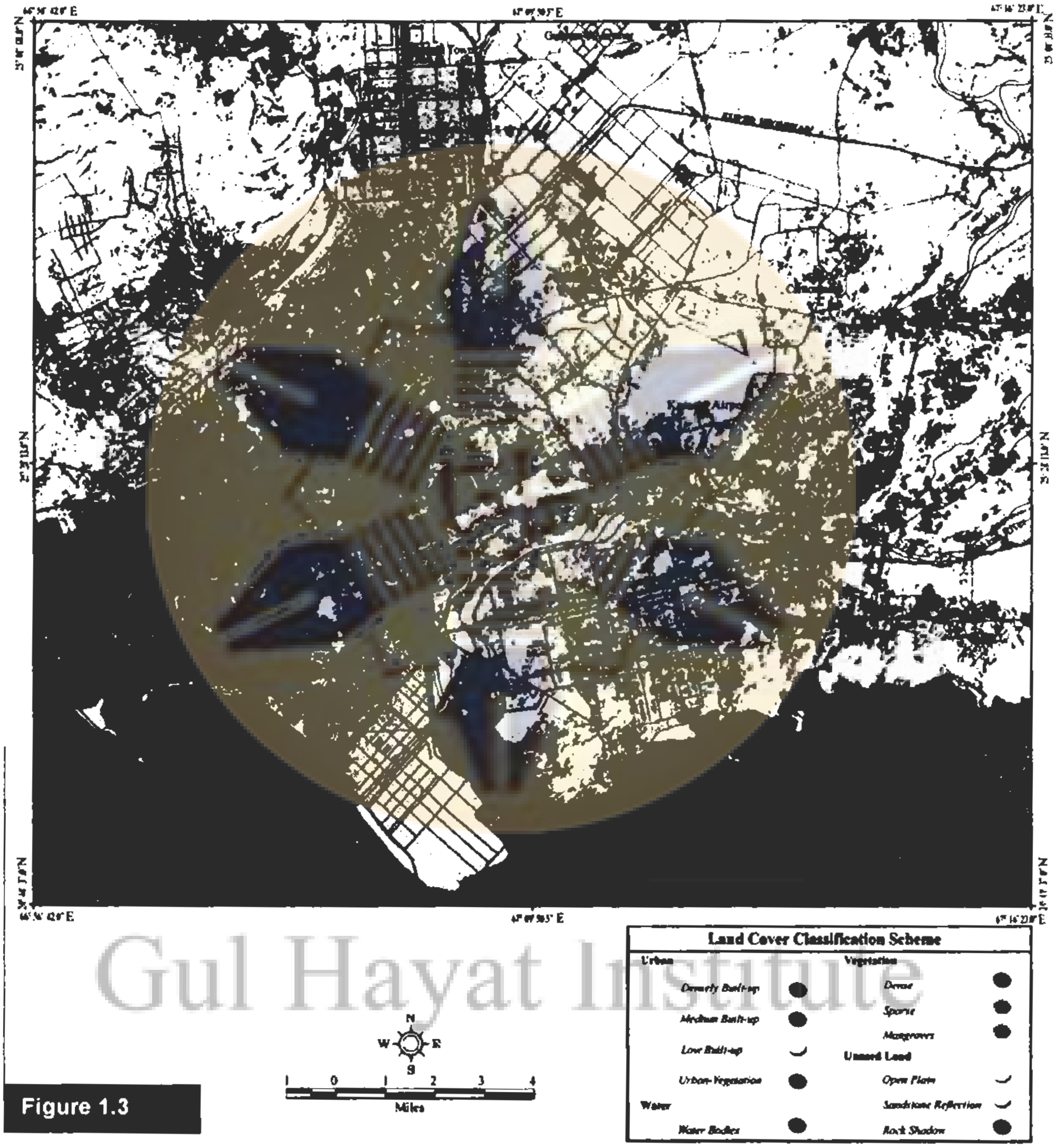


Figure 1.3

were being offered to the formal settlements. However, these facilities were inadequate and the state did not develop policies that provided support to the private sector in transport; nor did it have the finances to build an effective public sector owned transportation system (Hasan *et al.*, 1999). During this period the wholesale markets in the old city were expanding and facing problems of access as the old city consisted of narrow winding roads. Those increased activities densified the old city and overloaded its already fragile infrastructure, and created vertical slums in the middle and lower middle-income suburbs. It also led to the creation of a flat culture (Meyerink, 1983). The growth of *katchi abadi* has acquired a large spatial canvas in this expanding mega city. The *Katchi abadis* represent, in most cases, illegal occupation of land by the rural migrants. These slums initially consist of rough-and-tumble structures, later turn into concrete buildings. These squatter areas usually located on hillsides, along railway tracks, near water bodies and drains (Rangoonwala and Ahmed, 1991). Sometimes, they are located on valuable land in the middle of planned neighborhoods.

The dilemma, which has been associated with this influential city, is that the planning, development and maintenance agencies have not been able to function appropriately. Consequently, the change involving new developments are made without urban design exercises thus Karachi's environmental degradation is a result of this unrehearsed approach.

1.2.2 Climate

Karachi is a subtropical coastal low land area. Its geographical location is not favourable to receive sufficient monsoon rainfall. The average is about 8 inches whose maximum is received in July/ August. It is a warm semi-desert where sea breeze is dominant in summer when mean maximum is 95 °F while winter mean daily temperatures is 68 °F. The minimum humidity level in Karachi (particularly near the shore) is about 50% at least through out the year. Annual range is from 50% (December, driest month) to 85% (August, moistest month).

Karachi endures a long hot season from March to October. In July and August, temperatures are moderate because of monsoon winds. Sea breeze controls the severity of temperature but in the localities away from the coast temperatures are higher. In May and

June, low pressure develops from interior Sindh hence the northeastern winds increase the temperature and it soars up to 110 °F or a little higher.

Average wind velocity in winter is 6.5 miles per hours, which is considered as low wind. By the end of June or July, monsoon winds passes through the metropolitan and its surroundings increasing the speed of local wind system up to 11.7 miles per hours. In addition to these, there are local land and sea breezes near the coast. These sea breezes are accompanied by fall of temperature (from about 5° F to 3.5° F), rise of humidity (from 5% to 30% and above), shift of wind direction to west, south or southwest and an increase of wind velocity.

1.3 THE STUDY

The urban environmental degradation problem has to be explored and studied from a number of different perspectives, with emphasis on conditions in the developing countries. The literature on this subject is largely for the developed parts of the world. However, here is now a more refined understanding on the number of issues such as land use / land cover, population, epidemiology *etc.*, as compared to few years back. There has emerged a literature consensus (Ali, 1997; Drakakis-Smith, 2000; Arsalan, 2002) that the locus classicus ideas and solutions suitable for developed countries are not viable in the indigenous environment for the developing countries. The areas, which need further attention, are around understanding the diverse 'perceptions on environment', and utilization of modern tools in an integrated approach.

Land use attracts vehicular traffic that generates pollution in form of noise to degrade the quality of life in urban areas. The continuum of land use, traffic and noise pollution is quite complex that makes difficult to comprehend the exact dimensions of the problem, its interaction with other ecological variables. Therefore, for addressing such issues, an integrated environment of the 3-S technologies has been widespread and acquired acceptance in literature (*e.g.* Aronoff, 1989; Korte, 1992; Denegre, 1994; Verbyla, 2000; Steede-Terry, 2000). According to Fedra (1993) and Lillesand and Keifer (1994), the interface between GIS and remote sensing can be envisaged in different ways to solve the complex problems:

a.) Remote sensing can be used as a tool to gather data sets for use in GIS;

b.) GIS data sets can be used as ancillary information with which to improve the products derived from remote sensing and;

c.) Remote sensing data and GIS data can be used together for modeling and analysis.

In this study, the author has adopted the lastly mentioned approach for appraising the urban environmental parameters (Figure 1.4). For the exploration of these phenomena, a hypothesis is developed as "the high level of noise is associated with the geographical agglomeration of land use and traffic volume, which resulted in high incidence of noise related diseases and people working near those areas are on vulnerable risk".

1.3.1 Research Objectives

The primary objective of this study is to modulate the geographical information about land use, traffic and noise; and to visualize their adverse effects on human population, public health in a GIS matrix. The salient objectives of this research are envisaged as described herein:

1. To Assess land cover clusters in metropolitan Karachi using digital image processing techniques
   - To investigate human settlement growth through change detection procedures
   - To appraise city-wide land use / land cover classes for the study area
2. To map mobile sources (traffic) and interpretation of temporal patterns of traffic around the study area
3. To Study population distribution patterns across the city for further determination of human resources at risk
4. To uncover the current levels of noise pollution
   - To conduct a field survey for measuring the level of noise at various locations
   - To create geo-database and position of the monitoring stations
   - To present geographic appraisals of spatio-temporal variations of noise across the Karachi metropolis
5. To garner studies on potential noise induced diseases through literature

6. To spell out the pattern of emerging diseases and their risks out of noise pollution. Determination of the noise induced diseases of high epidemics by surveys of hospitals and physicians' experience.
7. To attempt connecting the missing social link of environmental studies through a rational review. A perception analysis to find out the level of awareness about noise pollution and its effects among the native population is envisaged.
8. Risk assessment of noise pollution through geo-statistical interpolation techniques
   - Formulation of Risk Criteria by statistical methods, and applying multi-attribute decision analysis to demarcate Risk zones.
9. Predictive modelling of noise intensities through traffic and land use variables.
10. To provide a basic GIS framework for engineers to conduct such environmental studies.

1.3.2 Research Structure

Environmental management, decision-making, and planning require a large and diverse ensemble of data that includes time series of monitored environmental variables and geographical datasets. Most environmental phenomena show five different dimensions of data: the location in space, (set of 3 coordinates - latitude, longitude and altitude), the position in time and the particular phenomenon (variable/theme being analysed) (Langram, 1993; Waters, 1995; Hibbard *et al.*, 1995; Oracle, 1995). The goals of an environmental monitoring and information system is thus to collect data in this five-dimensional world, store it and promote its use in the most efficient possible ways (Raper and Livingstone, 1995; Oliveira and Ribeiro da Costa, 2000).

Remote Sensing also facilitates environmental modeling indirectly, which may provide continuous data. In analyzing trouble spots, use of high resolution Satellite Imageries such as Landsat, SPOT, KVR, IKONOS and Quick Bird are useful in precise detection of land use patterns and traffic congestion locations. Amalgamation of RS/ GIS could be an excellent tool for environmental analysis and management, tested and applied at many locations around the globe (Dent *et al.*, 1998).

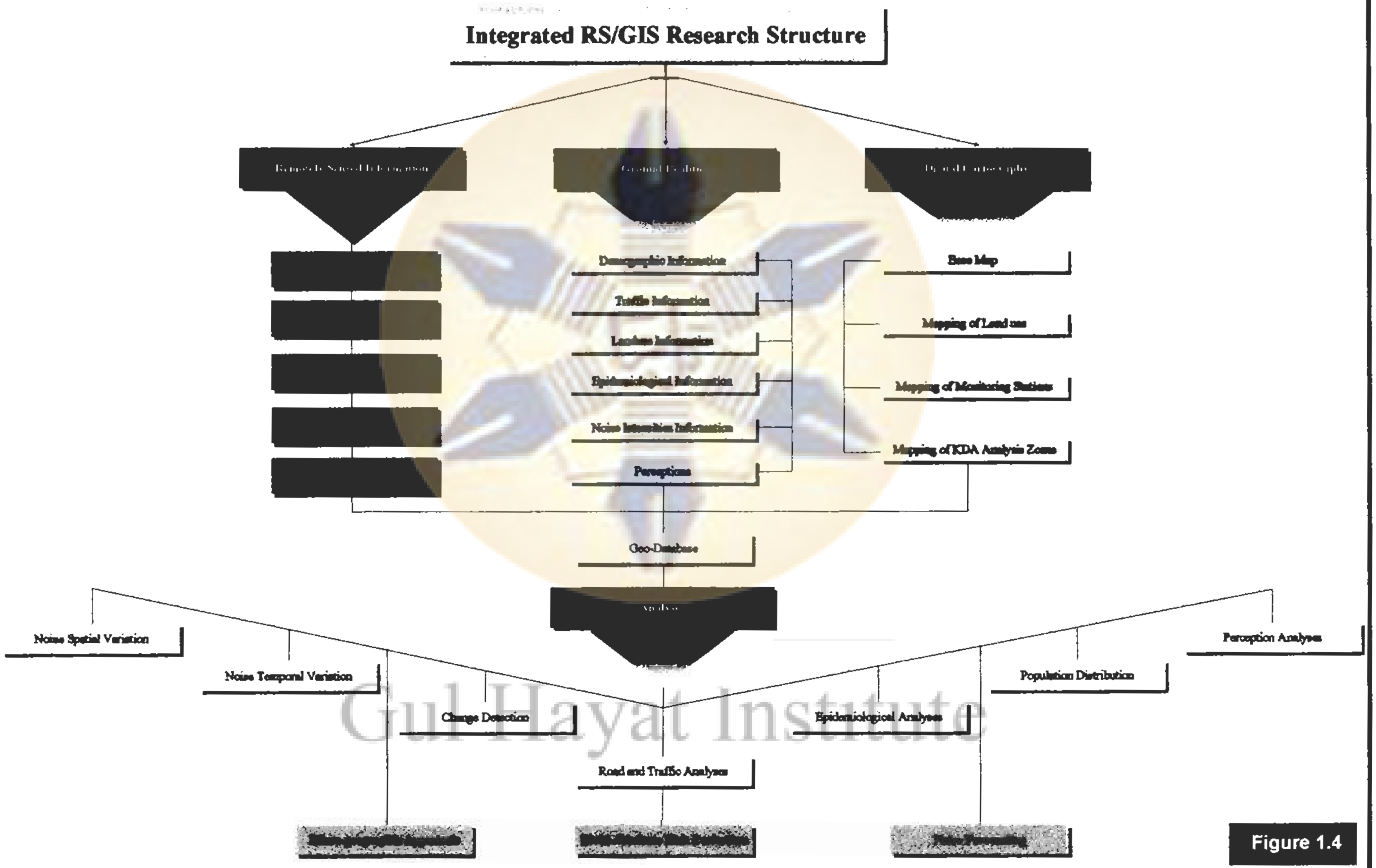

Integrated RS/GIS Research Structure
Demographic Information
Traffic Information
Landuse Information
Epidemiological Information
Noise Intensities Information
Perceptions
Base Map
Mapping of Land use
Mapping of Monitoring Stations
Mapping of KDA Analysis Zones
Geo-Database
Noise Spatial Variation
Noise Temporal Variation
Change Detection
Road and Traffic Analyses
Epidemiological Analyses
Population Distribution
Perception Analyses

Figure 1.4

It has been estimated that over eighty percent of the world's data have a spatial component (Worrall, 1991; MIC, 1999). These spatial components could include an address in a database or coordinates in sampling data. The Global Positioning System (GPS) provides continues availability \ capability of giving coordinates at any point on the earth surface to an acceptable accuracy (Bannister *et al.*, 1998) and thus suitable for ground control and referencing.

Geographic Information Systems have been used to manage natural resources, utility networks, government activities and environmental degradation monitoring *etc.*(ESRI, 1998; MIC, 1999; PCI, 2002). It has evolved to provide solutions in three areas: GIS as an information database, as an analytical tool, and as a decision support system (Bellman and Zadeh, 1970; Bodily, 1985; Banai-Kashani, 1989; Armstrong, *et al.*, 1991; Huizing and Bronsveld, 1994; Eastman, 1995). A trend affecting the GIS application is the result of recent advances of computer technology and graphic user interface operating systems. In particular, desktop GIS have emerged, capitalizing on the advancement of direct manipulation (Theobald, 1998; MIC, 1999; PCI, 2002).

More sophisticated GIS are being used to address a broader range of problems and in a wider variety of situations. For example, GIS is being applied to problems that require coupling of simulation models with GIS (Goodchild, 1993); the visualization of spatial data (MacEachren and Taylor 1994; Buttenfield 1996); the development of spatial decision support systems (*e.g.* Faber *et al.* 1998); and to support public policy and decision-making (*e.g.*, Hobbs *et al.* 1997).

Geographic Information Systems is the main investigative tool for this study while RS, GPS and field techniques to provide and process the inputs. Here GIS has been implemented according to elemental requirements. A general conceived GIS model for this study is shown in Figure 1.5.

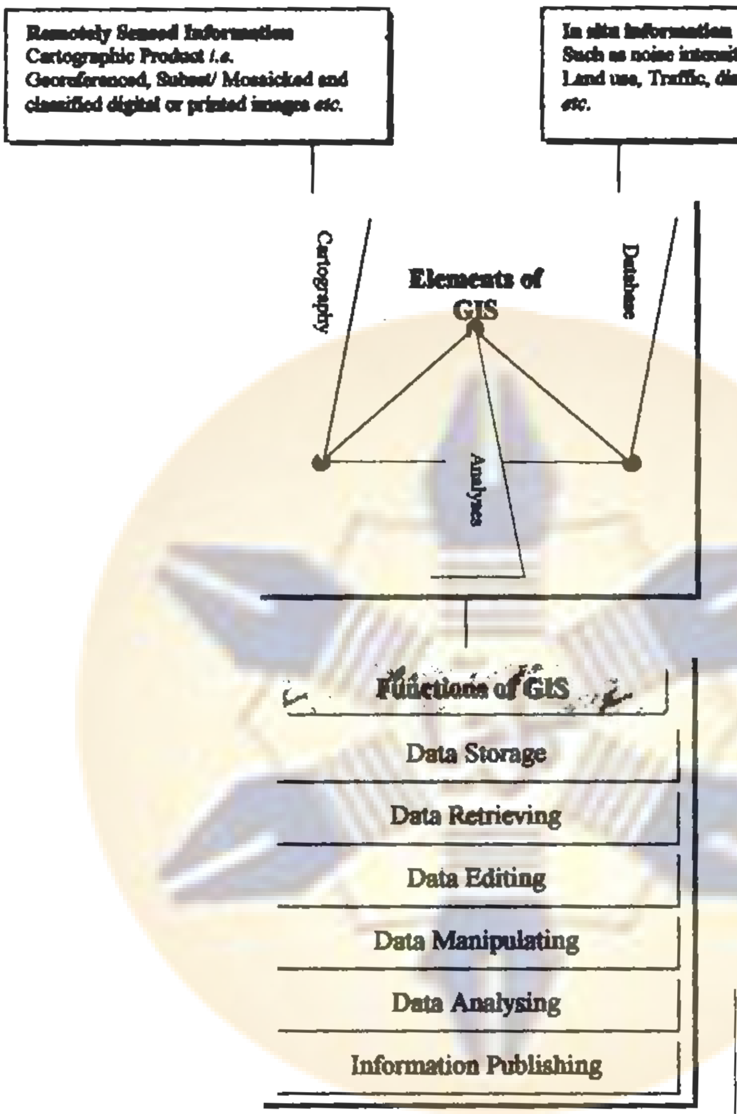


Figure 1.5 : GIS Organization
Source: After Arsalan, 2002

1.3.2.1 Cartographic Approach

Cartography (Map making) is one of the fundamental elements of Geographic Information Systems that provide the spatial canvas on which ancillary information are analyzed. The increased flexibility and capabilities of the new technology has enabled from manual cartography to Computer Assisted Cartography (CAC).

Environmental mapping and visualisation-work have gone a long way with the gradual innovations in technology (ICA, 1980; Pape, 1980; Grotjan, 1982; Kadmon, 1983; Lavin and Cerveny, 1987; EuroCarto 7, 1988). Hayes (1979) has given an example of more specific demands for environmental visualisations. By the late 1980s environmental cartography was also concerned with environmental data integration, the spatial characteristics of the data to be mapped and environmental databases (Ormeling, 1989). In the meantime, computer capabilities promoted to the development of systems for efficient environmental monitoring and impact studies and more realistic visualisations (IEEE 1984, Papathomas *et al.* 1988; Wolfe and Liu 1988; DiBiase *et al.* 1991; Abel *et al.* 1992a, 1992b; Emmett 1992; Gantz 1992; Lang, 1992; Lang and Speed 1992; Kruse *et al.* 1993; Stenberg 1993). The overall flow of the mappings performed in this investigation is illustrated in Figure 1.6.

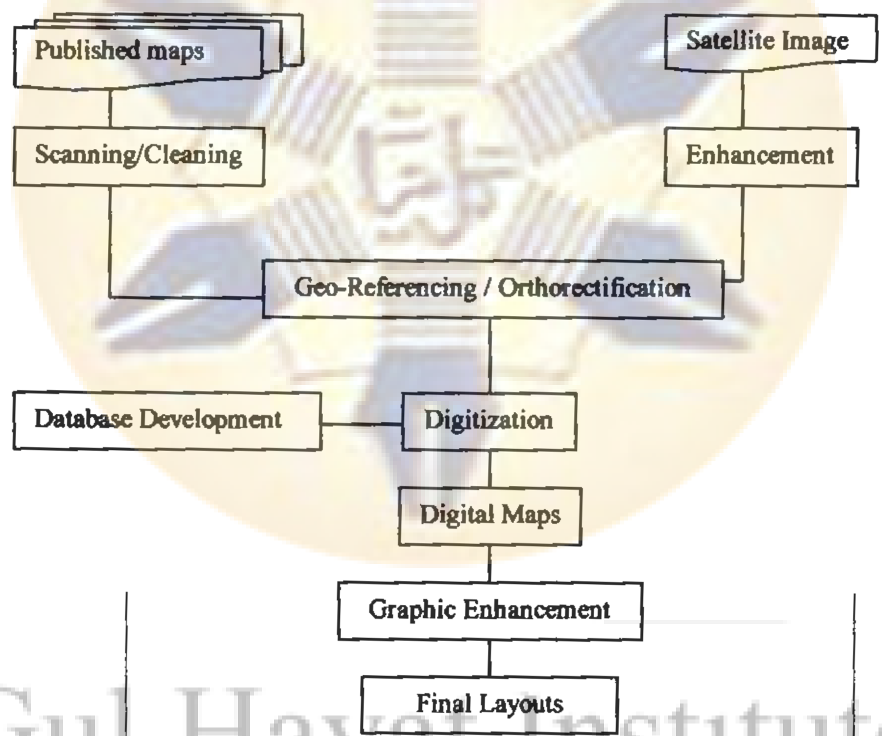
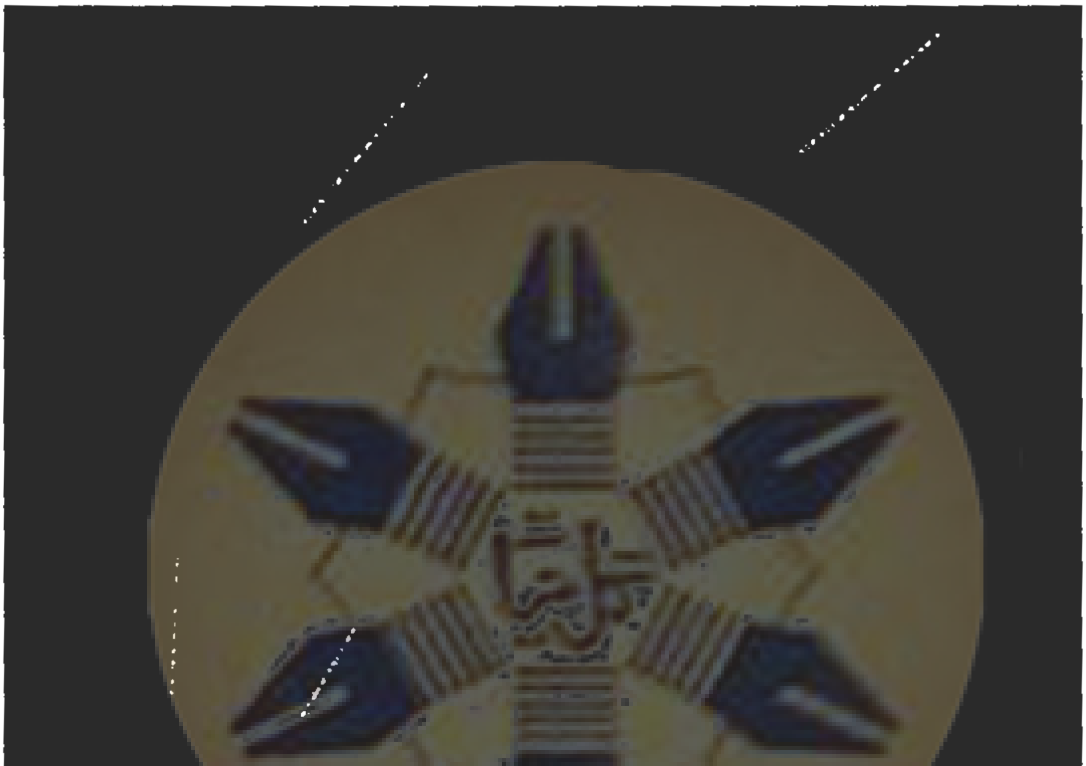


Figure 1.6 Development of Cartographic Products

Planimetrically corrected ortho-rectified digital images of high spatial resolution are being used all over the world for cartographic map preparation. Using remotely sensed satellite imageries and published maps under RS/GIS environment base map has been developed (Figure 1.7).

Base Map Specimen



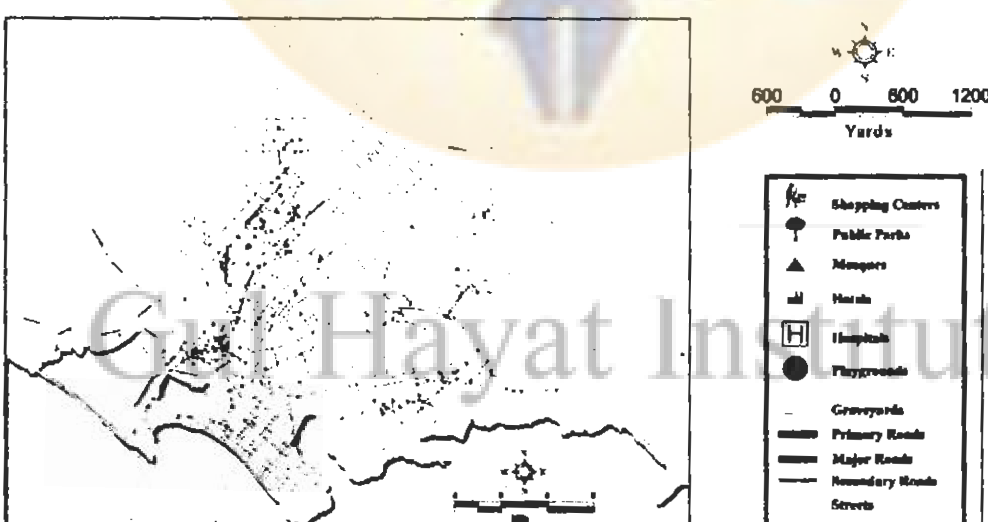


Figure 1.7

Without applying advanced digital cartographic techniques, it may not always be possible to comprehend the digital thematic results. After facilitating these requirements maps are aesthetically and logically legible for users. For finalizing layouts almost all GIS, Remote Sensing and Cartographic software have their toolboxes and editors. But advance graphics packages such as *Adobe® Illustrator, Adobe® PhotoShop, macromedia® FREEHAND, Map Publisher, PCI -Advance Cartographic Environment etc.* have very special tools such as graphic filters, effects *etc.* During the study, some of the tools have been used to produce enhanced images and comparatively better results.

1.3.2.2 Database Management

Relational Database Management System (RDMS) is second important element of GIS (Oracle, 1995). The data comes from many sources, such as maps, satellite imageries, and ground data collections. These diverse sets of information are not always easily integrated. The central data integrator for GIS is the profound *database engine* that accepts and merges diverse data sets and different types of facts and figures, giving the user flexible and powerful sets of information for analyses. Another major strength of GIS is the interactive link between the database and the map using parameters set out in form of tables (normally separately but) at times within map-linked tables. The following Table 1.1 is showing the inputs of attribute data tables and relational map objects.

Table 1.1: Input Data Tables Integrated with Map Objects

Input Information (Data Tables)	**Integrated with (Map Objects)**
Noise pollutant Data	Monitored sites' point
Noise pollutant Data	Analysis Zones
Traffic Data	Monitored sites' point
Demographic Data	Analysis Zones
Disease Data	Analysis Zones
Land cover (Image thematic)	Analysis Zones
Land use Data	Analysis Zones

1.3.2.3 Analyses

As third important element, analytical processes of this study composed of three kinds of functions, which were carried out simultaneously. The first was related to the creation of themes of data and its integration, generation of surfaces and interpretations. Secondly statistical analysis for forecasting of noise pollution was carried out. Thirdly all of these outcomes had to be qualitatively examined based on the knowledge of the metropolitan Karachi.

Several tasks have been designed to provide deep insight with a systematic approach to encompass various aspects of the study, as illustrated in Figure 1.4.

1.4 RESEARCH RELEVANCE

This research falls within the jurisdictions of quite a few disciplines such as Transportation engineering, Environmental management and Urban infrastructure studies, which have not yet attracted the significant attention of the researchers of developing countries such as Pakistan. Presumably, a study based on noise pollution, traffic and land use patterns in Karachi may not be equally valid in other metropolitans of developing countries. Nevertheless, it does attempt to develop a conceptual framework within which certain hypothesis about noise pollution and its indicators may be tested from which substitute generalizations may be formulated. Because noise pollution is a worldwide hazard especially in the rapidly growing cities, it is possible that the findings of this study might be useful in other countries with identical environmental conditions. Formulation of noise risk zones and indigenous epidemiological findings on Karachi are entirely new contributions, unavailable in any published works. The GIS themes have been developed from the integration of data collected on demography, traffic, land cover/land use, noise and prevalence of noise-induced diseases is also pioneered in any report or publication.

There has been no profound study of the impacts of noise pollution in Karachi although its most obvious effects are those related to human health (WHO, 1980; Correspondent daily Star, 1998). Noise pollution is now considered as a cause of otolaryngological (www.lhh.org/noise, 2001), psychological (Tarnopolsky *et al.*, 1980*)* and cardiovascular (Chapman, 1995) diseases, which are prevalent in any urban area. Years ago, a consultancy study (SEPA, 1994) focused the problem of noise pollution of Karachi metropolis, however, they could not address certain research aspects. Spatial patterns within the city on micro scale, dependence on built environment, epidemiological indicators, social aspects and impacts on dwellers, all call for an emergent focus.

As noise pollution is a multi-facet problem, it needs multi-disciplinary studies to address. In this study, the unification of fields of researches, and adding new technologies to an established field, has furnished groundbreaking appraisals. The results of this research would help in anticipating and planning for the future - an approach quite different from the developing countries' current reactive and ad hoc strategy to the environmental problems (after they turn critical). Thus, this study is expected to open new avenues for inter-disciplinary explorations in environmental studies in Pakistan. There exists a general dearth of such studies in the context of Pakistan. Hence, this research is expected to create a better insight about noise pollution, land use and traffic and their appraisals through advanced scientific techniques, which could help in controlling the environmental hazards in Pakistan.

2. ASSESSMENT OF LAND-COVER CLUSTERS

During the last decade, remote sensing has become an organised tool to provide digital outputs in the form of raw and classified data to study various environmental problems. This technology greatly enhances abilities to analyse landscape level relationship of environmental factors and their impacts. As a result, nowadays scientists around the world have been monitoring various environmental impaets by focusing on their factors with the help of Remote Sensing and GIS tools (Kazmi, 2001a).

2.1 REMOTE SENSING (RS) ON INTERNATIONAL ARENA

The advances in space technology have amply demonstrated their potential both for developed as well as developing countries (Verbyla, 1995). In fact, space activities have become one of the major generators and stimulators of scientific, technical, industrial, economic and all-round progress of societies and the lack of such activity leads to further widening of the gap between the developed and developing countries (Colwell, 1967; Meyer and Werth, 1990).

The development of space technology in the past four decades has indeed been an unparalleled event in human experience in terms of technological innovations, which characterized it, and in its impact on the human life. It provided a remarkable boost to increased efficiencies and miniaturization in imaging devices, (Drury, 1990) microcomputers, data storage/transmission systems, conversion of solar energy into electrical energy *etc.* These advances in space technology, besides making it possible to carry out research in terrestrial, (Jensen, 1986; Foody, 2002) interplanetary and deep space, permit applications in a variety of areas such as meteorology (Hubert and Timchalk, 1969; Battan, 1973; Spalding, 1974; Witter and Chelton, 1991), natural resource monitoring & mapping such as agriculture, soils, Landuse/land-cover, ecology, forestry, geology/geophysics (mineral exploration), water resources (Stancioff *et al.*, 1986; Niemi, 1975; McRoberts *et al.*, 2002; Chang and Islam, 2000), environment (Komjathy *et al.*, 2000; Miller and Yool, 2002; Friedl, 2002), communication (Wilke, 1990), search (Slavecki, 1964; Alpers *et al.*, 1981; Prakash *et al.*, 1995; Corbley, 1997; Zhang *et al.*, 1997) and rescue (Vekerdy and Genderen, 1999; Williamson and Baker, 2002) *etc.*

Remote sensing has been much extended by the invention and steady improvements of a variety of specialized instruments. Aerial photography had long been employed as a tool in urban analysis (Jensen 1983). Indeed, this form of remote sensing is still extensively used today and can now benefit from digital image-processing techniques, provided of course that the photographs are digitised first (Futz, 1996). Aerial photography has been used in various applications of earth resources monitoring, management and exploration (Collins, 1978; Kupfer *et al.* 1987, Long *et al.*, 1989; Lo and Noble, 1990; Fent *et al.*, 1995; Baker *et al.*, 1995; Mack *et al.*, 1995; Tomer *et al.*, 1997; Ramsey *et al.*, 2002).

Satellite Remote Sensing (SRS) has accommodated various technologies such as photographic camera, Vidicon camera, Infrared radiometers, Microwave radiometers, micrometer radar, Laser radar (Lidar) *etc.* (Barrett and Curtis, 1976; Curran, 1988; Lillesand & Keifer, 1994; Rango, 2000; Blackburn, 2002; Drake, 2002). Remote Sensing promises to have several advantages over the conventional methods (Chouhan, 1992). The major socio-economic and developmental factors like population, production and pollution exert strain on earth's resources due to which depletion or degradation of environment results and the world starts facing crisis (Nadakavukaren, 1990). In a scenario of dynamic changes taking place on land, water and atmospheric environment, the resources have to be periodically mapped and monitored (Nielsen *et al.*, 1998; Elmore *et al.*, 2000; Rogan *et al.*, 2002). To help in this spectacular task, the comparatively new technique of remote sensing provides an effective tool to the present-day planners, engineers and environmentalists (Faruqi, 1992). Comprehensive approach has great importance to study the interactions among biotic and abiotic creatures (Gates, 1967; Greegor, 1986) where remote evaluation empowers the environmentalist and decision-makers for better governance at affordable cost.

The trend of urban studies via remotely sensed data, was initiated with the advent of 'first generation' satellite sensors, notably the Landsat MSS, and was given further impetus by a number of second-generation devices, such as SPOT HRV. Data from the former were initially used to analyse regional urban systems and for exploratory investigations of some of the larger cities in North America (Forster 1983; Jensen

1983; Stow and Chen, 2002). The availability of still higher spatial resolution images from the latter enabled more detailed studies of the older, more compact urban areas characteristic (Forster, 1983). The advent of a third generation of very high spatial resolution satellite sensors is likely to stimulate the development of urban remote sensing still further (Aplin *et al.,* 1997; Fritz, 1999). The data as result facilitates improved discrimination of the dense and heterogeneous milieu of the old urban cores (Ridley *et al.*, 1997), and will also help to disentangle the urban fabric in the rapidly expanding agglomerations and 'edge cities' of many developing countries (Ganas *et al.*, 2002).

Silva (1996) accounted for Remote Sensing as a powerful technique for surveying, mapping and monitoring earth resources and environment. This technique has become indispensable and increasingly more meaningful because of the synoptic coverage of satellites over large areas rendering its cost and times effectiveness. Furthermore, in areas that are difficult to access, this technique is perhaps the only method of obtaining the required data more effectively and quickly. Shukla and Suchandra (1996) considered satellite remote sensing technology that provide an effective system of temporal monitoring of urbanization with consequent depletion of other natural resources in the immediate environs of big cities and metropolis. These easily available sources of information provide inputs in the urban Landuse planning of large cities and metropolis with a futuristic trend based on the past dynamic observation. Sutanto (1991) suggested remotely sensed data for urban problem evaluation and planning studies owing to fast growth of urban areas whereas the continuous provision of updated huge city maps on such a large scale is difficult for city officials. Conversely, acquisition of updated and highly detailed (with higher resolution) information is easy and cheaper.

Several studies have been conducted with the use of moderate resolution satellite data such as NOAA, Landsat and SPOT both panchromatic and multi spectral analysis. Gao and Skilleorn (1998) described the capability of SPOT-XS data in producing land cover maps at the urban-rural periphery. On similar lines Toll (1984); Gupta and Munshi (1985); Doi (1990); Forghani (1994); Shukla and Suchandra (1996); Coppin and Bauer (1996); Kwarteng and Chavez (1998); and Gao and Skilleorn (1998) have endeavoured to look carefully at the urban environment and land cover by using remotely sensed imageries. Brouwer (1990) used remote sensing techniques to rapid assessment of urban growth. Quattrochi and Luvall (1999) studied the growth of Atlanta (USA) city vis-à-vis meteorology and air quality using remote sensing. Anthony and Xia (1996) studied urban growth management in the Pearl River delta (USA) by using remotely sensed information.

Haack *et al.* (1987) found that in some cases Landsat TM data might not always lead to required results than Landsat MSS in mapping urban and near-urban land covers if they are less homogenous. Landsat TM data allowed many classes such as densely built-up (settlements), sparsely built-up (settlements), rangeland, irrigated crops, and irrigated pasture in suburban region of Denver (USA). However, the improvement was minimal for spectrally heterogeneous classes such as urban residential areas. From Landsat TM imagery, Harris and Ventura (1995) performed a five-category (residential, commercial, industrial, open spaces and freeways) classification for the small urban areas of Beaver Dam, Wisconsin (USA). The accuracy was improved after such ancillary spatial information as zoning and housing density was incorporated in the classification. Therefore, in spite of its being a primary data source, TM imagery functions better in a complementary role in mapping land covers at the urban periphery (Milazzo, 1980).

With the growing technology, several new techniques have been introduced to monitor changes in the land cover / land use. Some of these include image difference, ratioing, principal component analysis (PCA), and selective principal component analysis (*e.g.* Chavez *et al.*, 1977; Jensen and Toll, 1982; Gunther, 1982; Singh 1989; Chavez and Kwarteng, 1989; Chavez and MacKinnon, 1994).

In an indirect approach (*e.g.* Ulshöfer and Rosner, 2001) urban traffic pollution could be estimated by way of the monitoring of the relative parameters such as land use, traffic count and speed *etc.*. Remote Sensing could help to map the road network, geometry of choking regions, under threat population *etc.* (Gonzalez and Wintz, 1987, Lillesand and Keifer, 1987). These parameters have strong relationship with the generation, distribution, effects and control of urban traffic pollution (Hayes, 1979; Stern *et al.*, 1984; Collins *et al.*, 1995; Welde *et al.*, 1999).

2.2 REMOTE SENSING ON PAKISTANI ARENA

In Pakistan, Space and Upper Atmosphere Commission, Pakistan (SUPARCO), is the governmental organization involved in space technology development, claims to its credit a host of studies addressing diverse resource, mapping and environmental problems covering various disciplines such as hydrology, agriculture, forestry, geology, geography, oceanography, *etc.* (Mehmud, 1988; SUPARCO, 2000). Out of these projects, chief studies includes urban Land use/land cover studies of Lahore, Islamabad, Peshawar *etc.* with integration of GIS; Desertification monitoring of Cholistan desert at Dingarh, Fort Abbas and Islamgarh; Land degradation monitoring of Hyderabad district; mapping biomass and other terrain units around Chotiari in Sanghar district; coastal mangrove degradation from 1973 - 1998; Land suitability around Moen jo Daro Area; Water logging and salinity mapping -WAPDA (SCARP VI Project); 1 Km Land cover database of Asia; mapping of forests in northern mountainous regions of Pakistan; and urban sprawl studies of Karachi and other major cities of Pakistan (SUPARCO, 2000) .

Zareen *et al.* (1995) performed statistical analysis of wind speed and direction obtained through satellite based network in Pakistan. Baig *et al.* (1995) processed satellite-based data of Bannu basin, Pakistan to enhance the geological features. Siddiqui (1995a), elaborated the diversified applications of satellite imageries in exploration / development of oil and gas field in Pakistan. Rangoonwala and Ahmed (1995a), wrote a review article on integrated use of optical and Radar sensors for resource development. Khan and Siddiqui (1986) used Landsat data for urban growth monitoring in Karachi metropolitan area. Marie-Agnes (1989) used aerial photograph at scale 1:40,000, SPOT PAN image at scale 1:40,000 and SPOT XS image at scale 1:24,000 for identification of different patterns of development and produced the land use and road network maps of Karachi. Siddiqui (1991) merged high-resolution SPOT-PAN data with SPOT XS and Landsat TM data for urban land use application. Kazmi (1991) applied SPOT HRV-2 data to identification and mapping of types of land use classes and with the help of ground truthing, classes were checked. It was suggested that SPOT images could effectively be used for the identification and interpretation of land use.

Rangoonwala *et al.* (1991) used satellite remote sensing data for identifying residential units for change detection in Karachi. A follow-up study by Rangoonwala and Ahmed (1995b) described the urban growth monitoring and development planning using GIS technologies. Siddiqui *et al.* (1995) have undertaken an urban land use/land cover study through satellite remote sensing techniques by classifying Landsat and SPOT imageries. It was concluded that the systematic monitoring of urban growth, proper management of the city and planned future expansion would lead to improvement in the living standards and environmental conditions of the city as a whole. Siddiqui *et al.* (1996) used satellite remote sensing data for mapping and monitoring temporal changes in Larkana district and presented the application of satellite remote sensing data to urban land use classification studies. Siddiqui (1993 and 1995b) looked at the possibility of SRS technology in monitoring deforestation and land degradation in Pakistan. Malik and Majeed (1995) threw light on RS application in water resources research in Pakistan. Nasir and Raouf (1995) wrote a review article on remote sensing for coastal resources and marine pollution.

Kazmi (1995, and 2001b) utilized SPOT HRV and Landsat 5, imageries to monitor land degradation and crop assessment in the rural vicinity of Karachi. Afsar (2001) and Mehdi *et al.* (2001) contributed their work related to the significance of satellite remote sensing in the field of urban studies of Karachi metropolis. Afsar (2001) has estimated 195 square miles, built-up urban area with rapid growing rate. Mehdi *et al.* (2001) indicated that the major portion of urban built-up in 1998 was covered by medium density of settlements although the major concentration of population and settlement was in core Karachi.

2.3 CONCEPTUAL FRAMEWORK

Following section will explain the fundamental conceptual framework to extract land cover clusters from the satellite data. These extracted land cover data sets will then be embedded into final "Noise Risk Zones" of Karachi.

2.3.1 Remote Sensing Data Sources

The use of satellite imageries for mapping appears to be one of the most straightforward applications of remote sensing. Multispectral images are being used for land cover *classifications*. In this study Landsat TM (1998), SPOT Pan (1992) and SPOT XS (1992) multispectral data has been used to classify Karachi's Land cover and its distribution (Table 2.1).

Table 2.1: Satellite Imageries: Sensors, Resolution and Acquisition

Satellite / Sensors	Resolution	Acquisition
SPOT Pan	10 x 10 m	March, 1992
SPOT XS	20 x 20 m	March, 1992
Landsat TM	30 x 30 m	February, 1998
KVR	2 x 2 m	1998

Source: courtesy of Kazmi, J.H., University of Karachi

For targeting the congestion locations due to heavy traffic and dense land use, use of high-resolution imagery *i.e.* KVR (2m resolution) of Sovinform Sputnik, Russia has been employed in this research. Unfortunately it was not containing the whole of the metropolitan Karachi but had the coverage of about two larger districts. The author utilised this high-resolution imagery and his life time exposure of the city in deciding the list of more than 300 locations for the ground data collection.

2.3.2 Satellite Data: Quality and Processing

The remotely sensed image is processed in various steps according to the needs and objectives. Broadly speaking, the major steps in satellite images processing are image Rectification, Enhancement, Stitching/Sub-setting and Classification. These procedures are applied through high-speed computers using pertinent software. The quality of the images was found satisfactory however, *rectification*, *corrections* and *enhancement* was conducted as per protocols to further enhance the quality of images.

2.3.2.1 Environmental Attenuation

Atmospheric error creeps into the data acquisition processes and may degrade the quality. This in turn may have an impact on the accuracy of subsequent human or machine assisted image analysis (Meyer *et al.*, 1993). Therefore, it is highly recommended to pre-process the remotely sensed data prior to the final analysis and data extraction (Teillet, 1986). Rectification, a pre-processing step, involves application of some correction factors on the remotely sensed imagery acquired from the source.

2.3.2.1.1 *Seasonal Differences*

Angle of incidence imparts great influence on radiant flux from the surface objects. It changes digital numbers (DNs) during variations especially in temporal studies involving time spans of less than a year. It is important to compensate for the difference in sun elevation angle throughout the year.

The above-mentioned correction was accomplished using program available in Geomatica 8.x Algorithm library. The MODEL algorithm normalizes the sun's elevation angle to that of its zenith position. This is achieved by dividing each image by the sine of the solar elevation angle for the scene (PCI, 2002). Solar elevation angles were provided as ancillary data in the header of the acquired imagery.

2.3.2.1.2 *Haze Compensation*

Particulate matter in the atmosphere is responsible for the scatter of electromagnetic energy. This scattered component (known as "haze") increases the overall radiance thereby reducing the contrast in an image. A quick and simple method to compensate for haze is to estimate the additive haze factor independently for each channel. These values were obtained by observing the 'grey level' for scene features for which the reflectance should be known.

Having determined a quantitative measure for haze, compensation for this effect by subtracting the haze factor value from every pixel in the image has been adopted. Subtraction of an image by a constant grey level of above-mentioned additive haze was achieved using Image Database Arithmetic (ARI) algorithm:

2.3.2.2 Instrumental Errors

'Image noise' is the result of sensor malfunctions during the recording or transmission of information. In a digital image, this can manifest itself as either inaccurate grey level readings or missing data altogether. Unlike geometric distortions and other radiometric degradations, 'Image noise' is readily identifiable, even to those observers who are unfamiliar with the scene of the image. Satellite Image processing software offers correction algorithms for the most commonly encountered types of 'Image noise' such as Line Drop and Regular Stripping *etc.* To make proper image data set Line Drop Replacement (LRP) algorithm has been applied on imperfect images, which were used in this study. This function filled the several adjacent pixels or entire missing lines or noticeably different to each other.

2.3.3 Image Geometrics

Raw digital images contain geometric distortions, which make them not viable as maps. Map is a flat representation of a part of the earth's spheroidal surface. To be useful, a map should conform to an internationally accepted type of cartographic projection, so that any measurements made on the map will be accurate with those made on the ground. The steps to correct the satellite images as well as scanned maps, geometrically, are shown in the flow chart as Figure 2.1.

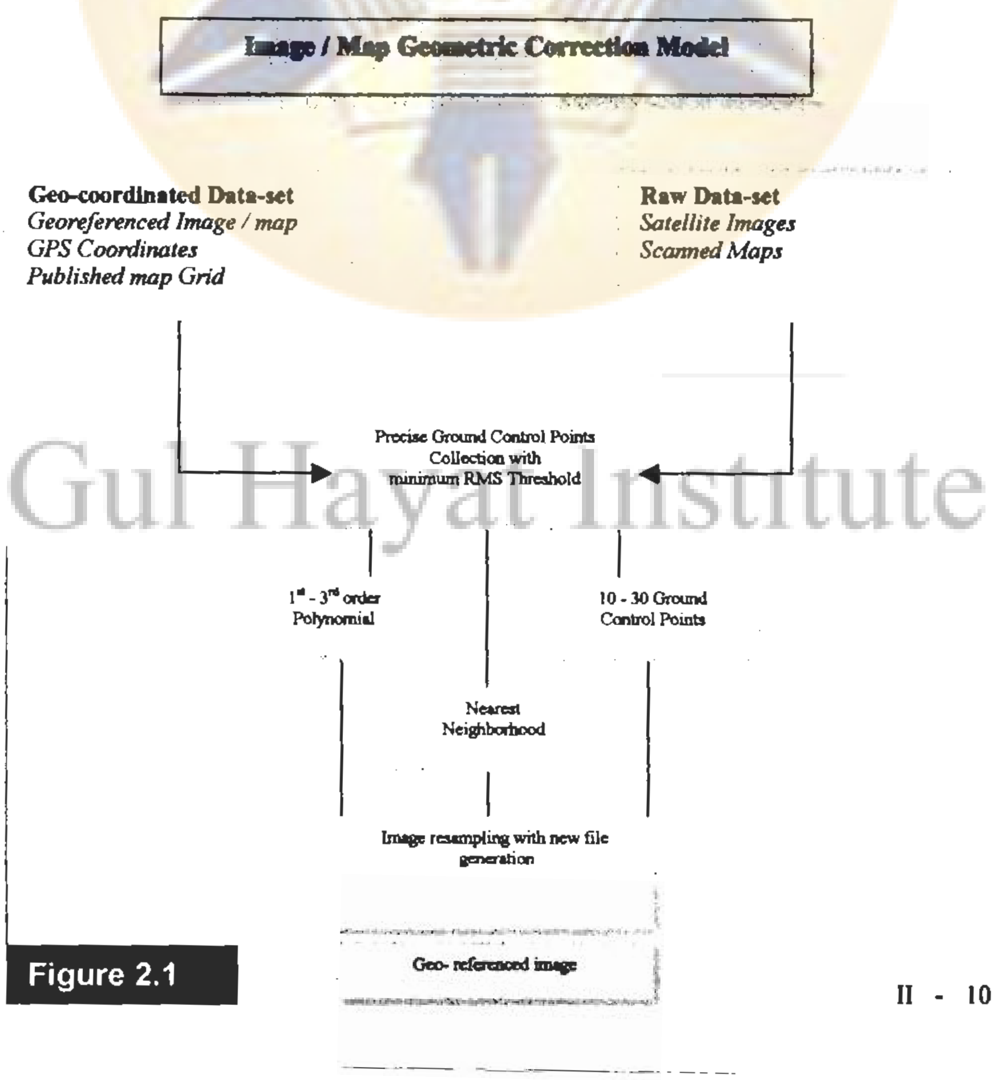


Figure 2.1

The geo-co-ordinated data set was projected on the Universal Transverse Mercator (UTM) Projection, which is one of the most appropriate projections for this region of the world.

2.3.4 Image Enhancement

Image Enhancement techniques are used to remotely sensed data to improve the appearance of an image for human visual analysis or occasionally for subsequent machine analysis. There is no such thing as the ideal or best image enhancement because the results are ultimately evaluated by humans, who make subjective judgements as to whether a given image enhancement is useful (Jensen, 1996). In this study, various enhancement algorithms have been used to improve the quality of images through world-renowned software: ERDAS Imagine version 8.3.1 and PCI Geomatica 8.x.

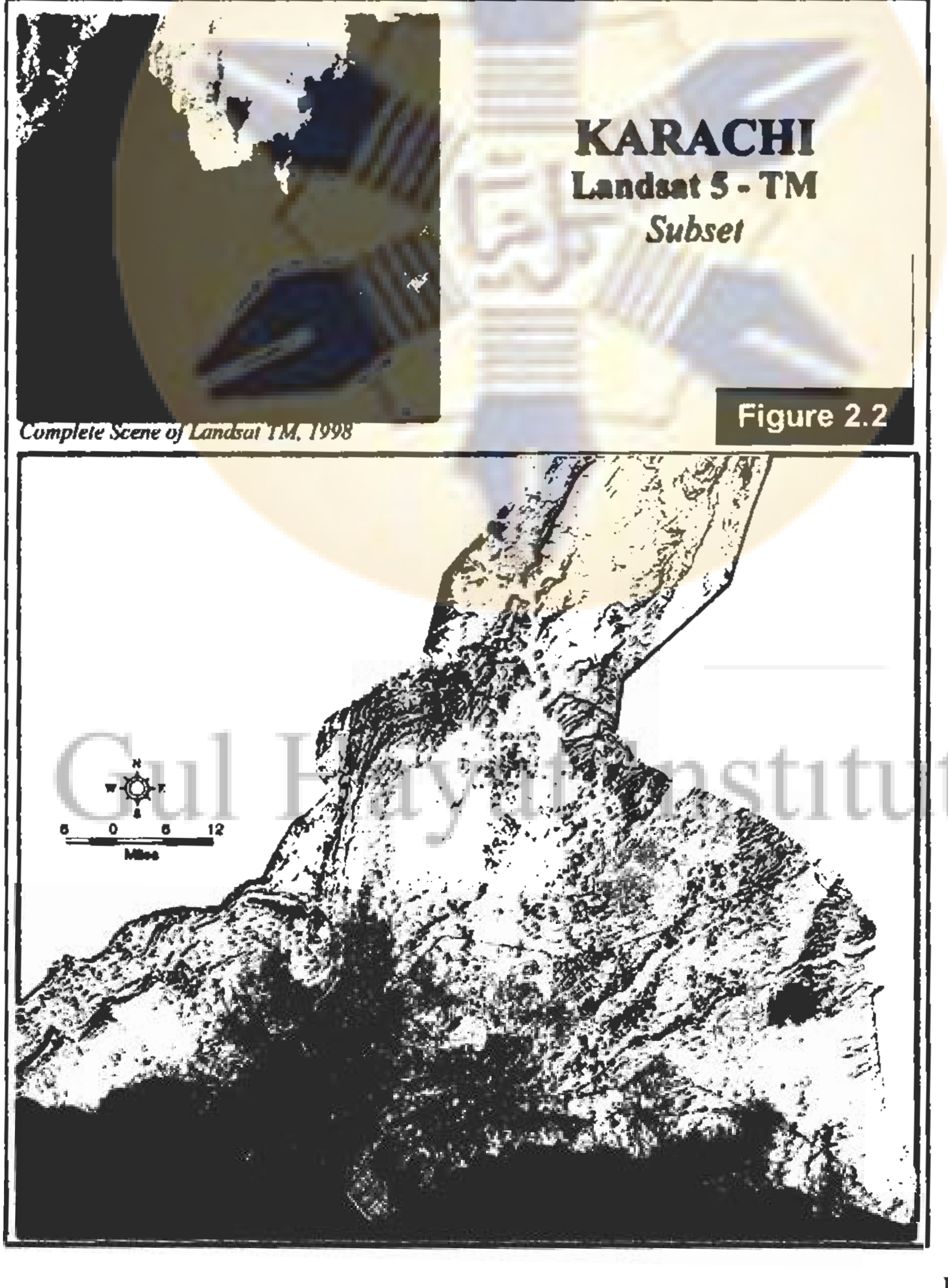
The algorithms employed are: Contrast Enhancement (Linear, Root, Frequency, Adaptive), Band Ratioing, Spatial Filtering (Low Pass filters including, Average (mean), Median, Mode, Gamma) and High Pass Filters (Gaussian Filter, Laplacian, Sobel, Prewitt Edge Detector and Edge Sharpening *etc*) (PCI, 2002).

For machine analysis, enhancement algorithms were permanently applied on the image bands and thereafter saved in the same file as Look Up Tables (LUT). These LUTs were applied at the time of visual interpretation over loaded image bands in RGB channels.

2.3.5 Targeting Area of Interest (AOI)

Owing to the difference in areal swath of SPOT and Landsat imageries, the area of interest *i.e* Karachi could be obtained both as subset and by mosaicking techniques, as the case may be. Mosaicking is the blending together of several arbitrarily shaped images, to form one large radiometrically balanced image such that the overlapping boundaries between the original images are not easily seen. This allows creating a complete study area as a single image, which could be consisted of several images before.

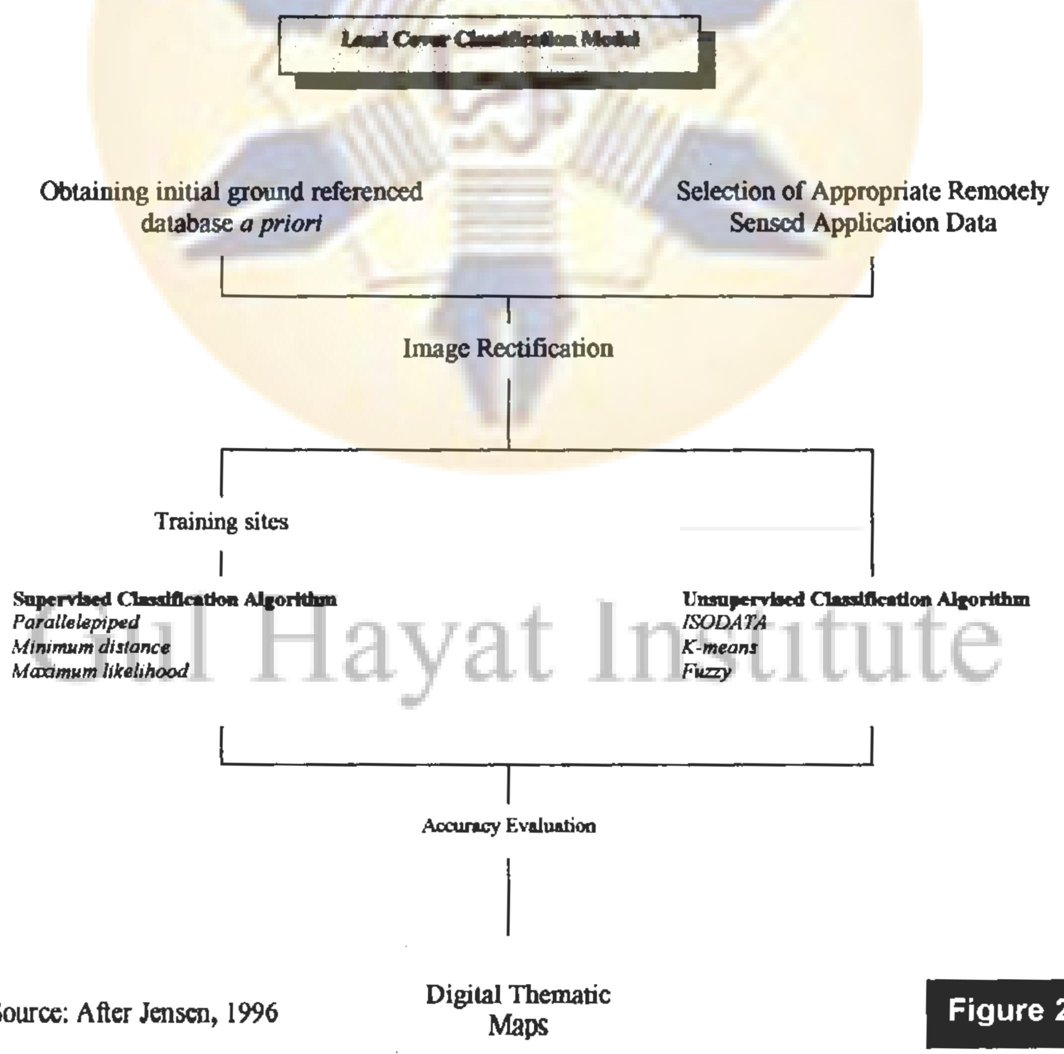
At times, the area under study is not wider than the satellite image single scene instead of mosaicking of several images subsetting of image is done. For the convenience of processing, it was necessary to overlook the image of adjoining areas and study the metropolitan Karachi only. This process of focusing the AOI and clipping the image of irrelevant locations is often known as Subsetting. Here the Karachi metropolis in Landsat synoptic coverage is extracted from the image through subsetting. Landsat TM image covers 185 x 185 km (34225 Sq. km) synoptic view. Karachi Division occupies 10.2 percent of the total TM scene. In this study, Area of Interest (AOI) has been developed in form of georeferenced vector data. Subset has been taken out from image on the basis of AOI. The total Karachi Division is covered in the same image illustrated in Figure 2.2.



2.3.6 Land-cover Extraction

Remotely sensed data of the earth surface may be analysed to extract useful thematic information. This raw data are then transformed into useful information. Multispectral classification is one of the most practising methods for the information extraction. This information is the best source of available, updated and synoptic Land-cover extraction. The scale of details and accuracy depend upon the image resolution, accuracy of algorithms along with their limits and expertise of users.

The land cover classification procedures used are illustrated in the form of a Flow diagram Figure 2.3. For the achievement of maximum land cover accuracy several supervised and unsupervised classification algorithms has been applied with different classification schemes on exercise level. The output of this exercise resulted in profound observation on the study area's land cover.



Source: After Jensen, 1996

Figure 2.3

2.3.6.1 Land cover Classification Scheme

With the detailed spectral examination of images, the following scheme of land cover classes has been designed, each of which has its own significance for this study. The classes studied were basically four and further classified depending upon the sparseness and density of that particular land cover illustrated as under Figure 2.4.

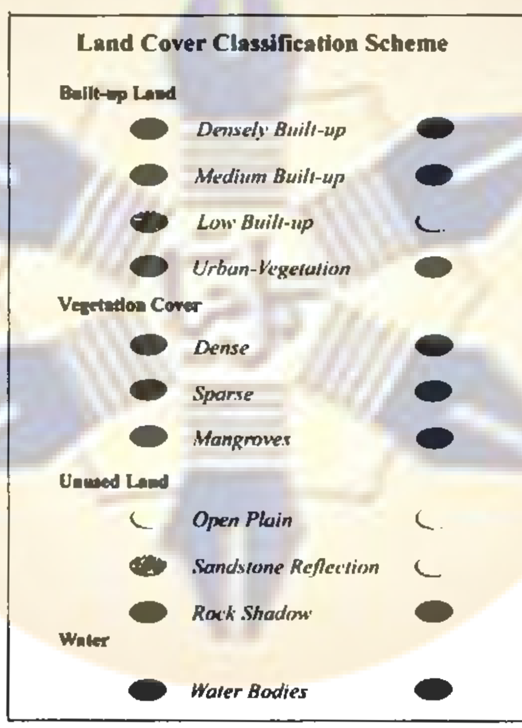


Figure 2.4

2.3.6.2 Supervised Classification Method

After going through in details of spectral distribution with individual bands and several combinations, criteria land-covers have been explored. After detection of proper land cover classification has been performed under the supervision of training sites.

2.3.6.2.1 *Targeting Training Sites*

An analyst may select training sites within the image that are representative of the classes of his/her interest. For each class 3 to 5 sample training sites has been marked. Complexity and overlapping was avoided and the sites were kept straightforward. Class homogeneity has been given the highest priority in the overall mining of training sites.

2.3.6.2.2 *Classification Algorithm*

Various available supervised classification algorithms have been tested. Eventually, *Minimum distance* classifier (MDC) was used with explicit training areas over the images. This classifier assigns each unknown pixel to the closest category mean. This algorithm is computationally simple and commonly used. When used properly it can result in classification accuracy comparable to other more computationally intensive techniques. The author was satisfied with the investigation results of this exercise.

2.3.6.3 Classification Result Editing and Aggregation

In any interactive (supervised or unsupervised) classification result, it is very rare that classification results are 100% accurate. One of the post-classification processes, "*Class Editing and Aggregation*" is one of the essential steps to enhance the accuracy. When classification results are analysed, it might be realised that the classifier had difficulty distinguishing two classes. These classes may be relatively similar land-covers. In this regard merging of two same land-cover classes completely or under the selected mask-covered area is a common one. Similarly, during the class editing results can be stored in a new class as well. In this study these facilities of today's powerful available toolboxes, has been used almost after all classification schemes.

2.4 THE FINDINGS

The previous section on methodological framework has thrown light on the pre-processing techniques often referred to as Rectification and Classification, adapted in this research. The most comprehensible approach towards the presentation of results on remote sensing products is to provide the visual comparisons, "Before and After" each step of processing. Figure 2.5 is the raw image acquired for analysis.

Figure 2.6 is the georeferenced version of the raw image. This exercise of georeferencing has made the image of Karachi more geometrically familiar for the users in the form of having geographical co-ordinates for 'manoeuvring' and 'environmental attenuation' and 'image noise correction'.

In Figure 2.7, 'a', 'c', 'd' are the set of selected pre-enhanced subsets whereas 'b', 'd', and 'f' are the enhanced outputs through *Linear distribution, Root distribution and Adaptive distribution* of spectral values respectively. These enhanced images helped in the upcoming classification process for the assessment of land cover clusters for metropolitan Karachi.

Figure 2.5, and Figure 2.2 are the before and after renditions of the image 'Subsetting' technique. As already discussed in the methodology, it is evident here that the subsetting techniques have successfully narrowed down the depiction of the developed study area. However, the land beyond inhibited areas was included in the picture as the administrative boundaries of the then districts that had to be accounted for. Secondly, the author wished to render a pictorial overview of the physiographic features surrounding the study area.

Karachi and its Environs from Space

(Landsat TM FCC)

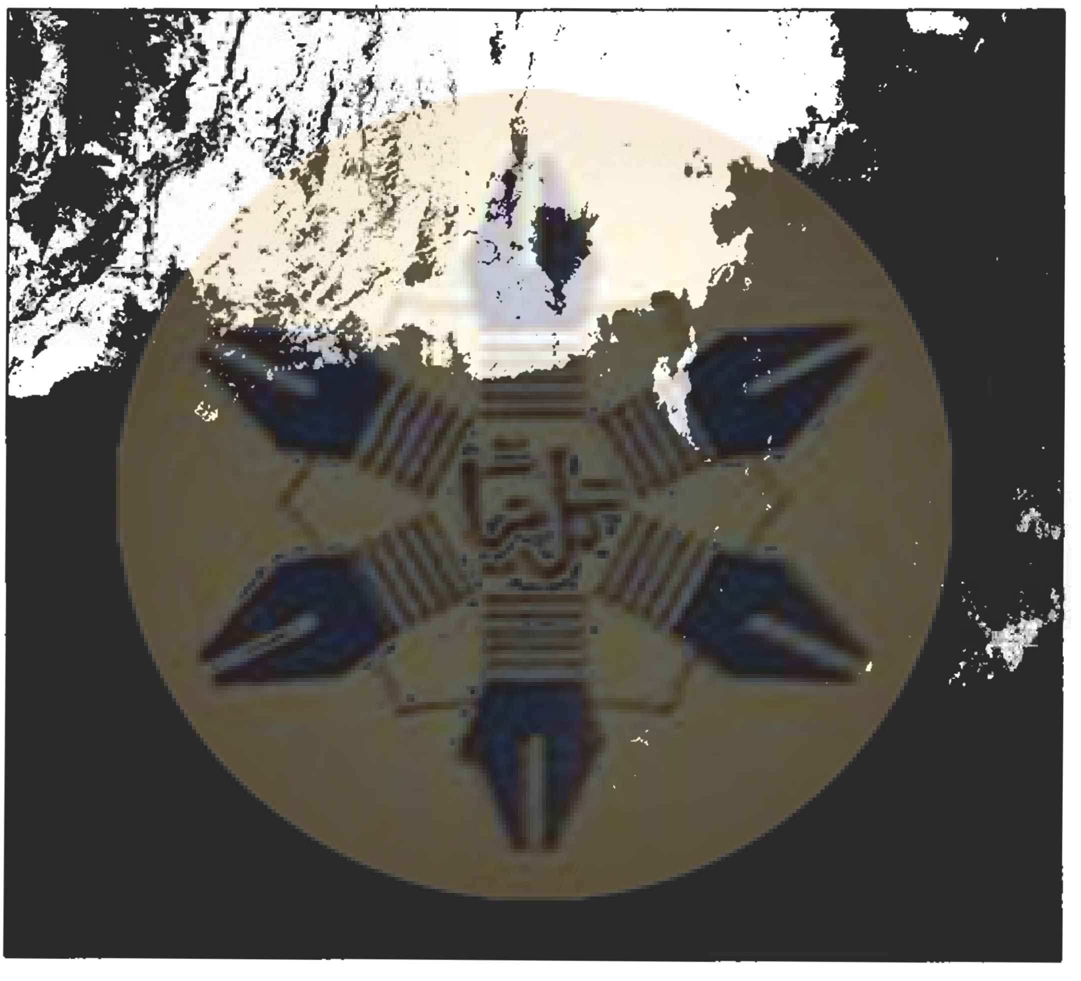


Figure 2.5

Satellite	: Landsat 5
Sensor	: TM
Bands	: 2, 3, 4
Date of Acquisition	: Feb 1998
Resolution	: 30 x 30 m

KARACHI AND ITS ENVIRONS

GEOMETRICALLY CORRECTED IMAGE

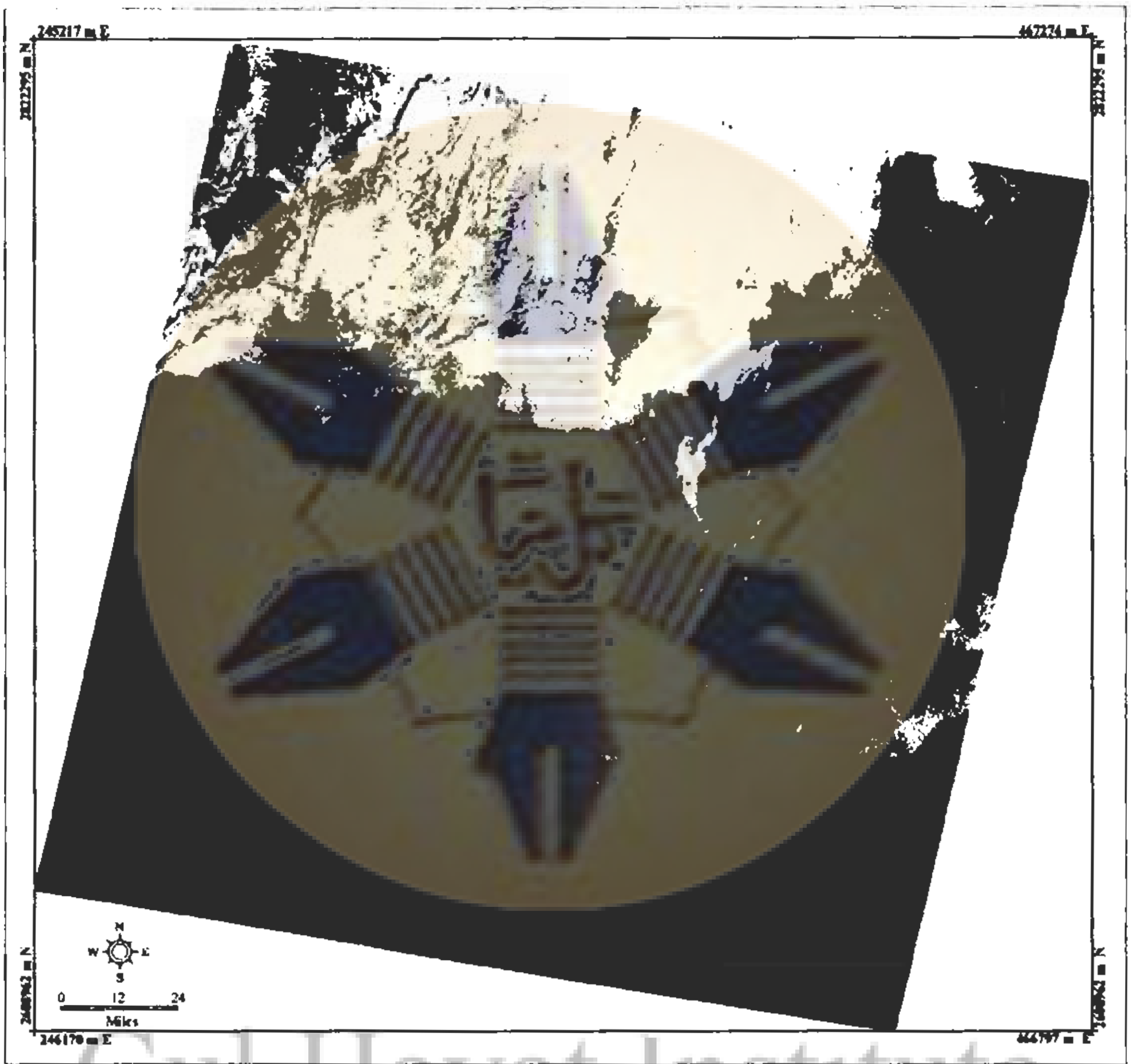
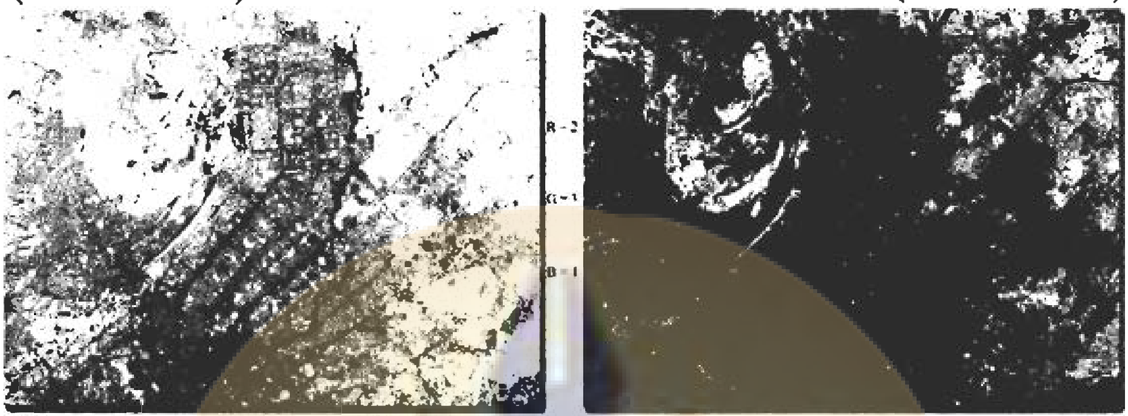


Figure 2.6

Selected Subsets of Pre and Post Enhanced Imageries

(Pre - Enhanced) **(Post-Enhanced)**



(a) *(Linear Distribution of Spectral Values)* **(b)**

(c) *(Root Distribution of Spectral Values)* **(d)**

(e) *(Adaptive Distribution of Spectral Values)* **(f)**

Figure 2.7

2.4.1 Prominent Clusters

Image classification of *Landsat-5 1998*, produced a value added digital thematic map (Figure 2.8) that contains itemized account of eleven land cover classes as illustrated in Table 2.2. This itemized account was for the subsetted version of acquired imagery.

Table 2.2: Classified Land Cover of the Karachi Division

S. No.	Area Sq. Miles	Land Cover	Cumulative Land Cover	Share of Cumulative Land Cover	
				mile²	%
1	31.032	Dense Vegetation			
2	8.683	Sparse Vegetation	Vegetation Cover	64.22	3.88
3	24.503	Mangroves			
4	55.771	Urban Vegetation			
5	43.678	Dense Urban Built up	Built up Land	193.44	11.70
6	33.349	Medium Urban Built up			
7	60.640	Sparse Urban Built up			
8	579.625	Open Land			
9	364.156	Sand Stone Reflection	Unused Land	1029.03	62.27
10	85.248	Rock Shadow			
11	365.585	Water	Water	365.58	22.12

The appraised land cover of Karachi division indicated that the major share by area is comprised Mountains / barren land *(81.5%)*, Urban Land use *(15.3%)* and Vegetation canopy *(3.2%)* however, the urban land cover has been found sprawling day by day.

The resultant classified thematic map (Figure 2.8) could be interpreted on the basis of physiography and historical expansion of urban land, which is mainly due to the human activities (as dwelling, transport and business).

Classification results indicate the existence of three distinct widely spread physiographic features. Karachi has plain land, coastal zone and hilly ranges. The processed image has yielded the area of plain land of Karachi division to be around 772.5 square miles. Out of which about 25 percent is covered by urban settlement, whereas the rest is either too far from the settlements or isolated pockets surrounded by hills. The planned development of the metropolitan has been mostly on the plain land. The likelihood of future expansion of urban cover lies around the plains near

Hawks Bay, Pipri, and Gadap. The coastline shown on the image has occupied more than 75 percent by the built environment. It has expanded due to reclamation of shore around Clifton and Defence Housing Authority (DHA), over the period of time. This reclamation process is on going ever since the date of image acquisition. The southern part of the city is connected with the Arabian Sea. On the south and southeast corridors lie a widespread extent of mud flats, sandbanks and mangrove swamps, crossed by a complex system of branching creeks and inlets.

The Kirthar Range can be seen on the northwestern portion of the classified image near the prominent Hub dam. The Pabb Range, south of Kirthar is manifested in the cluster of rock shadow and sand stone reflection. In the extreme Southwest to the centre of Karachi Division, Jhil Range is dominating, a series of hills and ridges, extending from Cap Monze to the Manghopir area. These features are quite obvious to pinpoint on the classified image.

The human settlements are portrayed in four clusters on the classified image. The most prominent cluster on the image is of densely built up land cover. The areas inscribed in this class are old city (core) areas (from south of Layari river to Club road), Nazimabad, Liaqatabad, Lasbela, Shireen Jinnah Colony and Shah Faisal Colony. The localities falling under densely built-up class are congested because the residential and economic activities that take place around them, have expanded over time. The dense road network and high rises have occupied all open spaces and amenities. URC, 2002 claims that population densities at some of these neighbourhoods are as high as 1,800 persons per acre. In these areas concentration of commercial activities are very high resulting in mixed land uses all over.

As evident on the classified thematic map, the class of low built-up area shows actually the suburban areas, urban outskirts and peripheries. This class includes Surjani Town, Gulshan-e-Maymar, Gulshan-e-Hadeed, Northwest of Orangi Town, Phase VI and VII of Defence Housing Authority (DHA).

A very interesting phenomenon was observed while examining the medium built up cluster of the classified output. The author observed that vegetation is almost non-existent in the densely built up class since most of it is historically pre-independence cantonment areas around Shahrah-e-Faisal, Clifton and Defence Housing Authority.

CLASSIFIED LAND COVER OF KARACHI METROPOLIS

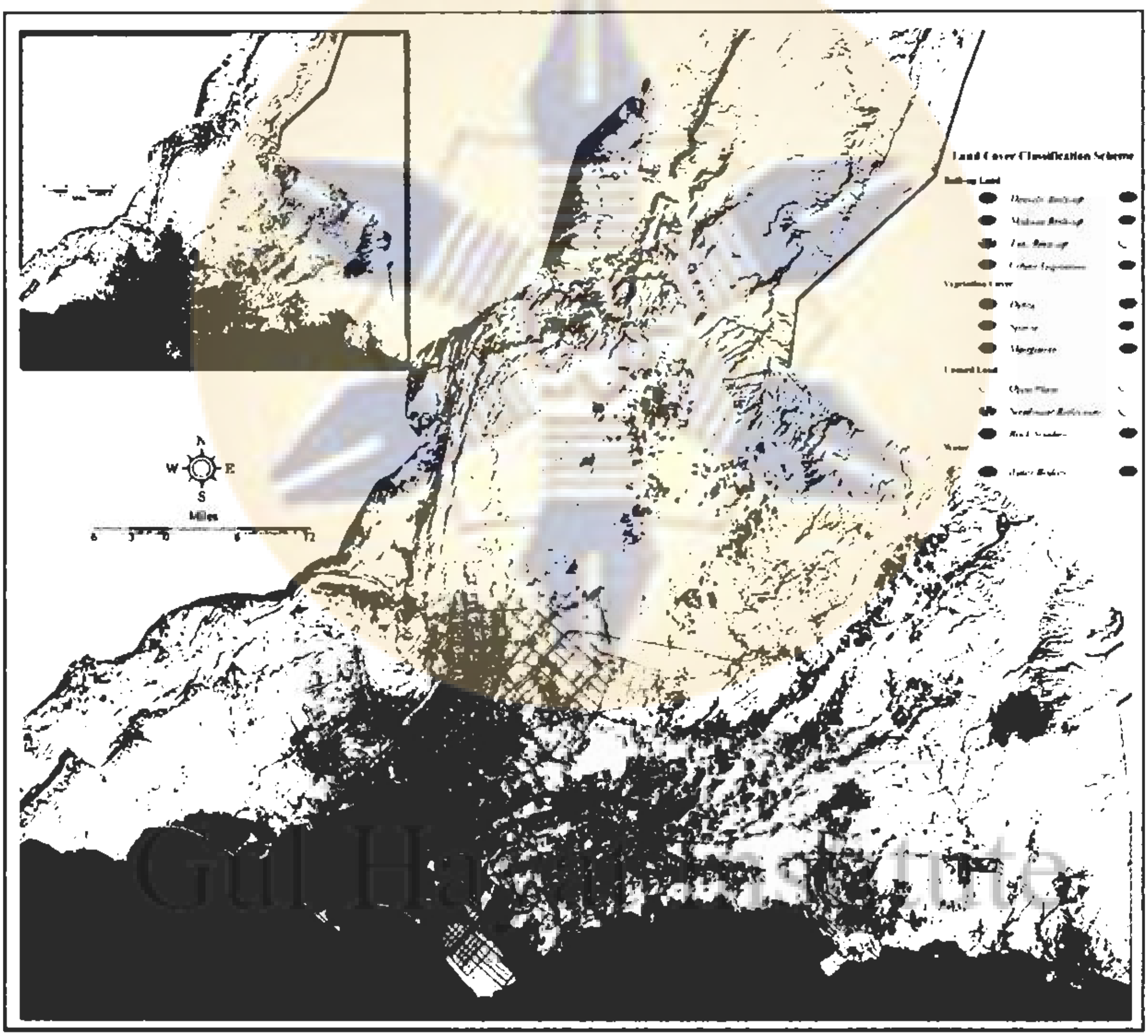


Figure 2.8

2.5 CHANGE DETECTION: GROWTH OF SETTLEMENTS

The growth of urban settlements is one of the key indicators to spot the potential noise .risk areas in a city. Advantage of image-based analysis could be extended to monitor the urban growth of the metropolis over a period of time. This could be done using two or more classified images of different dates of the study area to demarcate the new settlements. This is particularly useful for highlighting changes that have occurred over time such as in urban analysis. Change detection technique has been applied to see the changes in human settlement patterns across the metropolitan from 1986 to 1998.

The change detection procedure overlays two grids and determines the areas of change from the first grid to the second grid. An overlay of two identical Land-cover classes indicates an area of no change and it is therefore assigned a class value of zero (0). On the other hand, where there are changes, a new grid is created using the new classes. The cell size of the new grid is same as the lower of the maximum cell size of two input grids. The results of the overlay are organized into a table as well as map result (Stevens, 1999).

SPOT-xs October 1986 and March 1998 had been processed and classified by Afsar (2001). The digital versions of both the classified images were acquired and then change detection was conducted in *SPANS (software).*

It has been found that pinpointing of growth corridors is quite difficult. During the analysis period of twelve years (1986 – 1998) the city has grown literally in all land available directions as shown in Figure 1.3 and Figure 2.10. It was also deduced that the human settlements around Karachi during the analysis period, were the by-products of infrastructure development. Major growth has been observed along the National highway, Super highway, University road and RCD highway. Similar results were obtained by Afsar (2001), when Karachi's urban sprawl was studied. The Karachi Development Plan (KDA, 1991) had then identified future growth corridor directions. Figure 2.10 and Figure 2.9 present the updated reality.

There are three major highway projects in the pipeline, namely, the Northern Bypass, the Layari Expressway and the Southern bypass (Correspondent daily Dawn, 2002). It is envisaged that the Northern Bypass has acquired a priority among these projects. Its construction (Super highway to Karachi port) is expected to provide another corridor for future settlements. Decision-makers should start visualizing the future scenario of the metropolitan growth when all these highway projects would be materialized.

Concluding the findings of exercises on land-cover assessment and change detection, use attract the population and traffic that give rise to noise pollution. After land cover, the 'land use' of the city has to be scrutinised in depth.

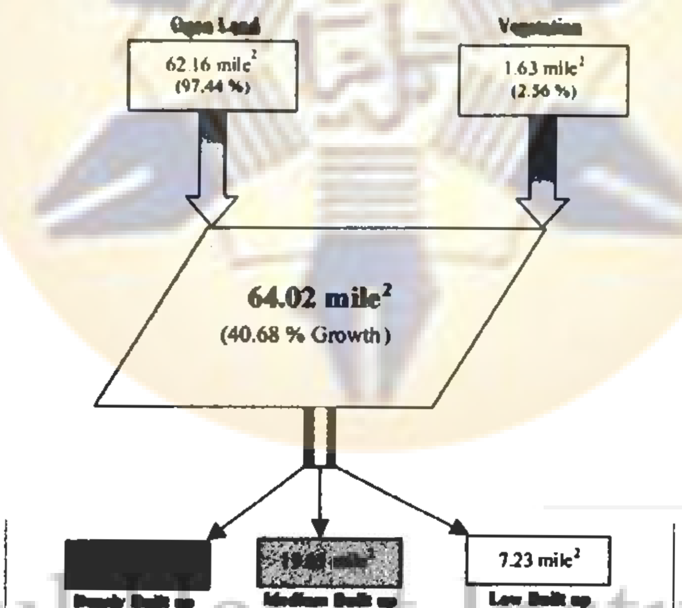
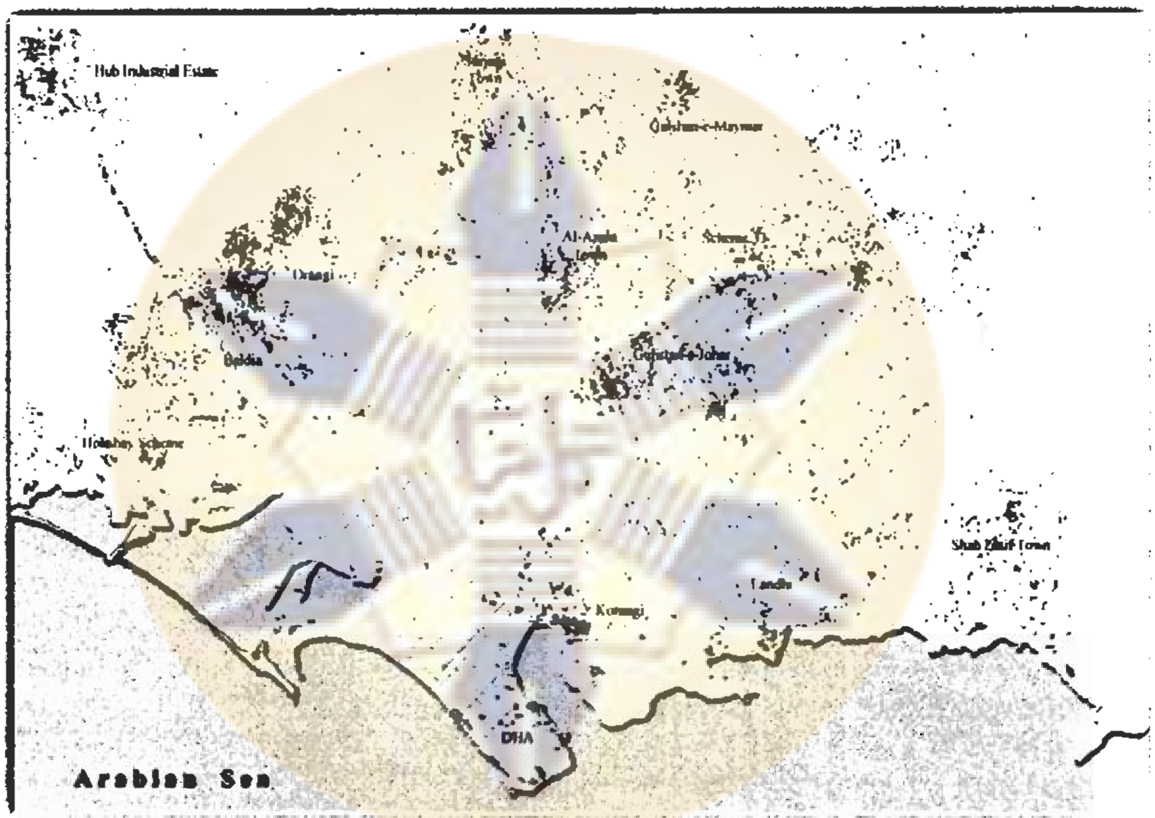


Figure 2.9: The Account of Land Cover Change

Growth of Settlements in
KARACHI METROPOLIS
(1986 - 98)



Source: SPOT XS, October 1986 and March 1998

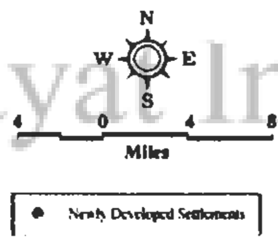


Figure 2.10

3. APPRAISAL OF LAND USE

Urban land use, infrastructure development and environment are mutually interdependent Rapid urban growth generally means that little land is reserved for agriculture, public space and amenity. Lack of recreational space is yet another cause of deteriorating urban quality of life in developing countries especially third world countries and contributes to increasing social instability (Barrow, 1995). It was estimated that about 25 percent of the urban population in Pakistan lives in slums and squatters. (GOP, 1988) Allied to low-quality housing, poverty, disruption of community cohesion and other declining urban conditions are the main public health threats. Karachi is no exception to these universal facts where fragmented development has been taking place, as there is no coordination among the agencies making and implementing these proposals (Khoro and Mooraj, 1997). Therefore, the author is now drawing the inquiry towards land use from land cover.

In 1870 the urbanised area of the Karachi district was 5 mile^2 (Pithawalla *et al.*, 1946). The 1972 census report gives the figure of 112 mile^2 . The 1974 Master Plan (KDA, 1972) defined metropolitan Karachi as 135 mile^2 and the Karachi Development Plan (KDA, 1991) gives a figure of 1,360 mile^2 for Karachi division. Hasan, *et al.* (1999) has speculated the current rate of urban land conversion at about 6,780 acres per year.

3.1 THE FRAMEWORK

It is known that urban land use studies (*e.g.* Schreiber and Kias, 1983) are designed to provide basic data on land characteristics and the various activities that occupy land in the urban area. These data are used in analysing the current patterns of urban land use to ascertain the character and quality of environment. Land use surveys furnish information on the use, misuse and non-use of urban land. In planning and zoning studies, it is essential to know the amount of land use for different purposes. The main purpose to seek land use patterns in this study is to outline "noise islands" associated with urban land use in Karachi.

3.2 SOURCES AND QUALITY OF INFORMATION

The available records from the Master Plan and Environmental control department of the Karachi Development Authority were studied and considered as the basis of land use information regarding the metropolis. These documents include:

1. Land use analysis (MP- RP/37) March 1972, KDA
2. The Karachi Development Plan 1974
    - Land use Map 1972
    - Land use Map 1985
3. The Karachi Development Plan 2000
    - Land use Map 1987
    - Land use Map 2000

Land use map 2000 (KDA, 1991) was the most recent among the above-mentioned publications hence it was adapted as the baseline information source for land use appraisal of this study. Although, it rendered projected figures for year 2000, however, the ground realities in 2002 have almost over run these projections.

Land use map 2000 (KDA, 1991) was scanned from the published document into a digital form and thereafter geo-referenced. This map was then digitised (vectorised) and finally converted into ESRI Grid format for further interpretation with the help of ArcView Spatial Analyst. It was found that the land use zoning maps developed by the Karachi Development Authority (KDA) were more towards aggregation/approximation and understanding on a macro scale. A spatial inquiry searching the micro patterns and the changes thereof, within the metropolitan city, needs an intensive and extensive information gathering effort requiring human and financial resources beyond the capability of investigator momentarily.

Year 2000 land use plan of Karachi Development Authority (KDA, 1991) was the source of information whose further explication yielded the categorised information. The categories spelled out in the document were not altered due to logical reasons. Primarily it was to maintain the relevance of analysis with the original document and to facilitate in comprehension. However, it should be noted that the boundaries of the metropolis are not the ones as the author had demarcated in the previous analysis of land cover. In fact this land use map of KDA had considered only the urban limits of Karachi. Another limitation of the source map was that the KDA had marked the classes / areas based on the dominant land use of localities.

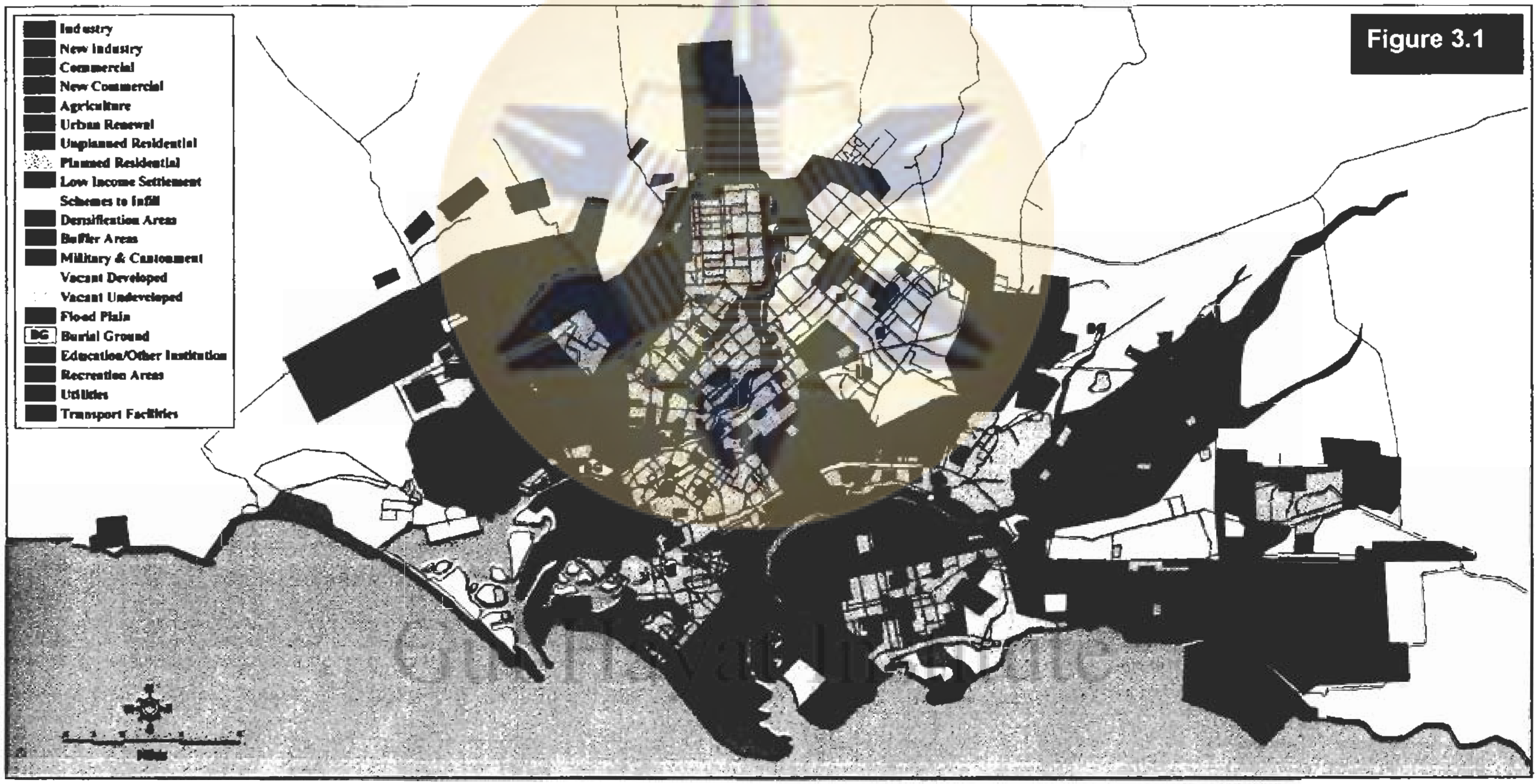
3.3 THE FINDINGS

Karachi is a cosmopolitan city and having multi-faceted urban functions. This has been manifested in the resultant categorized information illustrated in Figure 3.1 and Table 3.1. These tabular and geographically mapped outcomes can well be considered as value-added products of this study that will benefit the planners and administrators of the city.

Table 3.1: KDA Land Use 2000

Category	Area ($mile^2$)	Percent Share
Planned Residential	63.23	18.12
Military Areas	46.85	13.43
Schemes to infill	38.16	10.94
Low Income Settlements	31.94	9.15
Unplanned Residential	27.08	7.76
Industrial	25.88	7.42
Agriculture	19.66	5.63
New Industry	18.54	5.31
Densification Areas	18.46	5.29
Flood Plain	18.19	5.21
Vacant Undeveloped	6.45	1.85
Buffer Areas	5.52	1.58
Recreational	5.40	1.55
Transport Facilities	5.21	1.49
Urban Renewal	4.32	1.24
Commercial	4.13	1.18
Utilities	3.09	0.89
Education	2.97	0.85
New Commercial Centres	1.89	0.54
Burial Ground	1.24	0.35
Vacant Developed	0.73	0.21
Total	**349.01**	**99.99**

PROJECTED LAND USE 2000 OF KARACHI METROPOLIS



Source: Karachi Development Authority MP & ECD, 1991

These are actually the first ever development of a statistical and geo-referenced database on actual land use and functions for the metropolitan city of Karachi. The digital database has opened avenues for looking at the land use scenario. For instance, if some of these land use classes outlined by the KDA are grouped together broadly on the basis of their functions, interesting figures are derived, which are tabulated as under:

Table 3.2: Land use Groups of KDA defined Categories

Group	[illegible] Category		Area	Percent
		Total	**70.13**	**20.08**
	Recreational		*5.41*	*1.55*
	Transport Facilities		*5.22*	*1.49*
Infrastructure	Utilities		*3.09*	*0.89*
	Education		*2.98*	*0.85*
	Burial Grounds		*1.24*	*0.35*
		Total	**17.93**	**5.13**
	Planned Residential		*63.25*	*18.12*
	Schemes to infill		*38.18*	*10.94*
	Low Income Settlements		*31.96*	*9.15*
Housing	Unplanned Residential		*27.09*	*7.76*
	Densification Areas		*18.47*	*5.29*
	Urban Renewal		*4.33*	*1.24*
		Total	**183.27**	**52.5**
	Military Areas		*46.87*	*13.43*
	Vacant Undeveloped		*6.45*	*1.85*
Special Purpose	Buffer Areas		*5.53*	*1.58*
	Vacant Developed		*0.73*	*0.21*
	Flood Plain		*18.20*	*5.21*
		Total	**77.78**	**22.28**

These appraisals of land use in metropolitan Karachi provide legitimate ideas of urban and environmental inquiries. Amongst them, some are presented here, when the whole city is looked at comprehensive level:

- It would be very unfair with the metropolis if it we examine it purely according to conventional functional classification theories (*e.g.* Harris, 1943). In fact it has emerged as a "diversified city" with multi-faceted activities. Karachi cannot be viewed on the basis of functional specialization merely.

- In the context of Pakistan, Karachi metropolis may qualify to be placed under the "Central Place Theory" (Christaller, 1933). The groups of **economic** and **infrastructure** land use themselves indicate that the centrality that is crucial to the development of urban places, does exist in the light of a very large 'hinterland' and sufficient potential for *basic* and *non-basic* goods (*e.g.* Myrdal, 1967; Friedmann and Weaver, 1979)

  While introducing Karachi earlier, the two *Seaports*, an *International Airport* and rail/highway linkages were earlier discussed. Being a *transportation Hub* comprising of around 18 mile^2 of infrastructure land use (Table 3.2), Karachi's hinterland goes beyond Afghanistan up to Central Asia (MS Encarta, 2002; Correspondent daily Dawn, 2002). Therefore, the city has a 'multiplier' effect due to the economic expansion of its own kind (*e.g.* Friedmann and Weaver, 1979).

- Looking at urban morphology, it is observed that the metropolis understudy is different than the classical and theoretical 'Concentric zone' model (Burgess, 1925), Sector model (Hoyt, 1939) and Multiple nuclei model (Harris and Ullman, 1945). Reasons for this are deep rooted in Karachi's history and evolution, as touched upon in the initial chapters.

- Unprecedented huge migration is partially responsible for the mixed and chaotic land use across the metropolis. Refugee migrations of this kind are the cause of the high rate of increase in urbanization at Phnom Penh, Hanoi and Da Nang or Karachi (Scholz, 1983). Secondly, there has been no institutional control of land use due to weak governance. Moreover, the socio-economic eccentricity of the "*urban poor*" of Karachi has contributed to the emergence of many squatter settlements *katchi abadies* (further discussed in chapter 4).

- Over crowded and poor quality housing may aid the transmission of diseases and pollution (Barrow, 1995). In Karachi city, at prima facia, for the **housing** sector, (Table 3.1 and Figure 3.2) the area occupied jointly by *Low Income Settlements and Unplanned Residential* comes out to be about 58 mile^2 (17% of total urban land use). If these two *poor* residential categories are summed up and their share out of the total land for the housing group is assessed, it is one-third (32 %). Azad *et al.* (2001) has discussed the continually changing urban structure, peculiar to Karachi through a case study of residential neighbourhoods being transformed slowly into commercial markets.

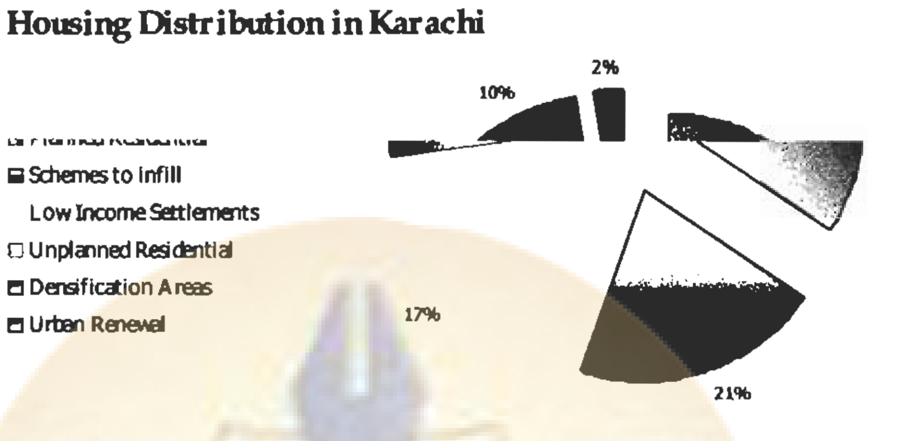


Figure 3.2

- It is to be emphasized that the functional agglomeration has put tremendous stress on **housing** and settlements. The western concept of a classical CBD is nonexistent due to mixed land use and night residing population all around the metropolis. This has obviously resulted into a host of manifestations of urban environmental degradation: chaotic Traffic and Noise pollution being two of them.

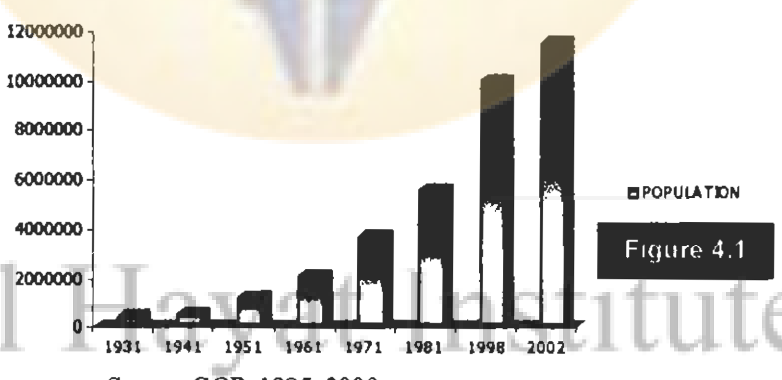
- For the investigation of **'Special Purpose'** group, reader's attention is drawn towards the resultants thematic map (Figure 3.1) produced in the previous chapter on land cover. The combined scenario revealed the abreast existence of Vegetation (land cover) and Military areas, flood plain (land use) sparsely located across the metropolis. The Recreational areas are mostly around or within the cantonment regions of military. Barrow (1995) had rightly resolved that lack of recreational space is a cause of deteriorating urban quality of life in developing countries. Meagre area of 5.4 mile^2 for recreational land use category (Figure 3.1) for the metropolitan population of 9.8 million (GOP, 2000$_b$) is awful. Endeavours to enhance the recreational space in future would definitely contribute to reduction in the over all atmospheric pollution, noise being a part of it.

4. DEMOGRAPHIC APPRAISAL

Studies of population dynamics clearly indicate that no population can sustain limitless growth. Nevertheless, no rational individual would advocate starvation, epidemics or war as a means of ending the population explosion (Nadakavukaren, 1990). Pakistan presently ranks 7th among the nations of the world (PRB, 2002), demographically. This research on appraisals of noise pollution, traffic and land use patterns in metropolitan Karachi is endeavoured by a holistic approach of considering causes as well as effects. This chapter focuses on the demographic patterns of the study area in a GIS mapping framework. Later salient findings are discussed.

The population of Karachi division was 9856318 persons in 1998 with over 3 percent annual growth rate (GOP, 2000_a) that estimates 11.3647 million in 2002. Almost 94.8 percent population lives in urban area, which indicates about 44875 persons per mile^2 population density on an average (GOP, 2000_b). Figure 4.1 indicates the population growth from 1931 to 2002.

POPULATION OF KARACHI 1931-2002



Source: GOP, 1985, 2000_b

Karachi's population is relocating from its core because of better residential and availability of basic goods and services (Hasan *et al.*, 1999). Environment and urban sprawl could be also major contributors of this deconcentration. In 1972 almost 63 % of the population lived within six miles of the city. By 1981, this had declined 52 %, as population growth shifted to the circular distance of 7 to 13 miles from the centre. At present more than 50 % of population of Karachi lives more than 6 miles from the city centre.

An increase in urban population is an indicator of the areal growth of towns, of spatial concentration and differentiation of economic, social and cultural activities (Scholz, 1983). Few studies have pointed towards certain trends in the population increase of Karachi. Hasan *et al.* (1999) reported the metropolis population for 1972 as 2,931,390 persons and 6,447,739 persons for 1987 that yields to 120 percent growth in 15 years.

Human activity produces pollution and human population is the ultimate victim itself. An environmental study has to quantify the impacts of specific pollution on population. Therefore, the initially formulated hypothesis of this study was revolving around the concept of risks and the population under risk. The assumption of this analysis is that higher the population concentration at a location would generate more vehicular travel yielding higher noise pollution and obviously affecting larger segments of population.

4.1 SOURCES AND QUALITY OF DATA

The source for obtaining the demographic data of Karachi metropolis is the Bureau of Census, Statistics Division, Government of Pakistan. Fortunately the data on population and its attributes have been managed comprehensively in the form of District Census Reports (DCRs) for the five districts (Central, East, South, West and Malir) of Karachi along with the maps that shows the boundaries of *circles* and *charges*. These *circles* and *charges* are the subdivisions in various localities. *Charge* being the larger entity while *circle* smaller. The Census maps are to be read in conjunction with the District Census Reports (DCRs) to extract the information on micro geographic scale. These reports portray detailed account on the *circles* and *charges* regarding the age and gender distribution of their respective populations.

4.2 THE FRAMEWORK

Since various inquiries of this study are done taking each of the 'Analysis Zones' defined by the KDA, as an entity. Hence, it was mandatory to reconstruct the population contained by 'Charges' and 'Circles' into the respective zones. It was a painstaking and laborious task but essential to focus the risk zones.

The transformed information was converted into a digital database compatible for geographic information system (software:MapInfo Professional). GIS data sets are finally developed for the whole of the metropolitan city incorporating the demographic information as fields and their records.

Population density is considered to be a better measure as compared to merely population numbers. Densities reflect the concentration and distribution patterns much better than the absolute figures. At large they are obtained arithmetically by dividing the numbers to the entity areas (Rehman, 1983). As the entities for this study are the fifty-eight (58) analysis zones of Karachi metropolis, the areas of these zones had to be computed through GIS.

Dot maps are often used to represent the distribution of spatially distributed phenomenon (McGlashan, 1972_b;Robinson, 1990). The result of differences in dot density is a visual impression of the distribution pattern of actual population (Campbell, 1984). The location of these dots on the map was governed by the sources that finally yielded the base map; classified satellite imagery, population census maps and knowledge about the study area.

GIS can present the population density with its gradient trends through population density *gradient map*. The density function generated a surface by applying a sampling radius to each point in the data layer. This function has generated an output in the grid data format. The value for each cell in the output grid is calculated based on the value of each point whose sampling radius overlaps the centre of that quad cell (PCI, 2000).

4.3 THE FINDINGS

The results of the pertinent analyses described in the framework are presented in Table 4.1 and Figures 4.2, 4.3 and 4.4. Karachi city has gone through phenomenal changes since the creation of Pakistan (Rehman, 1983). This is also reflected in the intra-urban distribution of its population. Deliberations on the spatial demographic patterns of present-day Karachi could be given by taking into account the historical, cultural and socio-economic factors.

The pre-independence population of Karachi *i.e.* 386655 in 1941 (GOP, 1985) was attributed to its port and strategic activities limiting its boundaries up to Soldier Bazaar. The population around 1068459 in 1951 (GOP, 1985) was because of the large influx of refugees from India. This inflow was accommodated in the *Jhuggies* (slums) around Numaish to Jamshed Road and via vertical expansion in the form of flats / apartments all across the old city. The population of 3515402 in 1972 (GOP, 1985) could be explained by factors as natural growth, migration from up country, development of industry (SITE, KITE *etc.*) and trade (wholesale and distribution) across the then metropolis. The city had grown to include F.B. Area, Nazimabad, North Nazimabad, Liaquatabad, Landhi, Korangi, Malir Extension, PECHS and other societies. The population of 5437984 in 1981 (GOP, 1985) includes the second migration from eastern parts of the Indian sub-continent, perpetual migration from up country (especially rural to urban) and natural increase. The city frontiers had been extended to Orangi Town, Gulshan-e-Iqbal, North Karachi, New Karachi, Kehkshan, and Defence Housing Authority. The latest published figures of exceeding 9 millions in 1998 (GOP, 2000b; MS Encarta, 2002) are for the times when Karachi has broadened to the present limits Figure 1.3.

The above discussion could be enhanced by indicating the need for a comprehensive demographic / spatial study for Karachi in the light of relevant variables. Jafri (1973) and Husain (1992) worked on these lines but time has outpaced their endeavours since Karachi is now considered to be one of *the top fifteen populous cities on the globe (PRB, 2001).*

KARACHI
POPULATION DISTRIBUTION

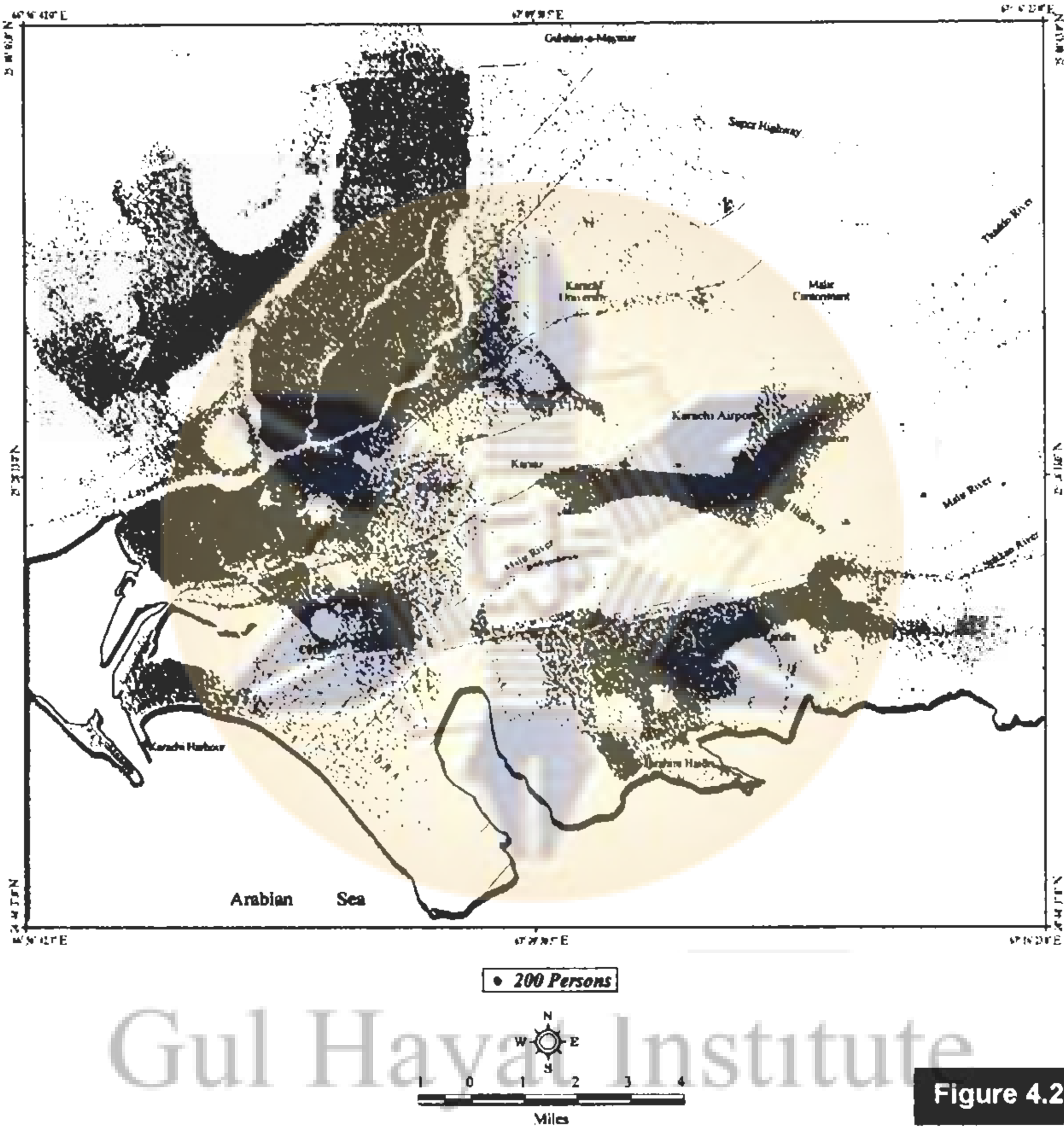


Figure 4.2

Remaining within the constraints of this study, the author has contributed towards the micro-geographic understanding of population distribution within the metropolis by presenting the following Figures 4.2, 4.3 and 4.4 and Table 4.1.

Table 4.1: Zone-wise Population Distribution of Karachi Metropolis

Zones	Population	Population Density (Persons / $Mile^2$)
1	96017	120664.6
2	218041	224682.6
3	59726	53930.4
4	86247	106385.4
5	31771	18757.5
6	194399	54356.0
7	169999	187418.8
8	104972	212422.6
9	162819	266926.7
10	248096	371721.3
11	248048	97141.1
12	148670	97505.3
13	76772	49718.0
14	230413	107125.4
15	40808	10595.6
16	99129	25603.9
17	10008	13550.6
18	79692	31069.9
19	19848	9034.8
20	119256	48111.0
21	132688	168534.3
22	267477	196666.0
23	78720	78745.5
24	210752	40118.8
25	71833	28242.3
26	203984	22222.9
27	236319	47807.3
28	536201	87674.7
29	239505	75908.9
30	291078	84969.8
31	819982	78682.7
32	320912	24773.5
33	678990	86503.6
34	375343	32866.2
35	47925	5001.6
36	19043	909.8
37	20995	742.7
38	6010	176.76
39	580155	58827.5
40	227837	33289.4
41	284750	26410.1
42	116040	9622.3
43	398289	83150.8
44	8601	1800.5
45	327285	56935.7
46	38361	6108.2
47	62449	10232.9
48	114504	10133.2
49	96036	1074.6
50	90158	1208.4
51	44464	2881.7
52	160278	4836.4
53	64719	5520.9
54	74126	6084.0
55	8628	244.8
56	12420	203.8
57	6735	138.7
58	11833	211.7

POPULATION DENSITIES

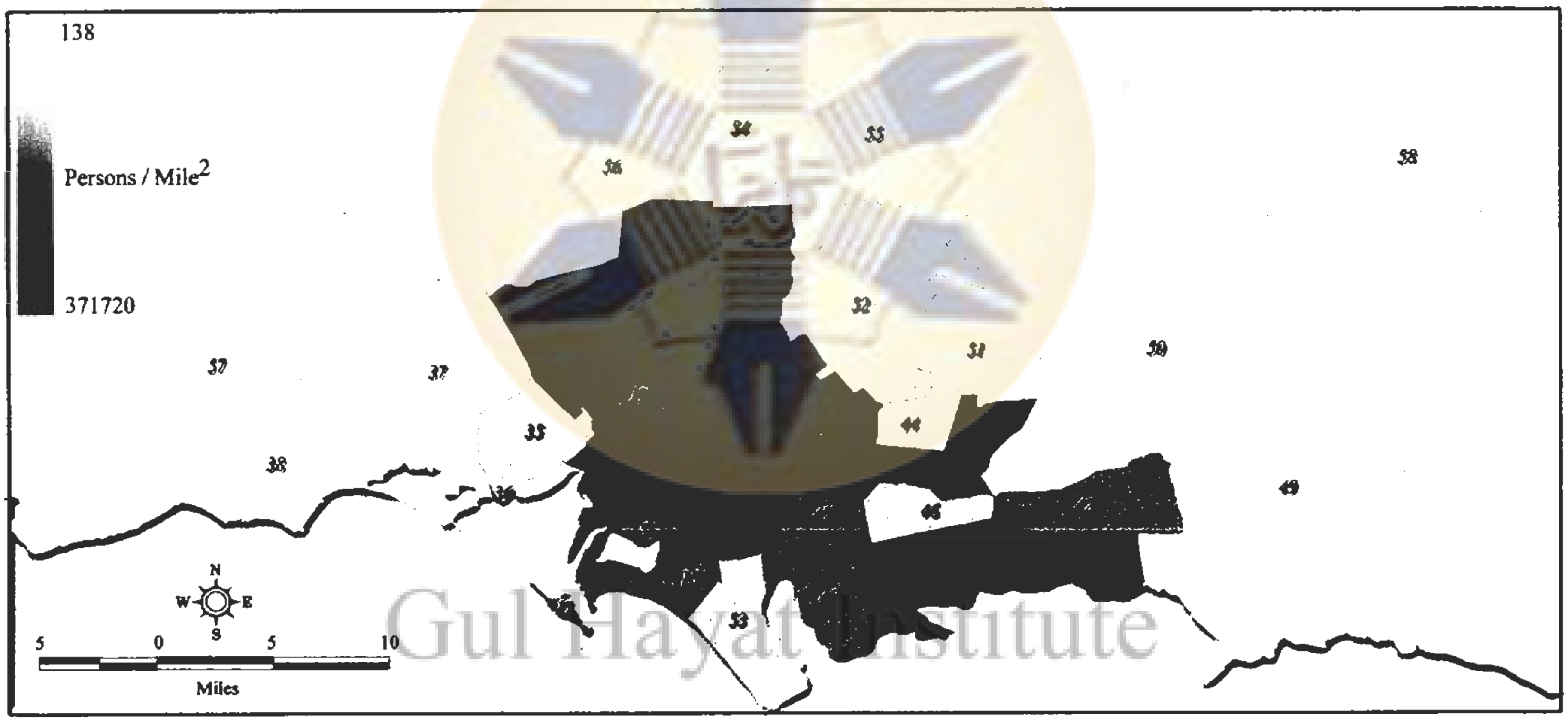


Figure 4.3 Choropleth Map showing Population Densities in Analysis Zones

KARACHI
POPULATION DENSITY GRADIENT

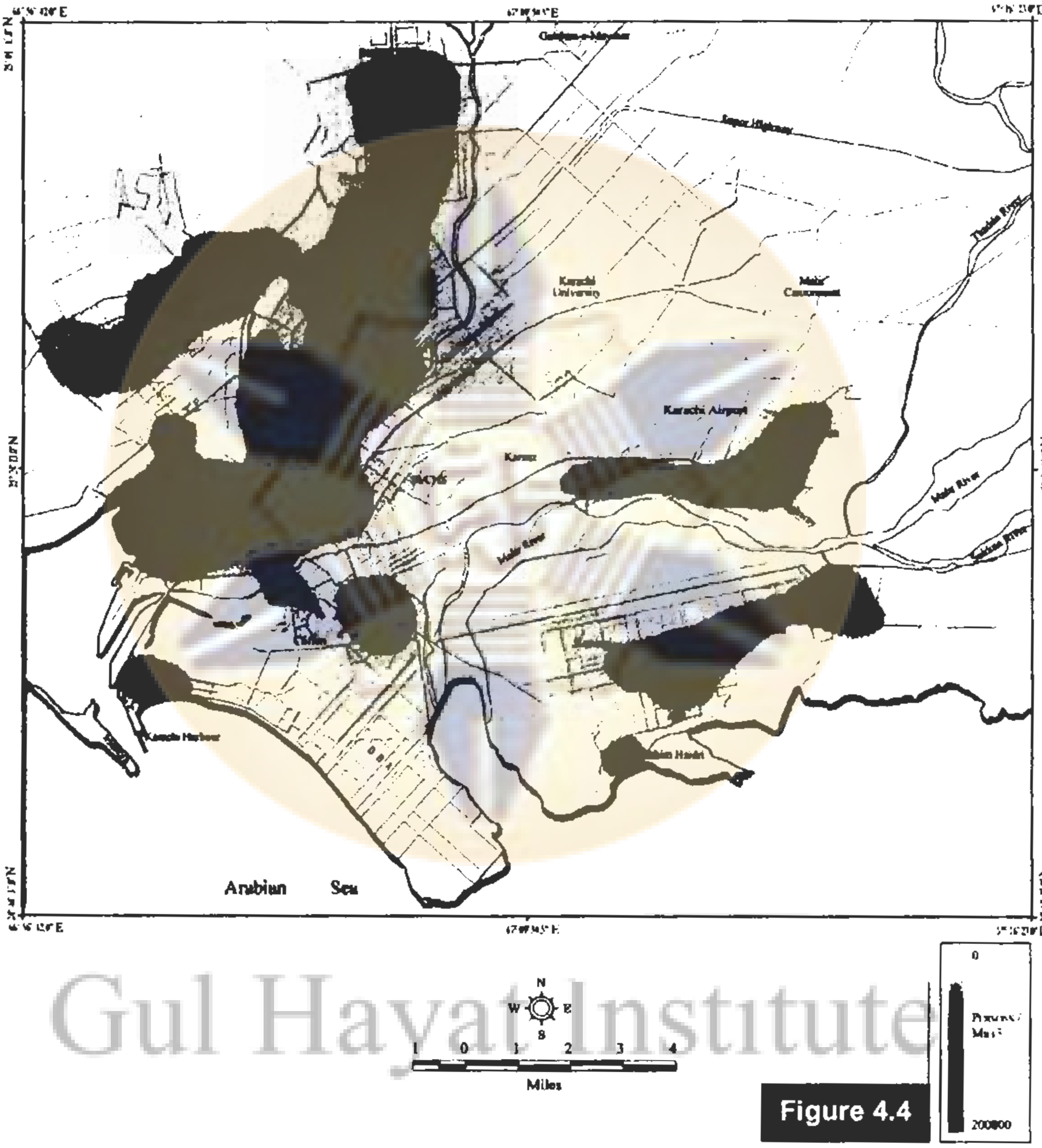


Figure 4.4

The lowest density of population (about 138 persons per square mile) occurred at zone 57 (Dehs in the west along Hub River), which is essentially a rural fringe of Karachi. While the highest population density (371721 persons per square mile) was found in zone 10 (Chakiwara, Kalakot *etc.*), which is an old neighbourhood of Karachi often referred as a portion of 'core of the city'. The figures of URC (2002) referred earlier seemed to be on a higher side . Out of fifty-eight, nineteen (19) zones (33%) exceed the population density of 65,000 persons per square mile. There are only five (05) zones in Karachi (09%) that are having a population density of less than 250 persons per square mile and incidentally these are all rural-urban fringe or rural areas. The following statistics (Table 4.2) are self-explanatory.

Table 4.2: Population Density:
Descriptive Statistics

Measures	Values
Mean	60106.6
Standard Error	9995.6
Median	31968.1
Standard Deviation	76124.2
Sample Variance	5794891115.5
Kurtosis	4.7
Skewness	2.0
Range	371582.6
Minimum	138.7
Maximum	371721.3
Sum	3486184.5
Count	58.0
Largest (2)	266926.7
Smallest (2)	176.8
Confidence Level (95.0%)	20015.8

The population density map (Figure 4.3) for Karachi illustrates noticeable distribution patterns. An elongated pattern of population concentration is clearly visible encompassing analysis Zones # 1, 2, 7, 8, 9, 10, 11, 12, 21, 22, 23, 28, 29, 30 and 31. The author is of the opinion that *cheaper land value* is the chief explanation for this elongated spatial pattern. Rehman (1983) had partially attributed the population agglomeration (at that time) to 'land value'. Zones # 1, 2, 7, 8, 9, 10, 11 and 12 are parts of Old City inhibited by initial settlers. Zones # 21, 22, 23, 28, 29, 30 and 31 comprise 'several subsidised schemes' furnished to the public by the government for settling the upper and lower middle social classes. For instance, Karachi Development Authority advertised the scheme of North Nazimabad at the rate of Rs. 07 per sq. yards (to be paid in easy instalments) in 1960s. The two exceptions, zone 33 (Orangi Town) and zone 43 (Malir and Model colonies) can also be credited to the author's raison d'être of cheap rather almost free land. Orangi, one of the largest *'Katchi Abadi'* (shantytown) of Asia was founded for the refugees from East Pakistan in early 1970s. Malir and Model colonies were established in 1950s for socially lower segment of population.

Another presentation of population distribution is portrayed in the form of 'Dot Map'. This gives a better picture of population distribution and its concentrations within study area. Figure 4.2 in which each dot represented 200 persons. The method is one, which has been internationally accepted (William-Olsson, 1963;Robinson, 1990). Through this map, analysis of the affected population (under risk) has been facilitated.

Further, cartographic output in the form of map (Figure 4.4) depicting population density *gradient* was also derived. Density gradient map shows the ascending and descending gradual changes across the metropolis (Rehman, 1983). The Figure 4.4 colour shaded thematic map has clearly manifested the five major pockets of population in the mega city. These major demographic pockets could be effortlessly recognized in the order of concentration as Old City (core), District (Karachi) Central, Orangi region, Malir and Mehmoodabad regions respectively.

As discussed in the context of land use, there are several factors responsible for the spatial concentrations of this kind in Karachi. Keeping the historical factors aside, the economic conditions of the urban inhabitant are also the cause of densely crowded neighborhoods. Like many third world countries, in urban areas of Pakistan, 25 percent of the population lives below poverty line (UNCHS, 1996; Drakakis-Smith, 2000). These poverty lines often fail to reflect the true hardships that people face in meeting the necessities of life (Weller and Hersh, 2002) and specific aspects of deprivation-such as water, food, ***shelter*** and education (Ercelawn and Nauman, 2002). Karachi's urban poor does not have the commercial worthiness to move home from where he/she was born. They also include population, which has no access to ownership of assets (GOP, 1988) and a very large number of households have only one earner (Ahmad, 1984). In the olden parts of Karachi, third generation of initial post independence dwellers is being witnessed residing.

5. APPRAISAL OF TRAFFIC PATTERNS

The role of transportation in a city is its impacts on land use patterns and environmental quality. There are many cities where urban development and land use patterns are coordinated with transport and traffic. Toronto, Paris, Stockholm, Hamburg, and a number of other cities are good examples of this relationship (Vuchic, 1981). Nonetheless, the number of vehicles per thousand persons is expected to increase in all regions of the world (MVMA, 1994; IRF, 1995). Urban traffic pollution is two folds – noise and air pollution. Noise pollution in the western world is checked by legislation but in Pakistan such kind of legislation alone would not help. Pakistani towns are noisier than their western counterparts. Karachi is one of the nosiest cities in the world (GOP, 1988). Its traffic is the main cause of noise pollution. Noise levels in Karachi varies between 72 dB (A) and more than 106 dB(A) (Zaidi, 1996; Sohail, 1997).

Karachi has a major road network (Figure 5.1) of more than 4,600 miles (KDA, 1991) that are in defective conditions. All sidewalks and roadway edges in the inner city are encroached upon by *patharas* and parking. In planned and redeveloped areas, roads are wide and carpeted as compared to unplanned neighbourhoods. Generally, the road widths are insufficient for heavy vehicles and higher traffic volumes, which create traffic jams, slow operating speed and choking points causing delays during rush hours. According to Hasan *et al.* (1999), Karachi has 14,854 intra-city buses, 513 inter-city buses, 13,613 taxis and 23,337 *rickshaws*. 72% of all commuters using buses travel by Karachi's 8,773 minibuses. Most of the environmental degradation in Karachi is result of the encroachments and absence of bus terminals, workshops (depots). Encroachments at key locations in Karachi are related to the transport trade. A sound public mass transport network, which should be in keeping with Karachi's spatial spread, does not exist.

5.1 SOURCES AND QUALITY OF TRAFFIC DATA

Being a non-funded research work, it was initially decided that the source of traffic data would be secondary *i.e.* data from the Traffic Engineering Bureau (TEB) of Karachi Development Authority (KDA). TEB was the department responsible to plan, design, and implement traffic control devices and geometric improvements in the Karachi metropolis.

It was found that the data collection efforts by the TEB were carried out way back in 1982 and 1994.These counts were available as hard copies. These counts were categorized as technical papers having discrete numbers and are termed as Classified Turning Movements of a particular intersection or a mid block location on a major roadway. These surveys by the TEB were conducted normally for sixteen hours. Table 5.1, presents the figures of daily traffic (16-hours) for the locations surveyed by the TEB, KDA. These were obviously, high volume locations in 1982 and 1994. Updated figures were direly vital for this study but unfortunately were not available from the concerned bureau, TEB.

Table 5.1: Sixteen Hours Daily Traffic at Major Intersections

S. No.	Intersections	Daily Traffic (16 hours)
1	Gurumandir	341317
2	Nazimabad Chowrangi No. 2	318438
3	Old Exhibition	302318
4	Gora Qabristan	270133
5	Civic Centre Square	256040
6	Liaquatabad No. 10	252624
7	Nazimabad Chowrangi No. 1	243765
8	Shaheed-E-Millat/University Rd	220831
9	A. Haroon Rd./Mere Weather Rd.	216498
10	Musical Fountain	210741
11	Mansfield Street / M.A. Jinnah Rd	205510
12	New Town	197007
13	Board Office	191522
14	Club Road / Abdullah Haroon Rd	191184
15	Dakhana (Liaquatabad)	189804
16	Dr. Dawood Pota Rd / M.A. Jinnah Rd	189083
17	Karimabad	181595
18	Aisha Manzil	174093
19	Nishter Rd/ Love Lane Rd	163685
20	Tin Hatti	162082
21	Nazimabad No. 7	156132
22	Shaheen Complex	145340
23	Sharea Faisal / Rashid Minhas Rd	144144
24	Abdullah Haroon Rd / Hoshing Rd	143598
25	Britto Rd / Nishter Rd	142677
26	Kda Chowrangi / North Karachi	131585
27	Water Pump (North Nazimabad)	130015
28	Lea Market	125185
29	Mere Weather Tower	118653
30	Pidc House	111689
31	Fatima Jinnah Rd / Shahrah e Faisal	105384

Source: Traffic Engineering Bureau, Karachi Development Authority (KDA),

Table 5.1 from the secondary source (TEB) and Table 5.2 (Traffic data of old city) from the primary data collection exercise helped in conceptualizing the traffic volumes and formulation of a denomination criterion. The sample size for current noise pollution levels in metropolitan Karachi was greater than 300 (*Annexure D*). For a meaningful appraisal of noise pollution vis-à-vis traffic volume, the study had no other option than to rely on the investigator's exposure during the survey for categorizing the locations qualitatively at different times of the day. The criteria formulated for the traffic volumes at study spots is as under:

Table 5.2: Grouping of Observed Average Hourly Traffic at Monitoring Stations

Category	Notation	Average Hourly Traffic (AHT)*
Very Low	VL	Less than 200
Low	L	200 – 400
Moderate	M	400 – 2,000
High	H	2000 – 10,000
Very High	VH	10,000 and above

* All modes and their turning movements, at the location, summed up

Table 5.3 tabulates the six temporal variations of traffic at 308 locations all across Karachi. Based on the above stated traffic criterion, qualitative thematic maps illustrate the state of traffic affairs for the metropolis, Karachi.

Table 5.3: Observed Traffic at Monitoring Locations across Karachi

Location No.	Weekend			Working Day		
	Mornings	Afternoons	Evenings	Mornings	Afternoons	Evenings
1	M	L	H	VH	M	VH
2	M	L	H	VH	M	VH
3	M	L	H	VH	M	VH
4	H	H	H	VH	VH	VH
5	L	VL	M	M	L	M
6	L	VL	M	M	L	M
7	M	H	VH	VH	VH	VH
8	VL	L	M	M	L	M
9	M	M	H	H	VH	VH
10	M	M	H	H	VH	VH
11	M	M	H	H	VH	VH
12	M	M	H	H	VH	VH
13	M	M	H	H	VH	VH
14	M	M	H	H	VH	VH
15	M	M	H	H	VH	VH
16	M	M	H	H	VH	VH
17	H	H	VH	VH	VH	VH
18	M	L	H	H	M	VH
19	H	H	VH	VH	VH	VH
20	M	L	H	H	M	VH
21	L	M	M	M	H	H
22	L	M	M	M	H	H
23	M	M	M	H	M	H
24	M	M	M	H	M	H
25	H	H	VH	VH	VH	VH
26	M	H	H	M	H	H
27	M	H	H	M	H	H
28	M	H	H	M	H	H
29	M	H	VH	VH	VH	VH
30	L	M	VH	M	H	VH
31	H	H	VH	VH	H	VH
32	H	H	VH	VH	H	VH
33	H	H	VH	VH	H	VH
34	H	M	H	H	M	H
35	H	H	VH	VH	H	VH
36	H	L	H	H	M	H
37	VL	VL	VL	L	VL	L
38	VL	VL	VL	L	VL	L
39	VL	VL	VL	L	VL	L
40	L	M	M	M	M	H
41	L	M	M	M	M	H
42	H	H	VH	VH	H	VH
43	L	M	M	M	M	H
44	H	H	VH	VH	VH	VH
45	H	H	VH	VH	VH	VH
46	H	H	VH	VH	VH	VH

Location No.	Weekend			Working Day		
	Mornings	Afternoons	Evenings	Mornings	Afternoons	Evenings
47	H	H	VH	VH	VH	VH
48	VL	VL	M	VL	VL	M
49	VL	VL	M	VL	VL	M
50	L	VL	M	VL	VL	M
51	VL	VL	VL	VL	L	VL
52	L	VL	L	VL	L	VL
53	M	L	VL	H	H	M
54	M	L	VL	H	H	M
55	VL	L	L	M	L	M
56	VL	L	M	VL	M	M
57	H	H	VH	VH	VH	VH
58	VL	VL	VL	M	L	M
59	VL	VL	VL	H	M	M
60	M	H	H	M	H	H
61	M	H	H	VH	VH	VH
62	L	M	L	H	M	H
63	L	M	L	H	M	H
64	VL	VL	VL	L	VL	L
65	M	H	H	M	H	VH
66	L	L	M	M	H	H
67	M	H	VH	VH	VH	VH
68	M	H	VH	VH	VH	VH
69	M	H	VH	VH	VH	VH
70	M	H	VH	VH	VH	VH
71	M	H	H	VH	H	VH
72	M	H	VH	VH	VH	VH
73	M	H	VH	VH	VH	VH
74	M	H	VH	VH	VH	VH
75	M	H	VH	VH	VH	VH
76	M	M	VH	H	M	VH
77	M	M	VH	H	M	VH
78	VL	VL	M	M	L	M
79	VL	VL	VL	L	L	L
80	VL	VL	VL	L	L	L
81	VL	VL	VL	L	L	L
82	VL	VL	M	M	L	H
83	H	H	VH	VH	VH	VH
84	H	H	VH	VH	VH	VH
85	VL	VL	M	L	L	H
86	VL	VL	L	L	VL	L
87	VL	VL	M	M	L	H
88	VL	VL	L	L	VL	L
89	VL	VL	L	L	VL	L
90	M	M	H	H	H	VH
91	M	M	H	H	H	VH
92	VL	L	L	M	L	M
93	VL	VL	VL	L	VL	L
94	VL	L	L	M	M	H

Location No.	Weekend			Working Day		
	Mornings	Afternoons	Evenings	Mornings	Afternoons	Evenings
95	VL	VL	VL	M	M	H
96	VL	VL	VL	M	M	H
97	VL	VL	L	L	L	M
98	VL	VL	VL	M	M	H
99	VL	VL	VL	M	M	H
100	VL	VL	VL	M	M	H
101	VL	VL	VL	L	L	L
102	VL	VL	VL	M	M	H
103	VL	VL	VL	M	M	H
104	VL	VL	VL	M	M	H
105	VL	L	VL	L	VL	VL
106	VL	VL	VL	M	M	H
107	VL	VL	VL	VL	VL	VL
108	VL	VL	L	M	M	H
109	VL	VL	L	M	M	H
110	VL	VL	L	M	M	H
111	L	VL	M	VL	VL	M
112	L	VL	M	VL	VL	M
113	VL	VL	VL	L	L	L
114	VL	VL	VL	L	L	L
115	VL	VL	VL	L	L	L
116	VL	VL	VL	VL	VL	VL
117	L	M	H	VL	L	L
118	M	H	VH	L	L	M
119	M	H	VH	L	M	H
120	VL	VL	M	L	VL	H
121	VL	VL	M	L	VL	M
122	VL	VL	M	L	VL	M
123	VL	VL	M	L	VL	M
124	VL	VL	VL	VL	VL	VL
125	VL	VL	VL	L	VL	L
126	VL	VL	VL	L	VL	L
127	VL	VL	VL	L	VL	L
128	VL	L	M	L	VL	H
129	VL	L	M	L	VL	H
130	VL	L	M	L	VL	H
131	L	L	VH	M	M	VH
132	L	L	H	M	M	H
133	VL	VL	L	VL	L	L
134	VL	VL	VL	VL	VL	VL
135	M	H	VH	L	M	H
136	L	L	VH	M	M	VH
137	L	L	H	M	M	H
138	L	L	H	M	M	H
139	L	L	H	M	M	H
140	VL	VL	VL	VL	VL	L
141	VL	VL	VL	VL	VL	L
142	VL	VL	L	L	L	M

Location No.	Weekend			Working Day		
	Mornings	Afternoons	Evenings	Mornings	Afternoons	Evenings
143	M	L	M	M	M	M
144	M	L	M	M	M	M
145	L	L	H	H	M	VH
146	L	L	H	H	M	VH
147	L	L	H	H	M	VH
148	VL	L	L	M	L	M
149	VL	VL	VL	VL	VL	VL
150	VL	L	L	M	L	M
151	VL	L	H	H	M	VH
152	L	L	M	M	L	H
153	M	H	H	VH	VH	VH
154	M	H	H	VH	VH	VH
155	M	H	H	VH	VH	VH
156	L	M	M	H	VH	VH
157	L	L	L	M	M	M
158	L	M	L	M	M	H
159	M	H	VH	H	H	VH
160	M	H	VH	H	H	VH
161	VL	L	M	L	M	H
162	VL	M	H	M	H	VH
163	VL	M	H	M	H	VH
164	M	H	VH	H	H	VH
165	L	M	L	M	M	M
166	VL	VL	VL	VL	L	L
167	L	M	H	M	H	VH
168	H	H	H	VH	VH	VH
169	M	H	VH	H	VH	VH
170	VL	L	M	L	L	M
171	L	M	H	M	H	VH
172	L	M	H	M	H	VH
173	L	M	H	M	H	VH
174	L	M	M	L	M	H
175	M	L	H	VH	M	VH
176	VL	VL	VL	VL	VL	VL
177	VL	VL	VL	VL	VL	VL
178	VL	VL	VL	VL	VL	VL
179	VL	VL	VL	VL	VL	VL
180	VL	VL	VL	VL	VL	VL
181	VL	L	M	L	M	M
182	VL	L	M	L	M	M
183	VL	VL	L	VL	L	M
184	M	M	H	H	VH	VH
185	H	VH	VH	VH	VH	VH
186	M	H	H	H	VH	VH
187	L	L	M	M	L	M
188	L	L	M	M	L	M
189	L	L	M	M	L	M
190	L	L	M	M	L	M

Location No.	Weekend			Working Day		
	Mornings	Afternoons	Evenings	Mornings	Afternoons	Evenings
191	L	L	M	M	L	M
192	L	L	M	M	L	H
193	L	L	M	M	L	H
194	L	L	M	M	L	H
195	VL	VL	M	M	L	M
196	VL	VL	M	M	L	M
197	VL	VL	M	M	L	M
198	VL	L	M	M	L	M
199	VL	L	M	M	L	M
200	VL	L	M	M	L	M
201	VL	L	M	M	L	M
202	VL	L	M	M	L	M
203	VL	VL	L	L	L	M
204	VL	VL	L	L	VL	L
205	VL	VL	L	L	L	M
206	VL	VL	L	M	L	M
207	VL	VL	L	M	L	M
208	VL	VL	L	M	L	M
209	M	M	H	H	VH	VH
210	M	M	H	H	VH	VH
211	M	M	H	H	VH	VH
212	M	M	H	H	VH	VH
213	L	VL	L	M	L	H
214	L	L	L	M	M	H
215	L	M	M	M	M	H
216	L	M	M	M	M	H
217	L	M	M	M	M	H
218	VL	M	L	M	L	M
219	L	L	M	M	L	M
220	L	L	M	M	L	M
221	VL	L	M	M	L	M
222	VL	L	M	M	L	M
223	VL	VL	VL	VL	VL	VL
224	VL	VL	VL	L	L	L
225	VL	VL	VL	L	VL	L
226	VL	VL	L	M	L	L
227	VL	VL	VL	L	L	L
228	VL	VL	VL	L	L	L
229	VL	VL	VL	L	L	L
230	VL	VL	L	L	VL	L
231	VL	VL	VL	VL	VL	VL
232	VL	L	H	L	L	M
233	M	M	VH	H	M	VH
234	VL	L	M	VL	VL	L
235	L	M	M	M	M	H
236	VL	VL	VL	L	VL	L
237	M	H	VH	VH	H	VH
238	VL	VL	VL	L	VL	VL

Location No.	Weekend			Working Day		
	Mornings	Afternoons	Evenings	Mornings	Afternoons	Evenings
239	VL	VL	VL	L	VL	VL
240	H	H	VH	VH	VH	VH
241	L	M	M	M	M	H
242	VL	L	M	L	L	M
243	VL	L	M	L	L	M
244	VL	L	VL	L	L	M
245	VL	L	VL	L	L	M
246	VL	L	VL	L	L	M
247	VL	VL	VL	VL	VL	VL
248	L	L	M	L	M	M
249	L	L	M	M	L	M
250	L	L	M	M	L	M
251	L	VL	M	M	L	M
252	L	VL	M	M	L	M
253	L	VL	M	M	L	M
254	L	VL	M	M	L	M
255	L	L	M	M	L	M
256	L	L	M	M	L	M
257	H	M	H	H	M	H
258	H	H	VH	VH	VH	VH
259	L	L	L	M	M	M
260	VL	VL	VL	M	L	M
261	VL	VL	VL	M	L	M
262	VL	VL	VL	L	L	L
263	VL	VL	VL	L	L	L
264	VL	VL	VL	L	L	L
265	L	L	L	M	M	M
266	L	L	L	M	M	M
267	L	L	M	M	M	H
268	L	L	M	M	M	H
269	L	L	M	M	L	M
270	L	L	M	M	M	H
271	M	M	H	H	M	VH
272	VL	L	L	L	L	M
273	L	L	M	M	M	H
274	M	M	H	H	M	VH
275	H	H	VH	VH	VH	VH
276	VL	VL	VL	VL	VL	VL
277	VL	VL	VL	VL	VL	VL
278	M	M	M	M	M	M
279	L	M	H	M	H	VH
280	L	M	H	M	H	VH
281	L	L	L	M	L	M
282	L	L	L	M	L	M
283	L	L	L	M	L	M
284	L	L	L	M	L	M
285	L	L	L	M	L	M
286	L	L	L	M	L	M

Location No.	Weekend			Working Day		
	Mornings	Afternoons	Evenings	Mornings	Afternoons	Evenings
287	M	H	VH	H	H	VH
288	M	H	VH	H	H	VH
289	M	H	VH	H	H	VH
290	M	H	VH	H	H	VH
291	L	M	M	H	VH	VH
292	VL	L	L	M	L	M
293	VL	L	L	M	L	M
294	VL	L	L	M	L	M
295	L	M	M	M	H	H
296	L	M	M	M	H	H
297	L	L	L	M	L	M
298	M	H	VH	H	H	VH
299	M	H	H	M	H	H
300	VL	VL	L	VL	VL	L
301	VL	VL	L	VL	VL	L
302	VL	VL	L	VL	VL	L
303	L	M	M	M	M	H
304	VL	VL	L	VL	VL	VL
305	L	M	M	M	M	H
306	L	M	M	M	M	H
307	VL	L	M	L	M	M
308	L	M	M	M	M	H

[1] Location numbers are same as described in *Annexure D*

5.2 THE FRAMEWORK

5.2.1 Roadway Geometrics

Congested road network is assumed to be one of the fundamental sources of noise pollution. It was observed that road intersections are more vulnerable as compared to smooth traffic streets due to choking in congested areas during peak hours. The base map had the road network of Karachi updated until 1998 (Refer to Figures 1.7 and 5.1).

Density of roadway network is actually a massiveness measure. The graphical presentation of this densely distributed aspect is illustrated in Figure 5.2. This map was produced with the help of GIS technology and the task is commonly referred as '*density mapping*' in the relevant texts (Demers, 1999). After generation of equidistant points along the roads, these have been categorized according to the roadway width. Weights were assigned to the points with respect to the functional importance of associated roads.

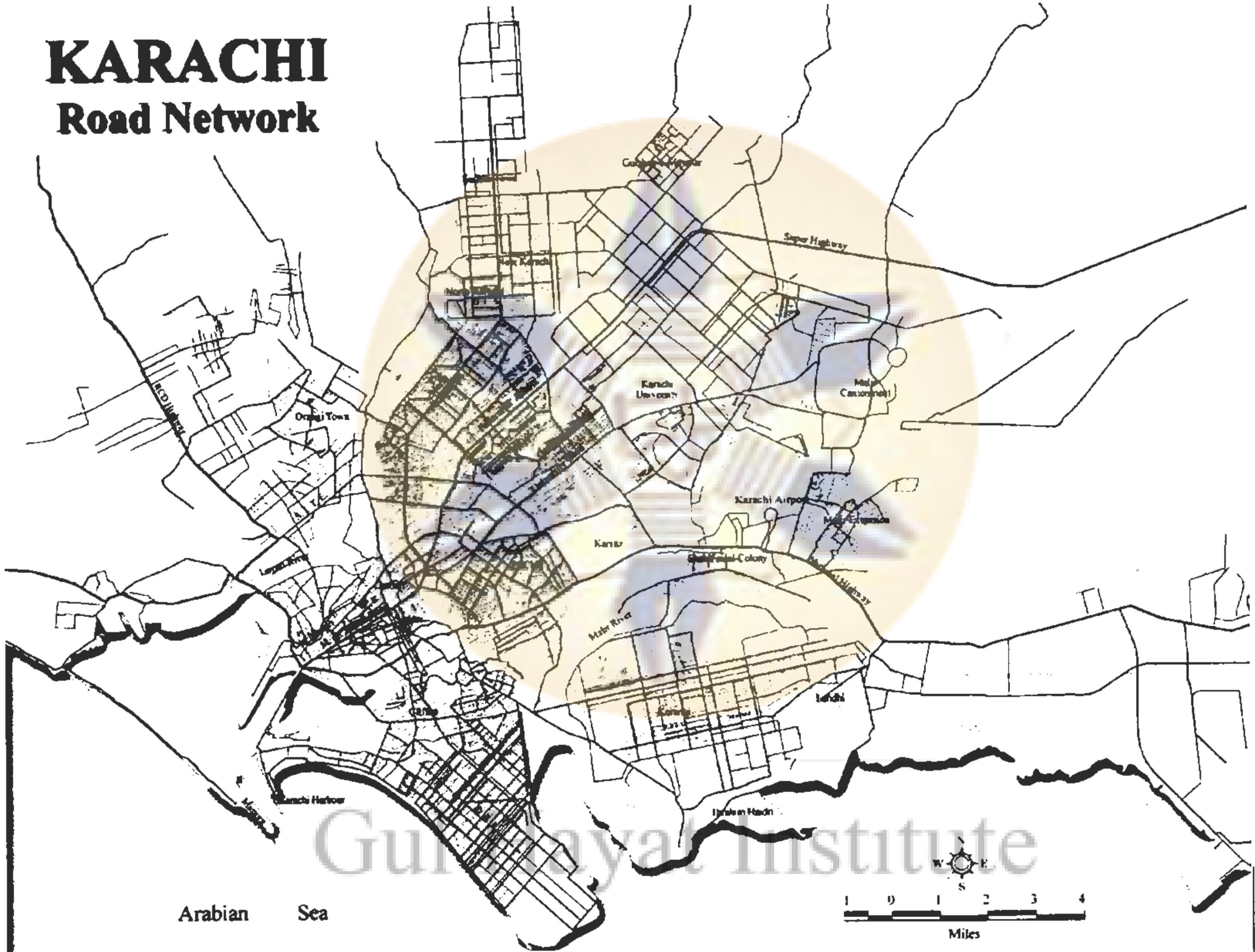

KARACHI
Road Network
Super Highway
New Karachi
Orangi Town
Karachi University
Karachi Airport
Landhi
Korangi
Karachi Harbour
Arabian Sea
N
W
E
S
1 0 1 2 3 4
Miles

Figure 5.1

The *density* function generated a *surface* by applying a sampling radius to each point in the data layer. No output values were calculated for areas lying outside of any sampling radius. This technique generated output in the ArcView *grid format*. The value for each *cell* in the output grid is calculated based on the value of each point whose sampling radius overlaps the center of that *quad cell*.

$$\text{Point Density} = \sum \frac{z_i}{\pi\, d^2}$$ (ESRI, 1998; Stevens, 1999)

Where:

z = Weight

d = distance from the center of the quad cell to the data point

i = each point at the center of the sampling radii that overlap the grid cell

Figure 5.3 is another endeavour using advanced cartography where roads' *proximity* is magnified through a technique known as *'linear buffering'* (Lang, 1999; Audet and Ludwing, 2000; Steede-Terry, 2000). This map could be considered complementing the (previous) Figure 5.2 of *density mapping*. The legend shows the lateral distances marked on both sides of the roads. Although, a different exercise in approach, it produced quite identical results to understand this scenario of road density variations from place to place.

5.3 THE FINDINGS

The density mapping and proximity buffers performed through GIS techniques have helped in understanding massiveness of narrow roads in the city (Figure 5.2 and Figure 5.3). On the map, the core city area (Old Karachi) has emerged as a special case study to be researched on its own merit. (Refer to Chapter 11). The neighbourhoods referred as co-operative housing societies also have some close and relatively dense roads. The road network developed by the Karachi Development Authority (KDA) can be appreciated as a spacious, aesthetically pleasant and well planned. The neighbourhoods of Clifton, North Nazimabad, Federal 'B' Area, Gulshan-e-Iqbal and Gulistan-e-Johar can be seen on this map as good examples of fairly wide roads. Noticeably, North Nazimabad can be taken as a model neighbourhood where planning has contributed in reducing the future environmental degradations.

ROAD DENSITY INDEX

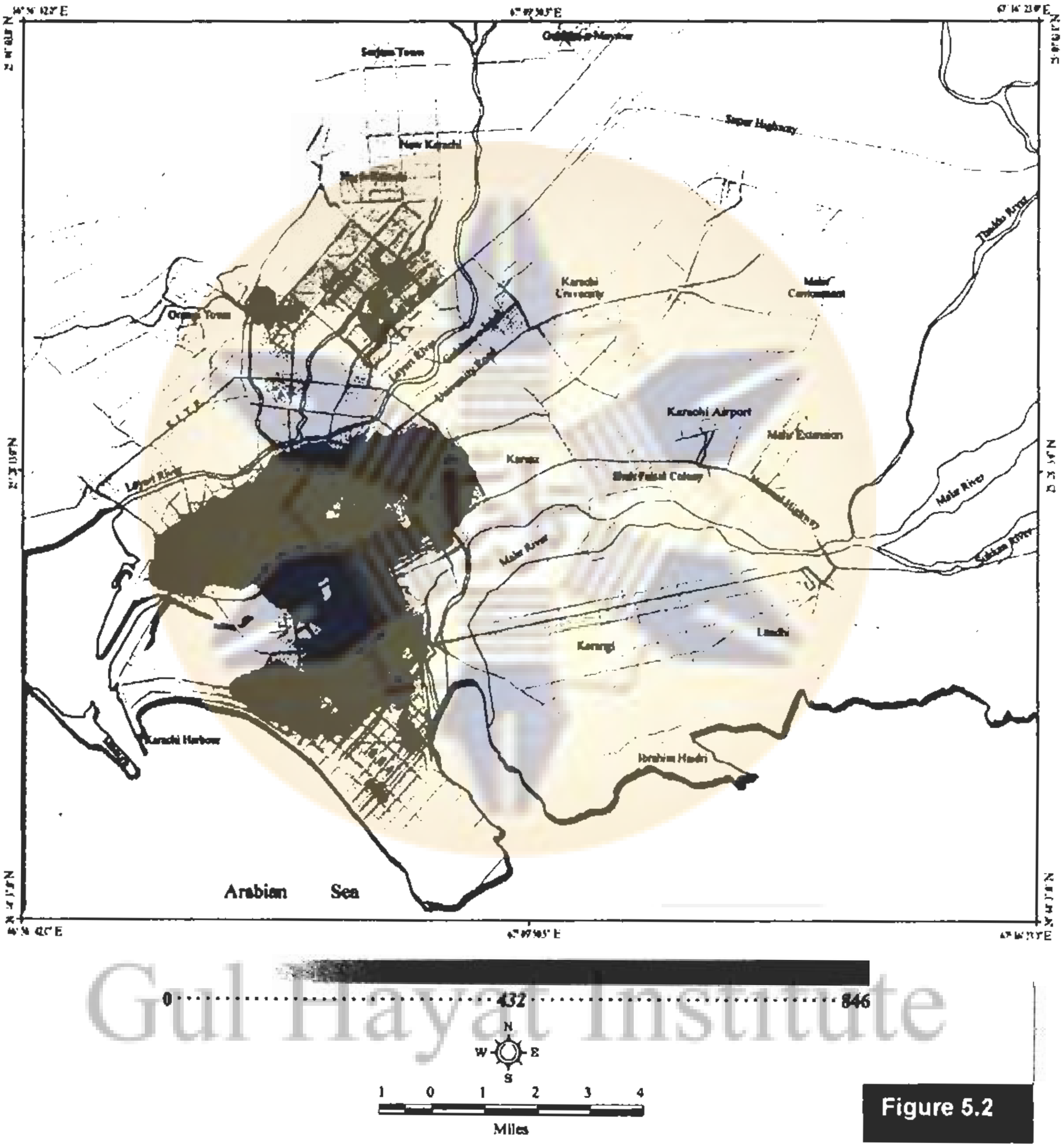


Figure 5.2

ROAD PROXIMITY BUFFERS

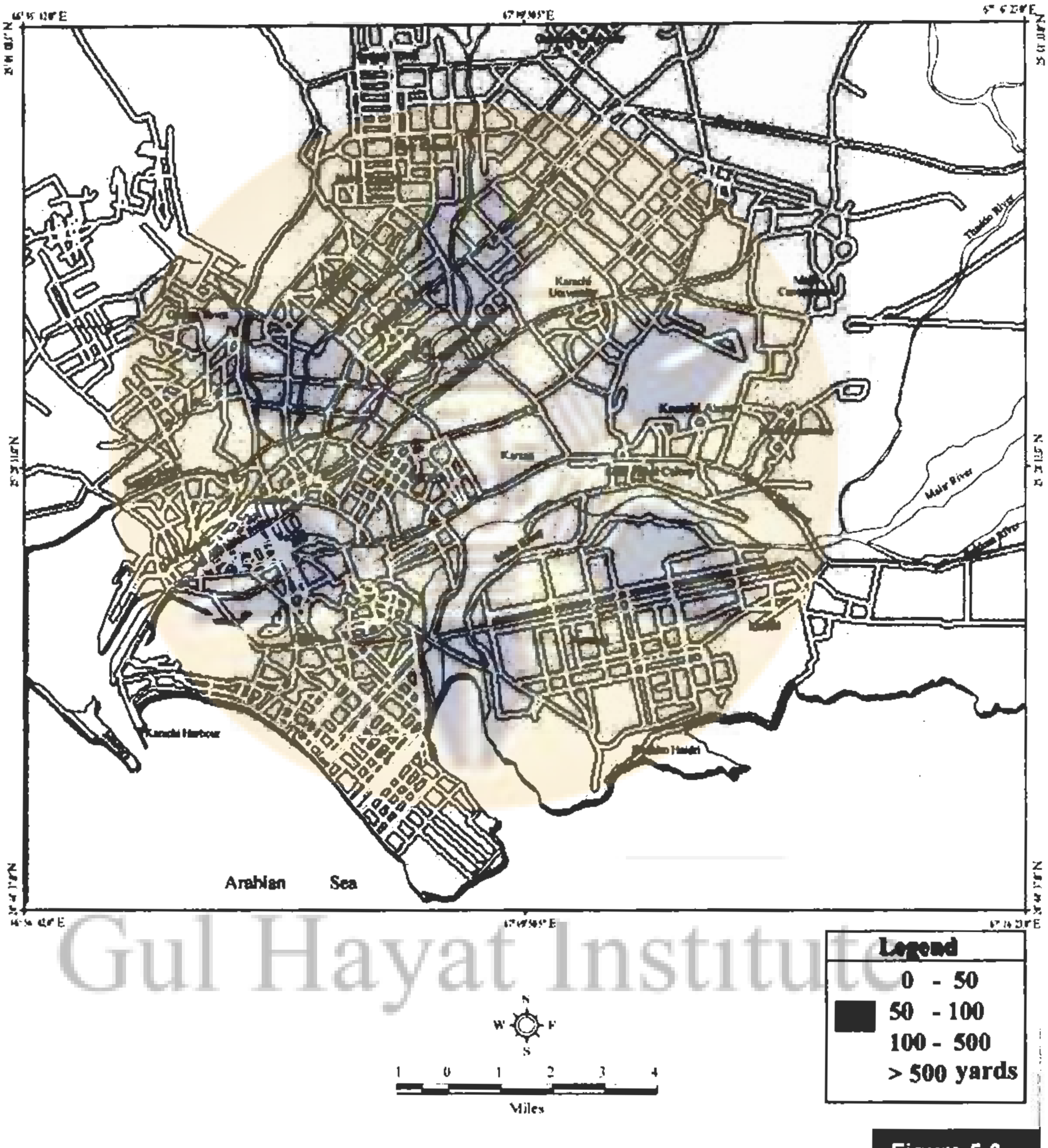


Figure 5.3

At this point, it has been attempted to give a general outlook of traffic conditions for the three daily variations and two-week wise variations. Figures 5.4, 5.5, 5.6, 5.7, 5.8 and 5.9, were produced as GIS themes indicating these six variations respectively. These maps represented the patterns of Traffic in Karachi from time to time and place to place.

Figure 5.4 shows the 'Morning' session on Friday / Saturday / Sunday. It is observed that high traffic at this juncture is along the major arterial roads. Most of the localities do not encounter congestion very often during this segment of time. The neighbourhoods of Orangi Town, Clifton, DHA and Landhi posses low traffic volumes while the roads from Lasbela / Teenhatti via Grumandir up to Tibet Centre (segment of M A Jinnah Road) remain the two busiest arterials of Karachi.

Slight changes occur in the patterns of traffic concentration in the 'Afternoons' owing to the citywide activities, Figure 5.5. Major roads remain same in their busyness but the arterial, which passes through industrial and residential zones in the city, shows comparative calm.

(Figure 5.6) 'Evenings' in Karachi, either during the business days as well as during holidays, are the peak hours of traffic activity across the whole metropolis. However, congestion is often experienced around Karachi District Central and the core city area. The roads that contain several congestion points are Shahrah-e-Pakistan, Shahrah-e-Faisal, M. A. Jinnah Road, S. M. Taufiq Road, Nawab Siddique Ali Khan Road, Rashid Minhas Road, and Abdullah Haroon Road. These roadways on the evenings of Friday / Saturday / Sunday carry high volume of vehicular traffic

The morning scenario of traffic in Karachi metropolitan (Figure 5.7) during working days exhibits fairly widespread moderate to very high volumes. With the exception of undeveloped parts of DHA, nearly all business and residential localities of districts Karachi South, Karachi Central and Karachi East remain pretty occupied.

KARACHI
Traffic Concentrations
Weekend Mornings

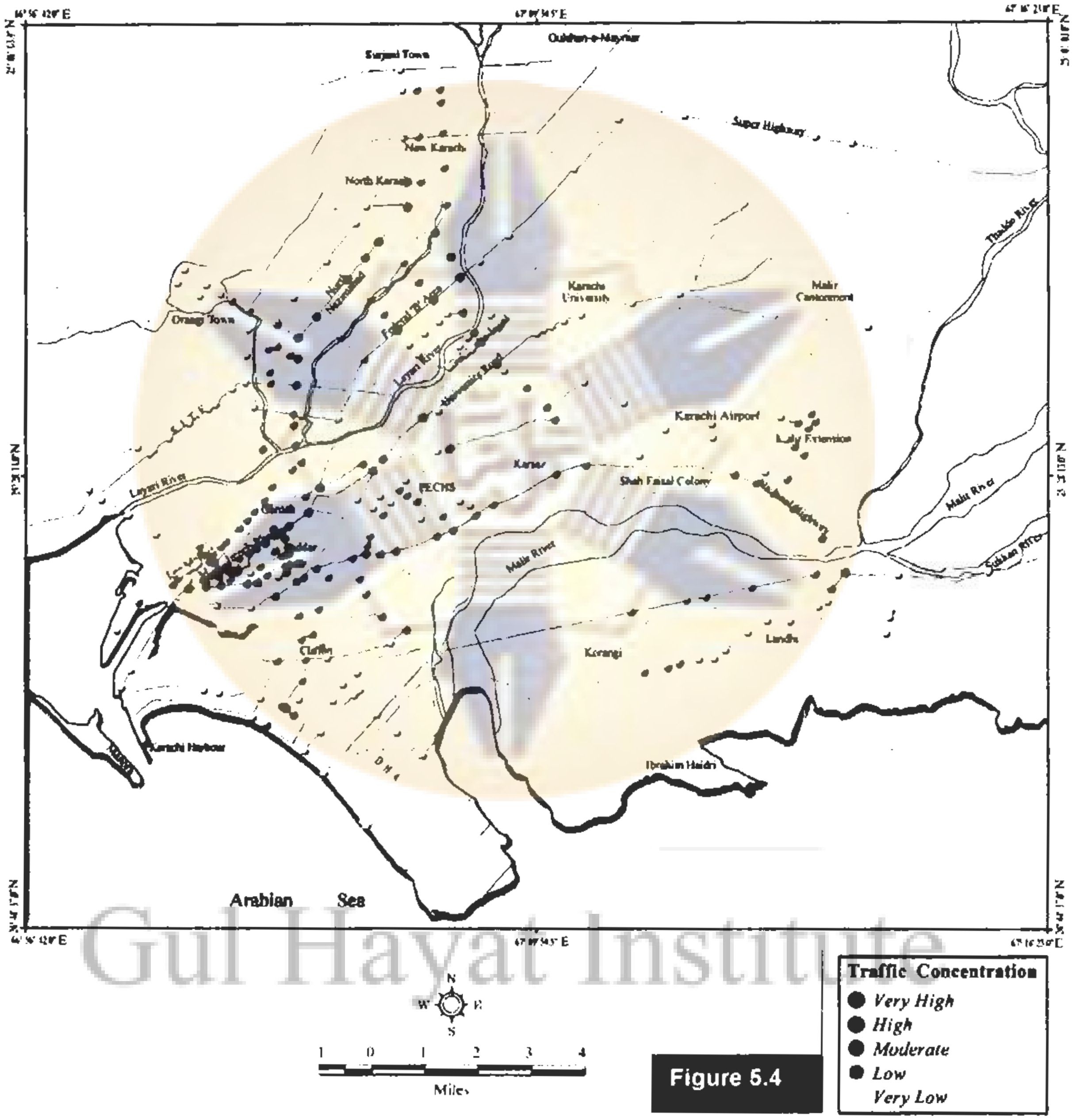


Figure 5.4

KARACHI
Traffic Concentrations
Weekend Afternoons

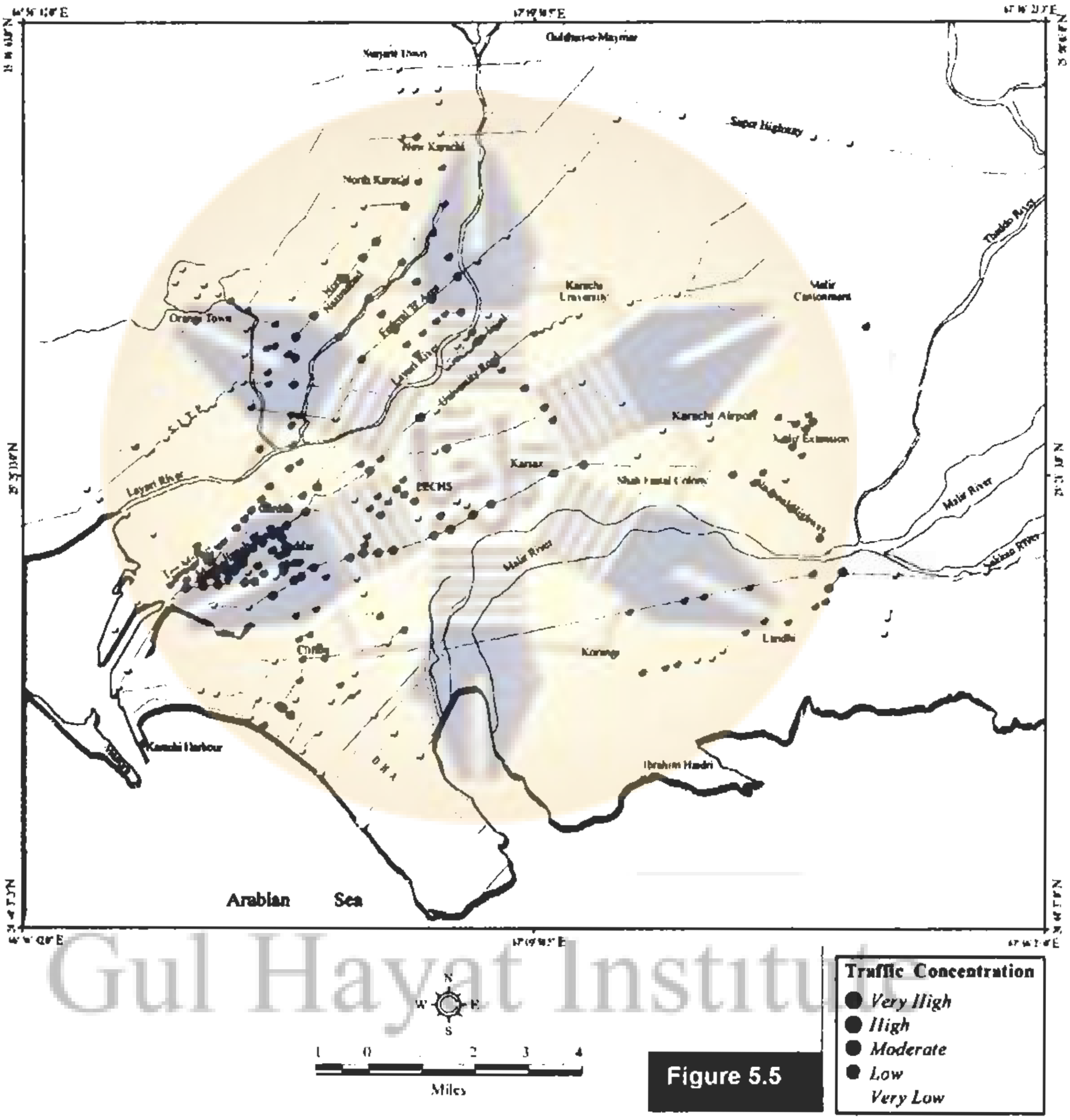


Figure 5.5

KARACHI
Traffic Concentrations
Weekend Evenings

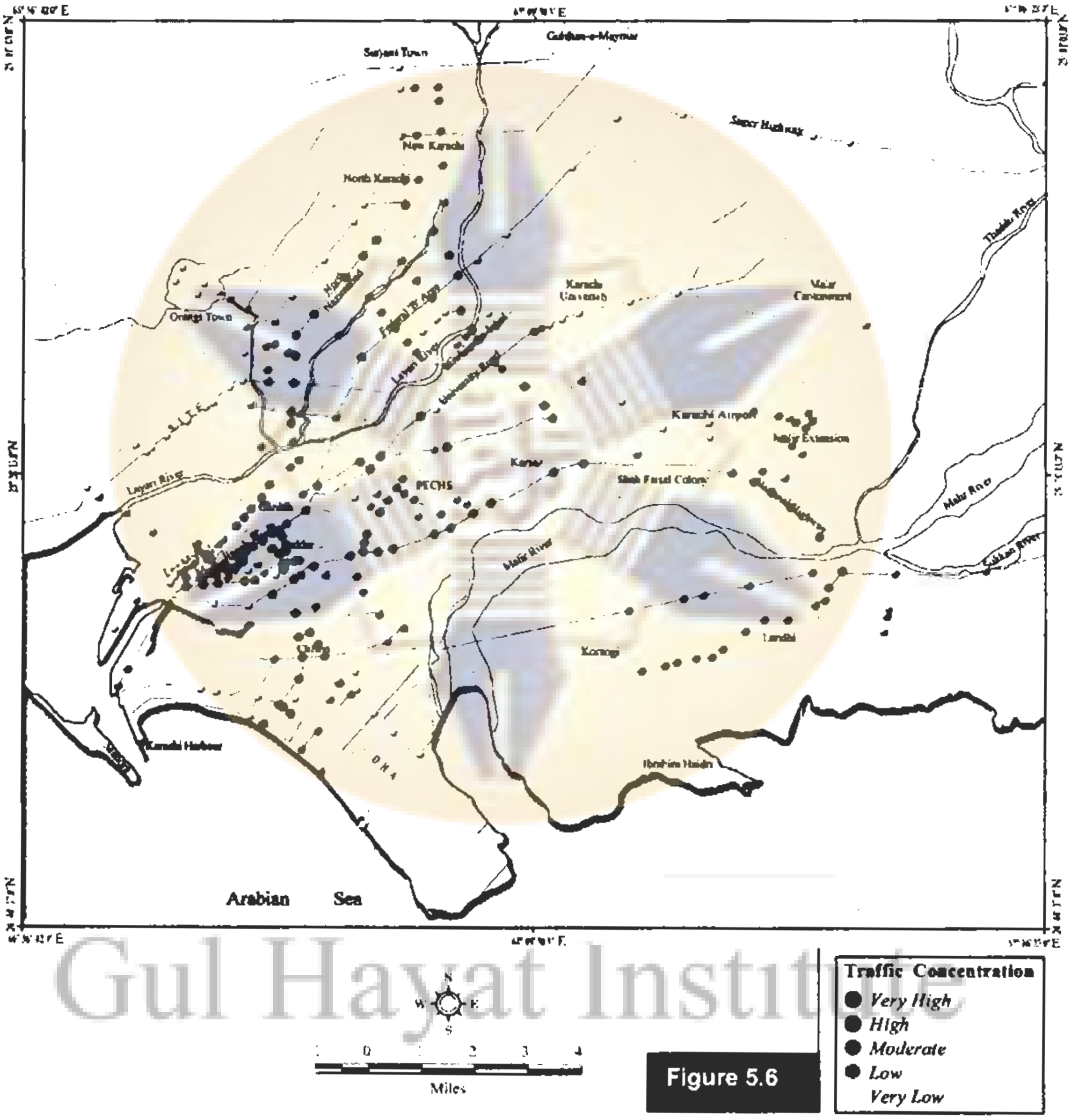


Figure 5.6

Afternoons of Monday / Tuesday / Wednesday / Thursday become less busy than other two time-segments of these days (Figure 5.8). Slight low trends are found and the major arteries are engaged with low, moderate and high volumes of traffic. The traffic activity surrounds the business centres and other trip generators in the city.

The thematic map Figure 5.9 portrays the appraisal of evenings of working day traffic volumes in metro-Karachi. This session happens to be the most congested of the six temporal sessions studied. The traffic volumes remain in the range of high to very high at more than 75 % of 308 intersections (Table 5.3). Nishtar roads, M. A. Jinnah Road, Shahrah-e-Faisal, Rashid Minhas Road, S. M. Taufiq Road, Nawab Siddique Ali Khan Road and Tariq Road have several bottle necked intersections. Whereas, Shaheed-e-Millat Road, Shahrah-e-Quaideen, and Abdullah Haroon Road give way to thousands of vehicles during this time segment comparable to the roads, previously mentioned. The industrial areas of SITE, Landhi and Federal B. Area are also involved in traffic congestion due to 'work to home' trips.

5.3.1 Discussion on Findings

Traffic engineering dispenses solutions for the three basic elements of transportation i.e. the vehicle, the travel way and the driver. In the preceding sections, the problems with respect to the vehicular movement and the roadways have been identified. Nonetheless, there are a few salient factors regarding the traffic in Karachi, which are summarised here:

- The driver behaviour, owing to very low literacy rate in Pakistan, is to an extent responsible for the state of affairs on the roads. The hostile manifestation of this behaviour is the undue noise created through pressure horns (SEPA, 1994; Mehdi, 1998). Traffic management programs for the metropolis could not succeed without reviewing the licensing procedure and reforms like mandatory drivers training.

KARACHI
TRAFFIC CONCENTRATIONS
WORKING DAY MORNINGS

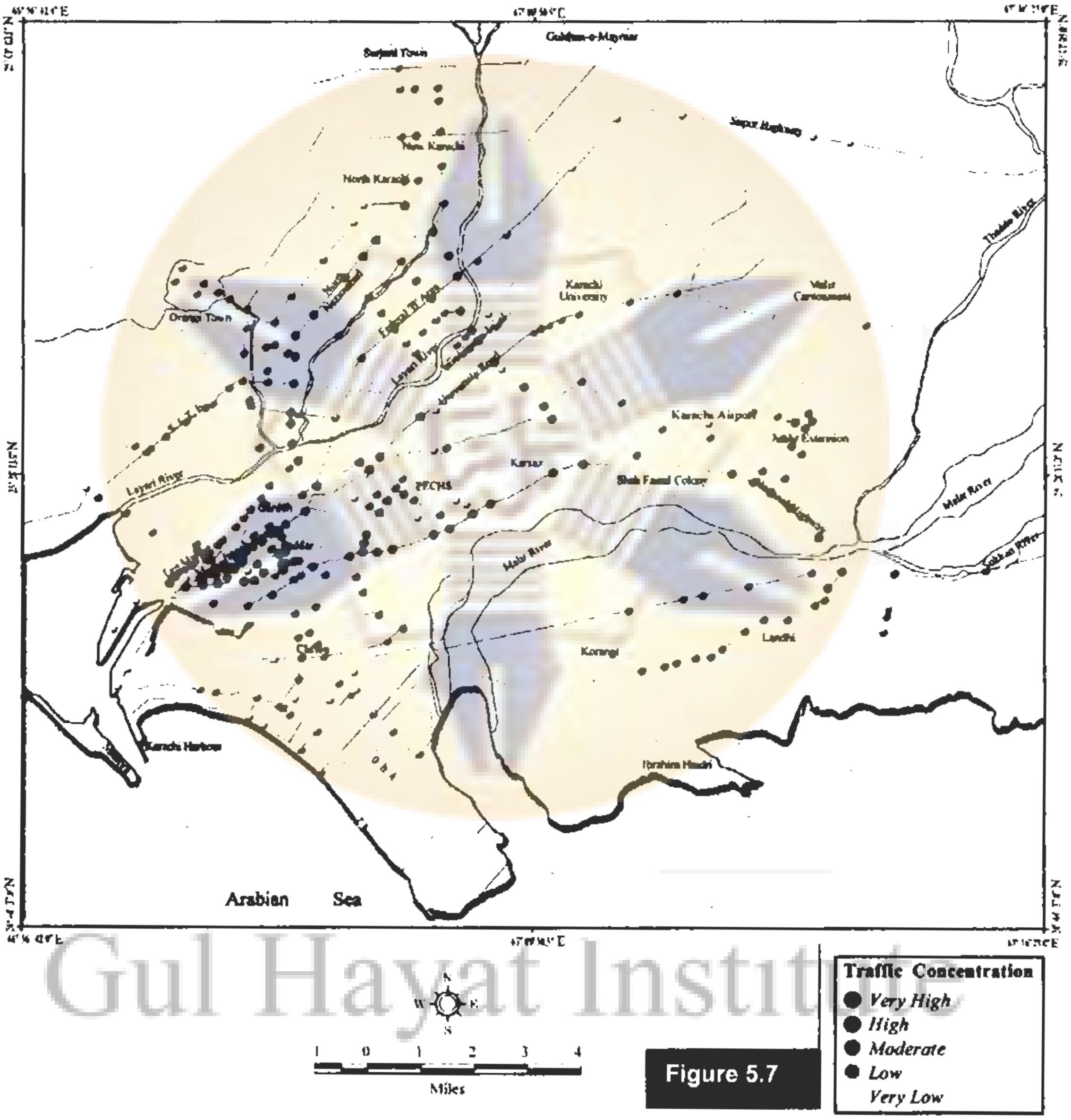


Figure 5.7

KARACHI
TRAFFIC CONCENTRATIONS
WORKING DAY AFTERNOONS

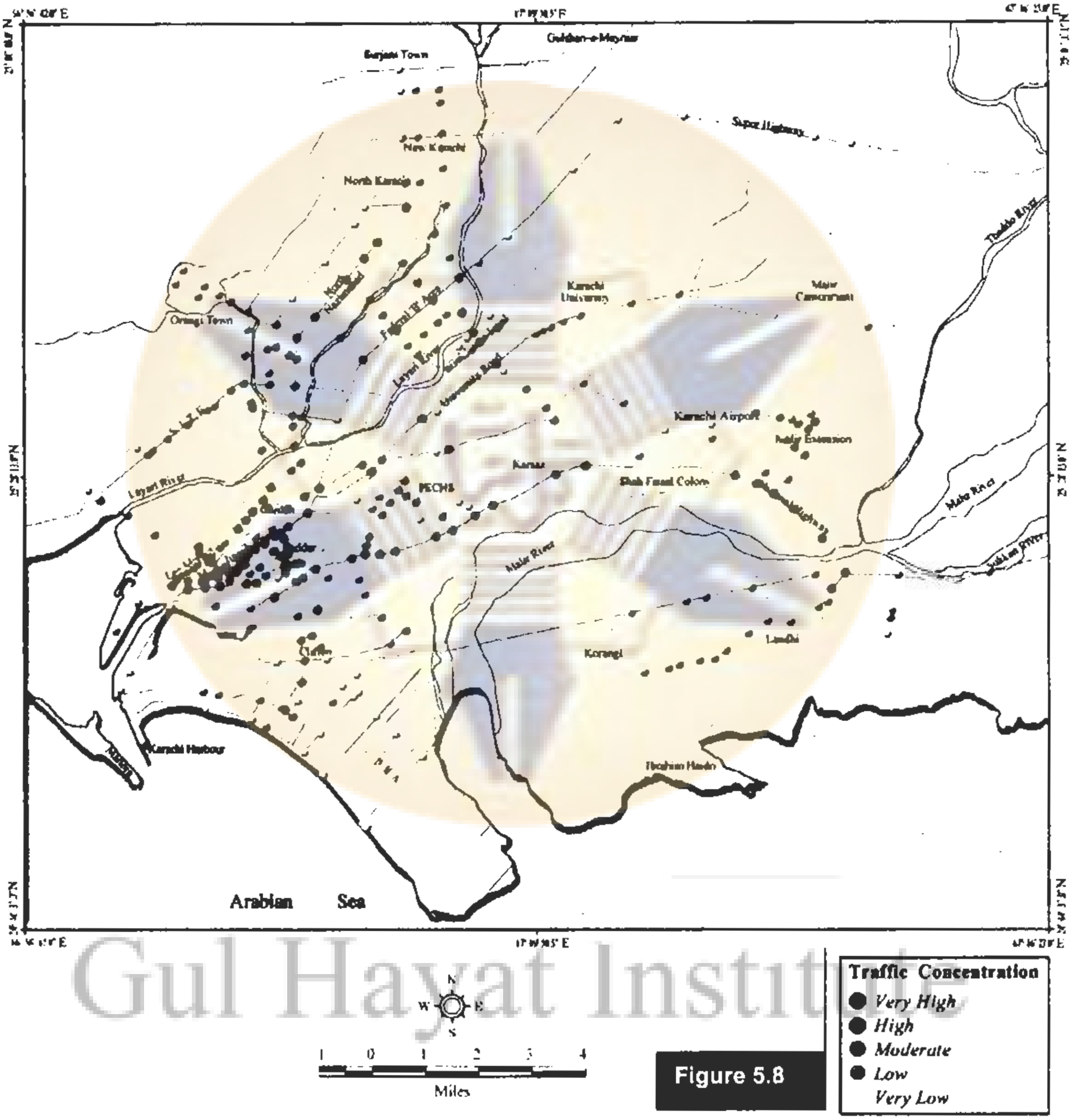


Figure 5.8

KARACHI
Traffic Concentrations
Working Day Evenings

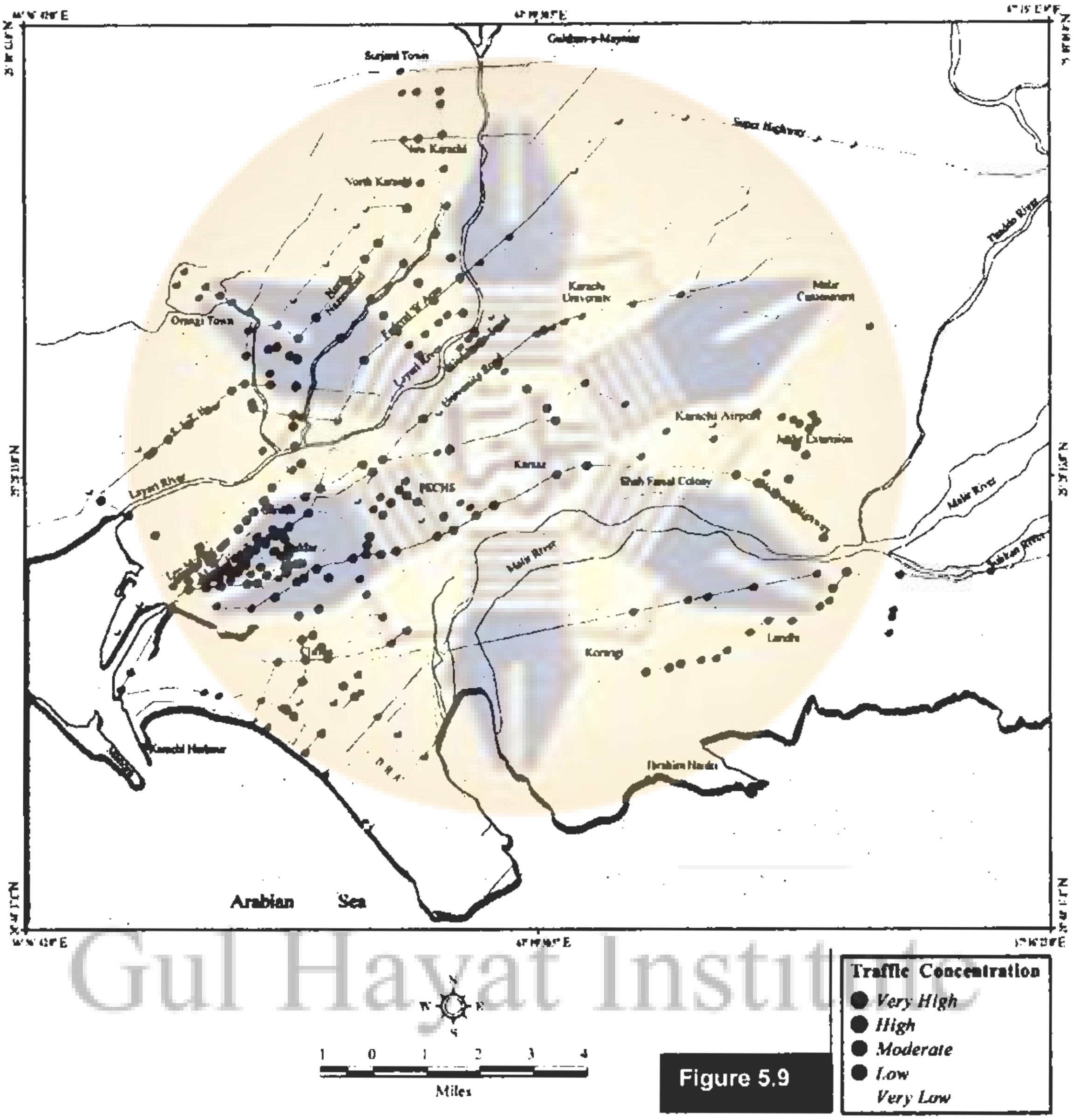


Figure 5.9

- The unusual composition of traffic in Karachi is contributing to problems of congestion and noise pollution. The presence of significant share of heavy modes (Minibuses, Buses, and Trucks) and two-wheelers powered by two-stroke engines along with animal drawn (donkey cart, camel cart, and *Tonga*) vehicles makes Karachi as a atypical city on the globe. The proportion of diesel-powered vehicles, and of motorbikes without muffler (silencer), strongly influences traffic characteristics and noise pollution.

- Registration of vehicles is growing rapidly in Karachi. Although, this is a worldwide trend (Schwela and Zali, 1999), in developing countries noise pollution caused by motor vehicles is already a serious problem in the large cities. Some countries in the Middle East (*e.g.* UAE and Qatar) have managed to curb the number of vehicles on road. Lessons need to be drawn on these lines.

- In the absence of any bypass route from the Kaemari port to the National and Super highway, all the cargo vehicles having up country destination have to pass through the narrow inner city roads. According to conservative estimates, the port generates about 20,000 heavy diesel vehicle trips per day (Hasan *et al.*, 1999). This is causing perpetual degradation of the road pavements along with air and noise pollution.

- Traffic congestion is a common occurrence and fairly widespread over the metropolitan Karachi. There are three major highway projects in the pipeline viz. the Northern bypass, the Layari Expressway and the Southern bypass (Dawn, 2002). It is envisaged that the Northern bypass has acquired a priority among these projects. Its construction (Super highway to Karachi port) is expected to provide another corridor for future settlements. Decision-makers should start visualising the future scenario of the metropolitan traffic movements and patterns, when all these highway projects would be materialised.

6. APPRAISAL OF NOISE POLLUTION

The impacts of rapid urbanization include settlements, traffic congestion, noise pollution and associated diseases (UNEP, 1999). There is no question that noise is both a public health hazard and an environmental pollutant as well. Road traffic noise results from the collective contribution of the noise produced by individual vehicle. The vehicular noise is itself a product of several auto-parts. Priede (1980) established the principal sources of engine noise. Engine noise is due to fuel combustion and due to the mechanical impacts. The different sources in an engine and their internal mechanism are covered by Challen and Croker (1982).

The main sources of surface radiated noise in the engine are engine crankcase, oil sump, front timing cover, gearbox, inlet and exhaust manifolds, crankshaft and fuel injection pump. Current levels of noise from transmission as a whole, range from 68 to 78 dB(A) at 7.5m (Tyler, 1987). Harland (1974) showed that at speeds above 100 Km/h on dry roads tyre-road surface becomes the dominant source of vehicle noise. Last but not the least pressure horns are the main contributor of vehicle noise when instead of machine, human behaviour is responsible.

Karachi is growing at 4.2 per cent per annum (UNEP, 1999). In Karachi, the blowing of horns have increased alarmingly and is up to 30 to 35 dB(A) above the tolerance limits (SEPA, 1994). The most noticeable sources of noise pollution in Karachi, are the auto rickshaws, trail motorbikes and the fag horns of public transport (Zaidi, 1990). The local administration has time and again attempted to impose a ban on the use of defective silencers and pressure horns (Correspondent daily Dawn, 1996). Previous studies have attributed vehicular noise pollution to large scale migration, increase in the numbers the number of vehicles (ESCAP, 1990), traffic jams, defective roads, defective vehicles, and above all the human factor which in our society is reflected by inherent impatience under social pressures giving rise to such acts as blowing of horns unnecessarily (*e.g.* Shaikh and Rizvi, 1990; SEPA, 1994; Ahmad, 1994; Mehdi *et al.*, 2002).

6.1 SOURCES AND QUALITY OF DATA

The most recent large-scale (n=78) noise level data monitored in Karachi was of 1993 (SEPA, 1994). Mehdi *et al.* (2002) had spotted noise risk zones (NRZs) through GIS with this limited data. The levels have changed significantly during the last decade and there is a need to explore the present ground realities with a greater sample size (*e.g.* n > 200).

Noise is not continuous and normally distributed phenomenon in between its peak and lowest values. In other words Noise intensity level changes rapidly with in seconds. Therefore average (mean) was not most representative for that skewed distributed variable. Average value is highly affected from extremes for instance during five minutes highest value is 100 dB(A) and lowest value 55 dB(A), which shows 78 as an average. Hence the people have to bear higher than 85 dB(A) mostly. To over come this factor, mode (most repetitive value) has been chosen. It was practically possible to record mode Noise levels, since the synchronization time of the digital instrument was less than a second. These Noise intensity levels were monitored in two ways:

1. **Mode** of five minutes at 4-5 meter from the source and 4 - 41/2 feet above the surface
2. **Peak** of five minutes at 4-5 meter from the source and 4 - 41/2 feet above the surface

6.1.1 Noise Meter

Sound Level measurements are in general, carried out through Electro acoustic methods in which the Noise is converted to an electrical signal by a microphone and subsequently amplified electronically prior to some form of analysis. The sound level meters are the basic portable instruments used for the measurement of continuous Noise. They comprise essentially a microphone to pick up the sound, an electronic amplifier, and one or more frequency-weighing network and a meter to display the level of sound. They are produced to meet various international standards, which define the important aspects of their specifications. The instrument employed in this study is illustrated in Annexure E.

6.1.2 Monitoring Sites' Sampling

Continuous noise monitoring is usually preferred for estimating the level of pollution because these data provide the best representation. In a developing country, such as Pakistan, this requires resources beyond the reach of the investigator. However, a database has been designed on the basis of primary field data collection. This database has comprehensive spatial and temporal coverage.

Coverage on micro scale throughout the Karachi was the huge and difficult task especially owing to number of financial and human resource constraints. Even then more than 300-site sample-size was targeted and successfully covered. When the sites studied are plotted on a map according to their geographical positions, it automatically forms the shape of metropolitan Karachi. Sampling was performed on following criteria:

- Potential of noise pollution
- Spatial coverage
- Target neighbouring parameter such as *near source, not in open grounds etc.*

Table 6.1: Noise Intensities at Monitoring Sample Locations around Karachi Metropolis

Location No.	Mode Noise dB(A)						Peak Noise dB(A)					
	Working Day			*Weekend*			*Working Day*			*Weekend*		
	Morn	After	Even	Morn	After	Even	Morn	After	Even	Morn	After	Even
1	85	83	93	80	72	81	92	88	90	101	93	89
2	85	77	86	82	72	83	90	92	89	96	92	88
3	83	78	81	79	72	81	89	87	88	89	88	86
4	88	81	85	83	78	83	93	92	91	94	93	90
5	80	73	81	74	72	76	87	92	86	80	86	84
6	78	71	77	77	72	77	85	89	86	92	88	86
7	86	80	86	78	67	79	95	93	95	98	97	93
8	84	84	89	79	67	80	94	95	92	93	94	91
9	86	85	94	83	80	84	92	93	90	86	90	88
10	81	74	81	79	71	79	87	85	89	89	88	86
11	85	76	84	76	72	77	95	91	92	93	93	90
12	81	72	79	76	72	76	87	83	92	80	86	84
13	81	77	83	77	74	78	95	95	97	92	95	92
14	80	76	84	70	64	71	92	101	96	98	97	94
15	84	80	83	75	61	75	92	94	92	96	94	91
16	86	76	83	82	70	83	94	94	97	96	95	93

Location No.	Mode Noise dB(A) Working Day			Mode Noise dB(A) Weekend			Peak Noise dB(A) Working Day			Peak Noise dB(A) Weekend		
	Morn	After	Even	Morn	After	Even	Morn	After	Even	Morn	After	Even
17	82	77	83	78	72	80	90	92	87	90	90	88
18	79	75	85	69	62	71	100	96	101	85	96	93
19	83	77	85	78	64	80	97	101	96	93	97	94
20	74	64	69	68	54	89	90	81	86	86	86	85
21	80	73	81	71	60	72	92	83	89	87	88	87
22	82	80	90	82	71	83	96	89	96	102	96	94
23	84	79	89	77	72	78	92	88	90	83	88	87
24	78	74	78	72	71	73	85	90	87	83	86	86
25	84	80	92	80	74	82	92	95	93	89	92	91
26	86	82	94	85	74	86	100	97	103	95	101	98
27	82	73	84	75	71	78	97	94	96	91	95	93
28	79	71	77	77	74	77	89	85	84	96	92	90
29	82	77	86	79	77	80	90	85	87	85	87	86
30	80	75	85	78	68	79	89	93	91	87	90	89
31	80	78	86	78	70	78	87	90	89	75	85	85
32	82	81	93	80	73	80	68	88	87	87	68	87
33	85	81	87	77	65	79	92	92	90	99	93	92
34	80	73	83	71	68	73	91	93	88	95	92	91
35	85	77	80	76	64	76	94	91	96	91	93	92
36	79	73	77	73	70	73	93	92	92	95	93	92
37	78	70	79	75	63	78	96	95	96	100	97	95
38	80	74	84	73	63	74	92	89	90	96	92	91
39	73	68	89	63	57	64	92	96	94	88	92	91
40	85	82	90	77	68	78	90	95	90	98	93	92
41	80	73	82	75	64	78	94	87	94	91	92	90
42	82	76	88	79	87	79	95	94	97	96	96	94
43	79	71	75	75	69	76	89	86	91	87	88	88
44	85	80	90	78	73	80	96	91	95	81	91	90
45	84	78	80	81	89	82	96	91	95	100	96	94
46	85	79	91	75	69	76	95	90	95	98	95	93
47	83	76	78	81	78	82	95	95	95	78	91	90
48	78	73	84	77	87	79	93	94	93	82	91	90
49	82	75	83	81	73	83	94	95	93	93	94	92
50	81	71	72	80	69	81	89	94	92	96	93	92
51	72	64	75	89	61	70	89	68	92	96	91	90
52	73	68	75	64	63	66	86	89	88	87	87	87
53	82	78	77	81	78	81	94	91	93	89	92	91
54	83	79	81	81	66	82	94	94	96	101	96	94
55	83	82	91	63	76	84	89	90	90	84	88	88
56	84	79	82	80	73	82	93	94	93	87	92	91
57	86	83	89	84	69	85	101	103	102	83	97	95
58	77	70	73	71	58	73	90	92	91	88	90	90
59	81	79	89	73	70	73	95	97	97	99	97	95
60	83	77	81	80	75	81	93	90	94	98	94	93
61	85	83	86	79	67	80	96	101	98	80	94	93
62	80	74	84	79	77	80	88	85	86	90	87	87
63	78	75	78	74	69	76	85	87	85	97	89	88
64	71	65	72	68	64	68	80	68	75	96	80	81
65	84	77	83	83	76	84	92	98	90	89	92	91
66	81	72	79	75	74	76	92	95	96	93	94	93
67	81	78	84	79	75	79	90	87	89	88	89	88

Location No.	Mode Noise dB(A)						Peak Noise dB(A)					
	Working Day			Weekend			Working Day			Weekend		
	Morn	After	Even	Morn	After	Even	Morn	After	Even	Morn	After	Even
68	82	78	84	76	62	77	89	95	93	91	92	91
69	81	78	89	79	75	80	90	80	86	99	89	89
70	80	78	90	76	67	77	89	93	89	100	93	92
71	80	74	77	80	80	81	91	94	90	96	93	92
72	79	76	86	76	67	77	92	97	93	97	95	94
73	82	72	81	72	68	72	90	84	88	95	89	89
74	82	78	79	76	66	77	92	90	88	98	92	91
75	80	74	79	76	69	77	90	85	66	92	88	88
76	80	77	83	78	75	78	89	85	89	86	87	87
77	85	78	83	78	65	80	89	83	88	98	90	89
78	82	76	80	73	58	74	92	91	94	90	92	91
79	68	58	89	65	59	65	103	101	99	98	100	98
80	73	66	77	72	69	73	84	77	80	95	84	85
81	74	68	78	70	62	72	83	83	82	94	86	86
82	76	67	73	73	73	73	91	94	87	91	91	90
83	83	75	80	75	74	77	90	89	88	91	90	89
84	84	78	81	84	82	84	90	93	88	90	90	90
85	77	71	76	73	80	74	92	86	90	87	89	89
86	74	64	68	68	67	69	90	91	89	94	91	91
87	78	71	80	73	72	73	94	100	97	95	99	97
88	69	66	75	68	66	68	86	90	84	99	90	90
89	67	62	73	66	55	67	85	82	82	101	88	88
90	82	74	77	79	88	79	89	81	85	92	90	90
91	82	79	90	80	69	82	90	94	89	90	91	90
92	73	68	72	71	57	72	90	97	90	87	91	91
93	68	59	60	58	46	59	88	96	68	94	92	91
94	81	75	84	73	62	74	96	100	99	100	102	99
95	76	70	77	72	62	74	89	89	87	93	90	89
96	82	78	84	79	66	80	92	89	89	93	91	91
97	77	68	77	76	66	78	88	87	85	83	86	86
98	79	70	78	77	72	78	89	91	92	94	92	91
99	73	64	76	70	88	70	88	90	90	89	89	89
100	72	66	70	64	62	64	82	82	84	84	83	84
101	68	59	62	65	57	67	82	92	85	85	86	87
102	76	70	77	69	57	70	88	90	87	89	89	89
103	85	82	89	82	68	83	90	82	89	90	88	88
104	86	76	87	84	75	88	94	91	94	92	93	92
105	76	74	86	69	56	69	84	82	87	88	85	86
106	86	78	88	77	83	79	96	90	97	91	97	95
107	84	82	93	84	72	85	84	87	81	76	82	83
108	86	86	90	76	71	77	96	101	96	90	97	96
109	77	68	77	72	70	73	90	87	86	80	86	86
110	81	76	84	76	67	77	90	96	90	90	92	91
111	81	71	76	75	65	77	92	99	96	100	97	96
112	74	70	74	64	56	65	88	96	87	90	90	90
113	74	65	77	71	70	72	88	89	90	99	92	91
114	61	59	69	59	55	60	86	85	86	92	87	88
115	62	54	59	61	46	62	88	96	91	93	92	92
116	65	62	69	62	52	62	75	78	76	74	76	78
117	76	68	73	75	66	76	88	89	87	92	89	89
118	81	74	82	77	68	78	89	97	92	96	94	93

Location No.	Mode Noise dB(A)						Peak Noise dB(A)					
	Working Day			*Weekend*			*Working Day*			*Weekend*		
	Morn	After	Even	Morn	After	Even	Morn	After	Even	Morn	After	Even
119	86	82	89	81	74	81	103	102	103	100	100	89
120	83	80	84	78	67	80	92	95	94	99	95	94
121	78	89	79	73	68	74	84	78	82	86	83	84
122	80	80	88	78	63	78	88	94	88	88	90	90
123	84	75	85	77	75	78	87	87	84	84	86	86
124	89	86	99	88	73	89	92	88	96	97	93	93
125	65	56	60	56	51	57	76	74	77	78	76	79
126	65	57	66	55	48	56	75	79	75	76	76	79
127	79	74	78	75	71	76	82	80	83	76	80	82
128	82	72	80	75	61	76	93	90	93	89	91	91
129	79	76	89	77	73	77	94	94	93	99	95	94
130	78	72	78	77	69	79	85	85	87	92	87	88
131	86	80	85	76	62	76	96	95	96	96	96	95
132	81	76	81	76	62	78	95	95	89	85	91	91
133	73	67	69	71	59	73	88	87	91	95	90	90
134	68	61	85	64	49	64	78	75	77	81	78	80
135	86	76	77	76	63	77	96	97	97	97	97	96
136	82	78	86	74	73	76	92	90	94	92	92	92
137	81	79	86	77	68	79	89	83	88	88	87	88
138	79	89	77	77	70	78	82	81	80	84	82	83
139	78	74	79	69	66	71	85	85	89	89	87	88
140	72	64	68	66	64	68	82	81	82	80	81	83
141	85	56	64	81	53	82	75	73	76	78	78	78
142	85	58	64	59	51	59	75	81	72	78	77	79
143	70	64	70	61	51	62	83	81	81	82	82	83
144	74	69	73	72	68	73	87	85	84	88	88	87
145	72	65	71	66	52	68	85	74	83	89	83	84
146	79	78	88	77	66	77	88	86	87	93	89	89
147	75	70	81	73	69	73	86	86	86	84	66	86
148	73	87	79	65	51	66	82	84	82	81	82	84
149	68	67	70	60	57	60	85	82	81	76	81	83
150	87	58	65	87	60	87	88	86	87	97	90	90
151	78	70	72	70	56	70	92	84	91	98	91	91
152	86	83	89	84	81	88	96	97	96	101	98	97
153	87	85	94	85	84	86	99	91	98	96	96	95
154	87	78	81	85	79	86	99	89	98	93	98	97
155	84	80	86	84	81	84	97	98	96	92	96	95
156	87	79	81	87	79	87	92	95	91	93	93	93
157	80	73	87	60	70	82	90	94	93	92	92	92
158	73	65	73	63	52	64	95	98	96	101	98	97
159	83	80	86	77	85	78	100	100	100	100	101	99
160	86	82	86	85	74	85	102	93	100	98	100	99
161	84	74	74	79	76	79	102	102	98	99	100	68
162	89	83	68	81	71	82	99	98	99	100	99	98
163	89	85	97	82	74	82	100	101	97	100	100	98
164	79	69	75	71	62	72	89	94	88	89	90	90
165	86	77	88	77	66	78	103	100	95	98	100	85
166	69	62	76	68	52	68	80	85	83	83	83	84
167	83	82	86	79	66	80	92	92	95	90	92	92
168	89	83	93	84	83	84	103	102	100	97	98	95
169	82	77	81	73	67	73	95	96	95	99	96	96

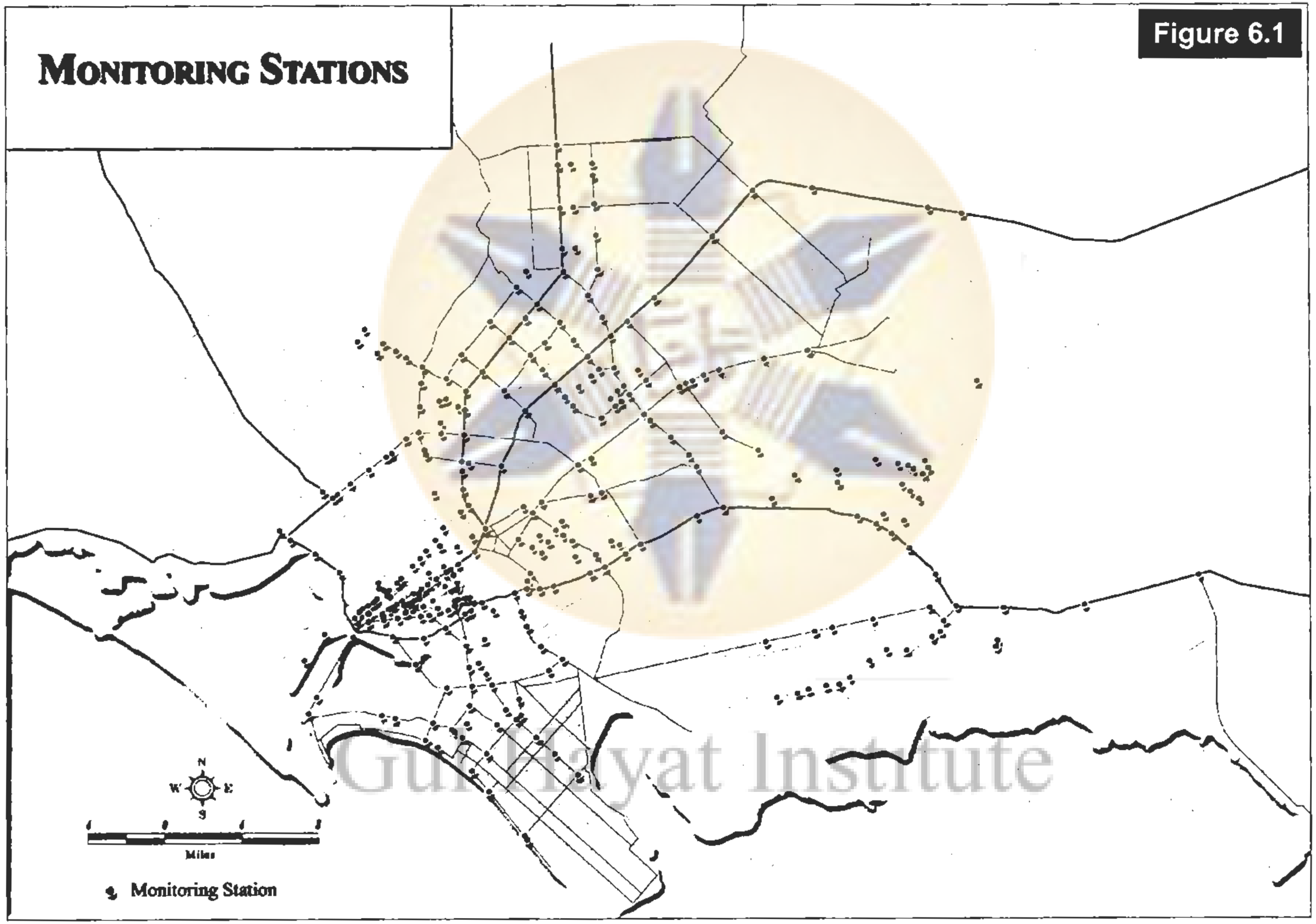
Location No.	Mode Noise dB(A)						Peak Noise dB(A)					
	Working Day			*Weekend*			*Working Day*			*Weekend*		
	Morn	After	Even	Morn	After	Even	Morn	After	Even	Morn	After	Even
170	79	71	83	69	56	69	91	88	89	86	89	89
171	84	80	83	82	75	82	93	87	93	97	93	93
172	87	81	86	84	71	85	98	94	97	101	98	97
173	86	83	88	83	72	85	93	99	95	99	97	96
174	79	75	78	71	61	72	91	88	91	99	92	92
175	87	81	90	85	71	87	95	95	97	99	97	96
176	78	73	77	69	65	70	98	95	101	102	102	100
177	70	65	69	65	59	67	98	90	100	101	101	99
178	76	66	77	74	69	74	93	96	94	91	94	93
179	67	63	72	66	63	66	87	91	84	85	87	88
180	67	64	74	67	65	67	87	89	88	69	88	89
181	77	72	82	72	64	73	80	84	83	91	85	86
182	82	79	88	73	60	74	91	89	90	89	90	90
183	74	65	77	66	60	67	90	90	87	91	90	90
184	83	77	87	77	73	78	96	101	97	95	100	99
185	63	82	87	75	62	77	102	95	98	99	99	98
186	81	79	89	78	75	79	89	84	88	86	87	88
187	78	73	78	70	68	72	93	88	94	96	92	92
188	79	70	76	74	63	75	90	91	89	92	91	91
189	70	85	88	69	55	71	85	82	85	93	86	87
190	85	79	90	82	81	82	96	98	96	96	99	98
191	80	72	75	76	73	77	92	93	93	100	95	94
192	82	74	79	77	70	79	90	80	87	81	85	88
193	84	80	87	76	71	76	92	92	92	100	94	94
194	83	77	78	81	73	83	91	90	87	89	89	90
195	84	79	89	80	72	81	91	87	89	89	89	90
196	80	74	80	80	75	82	90	90	86	84	88	89
197	79	69	79	75	61	76	94	90	92	93	92	92
198	71	69	79	66	56	67	90	92	94	99	94	94
199	72	65	73	63	61	64	80	71	77	82	78	80
200	73	65	67	68	56	68	80	70	77	80	77	80
201	74	67	70	68	60	70	82	91	85	90	87	88
202	82	74	87	78	63	79	89	92	90	90	90	91
203	74	68	78	66	66	68	95	86	92	92	91	92
204	68	62	68	64	50	66	72	75	68	67	71	75
205	75	71	80	68	66	69	85	87	87	81	85	87
206	63	80	86	80	76	80	97	102	97	99	99	98
207	75	66	70	66	63	66	88	90	85	86	87	88
208	80	71	74	78	65	80	85	78	82	88	83	85
209	80	71	79	71	56	73	85	80	83	89	84	88
210	82	78	80	76	76	77	92	100	95	93	98	97
211	82	73	77	80	68	81	89	93	86	87	89	90
212	64	77	82	82	69	83	90	84	88	91	88	89
213	75	67	69	68	59	70	88	89	67	98	91	91
214	85	76	83	81	72	81	89	85	88	92	68	89
215	88	82	86	80	71	80	99	95	99	93	97	96
216	76	69	79	75	72	75	82	75	80	83	80	82
217	78	72	75	73	70	75	82	82	83	84	83	85
218	77	72	73	70	63	72	89	91	84	84	87	88
219	75	69	76	69	59	70	84	88	88	96	89	90
220	74	69	77	67	62	67	84	79	79	79	80	83

Location No.	Mode Noise dB(A)						Peak Noise dB(A)					
	Working Day			*Weekend*			*Working Day*			*Weekend*		
	Morn	After	Even	Morn	After	Even	Morn	After	Even	Morn	After	Even
221	77	68	80	73	62	74	90	90	91	102	93	94
222	72	72	80	72	58	72	86	90	86	84	87	88
223	75	66	72	69	55	71	79	84	78	79	80	83
224	72	67	73	63	57	63	78	74	77	82	78	81
225	60	52	60	52	47	52	70	70	67	67	69	73
226	69	66	69	65	56	66	75	75	75	79	76	79
227	68	60	65	60	46	61	90	85	89	93	89	90
228	65	63	73	58	54	60	75	78	76	72	75	79
229	68	59	62	59	54	60	76	80	74	81	78	81
230	80	74	81	74	73	76	94	96	96	92	98	97
231	67	60	64	65	58	66	77	80	78	78	78	81
232	84	77	79	82	69	84	98	91	95	92	94	94
233	86	79	85	84	70	85	98	96	94	102	98	97
234	81	73	74	74	61	75	86	81	84	90	65	87
235	82	73	81	73	60	74	89	87	87	89	88	89
236	69	62	69	62	53	63	88	87	87	81	86	87
237	71	62	70	65	62	66	85	81	80	76	81	63
238	61	53	60	57	42	58	85	86	82	78	83	85
239	62	59	67	61	51	61	82	77	83	88	83	85
240	81	71	73	74	67	74	89	88	88	89	89	90
241	78	68	77	76	68	76	94	89	93	98	94	94
242	84	77	80	83	69	85	90	92	89	93	91	92
243	79	78	82	71	57	73	92	87	92	98	92	93
244	73	65	70	71	62	73	87	90	87	90	89	90
245	81	81	85	78	64	79	93	98	95	99	96	96
246	75	68	72	70	65	70	89	82	88	84	86	88
247	61	57	64	59	49	60	70	74	74	72	73	77
248	78	71	84	76	69	76	89	92	89	94	91	92
249	84	81	93	79	77	81	97	100	100	91	101	100
250	65	58	70	60	51	61	80	78	80	77	79	82
251	69	65	74	63	50	63	87	69	89	91	69	90
252	76	67	75	69	68	71	85	90	86	82	86	88
253	81	76	86	77	62	79	88	90	88	88	89	90
254	81	78	86	73	63	75	93	98	97	99	97	97
255	82	78	82	79	70	81	88	88	88	93	89	90
256	83	76	80	80	74	81	94	92	94	98	95	95
257	83	80	92	82	72	82	99	99	99	94	98	98
258	79	70	79	75	65	75	90	91	92	92	91	92
259	78	72	77	75	74	76	94	100	93	96	96	96
260	75	66	76	71	70	72	95	93	96	89	93	94
261	79	74	82	77	83	76	99	88	98	98	100	99
262	85	76	81	83	74	84	64	77	82	80	81	84
263	71	71	78	86	57	68	88	86	90	91	89	90
264	73	68	73	70	63	70	86	91	85	92	89	90
265	83	83	94	80	70	82	95	93	92	94	94	94
266	81	72	76	72	61	74	95	89	94	89	92	93
267	85	79	82	79	68	80	99	69	101	101	96	96
268	88	84	94	81	78	82	101	96	103	97	95	92
269	86	83	85	79	64	81	98	95	98	100	98	98
270	82	77	83	81	76	83	96	101	98	99	99	99
271	86	84	88	84	70	86	101	100	100	99	100	100

Location No.	Mode Noise dB(A)						Peak Noise dB(A)					
	Working Day			*Weekend*			*Working Day*			*Weekend*		
	Morn	After	Even	Morn	After	Even	Morn	After	Even	Morn	After	Even
272	83	80	93	75	66	75	98	101	102	98	98	93
273	79	77	86	70	70	70	96	98	98	98	98	98
274	87	84	90	83	74	84	100	98	101	92	102	101
275	84	78	79	76	71	76	100	98	100	99	99	99
276	74	65	77	69	62	70	89	88	91	93	90	92
277	71	62	71	71	59	73	85	82	82	83	83	86
278	84	76	80	83	77	85	95	92	93	96	94	95
279	84	79	88	83	76	84	98	96	94	90	95	95
280	86	81	89	76	67	77	101	97	101	102	100	100
281	83	79	85	80	72	80	98	100	100	90	102	101
282	81	77	87	81	69	82	99	102	96	97	99	99
283	84	76	84	77	73	79	98	93	98	89	95	95
284	85	76	84	76	64	76	96	89	92	95	93	94
285	85	76	84	80	72	82	102	95	102	100	99	97
286	79	74	81	79	67	80	95	94	97	89	98	98
287	85	77	88	80	75	81	93	96	91	93	93	94
288	84	79	81	79	66	80	98	92	95	80	91	93
289	85	76	86	76	66	77	97	97	97	91	99	99
290	84	78	85	77	75	78	96	95	97	99	97	97
291	83	75	82	76	70	78	95	101	97	91	96	97
292	82	72	82	72	65	73	94	98	95	100	98	98
293	81	81	89	78	73	79	98	92	97	96	96	97
294	78	72	79	76	62	77	96	84	93	99	93	94
295	85	79	81	83	79	83	102	102	101	99	101	101
296	84	77	80	81	70	83	95	98	96	94	96	97
297	82	77	80	77	71	78	97	85	93	96	93	94
298	78	72	83	72	66	72	96	90	97	99	96	97
299	77	72	78	70	84	71	95	94	97	99	99	99
300	71	64	68	83	50	65	96	89	100	96	99	100
301	69	63	74	62	62	63	92	88	92	85	89	91
302	68	60	68	65	50	85	84	82	83	101	88	90
303	79	74	78	70	57	71	94	100	96	101	98	99
304	71	68	75	69	68	70	93	88	94	92	92	94
305	70	66	71	70	62	71	92	90	91	99	93	95
306	75	67	78	73	72	74	97	99	99	94	97	98
307	76	73	77	68	54	69	88	91	92	95	92	94
308	79	72	81	78	72	79	99	94	98	98	97	98

Figure 6.1

MONITORING STATIONS



6.2 THE FRAMEWORK

It has been estimated that over eighty percent of the world's data have a spatial component (Worrall, 1991; MIC, 1999). Noise pollution is amongst them containing rigorous relationship with geo-spheres. Spatio-temporal analyses of this kind of variables do not only show the distributions, patterns and variations with respect to time but also assert to find out the reasons of these variations. Every phenomenon that have relation with earth, are spatially organized and be full of interaction with other spatially distributed objects / factors. Some times the study of those factors provide clues about the main studied objective owing to their spatial associations.

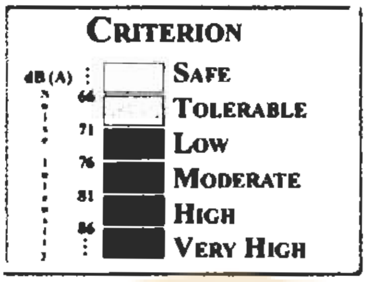
6.2.1 Development of Continuous Spatial Patterns

There are many situations where the available observations are insufficient to explore the spatial patterns in an area satisfactorily (Bernhardsen, 1999). In GIS analysis, 'Interpolation' is the procedure of predicting the most likely value of the new point based on available observations (Journel and Huijbregts, 1978; Clark, 1979; Mousset-Jones, 1980; Brooker, 1991; Geron *et al.*, 1994). Interpolation is used to convert data from point observations to continuous surface so that the spatial patterns sampled by these measurements can be compared with the patterns of other spatial entities. Spatially monitored data do not cover the domain of interest continuously (*i.e.* they are samples). Interpolation can be performed through miscellaneous statistical techniques in which Inverse distance interpolation is commonly used in environmental GIS modelling (Isaaks and Srivastava, 1989; Deutsch and Journel, 1992; Arsalan, 2000; Mehdi *et al.*, 2002) to create raster / grid overlays from point data.

Grid themes have been constructed for each set of samples in first step by completing appropriate values of required parameters under the ArcView Spatial Analyst environment with some cartographic limitations[1]. In second step interpolated grid has been reclassified according to the following criterion. For the purpose of demarcating

[1] It is worth mentioning at this point that while performing the surface interpolation in ArcView, the boundaries of the maximum diffusion were inadvertently not taken care of.

the spatial patterns of pollution, safe to very high-noise zones were spelled out for Karachi. Literature has been used to formulate the following criterion:



6.2.2 Temporal Variations

Time is one of the controlling factors of every dynamic phenomenon in this world. Noise generates and propagates with variety of speed depending upon the nature of the source and medium. That speed reveals the rate of dynamism with respect to time. It is difficult to monitor continuously (spatially) to some extent especially when spatial canvas is huge and with quite enough details. On such scale, time-to-time variation may be recommended to scrutinize with respect to morning, afternoon, evening or low to high peak times (Arsalan, 2002). GIS may provide spatio-temporal analysis functions that depict temporal variations as well as spatial variations at a time through different modes. The method that have been utilised to analyse collected data temporally is elaborated here under:

One of the themes, which have been developed for temporal variation, is the use of algebraic grid. Map algebra is a high-level computational language for performing cartographic spatial analysis using girded (raster) data. It provides a way to create mathematical and statistical operations that compare grid themes (Bernhardsen, 1999). In this regard collected data has been converted into interpolated grids for mornings, afternoons and evenings of working and off days. Finally standard deviation has been calculated for each grid to identify the variation of noise pollution during these times' sessions and days. These deviation based thematic surfaces would be used to give the importance to the temporal variations in multi-attribute risk assessment (as discussed in section 10.1).

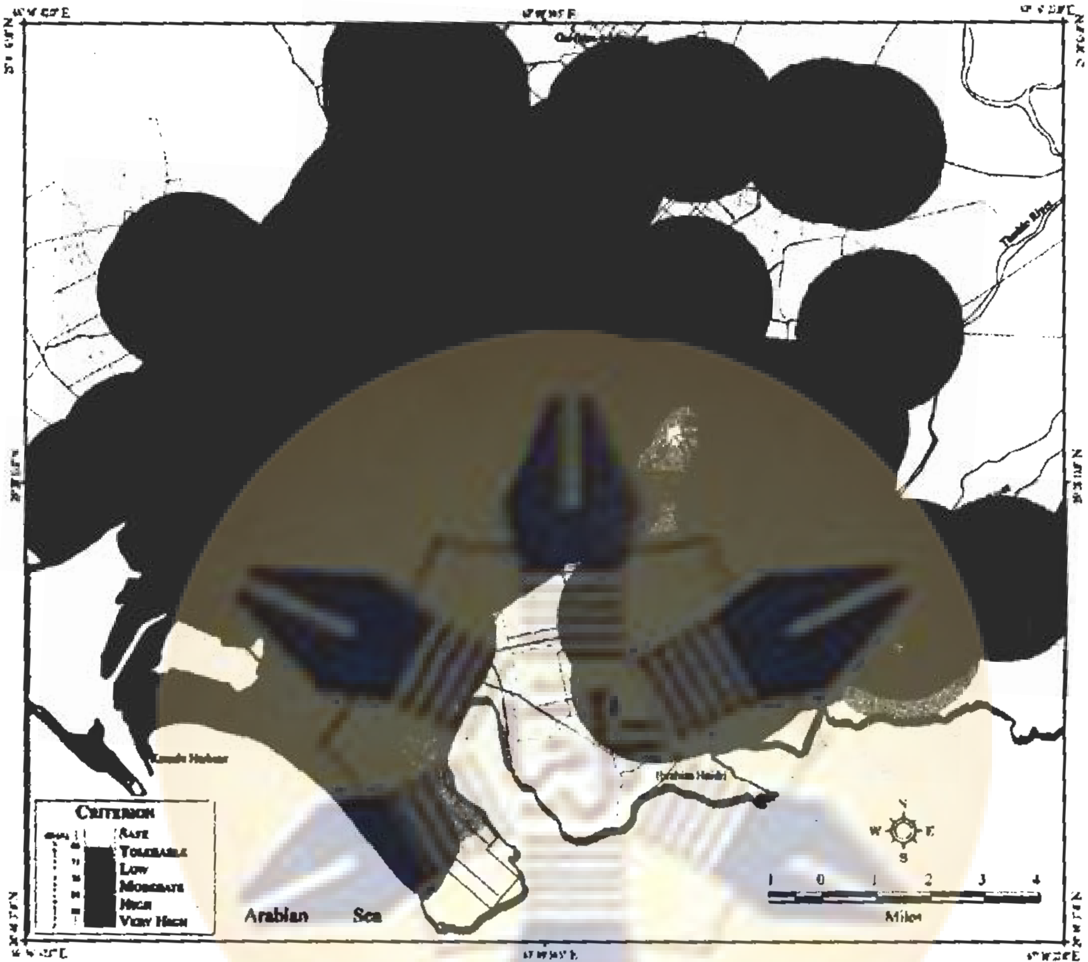
6.3 THE FINDINGS

The maps produced depicting the spatio-temporal patterns of noise pollution across the Karachi metropolis are now discussed under the headings of:

Table 6.2: Spatio-temporal variations of noise levels across Karachi metropolis

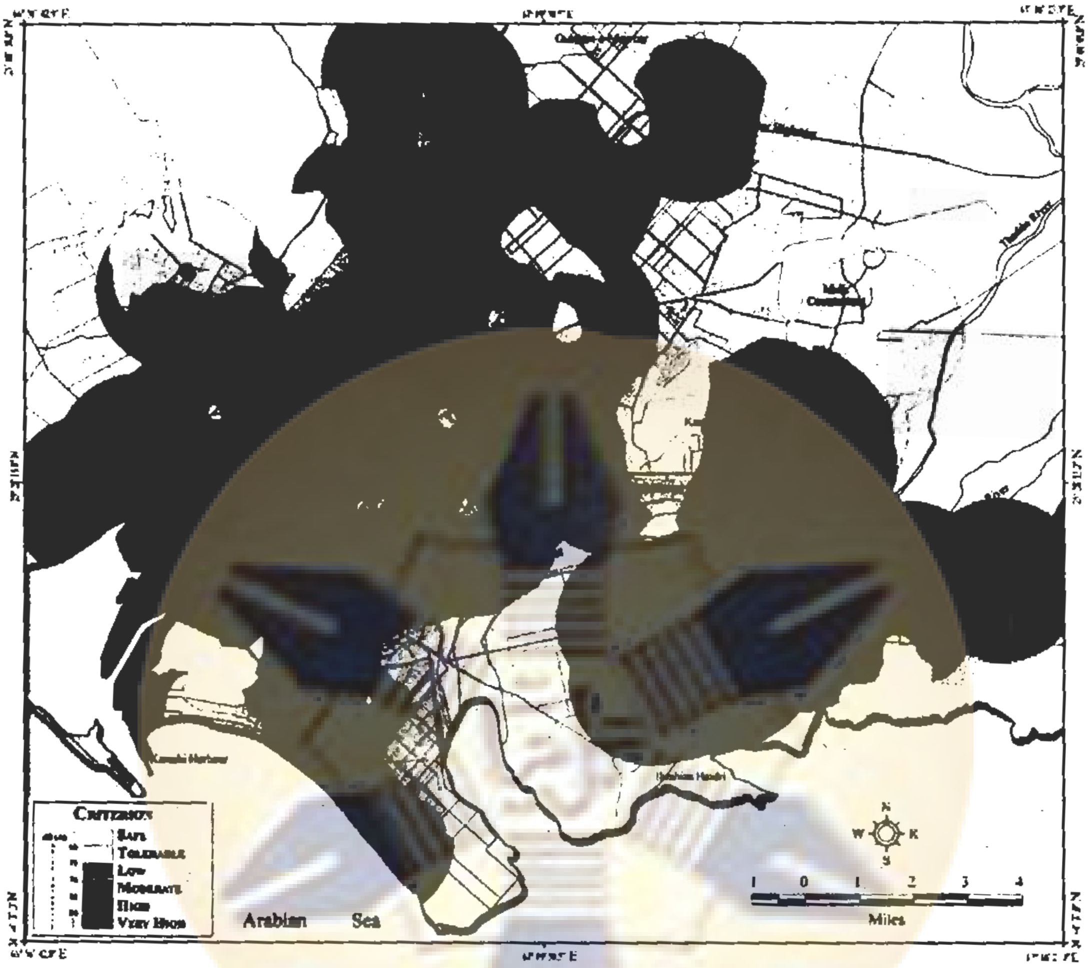
Parameter / Variations	Figure No.
Working Day Mornings	
Peak	6.2
Mode	6.3
Working Day Afternoons	
Peak	6.4
Mode	6.5
Working Day Evenings	
Peak	6.6
Mode	6.7
Weekend Mornings	
Peak	6.8
Mode	6.9
Weekend Afternoons	
Peak	6.10
Mode	6.11
Weekend Evenings	
Peak	6.12
Mode	6.13
Weekly Averages	
Mode	6.14
Peak	6.15
Total (Combined Mode and Peak)	6.16

Figure 6.2: Working Day Mornings: Peak



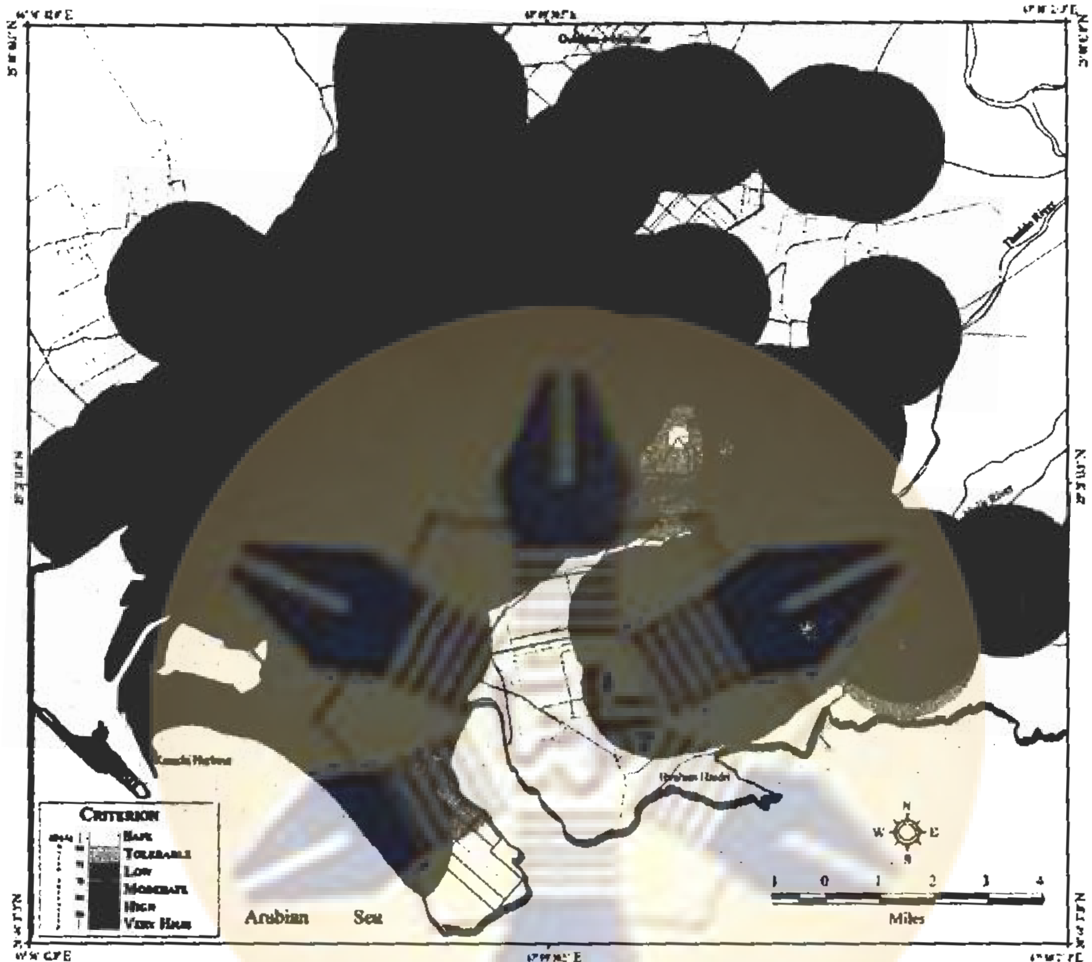
While performing the surface interpolation for this map in ArcView, the boundaries of the maximum diffusion were inadvertently not taken care of. Morning trips in Karachi are mostly school and work related. Portions of SITE, Orangi Town, DHA and Gulistan-e-Johar are in moderate noise zone; rest of the city is within the high noise, whereas the core old city and major intersections of district Karachi-central are under very high noise. *Noise islands* identified through this for this temporal situations are the major wholesale and commercial area *i.e.* core of Karachi city, Lasbela, Grumandir, vicinity of National Stadium, Qaidabad, Liaquat market Malir, Suhrab Goth and Nagan Chowrangi.

Figure 6.3: Working Day Mornings: Mode



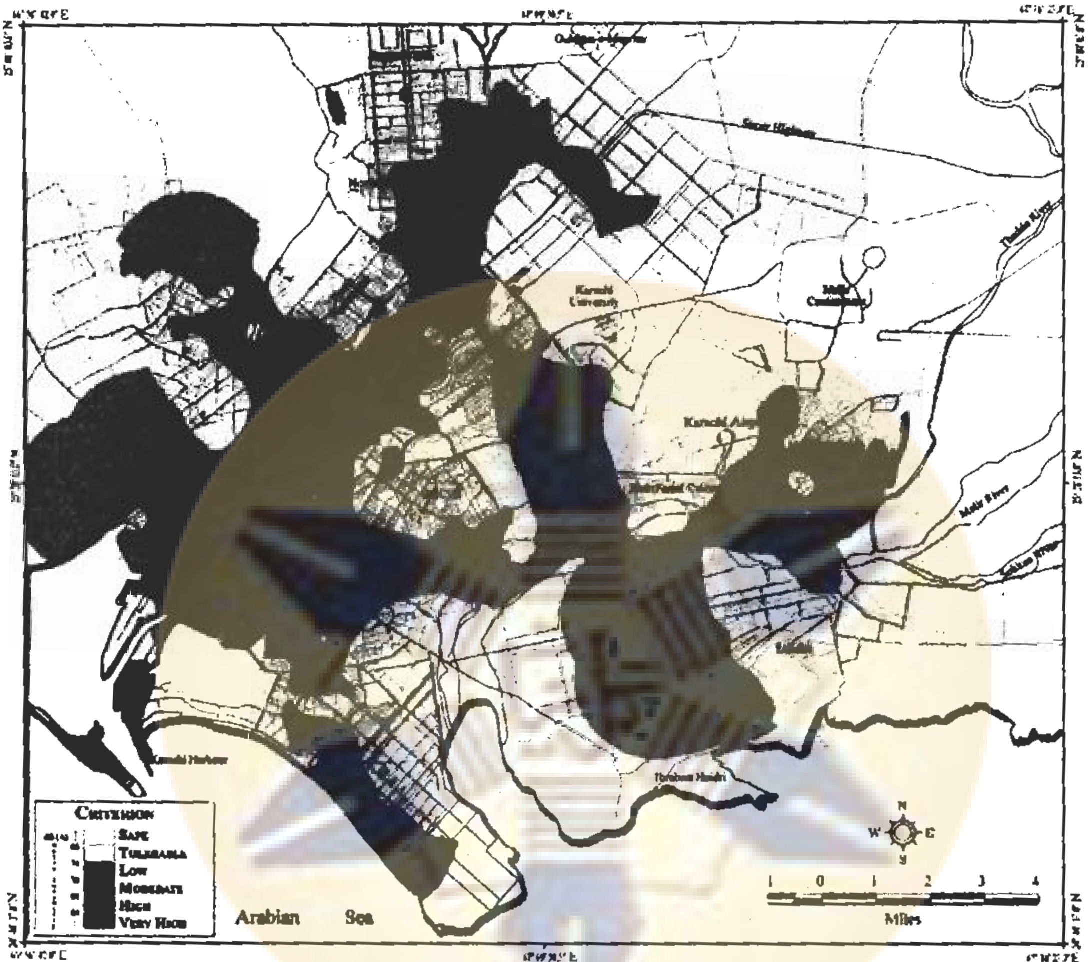
The undeveloped parts of housing schemes and DHA are safe while most of the city is under moderate noise. The core old city and vicinities of M. A. Jinnah road are under high noise extending up to Nazimabad. The *noise islands* at this time are areally wide covering old city (Core) area, Malir and Nagan Chowrangi. Unlike some western mega-city dwellers, the Karachiites are not early birds, which is manifested in this figure.

Figure 6.4: Working Day Afternoons: Peak

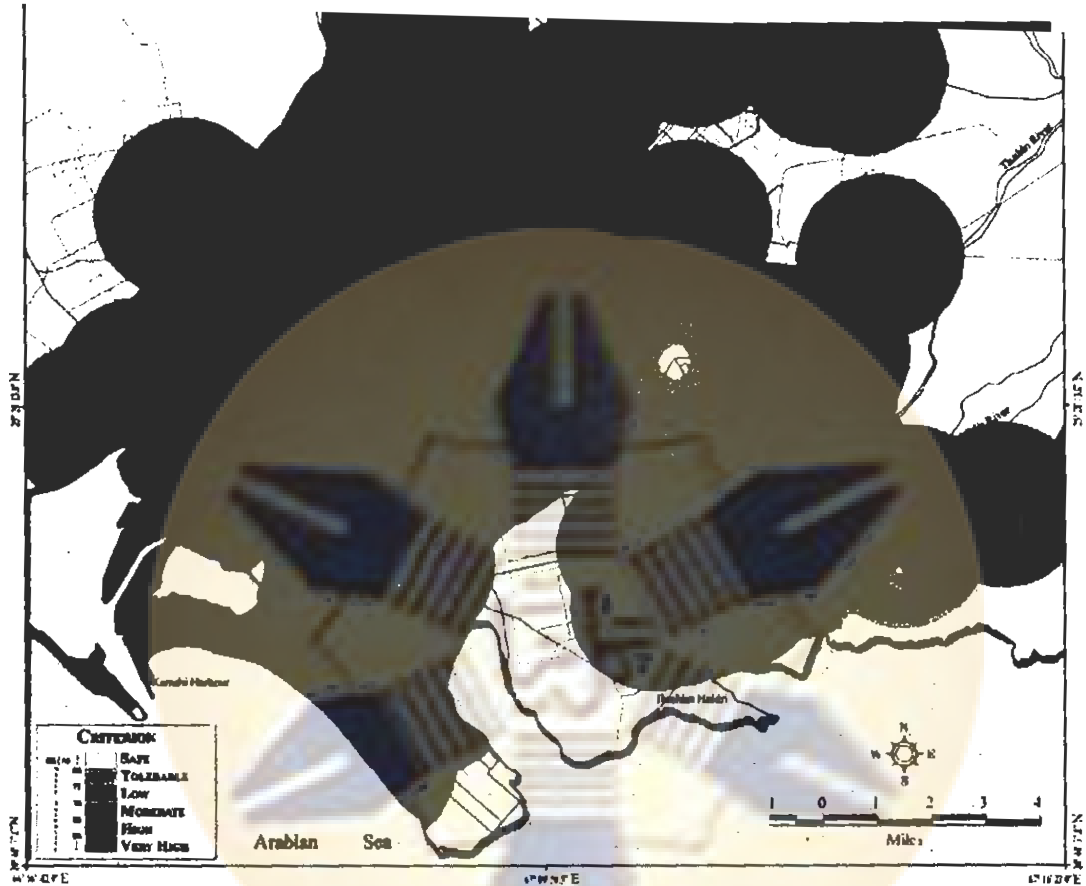


Monday to Thursday afternoons are occupied with work and other activity trips. The traffic and narrow roadway width produce congestion. In this figure the large areas are surrounded by very high-noise zone. Remarkably, high and very-high noise zones influence the city. The patterns formed help in understanding the traffic and trip trends of the city and answer the inquiry at micro geographic scale. Once again the reader is reminded of the cartographic limitations in the map. Two major *noise islands* could be observed in the figure. The first one encompasses the whole old city (core) of Karachi and elongates up to densely populated areas of Liaquatabad and Golimar. Large parts of district Karachi central (former) becomes *noise islands* during this period of time.

Figure 6.5: Working Day Afternoons: Mode

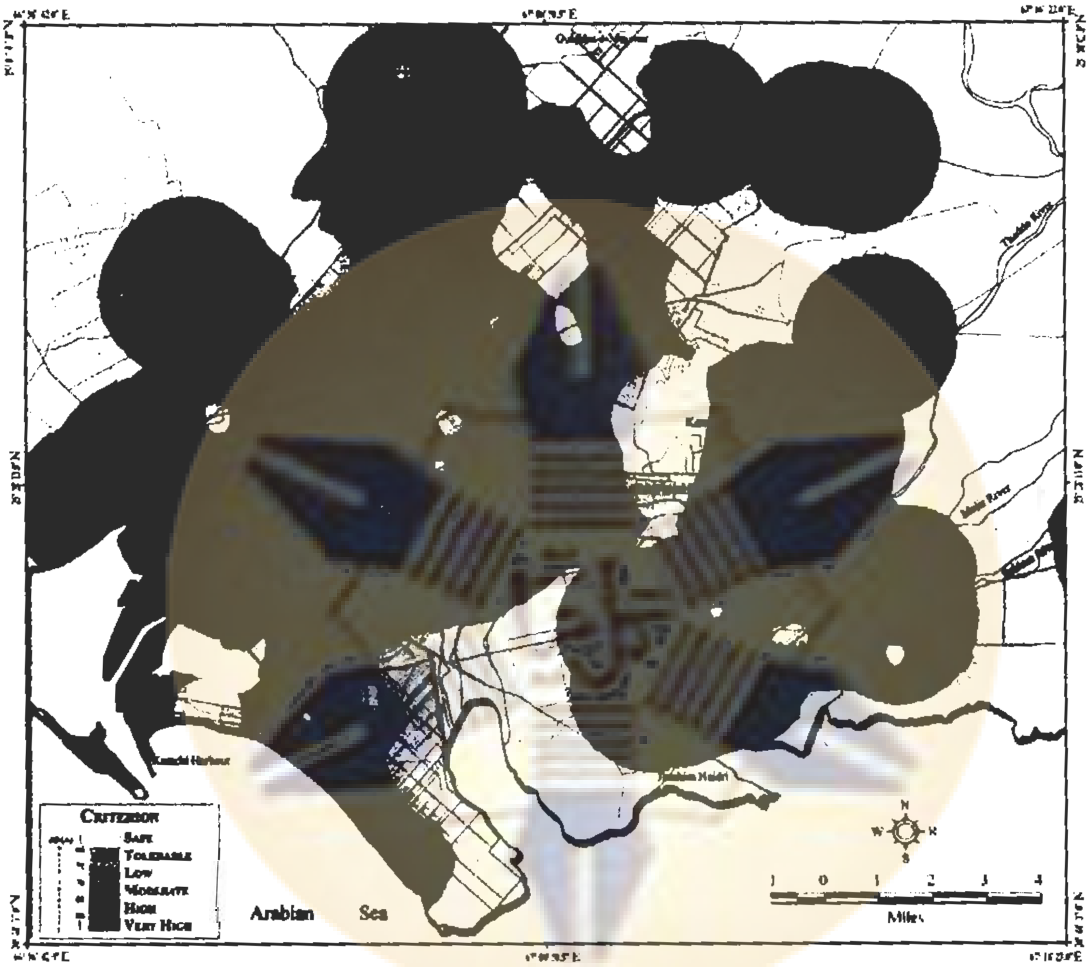


This figure has to be understood vis-à-vis its counter part for mornings. There are clear spatial contractions and the moderate noise zone has nucleated around the core old city and stretched out to localities where traffic manoeuvring is difficult due to geometric and space limitations. Overall the city remains under low and tolerable limits of noise. For this temporal variation only a small *noise island* can be seen around the Nazimabad Chowrangi.



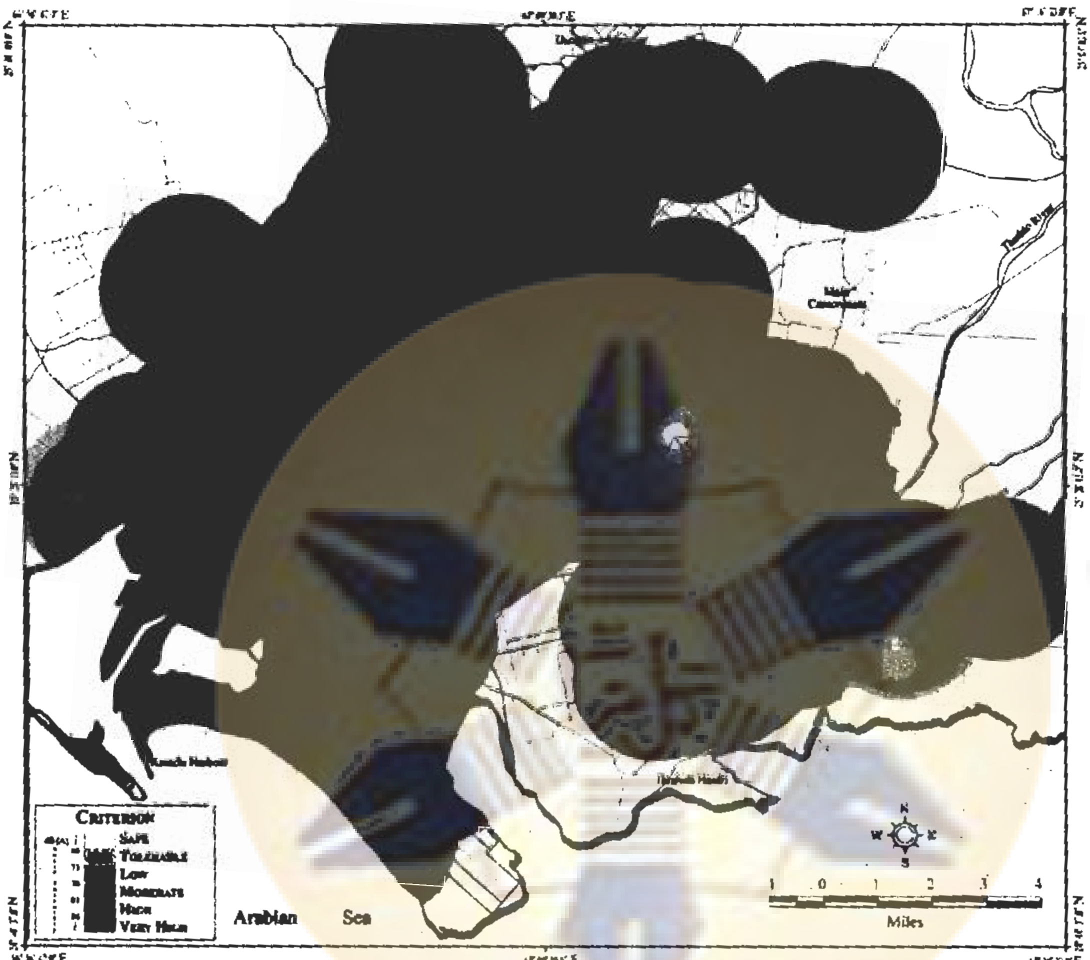
The scenario is overwhelmed by the high and very-high noise zones comparable to its counter parts (weekends). As the activities on Monday to Thursday are more than the three other days, the spatial patterns show agglomeration of high and very high-noise clusters. This figure confirms that the peak hours of activities and traffic in Karachi Metropolis are between 6:00 p.m. and 11.00 p.m. At this temporal juncture the noise recorded has created several spatially large *noise islands* all over the city, evident on the map.

Figure 6.7: Working Day Evenings: Mode



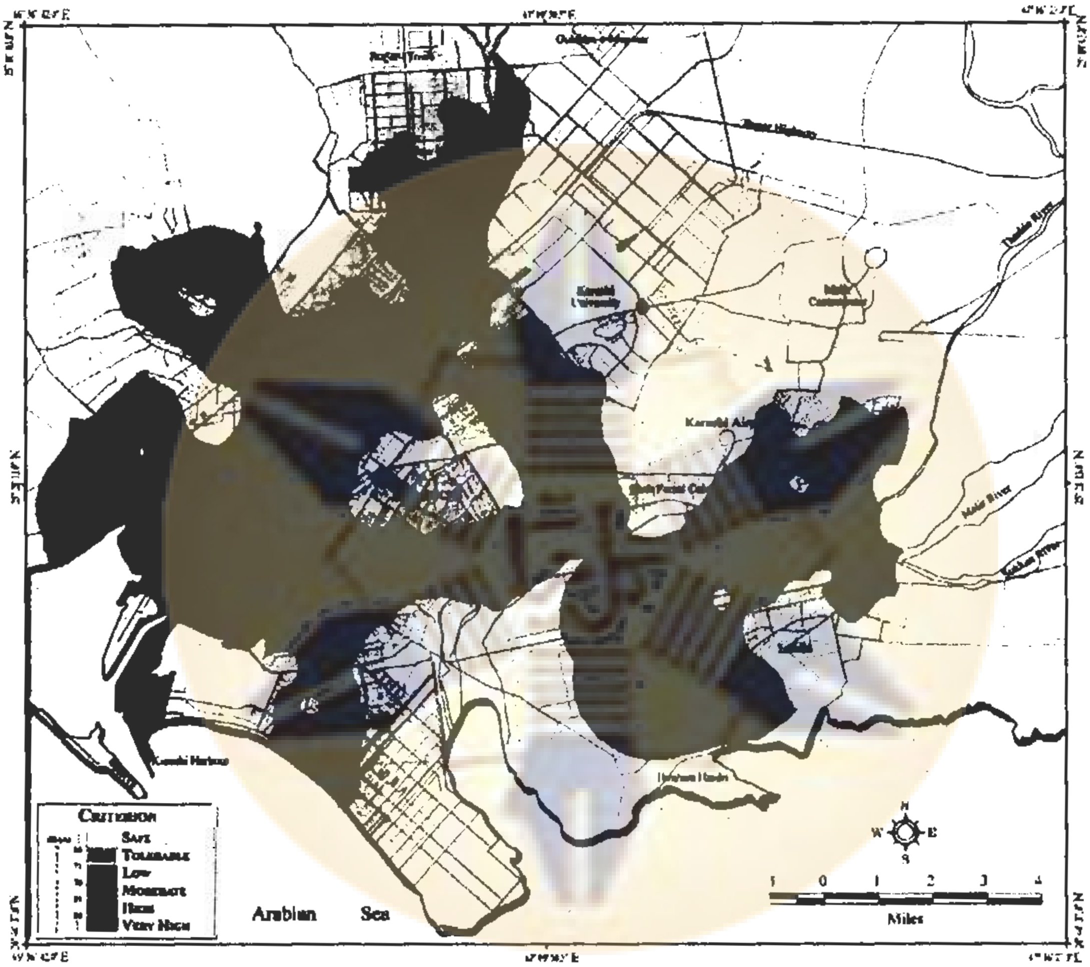
The trend of high noise zone seems to be shifting in this figure from old city towards district Karachi Central. The former districts West, Malir, East and partially South are in the moderate noise zone. The most populous district of Pakistan *i.e.* Karachi Central, although a planned and relatively younger locality is under high noise due to higher rate of vehicle ownership and urbanization. Even the mode readings of noise seems to be effecting the densely populated areas at this temporal juncture. The *noise islands* formed are around the intersections of district Karachi Central (former).

Figure 6.8: Weekend Mornings: Peak



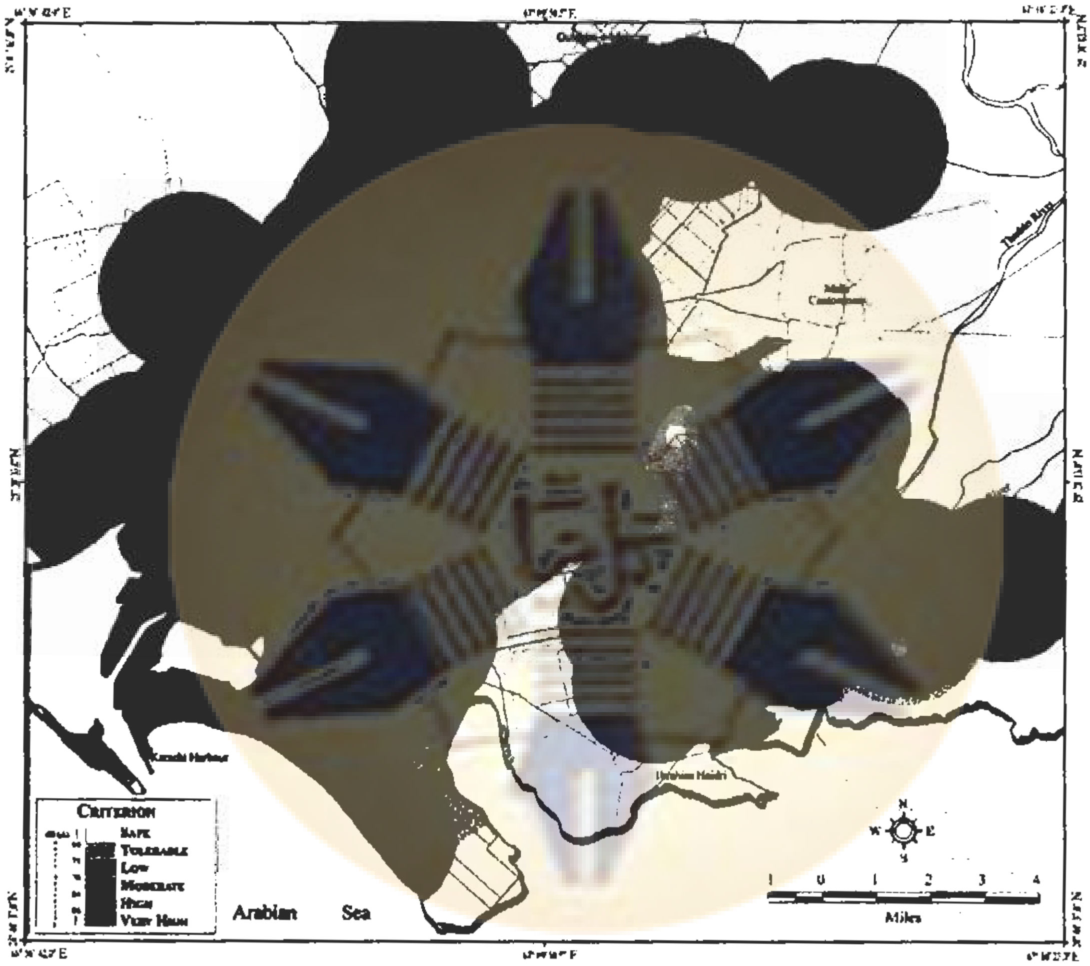
The peak noise levels recorded were mostly the horns blown by transit vehicles and likewise. Hence, whenever the peak behaviour of noise is portrayed, the difference of weekend and working day becomes irrelevant. Here the scenario is influenced by the very-high noise patterns, which covers a large part of the city. The boundaries of the maximum noise propagation were inadvertently not taken care of while performing the *surface interpolation*. Huge *noise islands* are clearly manifested in this figure showing very high noise zone all across the city.

Figure 6.9: Weekend Mornings: Mode



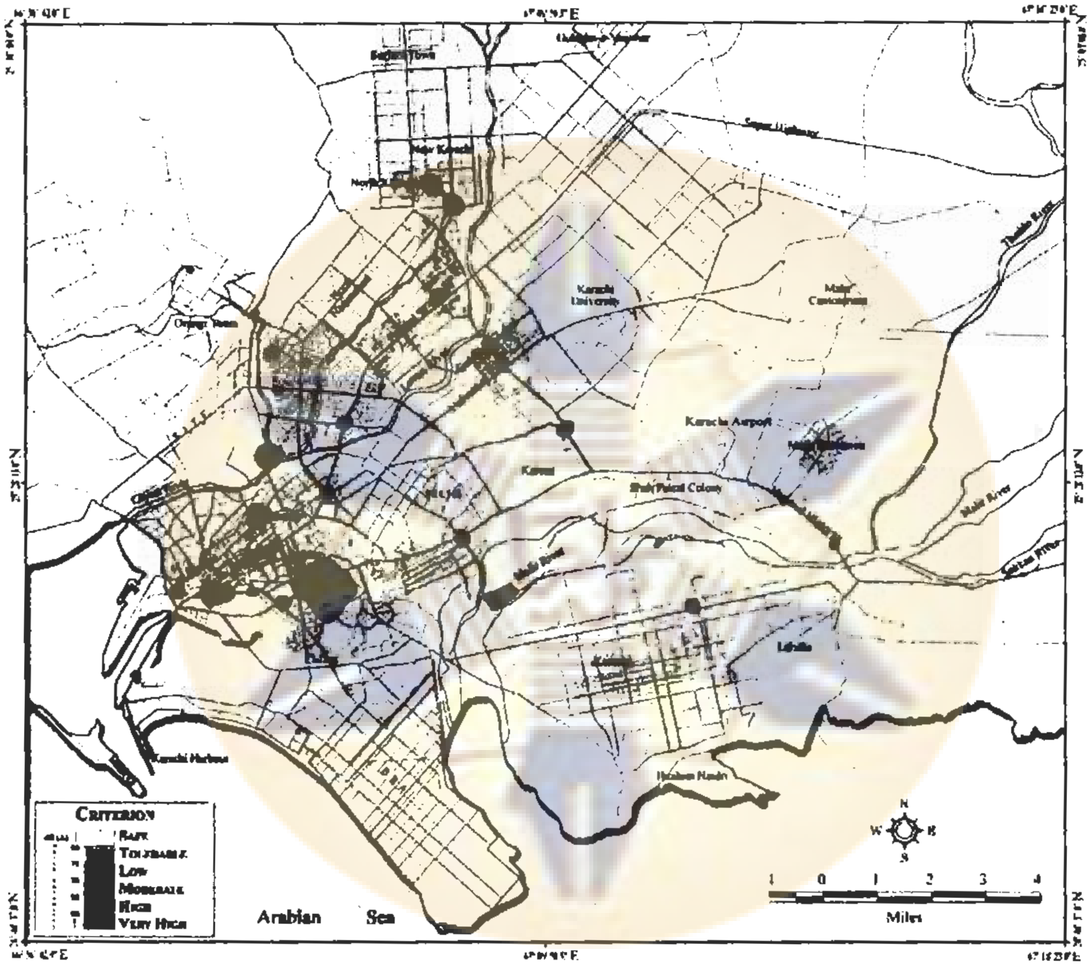
The spatial patterns seem to have direct relationship with vehicular traffic and the concentration of urban activities. The planned neighbourhoods of DHA and societies are under safe and tolerable noise zones respectively. The older parts of the city are under moderate noise. The inadequate roadway width has contributed for the sparse clusters of moderate-noise zones around Malir, Grumandir and Empress Market. No spot could be recognized as *noise islands* on this map.

Figure 6.10: Weekend Afternoons: Peak



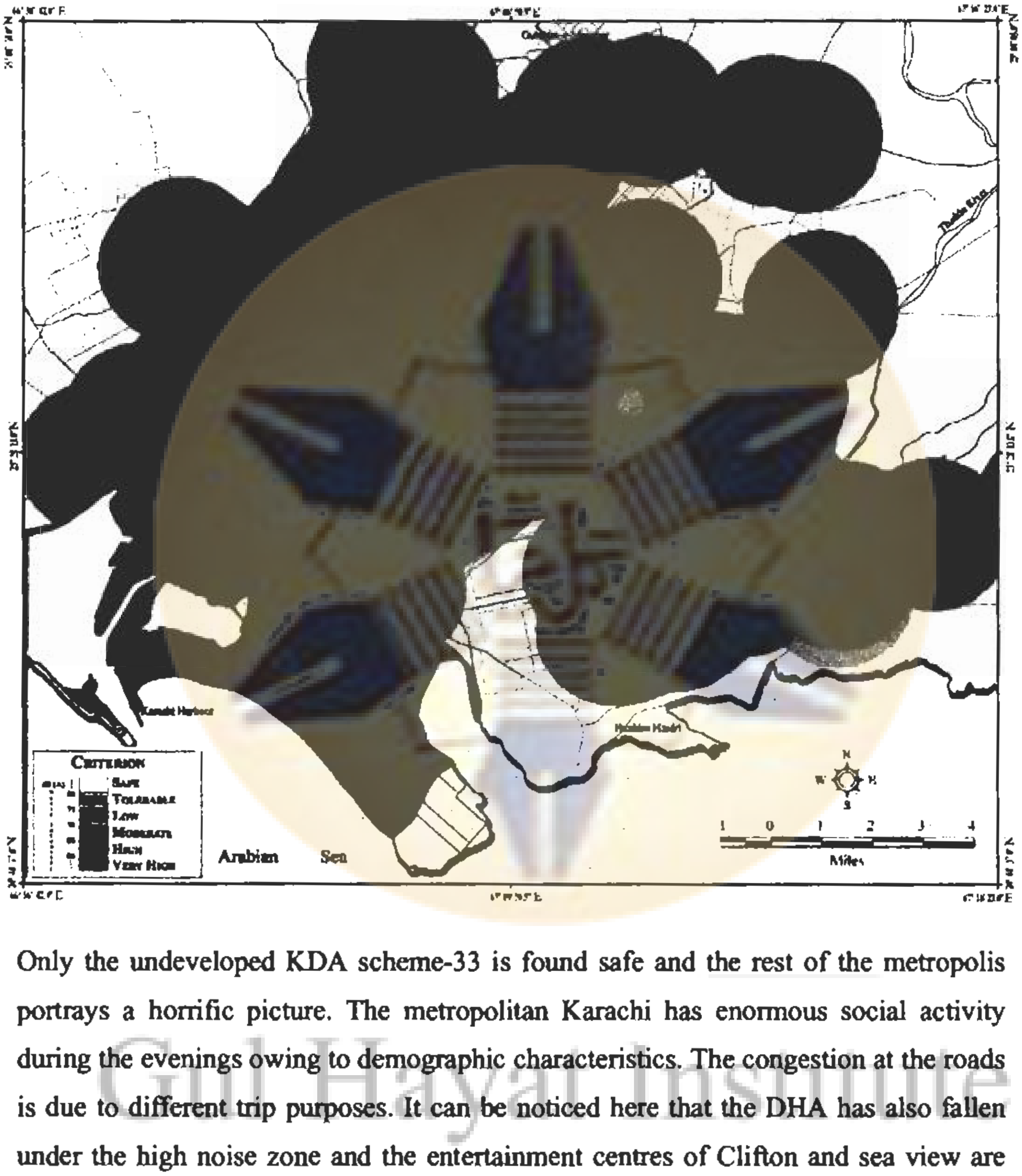
Apart from the cartographic limitations, this figure shows a slight spatial contraction as compared to the morning situation. The major arterial roads in district Karachi-Central are under high to very-high noise. The old city areas in district Karachi-South (former) show spatial similarity. The remaining metropolis falls under moderate noise temporally. Expanded *noise islands* for this particular occasion are vast and clearly manifested in this figure showing very high noise zone all across the city.

Figure 6.11: Weekend Afternoons: Mode



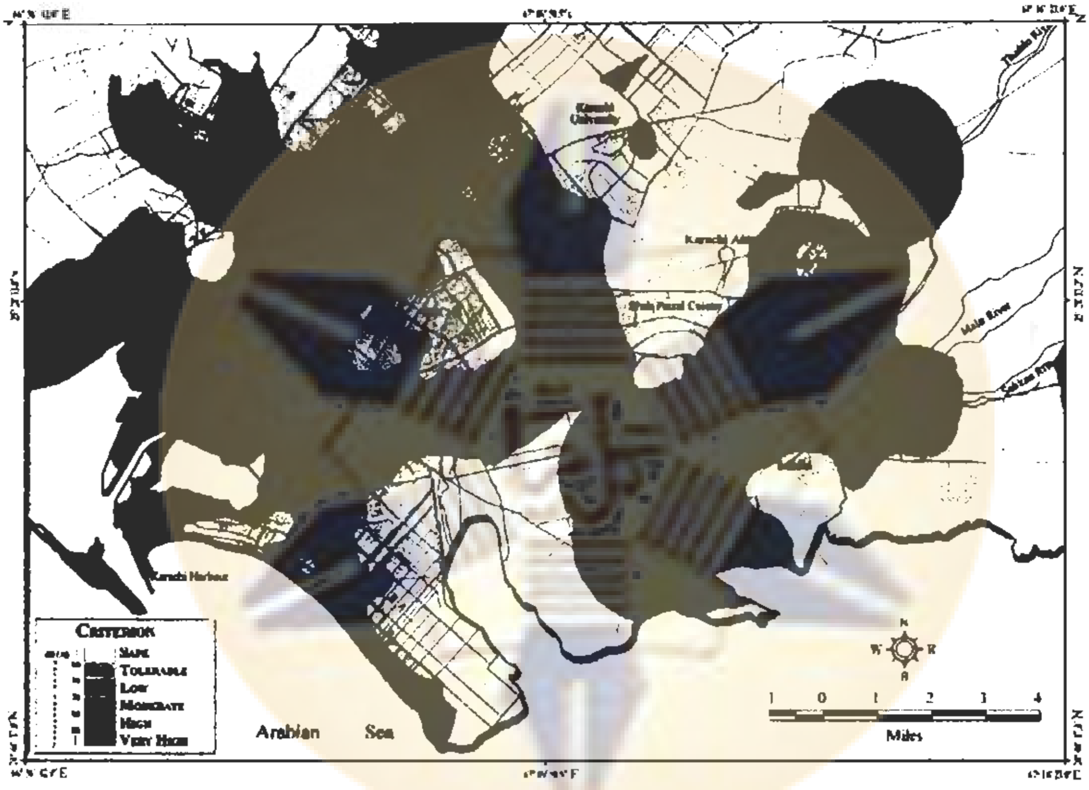
This figure could be discussed considering the propagation behaviour of noise and by comparing it with the spatial patterns of mode readings in the morning. The spatial elongation of tolerable noise clusters can be seen all around the metropolis. Probably, it is the calm period during the whole week. A *noise island* is found at the Empress market (Saddar) due to the bus terminal and retail market.

Figure 6.12: Weekend Evenings: Peak



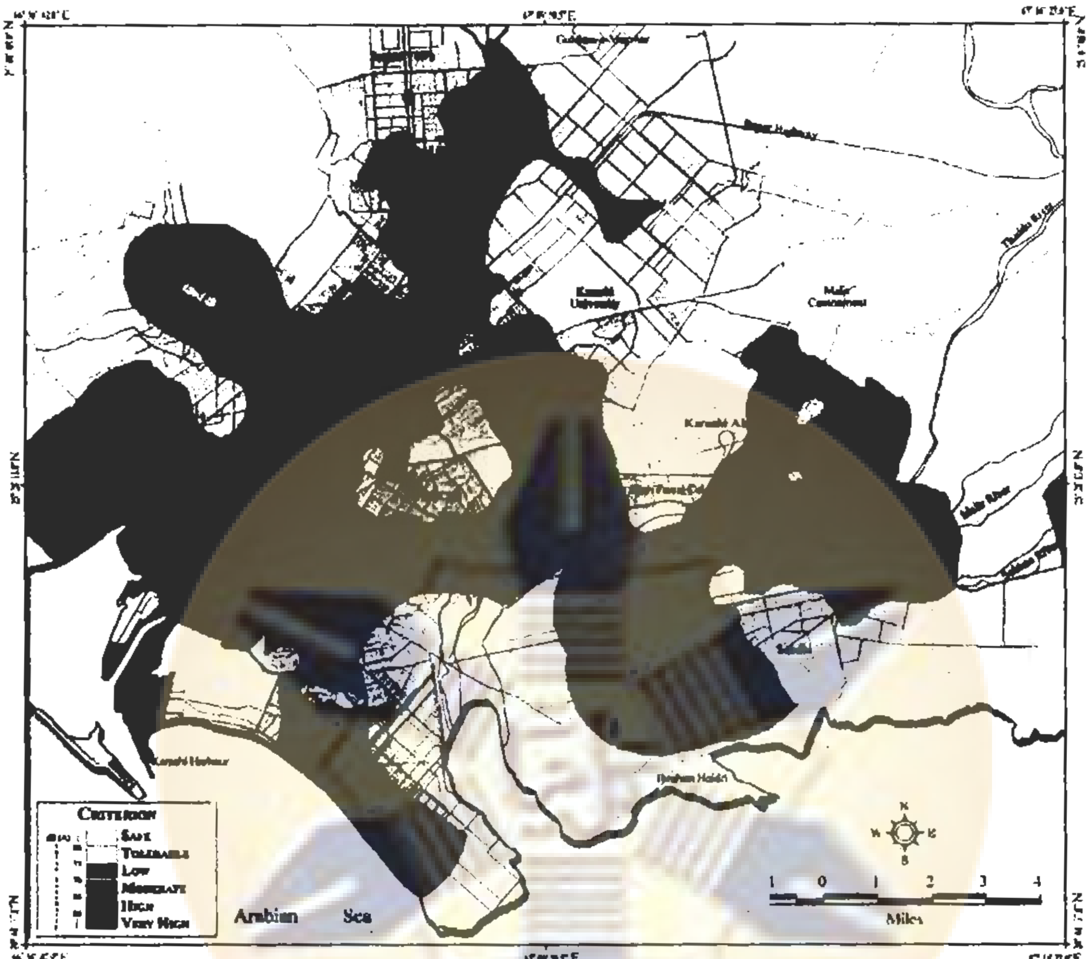
Only the undeveloped KDA scheme-33 is found safe and the rest of the metropolis portrays a horrific picture. The metropolitan Karachi has enormous social activity during the evenings owing to demographic characteristics. The congestion at the roads is due to different trip purposes. It can be noticed here that the DHA has also fallen under the high noise zone and the entertainment centres of Clifton and sea view are clearly under high noise. Some of the *noise islands* are associated areas of Aladdin and Sindbad amusement parks, Garden and various 4-legged Intersections of districts Karachi- Central and South.

Figure 6.13: Weekend Evenings: Mode

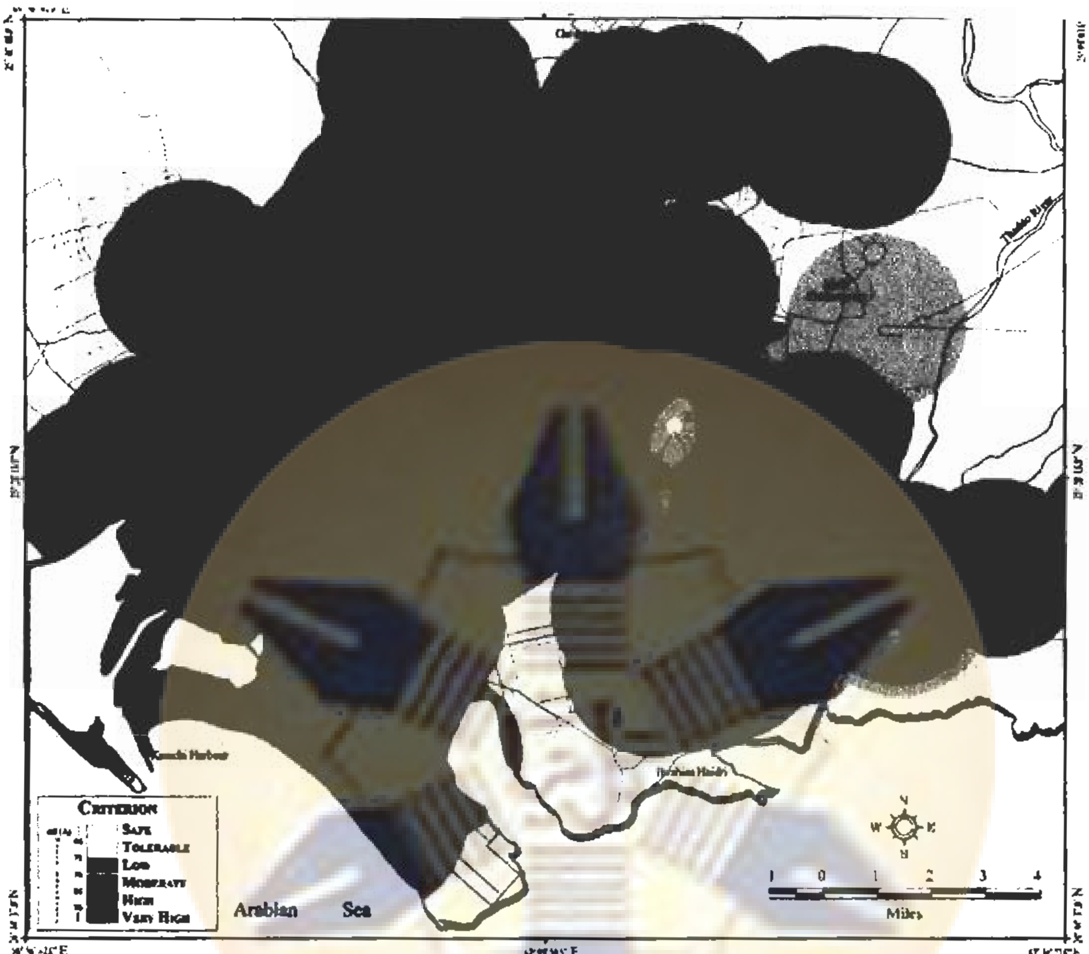


The spatial expansions with respect to afternoon scenario are quite visible but the affected neighbourhoods are more or less the same. The increase could be explained again due to the propagation behaviour characteristics of sound. Aladdin Park, Nazimabad Chowrangi, Sea View, and Lasbela could be identified as miner *noise islands.*

Figure 6.14: Weekly Averages: Mode

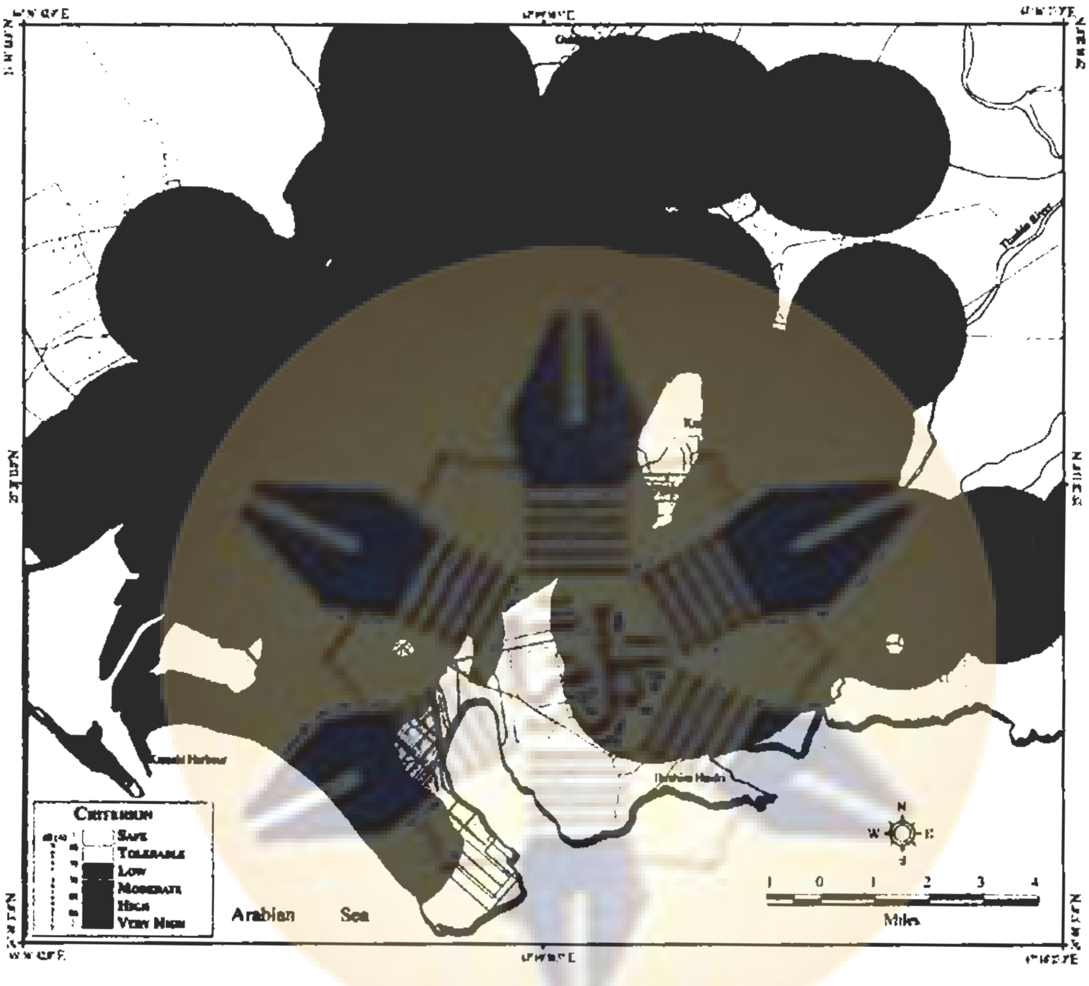


This output has been generated by means of GIS technique mostly cited under the headings of cartographic algebra or precisely map averaging (*e.g.* ESRI, 1998; Bernhardsen, 1999). The overall state of affairs with respect to noise pollution across the metropolis has been presented. There are few neighbourhoods that can be considered as safe (Gulshan-e-Mamar, Malir Cantonment, Ibrahim Haidri, undeveloped phases of DHA). Quite a number of localities are within the tolerable limits of noise (University area, Gulistan-e-Johar, Scheme 33, Surjani Town and North Karachi). Majority of the areas fall under the low noise zone. The most distinct pattern emerged on this map is the moderate noise zone influencing the old city (core) Karachi, and congested areas of Liaquatabad and Nazimabad (populous Karachi district central). Prominent *noise islands* besides this moderate zone are Malir, vicinity of Nagan Chowrangi and F.B. Area.



This map is illustrative of the overall situation of peak noise levels on the arteries of Karachi metropolis. There are hardly a very few portions of neighbourhoods, which falls under the safe, tolerable and low noise zones. Mostly they are low volume traffic areas. The massive share of the city is under the high peak noise while about more than 15 % area of the metropolis is constantly under extreme noise stress. A worthwhile outcome of this map is the formation of a distinct "*very high noise region*" in the vicinity of the most populous neighbourhoods of old city area (core), Liaquatabad, Nazimabad and North Karachi. Besides these neighbourhoods some diminutive intersections and localities are portrayed in the Figure 6.15, includes Sohrab Goth, NIPA Chowrangi, Johar Morre, Hasan Square, Liaquat Market Malir, Clifton Helipad *etc.*

Figure 6.16: Weekly Averages: Mode and Peak (Combined)



This thematic map (Figure 6.16) has been produced through the superimposition of twelve thematic layers of field observation noise intensity levels across the metropolis; at the two specified monitoring dimension (*i.e.* mode and peak), three predetermined times of the day, and two week wise variations. Here a relationship could be explored between the road density, traffic volume, population concentration and produced noise in the environment. Higher noise levels in this illustration are representing sever threat for the population owing to continuous technological hazard (noise) with most occurring (mode) maximum (peak) values in surroundings.

6.3.1 Epilogue

Urban noise and traffic congestion on roads is a major problem, especially since few third world governments have instituted effective noise-control programs on vehicles as in Europe and North America (Hardoy *et al.*, 1992). In some cities like Bangkok, Hong Kong and Jakarta, they are the most visible urban environmental problems (ESCAP, 1990). Findings from Western nations suggest that outdoor noise levels should be kept under 65 dB(A) to comply with desirable limits indoors. While noise pollution remains a major concern in Western nations, at least there are regulations, institutions to enforce them and democratic procedures through which protests can be organized; one or more of these is lacking in virtually all Third World nations (Hardoy *et al.*, 1992). This chapter has provided some of the grass root information on noise pollution in an emerging mega city of a *Least Developed Country* (Fellmann *et al.*, 1992).

7. PERCEPTION ANALYSIS

Wisdom of the community is a key-player around the world to control the quality of environment. *Perceptions* are based on the knowledge and experience of a person (Bernstein *et al.*, 1988); Knowledge creates *awareness* whereas experience strengthens the learning (Dember and Warm, 1979). Interestingly, the UN Conventions on Social, Cultural and Economic Rights; the ILO 'Declaration of Principles' define 'development' as sustained *realization* of an expanded range of rights (Ercelawn and Nauman, 2002). The formulation of a national environmental policy and the degree of its success are often dependent on the extent and quality of public environmental *awareness* (ESCAP, 1984).

Noise pollution is primarily a phenomenon of the urban environment. The city dwellers are materially affected by the intensification of nervous stimuli that emanated from such components of urban life as lights, noise and bustle (Gold, 1980). However, even in a country as United States, a USEPA official remarked, " Noise is something we grow up with, and it is very difficult to *believe* that such a common pollutant could be doing any thing serious to your health or the environment" (Nadakavukaren, 1990). In a developing country like Pakistan, acceptance of a noise as pollution and to *perceive* its harmful effects is very difficult for general public because of their *unawareness* of its injurious impacts.

7.1 THE FRAMEWORK

Researches surrounding social dimensions mostly assume that some form of basic knowledge is already available on the subject. However, in unexplored research in developing countries, official records and other basic research are usually not available (Bulmer and Warwick, 1983). In a developing nation where the literacy rate (and its definition) is controversial, carrying out a meaningful perception survey becomes more difficult. Factors conducive for awareness building of individuals are largely missing in the society.

7.2 SOURCES AND QUALITY OF DATA

In Pakistan, the socio-economic information on micro scale may not be always available. Public health data is not spatially managed. Living conditions of urban (and rural) localities are not scientifically documented. In the wake of scarcity and paucity of published data on environmental awareness, questionnaire survey is the best alternate to gauge the extent of pollution (Ali, 1997; De Souza, 1999). Therefore, it was indispensable to conduct the awareness/perception analysis through interviews and questionnaires. Three focus groups were identified to achieve this task:

1. Competent Physicians practising in different localities (Chapter # 8)
2. General Public of the metropolitan Karachi
3. Inhabitants of the 'noise zones/noise islands'

Subject receptive questionnaires were developed to accomplish the following targeted objectives:

1. Understanding the noise induced disease patterns on micro scale
2. Perception assessment of Health professionals (Chapter # 8)
3. Awareness appraisal of the society

To overcome the local data acquisition problems and to collect relevant information in depth, target-group oriented special questionnaires were designed. These questionnaire surveys were carried out around the city. The basic aim was to achieve a well-distributed spatial coverage of the metropolis. The health professionals were targeted to describe the linkage between noise pollution and noise induced disease prevalence (*Annexure B Q-1*). The other target groups were adults (> 18 years) among the general public and dwellers of 'noise islands' to inquire about the socio-economic and environment related issues (*Annexure B Q-2*). The results of these surveys give a handful of significant information, which will be helpful in developing a cognition scenario of the problem and its intensity.

The critique of physicians' perception is dealt in detail in Chapter # 8.

7.3 THE FINDINGS

The questionnaires supplemented the erstwhile quantitative data. It has provided insights into the perception dynamics of noise pollution (Environment), traffic (Transport), housing infrastructure and epidemics (Health).

The focus cluster included various demographic and income groups. The participants were selected and organised by age, gender, education, occupation and income levels. The participants were also selected to ensure racial and ethnic diversity associated to the cosmopolitan city of Karachi for ascertaining their attitudes and perception of the urban pollution problems.

The people working across the old city (core) area of Karachi were pre-dominantly *(72%)*, '*Patharay walas*' vendors and small businessmen; the rest were kind of office workers. Fortunately, the author reached *22%* female respondents, which was a high split in a pre-dominantly male chauvinistic society. Having known the international debate about education and income (De Souza, 1999), the focus was to target the segments denominated as urban poor *(12%)*, working (lower middle) class *(50%)* and middle class *(28%)*. The definitions of literacy and social classes were according to indigenous (Pakistani) standards. About *08%* of participants were illiterate, *37%* had gone up to secondary school and the rest had higher educational qualifications (*21 %* higher secondary certificate, *27 %* university bachelors and *07 %* postgraduate masters degree).

Worldwide interest in the relationship between environment and the psychological processes has been steadily growing (Ittelson, 1973). For that reason, the perceptions regarding the linkage among environmental problems and ***urban / infrastructure*** variables were uncovered through various queries. Most of the Karachi's workers live in the peripheries (Surjani Town, New Karachi, Landhi, Korangi, Orangi, Malir *etc.*) so they have to commute long distances everyday. About 3/4th of the respondents have daily work trip time exceeding 2-hours. The 'inhabitants at risk' were asked to identify the mode of transportation for their work-related trips. Most of the participants *(55 %)*, owing to their social status were compelled to use the noisy, cheap fared, low quality and over crowded transport modes. Motorcycle *(25%)*, another noisy vehicle, has emerged as a symbol of lower middle and middle working class means of transport, according to the findings of this survey. Some *(20%)* respondents appeared to be the residents of adjacent neighbourhoods as they walk for their work trips, thus their exposure to noise and induced diseases is higher and perpetual.

Drawing conclusions towards the ***environs***, pertinent respondents were inquired about the nearest road to their workplace/residence, its traffic conditions, operating speeds *etc.* The question of how we perceive and react to streets is not trivial (Ittelson, 1973). The participants perceived their proximity to the nearest main road within 100 feet *(50%)*, within 300 feet *(40 %)*, and beyond *(10 %)*. It appeared that habitants were too close to the source of noise pollution *i.e.* the traffic. Congestion (Traffic jams) was perceived as a chronic problem throughout *(87%)* the study area.

The AM rush hours discovered were 07:00 – 09:00 *(80%)* and 9:00 – 11:00 *(92%)*. (Refer to Figure 7.1). The public judgement on PM peak hours was 5:00 – 7:00 *(93%)* and 7:00 to 9:00 *(81%)*.

Three-fourth of the participants linked the congestion during rush hours with slow traffic operating speed, which is because of the narrow roadway widths. They were also requested to furnish the reason for the slow operating speed at the nearest road. Unmanaged high volumes *(50%)*, roadway conditions *(33%)* and on-street parking and encroachments *(17%)* were seen as the chief reasons for congestion.

Participants indicated that the reckless *driver behaviour* of heavy vehicles (trucks, minibus and buses) and lack of enforcement of traffic rules (*weak governance*) made it difficult to expect any change. The roads in the old city (core) region of Karachi could not be widened due to the space constraints and built environment.

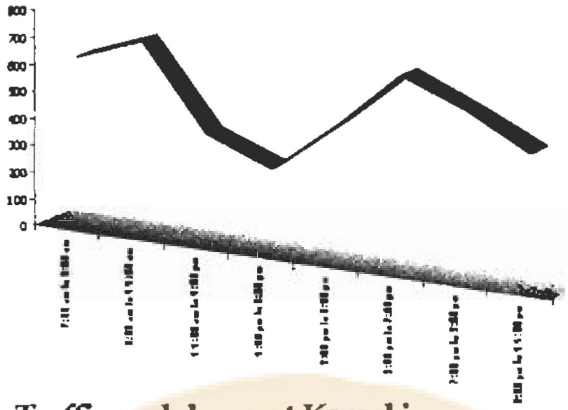


Figure 7.1

Traffic peak hours at Karachi

To examine the quality of societal perception and to see if the population at risk could establish the link between cause and effect themselves, the focus group was finally probed on the affects of the prevailing conditions. Understanding of a problem, its insight, effects, personal impact and controlling measures are all dependent upon the collective perception of the pertinent population.

The most important source of noise pollution in the city of Karachi is the urban transport system. Opinions were gathered about the adverse affects of the traffic present nearby. The responses varied again, according to their levels of understanding. *(75 %)* of the respondents could only perceive up to pollution, whereas *(16 %)* of the responded had the ability to think beyond. Some people *(12%)* had the approach to correlate these conditions with health problems in an open-ended question. Similarly very few *(04 %)* perceived that the traffic on road could be the cause of wearing away (corrosion) of their buildings. The wear and tear cost a lot to the building residents because they had to spend money repeatedly on repairs. Few (10 *%)* respondents were unable to perceive any problem whatsoever, related to the built environment from the nearest road and traffic.

Industry, a source of pollution in the environment, was situated in the neighbourhood of some *(25%)* partakers. Nearly half of them *(52%)* attributed noise pollution to the positioning of nearby industry and a good number *(41%)* linked its impacts on their health.

Insight regarding noise pollution around the neighbourhoods varied according to the level of education and economic status of the respondents. Inhabitants of the study area (90 %) were aware of high noise pollution in their neighbourhoods and its possibility of affecting their *quality of life*. Nearly all participants *(99%)* clearly considered that noise pollution was having adverse affects on their health. However, when asked to rate the extent at which they perceive noise pollution distressing human health, the perceptions varied according to the educational level of the respondents. A high association was found among educated participants and problem intensity ratings (Figure 7.2).

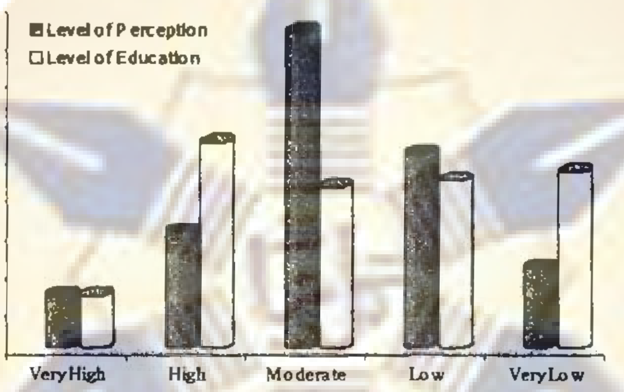


Figure 7.2: Connection between Levels of Discernment and Education

There has arisen a dilemma of comprehending the complete dimensions of noise pollution problem among the Karachiites. After having an almost cent per cent affirmation on the adverse affects of noise pollution, the same percentage of people literally do not know about any remedial measures. It is a typical third world citizen's pessimistic psychology and confused behaviour. Such perceptions about personal impact on pollution intensify risk at community levels.

It is interesting to note that in a country of 147 million (MS Encarta, 2002) with an annual population growth rate of 2.8 (PRB, 2001) and a literacy rate of 33% (WRI, UNEP, UNDP, and WB, 1996, 1998), *(90%)* of the urbanites interviewed thought that growing population was the primary contributor to environmental degradation. Nearly all the government regimes in Pakistan have been generous in advertising the slogans of "small family, wealthy future", and population planning. Large-scale media campaigns have influenced the citizens to start perceiving population as a problem than resource.

To explore the notion of 'safe haven', a deliberate question was coined. Substantial *(42%)* number of people believed the places of worship, approximately one third considered their homes and some *(22%)* perceived recreational places as 'away from environmental stresses'.

Summarizing the critique on Perception analysis, the author would like to offer his own observation about the issue. If the detrimental effects of traffic pollution and chaotic land use on public health were more promoted in the Pakistani society, the public would be more willing to change their mind-set. It is important not to underestimate the role played by human powers of adaptation during such behavioural studies (Gold, 1980). City residents do adapt to noise, dirt, and crowding all of which have direct impact upon the quality of life.

In the efforts to reduce noise pollution, initiatives and incentives are needed. Legislation and enforcement could only produce results partially. The bottom line lies in the poverty and socio-economic conditions of the citizens and the country. The living conditions of the public go together with the financial health of the state. Due to desolation and class disparities; politics and governance in developing nations as Pakistan manifest negative impressions on the public psychology. Pessimism could be traced in the qualitative results of this perception critique.

8. PUBLIC HEALTH ACCOUNT

Although relating disease causes with environment is dated back to the Greek period, but it took a proper shape in the last century when disciplines like Public Health Engineering and Environmental Epidemiology were developed, which are concerned with the distribution of health and disease in terms of morbidity, injury, disability and mortality in populations often referred as *Vital Indices.* Epidemiological analyses determine why certain diseases concentrate among particular population group (Learmonth, 1972, Moon *et al.*, 2000). These disciplines focus on the environmental health, monitoring the levels of diseases (in the dwellers) and looks for causal relationships between exposure and a subsequent disease (McGlashan, 1972; Barker, 1987; Bentham, 1994). In the environmental framework, studies with spatial dimensions are at large used to assess the impacts on public health.

8.1 SOURCES AND QUALITY OF DATA

In terms of prevalence and incidence of diseases, there is an extensive variation in developed and developing countries. Pakistan being a developing nation is no exception as continual environmental degradation, inadequate health-care services and its inaccessibility are making it an ideal breeding ground for environmental diseases (Lakshamanan and Chatterjee, 1977). Unfortunately, there is a very little information available on such environmental diseases. As a result, the prevalence and frequency of "noise pollution based diseases" and their variations on landscape in Karachi, is an area yet to be discovered. To study these phenomena, two sources were identified as *secondary* and *primary*.

The *secondary* source was the records of the major public sector's hospitals, while the quest to explore from primary sources resulted in the formulation of questionnaires for the citizens residing and the physicians practicing in the different neighbourhoods of Karachi. Tables 8.1 and 8.2, provide the recent disease data, acquired from two major hospitals of Karachi. The absence of recording and compiling the patient's detailed address has created several deficiencies in the indigenous data provided by these hospitals. Elsewhere in the world, both in developed and developing countries, linking of postal / zip codes (Banta *et al.*, 2001; Stone, 2001) with disease occurrence has provided the basis for spatial analysis on micro-geographic scale.

Table 8.1: Indoor Morbidity and Mortality Statistics 2001

Disease Code No.	Name of Diseases, Injury and Cause of Death	Number of Cases			Number of Deaths		
		Male	*Female*	*Total*	*Male*	*Female*	*Total*
559	Injuries.	381	3991	7802	167	113	280
529	Burns	257	610	867	51	83	134
299	Cerebrovascular diseases	339	164	503	63	27	90
499	Intracranial and internal injures including nerves	442	181	623	48	29	77
323	Bronchitis, emphysema and asthma	167	118	285	21	23	44
359	Other diseases of urinary system	232	156	388	30	12	42
270	Acute myocardial infarction	63	47	110	20	8	28
46	Viral Hepatitis	221	143	364	12	14	26
191	Nutritional marasmus	149	108	257	12	14	26
36	Meningococcal infection	93	74	167	14	12	26
350	Nephritis, nephrotic syndrome and nephrosis	131	41	172	14	11	25
479	Fractures	1310	886	2196	11	13	24
320	Acute bronchitis and bronchiolitis	89	79	168	11	9	20
181	Diabetes mellitus	271	151	422	9	10	19
52	Malaria	149	168	321	11	6	17
38	Septicemia	138	174	312	11	5	16
331	Diseases of the jaw	163	104	267	11	5	16
360	Hyperplasia of prostate	198	121	319	6	7	15
37	Tetanus	114	59	173	8	7	15
279	Other ischemic heart diseases	71	47	118	8	7	15
47	Rabies	34	20	54	8	7	15
20	Pulmonary tuberculosis	59	52	111	7	6	13
101	Malignant neoplasm of trachea, bronchus and lung	91	64	155	7	5	12
209	Iron deficiency anemia	161	172	333	5	6	11
91	Malignant neoplasm of stomach	33	17	50	6	5	11
93	Malignant neoplasm of colon	49	31	80	7	3	10
341	Ulcer of stomach and duodenum	739	218	957	4	3	7
321	Pneumonia	81	38	119	4	3	7
329	Other chronic obstructive pulmonary diseases and allied conditions (bronochiectasis *etc.*)	39	32	71	4	3	7
229	Other inflammatory diseases of the central nervous system	34	28	62	3	4	7
229.1	Hereditary and degenerative diseases and other disorders of the central nervous system	54	41	95	4	2	6
189	Simple and unspecified goiter	32	24	56	4	2	6
251	Chronic rheumatic heart diseases	89	49	138	3	2	5
489	Dislocations sprains and strains (of joints and Muscles)	62	40	102	2	3	5
239.1	Corneal opacity and other disorders of cornea	39	38	77	3	2	5
94	Malignant neoplasm of rectum, recto sigmoid junction and anus	23	21	44	3	2	5
159	Other benign neoplasm	18	61	79	3	1	4

Disease Code No.	Name of Diseases, Injury and Cause of Death	Number of Cases			Number of Deaths		
		Male	*Female*	*Total*	*Male*	*Female*	*Total*
11	Typhoid fever	168	85	253	2	1	3
230	Glaucoma	74	38	112	2	1	3
23	Tuberculosis of intestines, peritoneum and mesenteric glands	52	31	83	3	-	3
141	Leukemia	20	13	33	2	1	3
229.2	Disorders of the peripheral nervous system	38	21	59	1	1	2
239.2	Disorders of conjunctiva	36	21	57	1	1	2
42	Measles	12	8	20	1	1	2
419	Normal delivery	-	4090	4094	-	-	-
389	Abortion	-	1986	1986	-	-	-
429	Diseases of skin and subcutaneous tissue	810	311	1121	-	-	-
339	Other Diseases of bones	331	139	470	-	-	-
231	Cataract	298	139	437	-	-	-
21	Other respiratory tuberculosis	229	168	397	-	-	-
315	Chronic diseases of tonsils and adenoids	161	189	350	-	-	-
449	Congenital anomalies	204	143	347	-	-	-
239.3	Other diseases of eye	172	138	310	-	-	-
399	Direct obstetric causes	-	301	301	-	-	-
369	Other diseases of male genital organs	281	-	281	-	-	-
14	Amoebiasis	140	89	229	-	-	-
269	Hypertensive diseases	129	41	170	-	-	-
113	Malignant neoplasm of female breast	-	161	161	-	-	-
250	Acute rheumatic fever	58	43	101	-	-	-
374	Uterovaginal prolapse	-	98	98	-	-	-
329.1	Diseases of respiratory system	54	28	82	-	-	-
12	Shigellosis (bacillary dysentery)	49	31	80	-	-	-
149	Other malignant neoplasms	59	21	80	-	-	-
15	Intestinal infections due to other specified organism	31	39	70	-	-	-
13	Food poisoning (including salmonella)	41	28	69	-	-	-
24	Tuberculosis of bones and joints	38	25	63	-	-	-
371	Salpingitis and oophoritis	-	62	62	-	-	-
192	Other protein calorie malnutrition	22	20	42	-	-	-
49	Chickenpox	24	10	34	-	-	-
75	Acnylostomiasis and neatoriasis	24	10	34	-	-	-
2092	Hemolytic and other blood diseases	19	10	29	-	-	-
40	Acute poliomyelitis	16	11	27	-	-	-
189.1	Other disorders of thyroid gland	13	14	27	-	-	-
79	Other cestoide infection	18	8	26	-	-	-
219	Mental disorders	9	8	17	-	-	-
220	Menacis other than tuberculosis	8	9	17	-	-	-
33	Diphtheria	9	7	16	-	-	-
249	Other diseases of the ear and mastoid process	8	7	15	-	-	-
79.2	Other infectious and parasitic Diseases (including scabies)	9	3	12	-	-	-
330	Diseases of the teeth and supporting structures	7	4	11	-	-	-
34	Whooping cough	6	2	8	-	-	-

Source: Medical Records and Statistical Office, Civil Hospital, Karachi

Table 8.2: Indoor Morbidity and Mortality Statistics of Diseases: 2000 and 2001

Disease/Symptom	2000	2001	TOTAL
Anaemia	40	40	80
Arthritis	8	19	27
Asthma	20	35	55
Brain Diseases	15	13	28
Bronchitis	53	40	93
Cancer	170	440	610
Cholera	50	44	94
Diarrhea	1	5	6
Eye diseases	5	11	16
Fever	15	17	32
Gastroenteritis	5	11	16
Heart Diseases	4	11	15
Jaundice	8	32	40
Kidney Infections	0	1	1
Leukaemia	0	3	3
Liver Diseases	35	96	131
Lungs Diseases	10	39	49
Muscles Diseases	2	1	3
Nasal Irritation	13	58	71
Reproduction Problems	523	439	962
Stress	0	2	2
Tuberculosis	1	49	50
Thalesemia	0	4	4
Thyroid	6	23	29
Ulcer	7	17	24
Total	2991	3451	6442

Source: Medical Records and Statistical Office, Jinnah Postgraduate Medical Centre, Karachi

To generate *primary* disease data a careful literature search was conducted to identify diseases, whose relationship vis-à-vis noise pollution has been established (*e.g.* Bugliarello *et al.* 1976; Waldbott, 1978; Terry, 1979; Rylander, 1986; Regecova and Kellerova, 1995). To make this search more meaningful, a critique by physicians (usually called *doctors* in Pakistan) was obtained. The instruments employed were questionnaires. Certified physicians were decisively asked some questions such as: **"What do you think about noise pollution as a contributing factor among the listed diseases?"** and further **"Mark the diseases frequent in your practicing area from the given list."**

The diseases having significant relationship with noise pollution were ranked based on the physicians experience at various localities of Karachi. The highly technical names of diseases were avoided, as these had to be further and later asked to a common man. It was necessary to rephrase the diseases with their symptoms to make the list understandable for the latter target group. Thus a list of noise-borne symptoms (diseases) was incorporated in the questionnaires *Annexure B* . Proforma B.Q1 was presented to the physicians whereas Proforma B.Q2 was presented to:

a. Dwellers of pollution risk zones *(core city area)*

b. General Public across the metropolis

The questionnaires provided the data on the occurrence of each of these symptoms / diseases on a micro regional scale *i.e.* for various areas in Karachi. Later, this data on noise pollution based diseases was integrated with the GIS database to discover the occurrence and prevalence in each zone.

8.2 THE FRAMEWORK

8.2.1 Analyses on Physicians Questionnaire

To inquire more about the frequency (occurrence) of noise induced diseases, Seventy-five (75) accredited practicing physicians were unambiguously asked to mark the diseases frequent in their practicing areas. These public health statistics can be very useful in understanding local patterns of diseases in Karachi.

8.2.1.1 Disease Rankings

After establishing the contribution of noise pollution in the occurrence and prevalence of some diseases through some scientific studies (Poliak, 1981; Feder, 1983; Bjorkman, 1983; Dejoy, 1984; Beg, 1990; Solerte *et al.* 1991) and *morbidity* data from hospitals and practitioners in Karachi, there appeared an obligation to find what do the professionals think about it. Therefore a specific question was asked: **"What do you think about noise**

pollution as a contributing factor among the listed diseases?" to seek not only their perceptions but also empirically deduce a linkage between spread of disease and noise pollution in Karachi.

Assigning of weights to predetermined responses is a familiar approach in such inquiries (Manheim, 1979). The arithmetic summation ranks the diseases (symptoms) as Highly associated, Fairly associated or Less associated with noise pollution in Karachi.

8.2.1.2 Morbidity treated by Physicians

To inquire more about the frequency of noise pollution based diseases, the seventy- five (75) practicing physicians were explicitly asked to mark the diseases frequent in their practicing areas. This epidemiological information happens to be new and very valuable in comprehending the indigenous disease patterns in the study area.

8.2.2 Analysis on Community based Questionnaires

Available public hospital records of Karachi were not able to relate the disease information with (residence) location, whereas linking of postal / zip codes (Banta *et al.*, 2001; Stone, 2001) with disease occurrence provide the basis for spatial analysis. Lack of proper record keeping of these principal service providers convinced the author that most of these sources, could not furnish statistics on scientific premises. Therefore some quantitative and qualitative epidemiological analysis has been performed on the data generated primarily by eleven hundred (1100) questionnaires.

8.2.2.1 Disease Prevalence

The prevalence of noise pollution induced diseases indicates the effected population during a certain time period. This measure provides weight to the trends of environmental impacts (Woodward and Francis, 1988). The following relation calculates prevalence:

$$\textit{Prevalence of noise-induced diseases} = \frac{\text{population affected by noise pollution}}{\text{Average population}}$$

(After Moon *et al.*, 2000)

To get the results of diseases prevalence on micro geographic scale, the instrument of questionnaire has been used. With the combination of three queries the relevant information has been extracted to achieve this objective. These were:

1. Address of the respondent
2. Houschold size
3. Diseases prevailing among family.

Addresses helped to geocode the extracted results on zonal basis; sample zone wise population was obtained through survey whereas numbers of diseases occurrence were the representatives of affected population cases. Later, this data on noise pollution based diseases was integrated with the GIS database to discover the occurrence in each zone.

8.2.3 Analyses on Hospital Data

Qualified and unqualified medical practitioners, Homeopaths and Hakims treat the vast majority of Karachiites. There is also a strong tradition of self-medication in this part of the world, where every medicine is available over the counter, without any prescription. Patients are carelessly handled in private and public sector hospitals of populous Karachi. Lack of proper record keeping of these service providers convinced the author that most of these sources, could not furnish statistics on scientific premises. However, the author did some analysis to explore *morbidity, mortality* and so forth.

The number of Yearly Indoor Patients (YIP) treated at the two biggest and teaching hospitals has been separately presented as Tables 8.1 and 8.2. This data gives an overall picture of various diseases prevalent in the metropolis. Some of the diseases have a significant linkage with noise pollution. The share of patients affected by noise-induced diseases from the total number of patients is an interesting dimension to be looked at. Likewise, viewing the *morbidity*, moreover the *mortality* (if any) due to the diseases having linkage with noise pollution was considered worthwhile for this study.

8.3 THE FINDINGS

8.3.1 Findings from Doctor's Questionnaire

In many health applications, a crucial issue is data quality: the use of complete and reliable data based on standard disease definition is prerequisite. In Pakistan, the quality of most routine health data is often questionable (Kazmi and Pandit, 2001) therefore, instead of relying on the data from hospitals, most of the analysis presented hereunder is from the data primarily generated through questionnaires. This practice data based on the Physicians' experience has much higher quality than the conventional hospital statistics due to the educational background of the health professionals.

Most of the physicians were belonging to the age group of 25 to 40 years. They were fresh as well as experienced male and female doctors. They had been practicing their profession in governmental and private hospitals and clinics. However about *30* percent, doctors who were in the age group of fifties were highly experienced. Approximately *50* percent of the respondents had MBBS degrees and the remaining half had additional specialized qualifications (MCPS, DLO, FCPS *etc.*). Majority of respondent's *(65%)* had more than five years experience. Whereas, *39* percent doctors had more than 15 years experience. About *37* percent had started their career recently and had less than five years experience. Thirty five percent of doctors had diversified, spatially distributed information on noise-induced epidemics because they practiced at more than one location with in the city.

8.3.1.1 Disease Ranking by Professionals

Another task to perform was to assess how much noise pollution was considered as a contributing factor for the incidence of specified diseases. The diseases that have known and established relationship with noise pollution (Gold, 1980; Thomson, 1981, Thomas, 1990; Kaplan and Sadock, 1991; Adair and Havranek, 1995; Rylander, 1999) were listed and the focus group (Physicians practicing in Karachi) was requested to rank their perceived contribution for each of them, quantitatively (Refer to Table 8.3). The summary of this grading has been narrated under the titles of:

- Highly associated
- Fairly associated
- Less associated

The diseases that emerged as *highly associated* with noise pollution were, in descending order: Stress, Hearing Loss, Anxiety, Ulcer, Tinnitus, Hypertension, Palpitation (increased heart rate) and Learning Loss.

The diseases perceived as *fairly associated* with noise pollution, were. Headaches, Efficiency Loss, Irritability, Sleeplessness, Aural Pain, Brain impairments, Arteriosclerosis and coronary heart disease and Elevated Cholesterol

The diseases perceived as *less associated* by physicians with noise pollution, in descending order, were: Nausea, Reduced Muscular Control, Nerve impairments and ataxia (irregular movements), Birth Defects, Muscular impairments, Liver malfunctions, Colitis and Kidney malfunctions.

Table 8.3: Disease ranks by Physicians

Disease /Symptom	Rank
Stress	1
Hearing Loss	2
Anxiety	3
Ulcer	4
Tinnitus	5
Hyper tension	6
Palpitation	7
Learning Loss	8
Headaches	9
Efficiency Loss	10
Irritability	11
Sleeplessness	12
Aural Pain	13
Brain impairments	14
Arteriosclerosis and coronary heart disease	15
Elevated Cholesterol	16
Nausea	17
Reduced Muscular Control	18
Nerve impairments and ataxia (irregular movements)	19
Birth Defects	20
Muscular impairments	21
Liver malfunctions	22
Colitis	23
Kidney malfunctions	24

8.3.1.2 Morbidity treated by Physicians

Through the same questionnaire, Physicians practicing across Karachi were asked to provide information on the morbidity and frequency of noise pollution induced diseases. Figure 8.1, ranks symptoms and diseases frequent in Karachi metropolis. This review has consequently categorised 24 Symptoms and diseases into three broader distinctions.

- Frequent
- Fairly Frequent
- Least Frequent

Epidemics of Noise-Induced Diseases
(2001)

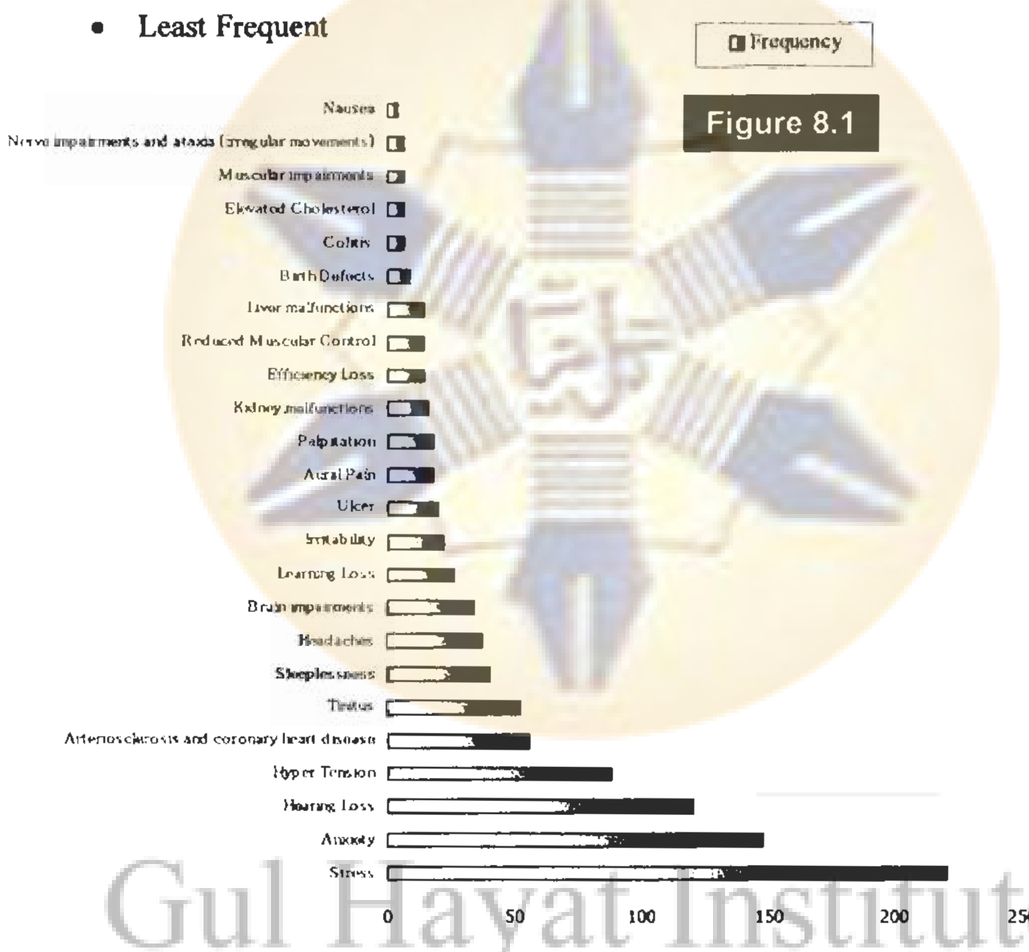


Figure 8.1

The critique of physicians has marked the symptoms / diseases of ***Stress, Anxiety, Hearing Loss, Hypertension, Arteriolosclerosis and coronary heart disease, Tinitus, Sleeplessness,*** and ***Headaches*** as the most *frequent* in their respective practising neighbourhood.

The symptoms and diseases that were evaluated *fairly frequent* other than the ones already mentioned, in descending order, these were: ***Brain impairments, Learning Loss, Irritability, Ulcer, Aural Pain, Palpitation, Kidney malfunctions,*** and ***Efficiency Loss.***

This critique would remain incomplete if the diseases marked as *least frequent* in the practising localities of the doctors are not mentioned. In descending order these were ***Reduced Muscular Control, Liver malfunctions, Birth Defects, Colitis, Elevated Cholesterol, Muscular impairments, Nerve impairments and ataxia (irregular movements)*** and ***Nausea.***

The learning from this exercise was that focusing on symptoms rather than detailed medical terminology was less time consuming for the respondents. Obviously, the professionals had a limited portion of their precious time for this questionnaire.

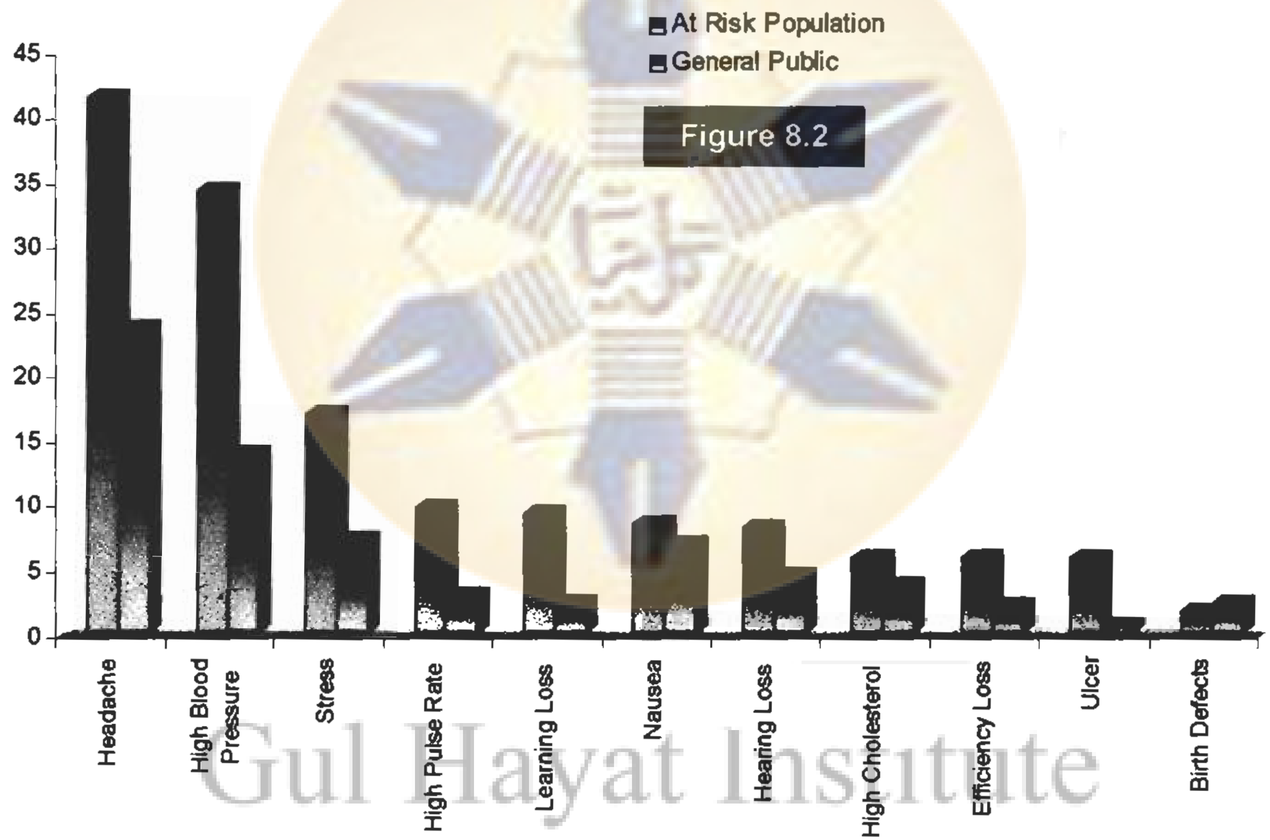
8.3.2 Findings from the Community Based Questionnaires

8.3.2.1 Spatial Distribution of noise related Diseases

A comparison between the prevailing diseases among general public and population at risk (working near the congested areas) is presented in Figure 8.2. The comparison appeared to be pretty consistent within the framework of both of these focused groups. The family members of the respondents were largely suffering from ***Headache***, ***Hypertension***, ***Stress***, while ***Palpitation***, ***Nausea***, ***Hearing Loss***, and ***Learning Loss***, were prevalent disorders to a lesser extent found in the respondents.

An interesting convergence could be deduced if Figure 8.2 is studied along with Figure 8.1. Keeping the differences in technical and popular terminologies in mind, the highly prevalent diseases (from the questionnaires) are also those categorized *frequent* by the Physicians critique. The symptoms of ***Headache***, ***Hypertension***, and ***Stress*** were highly prevalent, according to the outcome of this analysis. Moreover, the frequent diseases, according to the Physicians critique, were ***Stress, Anxiety, Hearing Loss, Hyper tension, Arteriolosclerosis and coronary heart disease, Tinitus, Sleeplessness***, and ***Headaches etc.***

Disease Prevelance Comparison



The disease data collected covered 55 out of 58 analysis zones. This data was pertaining to the occurrence and prevalence refers to Table 9.5. The characteristics of data are given in Table 8.4 and Table 8.5.

Table 8.4: Disease Occurrence: Descriptive Statistics

Measures	Value
Mean	8.67
Standard Error	1.23
Median	5
Mode	4
Standard Deviation	9.17
Sample Variance	84.15
Kurtosis	5.53
Skewness	2.19
Range	46
Minimum	1
Maximum	47
Sum	477
Count	55
Largest(2)	32
Smallest(2)	1
Confidence Level(95.0%)	2.47

Table 8.5: Disease Prevalence: Descriptive Statistics

Measures	Value
Mean	13.88
Standard Error	1.96
Median	9.33
Mode	9.09
Standard Deviation	14.54
Sample Variance	211.42
Kurtosis	5.45
Skewness	2.26
Range	66.12
Minimum	1.02
Maximum	67.14
Sum	763.79
Count	55
Largest(2)	66.66
Smallest(2)	1.80
Confidence Level(95.0%)	3.93

Occurrence of Noise induced Diseases in Analysis Zones

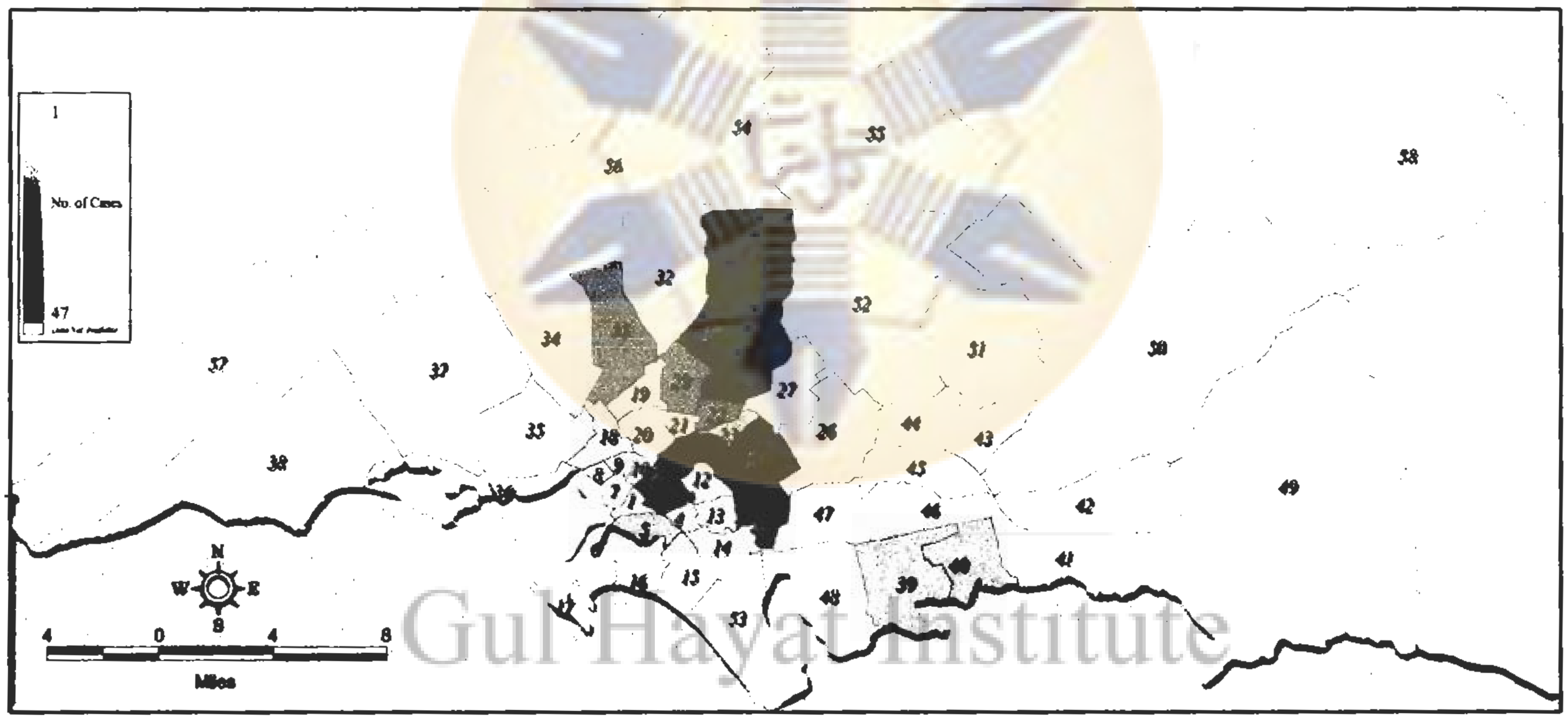


Figure 8.3

POINT PREVALENCE OF NOISE INDUCED DISEASES IN ANALYSIS ZONES

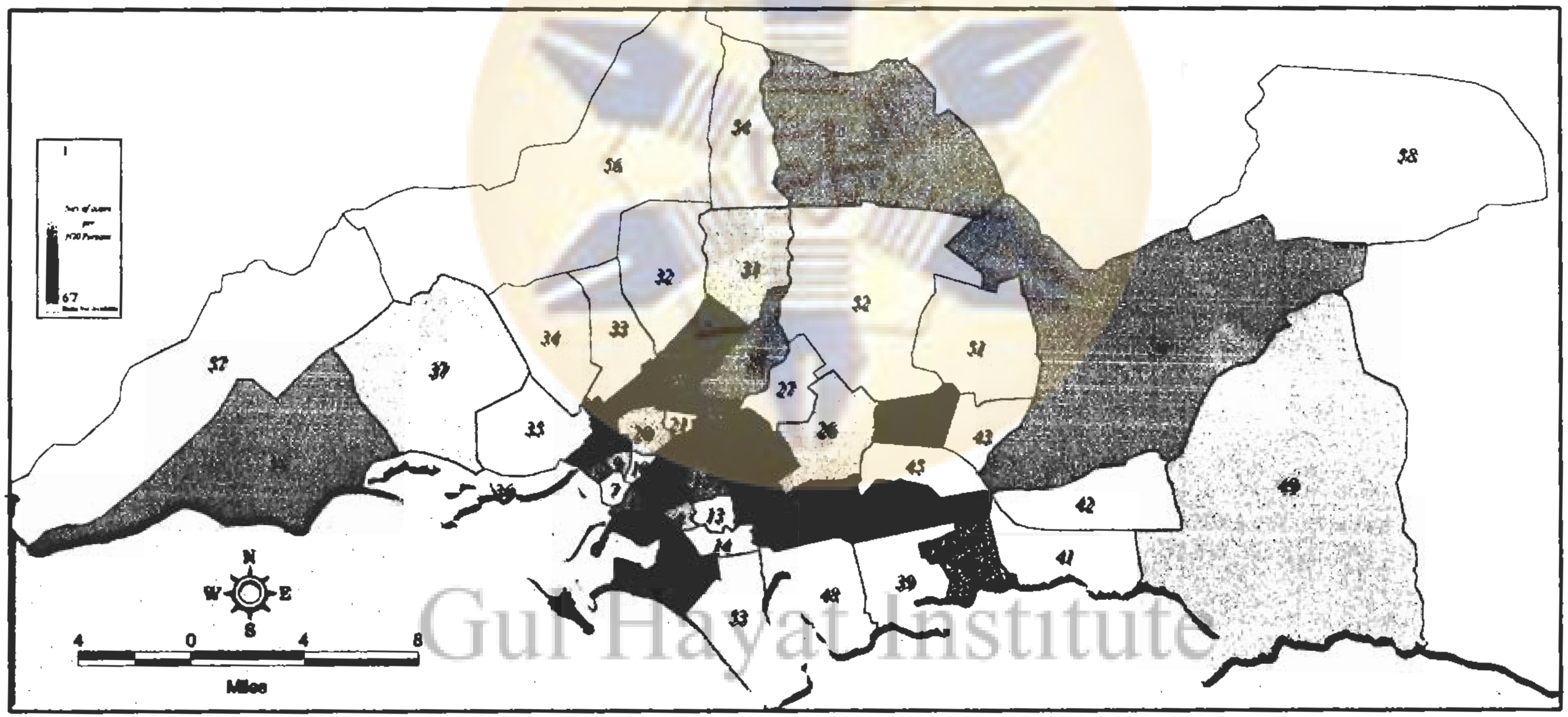


Figure 8.4

The analysis zones determined by the then Karaehi Development Authority serves as the basis of metropolitan Karachi for the purpose of this study. Figure 8.3 maps the disease occurrence for Karachi. The higher occurrence of noise pollution based diseases in the study area was in the district Karachi Central, specifically, North Karachi (Zone # 31), F. C. Area and Mansoora / F B Area (Zone # 28). The affected zones of district Karachi East were Garden, Soldier Bazaar, Jamshed Quarters (Zone # 11), Korangi (Zone#39), Landhi Colony (Zone # 40) and Akhtar and Baloch Colony, Chanesar Goth (Zone # 25). In district Karachi South, which comprises of mostly the old city (core) localities of Karachi, Saddar and Artillery maidan (Zone # 3) had the highest occurrence of noise related diseases. Orangi, Metroville-I (Zone # 30) of district Karachi West posses a significant disease problem.

Figure 8.4 map the normalised disease point prevalence for the metropolis of Karachi. The wide coverage of metropolis was made possible via extensive questionnaire survey (N>1000). The outskirts and relatively rural zones of Karachi having scattered population were fortunately involved. The spatial patterns of disease point prevalence are diffused from the city centre towards the peripheries. These results are apparent outcome of the existing demographic and socio-economic behaviour of the analysis regions (zones), which may create the urban functional agglomerations and accessibility to the health facilities.

8.3.3 Findings from Hospital data

8.3.3.1 Morbidity and Mortality

Noise pollution plays a role to mortality and morbidity. Kunzli *et al.* (2000) estimated the impact of outdoor (total) and traffic-related pollution on public health in Austria, France and Switzerland. Attributable cases of morbidity and mortality were estimated in this European assessment.

On the basis of literature reviewed on clinical discoveries (Refer to section 8.3.4), the diseases that could be categorized as 'noise-induced' were extracted. Prominent among those were cardiovascular diseases, stress, anxiety, hypertension, palpitation, irritability, hearing loss, aural pain, tinnitus, learning loss, cerebrovascular disorders, efficiency loss, ulcer, kidney malfunctions, brain impairments, muscular and nerve impairments. The records of leading public sector hospitals (where reputed medical colleges are being run) were scrutinized to find out the spread of diseases over the metropolis.

Civil Hospital, Karachi located in the old city (core) Karachi caters thousands of patients daily on the Out Patient and Emergency departments. There has been no disseminated data for this huge influx of Out Patients at the busiest public sector hospital of Karachi. Fortunately, the statistics for Indoor Morbidity and Mortality has been managed according to the disease code number and detailed list number. Table 8.6, manifests the findings of twelve months statistics of this largest hospital in Karachi. Analyses reveal Noise-induced diseases capture about one tenth of the morbidity. Two in every seven deaths in Civil Hospital Karachi was on account of noise pollution based diseases. This limited data exhibit that had there been daily Out Patient figures publicly available, surprising findings could have been possible to derive.

Table 8.6: Indoor Morbidity and Mortality Statistics (2001)

	Morbidity (No. of Cases)			Mortality (No. of Deaths)		
	Male	Female	Both Sexes	Male	Female	Both Sexes
Total Cases	14179	16921	30709	629	480	1109
Noise Induced Cases	1111	2286	3397	145	196	341
Proportion of Noise Borne Diseases (%)	7.8	13.5	11.1	23.1	40.8	30.7

Data Source: Medical Record and Statistical Office, Civil Hospital, Karachi

The second major hospital managed by the federal government in Karachi is the Jinnah Post-Graduate Medical Centre, located near old city (core) of Karachi. Here too, thousands of patients are daily catered at the Out Patient and Emergency departments. The hospital has several Indoor treatment sections.. Table 8.7, shows the Mortality and Morbidity statistics. Again, the statistics on Out Patient was not maintained at this important hospital. The numbers presented in Table 8.7, calls for the dire need of managing this vital public health data more scientifically so that surprising results could be explored.

Table8.7: Morbidity and Mortality, Noise induced Diseases

	Morbidity (Cases)	Mortality (Cases)	Mortality - Morbidity Ratio (%)
Male	44	7	15.9
Female	27	8	29.6
Both Sexes	71	15	21.1

Data Source: Statistical Department, Jinnah Post Graduate Medical Centre, Karachi

8.3.4 Literature Conformity

No one can prevent the automatic biological changes which noise provokes. It as a source of stress can have detrimental physiological effects, including the promotion of hypertension, which in turn increase the risk of cardiovascular disease. The principal indicator of adverse cardiovascular effects is hypertension, defined variedly, as adult blood pressure above 160/100 (Taylor and Wilkins, 1987), 140/90 mmHg (Chapman, 1995) *etc.* The exposure to acoustic defilement may be considered as a factor for the occurrence of cardiovascular complications. (Bjorkman, 1983; Dejoy, 1984; Solerte *et al.*, 1991; Babish *et al.*, 1993; Chapman, 1995).

The results from some early studies show slightly higher blood pressure among people living along roads with heavy traffic compared with those living in quiet areas (Knipschild and Salle, 1979). Based upon observations of an increase in blood pressure after acute exposure to noise, it has been suggested that long-term exposure to noise could cause a persistent increase in blood pressure. A review of the cardiovascular effects of noise reported that 55 studies had been performed on the relationship between noise and blood pressure and about 80 per cent of these had reported some form of positive association (Dejoy, 1984). Yiming *et al.*, (1991) studied a group of 1,101 female workers in a textile mill in Beijing, China. Logistic regression indicated that exposure to noise was a significant determinant of prevalence of hypertension. Hypertension was used in ten studies cited by Thompson [1981], out of which six studies report greater incidence of hypertension in groups with high-noise exposure. Another study by Meechan and Shaw

[1979] concerning mortality rates in areas exposed to high level of noise in Los Angeles. The researchers concluded that mortality due to stroke was significantly higher in the area.

According to authentic governmental data, more than 30 million Americans were exposed
estimated that more than eight million workers in the United States were affected by some noise-induced hearing loss. Research has shown that when daily noise levels average about 85 dB (A) or more, permanent hearing loss can occur (USEPA, 1978). Individuals' experiencing hearing loss tends to become suspicious, irritable, and depressed; some times to the point of complete withdrawal (Perham, 1979)

Noise may also cause "tinnitus," a ringing in the ears. Besides being a constant annoyance, tinnitus often signals impending hearing loss. The structures of the inner ear may be severely damaged. Hearing loss and tinnitus may be experienced in one or both ears. Tinnitus is a symptom of almost any ear disorder including ear infections, foreign objects or wax in the ear, otosclerosis, Meniere's, acoustic trauma, and others. Tinnitus may be associated with hearing loss including occupational hearing loss. It is also a symptom of certain forms of cardiovascular disease such as occlusion of the carotid arteries, anaemia, vascular (blood vessel) malformations, aneurysm, and tumors in the head (http://www.nlm.nih.gov/medlineplus/ency/article/001336.htm). People with hearing deficiencies are also at risk from exposure to noise. Aniansson *et al.* (1983) studied speech interference, annoyance and changes in mood in groups of people with different degrees of hearing deficiency. These groups were exposed to 45 dB(A) and 55 dB(A) traffic noise in a laboratory where they had to perform four everyday activities. The major finding was a higher rating of annoyance among men with noise-induced hearing loss compared with men with normal hearing.

Hearing loss is the most obvious health threat posed by noise pollution but it is by no means the only one. Exposure to unwanted noise involuntarily induces stress, and stress can lead to a variety of physical ailments including an increase in heart rate, high blood pressure, elevated levels of blood cholesterol, ulcers, headaches and colitis

(Nadakavukaren, 1990). Studies under UNEP and WHO seem to have established links between noise and several diseases, including stroke, cardiovascular disease, hypertension, and peptic ulceration (Correspondent daily Leader, 1996). Noise can create changes in blood circulation and, anxiety and emotional stress.

Noise appears to have its greatest behavioural impact when it is infrequent, intense, and unexpected. Laboratory research has suggested that exposure to unpredictable and uncontrollable noise is associated with poorer performance of tasks (Glass and Singer, 1972), findings that are supported by environmental studies that have traced correlation between the reading abilities of children and traffic noise (Cohen *et al.*, 1973; Bronzaft and McCarthy, 1975). Examples may also be found of studies that have found positive correlations between high noise and pathologies as varied as mental illness, psychosomatic complaints and ailments caused by tension, such as duodenal ulcers (McCord *et al.*, 1938; Farr, 1967). Several studies have discussed the effects of traffic density upon the quality of urban life. Lawson and Walters (1974), who analysed the impact of a new urban motorway upon a high-rise housing estate in Birmingham (England), with the hypothesis that greater noise levels would produce annoyance and reaction from the community.

Annoyance is generally defined as a feeling of displeasure against a source of pollution in the environment, which the individual knows or believes, will adversely affect his health or well being (WHO, 1980). A large number of studies have been performed to evaluate the relationship between exposure to road traffic noise and the extent of annoyance in the exposed populations. Large investigations in road traffic noise were performed in London by Langdon (1976). These studies agree that exposure to road traffic noise is one of the most important sources of annoyance in the general population. The number of persons affected far exceeds the number disturbed by aircraft noise or other environmental noise sources. Many studies on road traffic noise demonstrate a fairly linear correlation between the equivalent noise level and the extent of annoyance (Langdon, 1976; Fidell and Baber, 1991). The WHO Task Group on Community Noise noted that noise annoyance varies with activity (Berglund and Lindvall, 1995).

The most serious adverse effect is sleep disturbance with its long-term consequences for health and well being (Rylander, 1999). There is fairly uniform consensus that changes in the depth and pattern of sleep represent acute effects following exposure to noise. In an investigation from France, sleep disturbance was studied among a population living near a railway and a major road (Vernet, 1979). About 25 percent of noise events at 70 dB(A) caused sleep interference. Long term effects of noise induced sleep interruption could be subjective fatigue, changes in performance and subjective mood changes (Schwela and Zali, 1999). An interesting field study was conducted close to a road with heavy traffic and in a quiet area far from the road to observe effects of noise exposure during sleep (Ohrstrom, 1989). The area close to road with heavy traffic, showed deterioration in sleep quality and mood, and a higher frequency of other symptoms such as tiredness, headache and nervous stomach.

Noise may, nevertheless, act as a 'stressor', inducing symptoms among sensitive individuals. Biochemical reactions indicating a general stress effect from noise have also been reported in animal and human studies (Cantrell. 1974). Noise can be bothersome and can give rise to psychological and psychosomatic symptoms in the form of headaches, fatigue and irritability. Abey-Wickrama *et al.* (1969) described an increased psychiatric admission rate to hospitals among a population living in an area exposed to high levels of noise. In another study on the effect of aircraft noise on mental health (Tarnopolsky *et al.* 1980), of the noise-related effects, depression, irritability, awakenings and difficulty in falling asleep were significantly more frequent in the high noise areas. According to previous studies on noise effects, it could be assumed that physical and psychosocial symptoms and reduced work capacity may occur. The individual capacity to handle stress might also be of importance in the development of different symptoms.

In Pakistan, some studies have been conducted to observe the health effects of noise pollution. According to GOP (1988), Lahore, Peshawar and other cities of the country were no different than Karachi. A study completed by a group of physicians and psychiatrists revealed that noise and urban traffic pollution were contributing largely towards the deteriorating health conditions of the patients admitted in the combined military hospital (CMH), Peshawar. It had greatly slowed down their pace of recovery and complicated their diseases despite the best medical care (Correspondent Frontier Post, 1998). In a research carried out at the ENT department of the Rawalpindi Medical College, it was discovered that noise was increasing the level of deafness among the citizens of Rawalpindi and telling upon their nerves. It was also increasing the proportion people with impaired hearing in Rawalpindi, day by day (Correspondent daily Dawn, 1999). A report mentioning an official of the ENT department King Edward's Medical College, Lahore testified that noise pollution was causing physical and psychological problems to the people of Lahore, hearing loss, cardiac disorder, emotional problems and restlessness were amongst them (Correspondent the Muslim, 1998).

For Karachi, an early status report was prepared that pinpointed 11 areas in the often referred old city (core) facing high noise levels (KDA, 1981) but did not studied the public health impacts. However SEPA (1994) reported that at the outpatients department of the ENT ward of the Jinnah Postgraduate Medical Center (JPMC) Karachi, the statistical data suggested that the number of patients reporting had increased from 75,000 in 1979 to over 160,000 in 1991. Although this number did not exclusively pertained to ear diseases yet it gives an idea that they were on an increase. JPMC workers viewed the increase in the ear aliment cases as proportionately high. The study remarked that cases due to effects of noise could be those of nervous disorders, headache, high blood pressure, impairment of memory, loss of sleep, *etc*. Such cases are not normally referred to the ENT department of a hospital.

Naim (1995) reported an IUCN and Baqai University's study of 100 traffic police personnel in Karachi indicated that about one-third of the healthy young men recruited from the rural areas develop central nervous system problems, including vertigo, loss of concentration and headaches, within two years of serving on the city's streets.

Shams (1997) reviewed some statistics that revealed documented effect of road traffic and noise pollution on human health in Karachi. He referred to the Excise and Taxation Department of the Sindh province, mentioning that during 1986 – 96, only 33 per cent increase in rickshaws had been registered compared to 205 per cent increase in taxis, 85 per cent increase in cars, jeeps and station-wagons, 58 per cent increase in motorcycles and scooters, 40 per cent increase in trucks and 37 per cent increase in buses and minibuses. To him, Loud and never shattering noise in Karachi had been responsible for a number of physiological problems. It had caused fatigue and stress and the body reacts to such a stress by changes in heartbeat rhythm, increase in blood pressure, dilation of pupils, contractions of muscles, rise in blood cholesterol level and in secretion of hormones which was linked with negative feedback system of the brain.

A recent report portrayed an integrated effort of IUCN, Baqai University and URC (Correspondent daily Dawn, 2000). Most of the traffic policemen on the streets of Karachi metropolis had difficulty in hearing, and had ringing or buzzing sound (*Tinnitus*) in the head; felt grumpy and irritable.

in Karachi metropolis with the limited data available. Although, individual health risks of noise pollution are relatively small, the public-health consequences are considerable. Traffic-related noise pollution remains a key target for public-health action in developed countries (WHO 1980; Rylander, 1986; Ohrstrom *et al.* 1988a, 1988b). The results presented in this chapter have attempted to provide the decision makers, quantitative assessment of environmental health scenario for the metropolitan city of Karachi.

9. MICRO-GEOGRAPHIC APPRAISALS

An intra-metropolitan analysis shows the spatial variation, similarities, differentiation, distributional pattern, intensive risk zones *etc.* within city on a micro geographic scale. Micro–geographic appraisals for the entire Karachi metropolis has been performed. Each regional assessment included area, population density, distribution of land cover, split of land use, and frequency of noise-induced diseases, their prevalence scenario and temporal variations in noise levels within the analysis region.

9.1 SOURCES AND QUALITY OF DATA

Karachi Development Authority (KDA) had divided the whole metropolis into 58 analysis zones, covering the urban area and adjacent rural settlements Table 9.1 and Figure 9.1. Various inquiries of this study are done taking each of the 'Analysis Zones' defined by the KDA, as an entity.

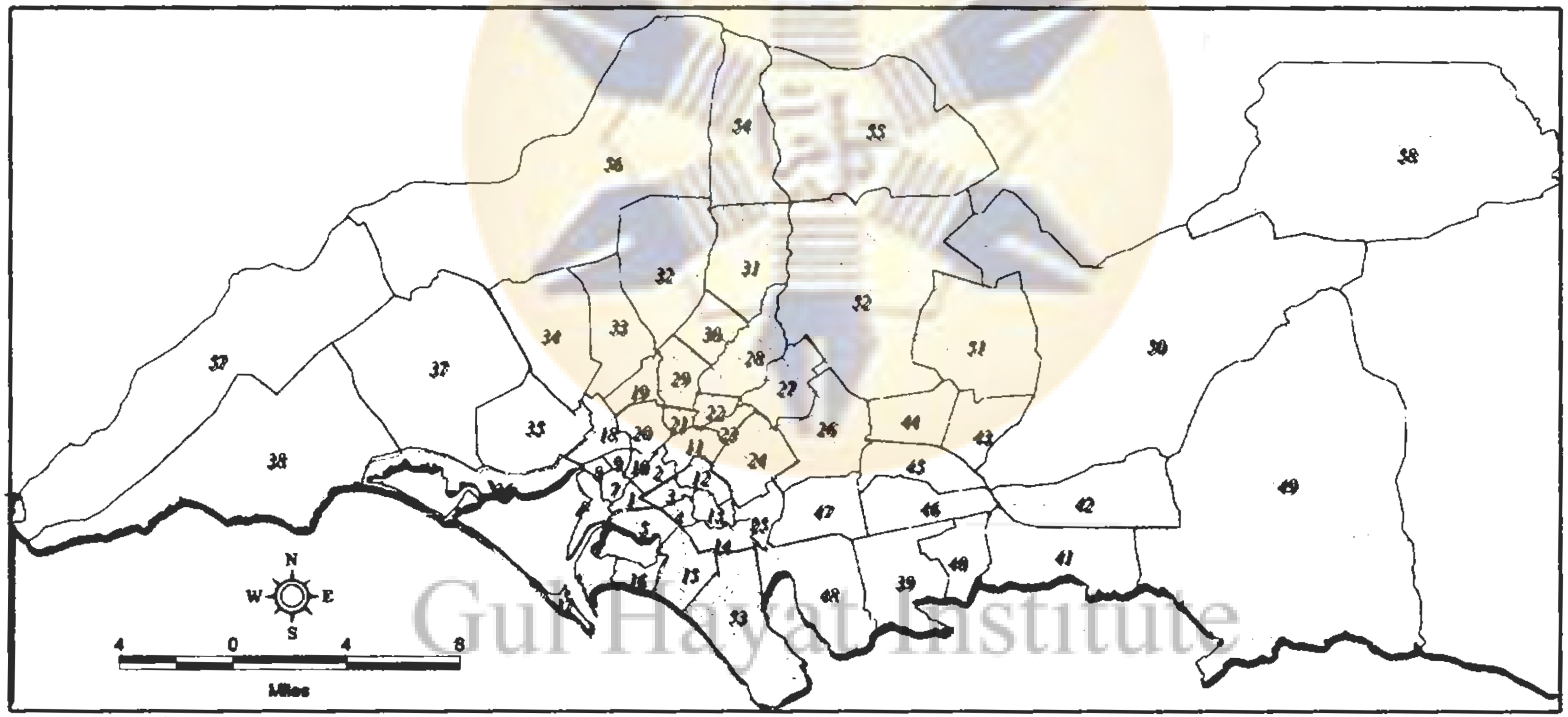
The developed map shows the analysis digital format. Later, the analytical data has been integrated with this map. zones as polygonic entitical set. In this study KDA map has been converted into vector based format.

Table 9.1: Analysis Zones

Zone No.	Zone Name	Zone No.	Zone Name
1.	Juna Market, Old Town area	30.	North Nazimabad
2.	Ranchore Line & Ramsawami	31.	North Karachi
3.	Saddar & Artillery Maidan	32.	Qasba, Manghopir Area
4.	Civil Lines Area	33.	Orangi, Metroville-I
5.	I.I. Chundrigar Road & New Queens Road	34.	Baldia
6.	Port Area	35.	Masroor (Mauripur)
7.	Nawabad, Baghdadi Lane, Kharadar	36.	Hawkesbay and Adjoining Area
8.	Agra Taj, Bihar Colony	37.	Deh Moach, Naval Depot
9.	Lea Market, Gul Mohammad Lane	38.	Deh Lal Bhakhar & Hawkesbay Scheme
10.	Chakiwara, Kalakot	39.	Korangi (Part)
11.	Garden, Soldier Bazaar, Jamshed Quarters	40.	Landhi Colony
12.	Lines Area & Khudadad Colony	41.	Landhi Industrial, Scheme 3 & 4
13.	Naval Hospital, JPMC and Liaquat Barracks	42.	Shah Latif, Deh Khanto
14.	Bath Island, Frere Town, Defense Society (part)	43.	Model and Malir Colonies
15.	Gizri Area, Delhi Colony	44.	Karachi Airport
16.	Clifton	45.	Drigh Colony & Malir
17.	Baba Bhit Islands	46.	Korangi Industrial Area – East
18.	Shershah, S.I.T.E. (part)	47.	Korangi Industrial Area – West
19.	S.I.T.E. (Sindh Industrial Trading Estate)	48.	Korangi Creek and Refinery
20.	Asif, Pak Colony & T.P.I.	49.	Steel Mill and Port Qasim
21.	Rizvia, Firdous Colony, Golimar	50.	Deh in the East
22.	Liaquatabad	51.	Malir Cantonment
23.	Gulshan-e-Iqbal (part), P.I.B. Colony	52.	Scheme 33
24.	Gulshan-e-Iqbal, Chandni Chowk, Society Area	53.	Defence Society
25.	Akhtar & Baloch Colony, Chanesar Goth	54.	Surjani Town
26.	Drigh Cantonment, 9th Mile	55.	Taisar Town
27.	Gulshan-e-Iqbal, National Cement Factory	56.	Halkani Scheme
28.	F.C. Area and Mansoora	57.	Dehs in the West along Hub River
29.	Nazimabad, Paposhnagar	58.	Dehs along Super Highway

Source: Karachi Development Authority (KDA), 1991

KARACHI METROPOLIS
Analysis Zones



Source: Karachi Development Authority (KDA), 1991

Figure 9.1

9.2 THE FRAMEWORK

The noise samples were collected from all over the Karachi metropolis according to sampling criterion. Geographic Information System has the strong topological intelligence such as adjacent / neighbouring, containing, and intersecting features information. That topological intelligence has been used to select spatial objects (*i.e.* underling grid cells) within each individual KDA zone. The territorial noise pollution surfaces (*i.e.* portion of underlying surface) were aggregated for that particular territory (KDA zone). This analysis would provide the data behaviour in terms of minimum, maximum, mean, range and standard deviation (ESRI, 1998; MIC, 1999)

The map of analysis zones was overlaid on the thematic land cover and year- 2000 land-use map for the quantification of each of their categories per zone. SPANS PCI, Canada was used for this analysis. This software terms such analysis as *area cross tabulation analysis*. The information collected on population and diseases in terms of different parameters was transformed to the grass root level *i.e.* the 58 analysis zones of this study. Tabulations in Microsoft Excel, and data integration into a GIS in ArcView facilitated to map these phenomena. *Classed Choropleth maps* (Campbell, 2001) of disease(s) occurrence, disease point prevalence and population densities are used to show the regional variations in epidemiological and demographical studies (Aral *et al.*, 1994; Jacquez *et al.*, 1996; Goodchild, 1998; Jacquez, 1998; Haining, 1998; Kulldorff, 1998). Similar methodology has been adopted here in this study.

9.3 THE FINDINGS

The analytical tools (summarized zones, rank summation *etc.*) used in this study have yielded new quantitative appraisals on the basis of analysis zones developed by Karachi Development Authority (KDA). The upcoming pages would be illustrating various themes consecutively. Zone-wise assessments of land cover, land use, population, disease, and noise pollution are given as Tables 9.2, 9.3, 9.4, 9.5, 9.6 and 9.7 respectively and Figures 9.2 to 9.8.

Table 9.2: Micro-geographic appraisals of land cover

Zone No.	Dense Built-up	Moderate Built-up	Sparse Built-up	Urban Vegetation	Vegetation	Open Land	Water	Area (Acre)
1	85.5	8.0	1.1	3.0	1.5	0.9	-	509.0
2	73.9	11.4	1.4	9.5	3.3	0.5	-	803.0
3	76.9	6.2	1.8	5.7	8.7	0.7	-	679.1
4	41.8	3.9	3.2	15.6	34.5	0.9	-	518.6
5	57.9	20.3	4.3	10.7	5.6	1.2	-	1255.2
6	73.0	11.4	3.0	2.5	9.5	0.7	-	2405.7
7	83.7	12.2	2.3	0.6	0.2	1.1	-	580.2
8	76.2	8.3	1.3	1.5	11.1	1.6	-	288.3
9	81.9	6.9	3.0	1.8	6.3	0.2	-	348.5
10	78.7	9.6	4.1	3.5	3.3	0.7	-	389.8
11	60.8	13.2	2.1	16.8	6.2	0.9	-	1420.6
12	56.4	15.8	7.0	13.1	4.7	3.0	-	1080.3
13	37.8	22.9	8.5	20.3	7.0	3.6	-	913.5
14	23.6	20.2	5.9	36.6	7.8	5.8	-	1369.3
15	24.4	22.2	11.2	32.4	7.3	2.3	0.2	2546.6
16	50.2	16.5	4.2	7.6	1.5	3.7	16.4	959.6
17	15.6	20.5	24.4	6.5	1.6	31.4	-	447.1
18	40.4	20.0	19.2	8.2	5.3	6.9	-	1710.4
19	18.0	23.9	32.6	10.4	1.1	13.9	-	1366.8
20	34.3	11.1	7.4	14.3	26.5	6.3	-	1604.7
21	73.3	12.8	1.6	9.1	1.8	1.4	-	549.3
22	79.0	7.2	2.0	6.9	3.8	1.0	-	870.4
23	53.5	24.4	8.1	9.3	2.8	1.9	-	630.8
24	26.1	17.5	8.8	38.0	6.7	2.9	-	3566.7
25	18.2	50.8	18.5	7.4	2.3	2.9	-	1302.5
26	6.7	9.7	23.9	15.2	13.3	31.3	-	5441.2
27	11.9	32.5	21.8	22.0	3.9	7.9	-	3113.6
28	18.8	37.2	16.9	17.8	2.4	6.9	-	3744.1
29	40.2	25.5	7.1	22.1	1.0	4.0	-	2069.6

30	11.7	31.9	21.6	23.8	1.8	9.2	-	2213.0
31	5.4	34.2	36.8	7.6	1.9	14.1	-	6086.9
32	2.4	7.3	9.9	6.9	3.5	69.9	-	8715.1
33	6.9	34.6	35.9	7.6	0.4	14.6	-	5021.2
34	2.8	15.7	22.9	3.8	1.2	53.6	-	7305.6
35	2.9	8.6	23.5	8.2	6.3	50.5	-	6129.5
36	7.7	10.8	19.8	9.8	0.6	43.4	8.0	3923.4
37	0.1	0.6	2.8	0.8	0.2	95.5	-	18083.4
38	0.0	0.0	0.4	0.2	0.1	99.3	-	22721.3
39	7.3	35.0	23.3	15.9	2.2	16.3	-	5824.4
40	6.7	19.3	16.9	19.2	9.7	28.1	-	2874.6
41	6.0	15.7	19.1	13.1	4.3	41.8	-	7444.8
42	1.8	4.9	11.4	7.0	4.0	70.8	-	7723.3
43	5.3	33.6	23.1	16.8	5.9	15.3	-	3187.1
44	6.0	9.3	16.6	11.9	5.9	50.3	-	3349.9
45	14.7	17.7	16.1	19.7	20.4	11.4	-	3442.7
46	8.6	14.5	17.2	23.3	22.2	14.2	-	4089.7
47	5.2	13.5	24.0	12.8	14.7	29.8	-	4008.7
48	8.8	17.3	29.0	12.4	3.8	28.7	-	6552.6
49	0.6	1.6	6.1	7.2	7.4	77.0	-	56356.1
50	0.1	0.6	3.8	6.7	7.9	80.9	-	47750.4
51	0.2	2.3	17.5	8.8	4.8	66.4	-	9870.2
52	1.1	4.5	15.0	6.2	3.8	69.3	-	22932.0
53	2.2	12.4	22.1	10.3	2.2	50.8	-	7564.9
54	0.1	2.4	10.0	1.8	0.9	84.8	-	7841.7
55	0.1	0.1	1.3	0.7	0.8	97.1	-	20638.5
56	0.0	0.1	0.4	4.4	4.6	90.5	-	36969.5
57	-	-	-	2.1	1.3	96.6	-	27468.6
58	0.1	0.3	0.6	1.8	2.5	94.7	-	38716.0

Table 9.3: Micro-geographic appraisals of land use

1 =	Planned Residential	L-8 =	Education	L-15 =	Vacant Developed
2 =	Unplanned Residential	L-9 =	Vacant Undeveloped	L-16 =	New Industry
3 =	Burial Ground	L-10 =	Military Areas	L-17 =	Densification Areas
4 =	Utilities	L-11 =	Recreational	L-18 =	Low Income Settlements
5 =	Agriculture	L-12 =	Flood Plain	L-19 =	New Commercial Centres
6 =	Commercial	L-13 =	Transport Facilities	L-20 =	Urban Renewal
7 =	Industrial	L-14 =	Schemes to infill	L-21 =	Buffer Areas

Zone No.	L-1	L-2	L-3	L-4	L-5	L-6	L-7	L-8	L-9	L-10	L-11	L-12	L-13	L-14	L-15	L-16	L-17	L-18	L-19	L-20	L-21	Area (Acre)
1	-	-	-	-	-	22.3	-	-	-	-	-	-	-	-	-	-	-	-	-	77.7	-	509.0
2	26.9	-	-	-	-	10.1	-	-	-	-	-	-	-	-	-	-	-	-	-	63	-	803.0
3	1.2	-	-	-	-	70.7	-	-	-	-	-	-	-	-	-	-	-	-	-	28	-	679.1
4	40.4	-	-	-	-	58	-	1.6	-	-	-	-	-	-	-	-	-	-	-	-	-	518.6
5	40.5	7.6	-	-	-	6.8	-	-	-	-	-	-	35	-	-	-	-	-	-	10.1	-	1255.2
6	-	4.4	-	-	-	8.5	29.5	-	-	-	-	-	42.1	-	-	-	2.8	-	-	12.7	-	2405.7
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	580.2
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	288.3
9	-	0.1	1.1	-	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-	98.6	-	348.5
10	0.8	2.2	1.1	-	-	8.3	-	-	-	-	12.8	-	-	-	-	-	-	-	-	74.9	-	389.8
11	94.3	2.9	-	-	-	-	-	2.4	-	-	0.4	-	-	-	-	-	-	-	-	-	-	1420.6
12	82.1	-	-	-	-	5.1	-	4.5	-	-	8.2	-	-	-	-	-	-	-	-	-	-	1080.3

13	60.3	13.8	-	-	-	8.1	-	17.8	-	-	-	-	-	-	-	-	-	-	-	-	-	913.5
14	78.4	6.8	-	-	-	2.9	-	-	-	-	3.3	-	-	-	-	-	8.6	-	-	-	-	1369.3
15	56.1	6.9	-	-	-	-	-	-	-	-	8.8	-	-	-	-	-	28.2	-	-	-	-	2546.6
16	-	-	-	-	-	11.2	-	-	-	-	5.9	-	-	-	-	-	82.8	-	-	-	-	959.6
17	-	-	-	-	-	-	-	-	-	98.1	1.9	-	-	-	-	-	-	-	-	-	-	447.1
18	21.7	32.4	8.2	2.7	-	-	29.8	4	-	-	-	-	-	-	-	-	-	1.1	-	-	-	1710.4
19	0.6	31.1	-	-	-	0.1	62.2	-	1.3	-	-	-	-	-	-	-	-	4.7	-	-	-	1366.8
20	6	32.1	10	9.2	31.3	-	11.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1604.7
21	15.2	76.2	-	-	-	8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	549.3
22	61.3	22.8	-	-	-	15.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	870.4
23	49.1	22.8	-	-	-	19.7	-	8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	630.8
24	85.1	0.6	-	-	-	5.1	-	5	-	2.6	1.1	-	-	-	-	-	0.4	-	-	-	-	3566.7
25	14.8	57.6	-	2.1	-	-	-	-	-	5.1	-	3.4	-	-	-	-	17	-	-	-	-	1302.5
26	7	4.8	-	0.1	-	-	0.6	-	-	71.1	6.4	0.8	-	-	2	-	7.2	-	-	-	-	5441.2
27	75.3	3.2	-	1.7	-	-	1.9	3.9	-	-	6.2	-	-	0.4	-	-	7.3	-	-	-	-	3113.6
28	67.8	11.6	-	-	-	5.5	9.5	2.2	-	-	-	0.2	-	-	-	3.3	-	-	-	-	-	3744.1
29	62.3	13.1	-	0.6	-	18.2	-	-	5.7	-	-	-	-	-	-	-	-	-	-	-	-	2069.6
30	70.5	22.6	1	-	-	4.9	-	-	0.9	-	-	-	-	-	-	-	-	0.2	-	-	-	2213.0
31	83.2	1.8	0.9	0.7	-	-	0.6	-	-	-	-	0.8	-	-	-	6.7	-	5.4	-	-	-	6086.9
32	1.4	45.4	0.3	2.1	0.2	-	-	-	-	-	1.9	-	-	-	-	2.8	-	45.7	-	-	-	8715.1
33	27.9	61.6	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	10.4	-	-	-	5021.2
34	-	52.5	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44.4	-	-	-	7305.6
35	-	6.5	-	-	-	-	5.2	1	0.5	86.5	-	-	-	-	-	-	-	0.5	-	-	-	6129.5
36	7.6	12.7	-	-	-	-	5.6	-	-	29.5	24.5	-	-	20	-	-	-	-	-	-	-	3923.4
37	0.7	-	0.5	0.6	1.5	-	-	-	13.7	74.3	-	-	-	5.6	-	-	-	3.2	-	-	-	18083.4

38	-	-	-	21.8	-	-	-	-	-	-	28.3	-	-	49.6	-	-	-	0.3	-	-	-	22721.3
39	67.8	3.4	1.1	0.6	-	-	1.9	-	10.2	2.3	1.7	-	-	-	7.3	-	3.6	-	-	-	-	5824.4
40	39.6	0.3	-	4.3	-	-	0.5	-	42.3	13.1	-	-	-	-	-	-	-	-	-	-	-	2874.6
41	4.8	2.9	-	0.5	-	-	10.6	-	11.2	-	-	-	0.1	0.2	-	6.9	-	62.9	-	-	-	7444.8
42	1.4	4.3	-	2.4	13.3	-	0.5	0.5	-	-	-	2	-	72.4	-	1	-	1.2	-	-	1	7723.3
43	93	-	-	-	-	-	-	-	-	6.9	-	0.1	-	-	-	-	-	-	-	-	-	3187.1
44	12.4	-	-	7.3	-	-	-	-	-	69.2	-	-	6	5.2	-	-	-	-	-	-	-	3349.9
45	46.2	20.2	1	5.1	-	-	-	-	-	-	-	22.1	-	-	-	5.4	-	-	-	-	-	3442.7
46	7.7	0.7	-	-	-	-	21.4	-	-	2.5	1	3	-	1.7	-	62	0.1	-	-	-	-	4089.7
47	1.1	0.2	-	-	-	-	21.6	-	-	4.1	-	25	-	-	-	45.5	2.4	-	-	-	-	4008.7
48	4	4.8	-	-	-	-	3.3	-	5.2	19.5	4.1	7.1	-	-	-	47.7	4.2	-	-	-	-	6552.6
49	9.6	-	-	0.2	-	-	43.2	-	-	-	-	2	7.8	0.4	-	-	17.1	6.1	-	-	13.6	56356.1
50	5.7	-	0.1	-	48	-	-	-	-	4	-	37.9	-	2.5	-	0.5	1.2	-	-	-	-	47750.4
51	0.6	-	-	-	-	-	-	-	-	72.7	-	0.1	-	24	-	2.6	-	-	-	-	-	9870.2
52	2.1	0.3	-	1	-	-	-	5.2	-	1.4	0.6	1.4	-	69.3	-	10.6	-	1.8	6.1	-	-	22932.0
53	11.9	1.9	-	-	-	-	-	-	-	9.1	12.5	-	-	-	-	-	64.6	-	-	-	-	7564.9
54	6.9	-	-	-	-	-	-	-	-	-	-	5.6	-	-	-	11	-	76.5	-	-	-	7841.7
55	-	-	-	-	-	-	-	-	-	-	-	8.5	-	-	-	14.1	-	77.4	-	-	-	20638.5
56	-	2.4	-	-	41.4	-	-	-	-	-	-	8.6	-	-	-	-	-	47.6	-	-	-	36969.5

Table 9.4: Micro-geographic appraisals of population

Zones	Population	Area (Acre)	Population Density (Persons / Acre)
1	96017	509.0	188.63
2	218041	803.0	271.55
3	59726	679.1	87.94
4	86247	518.6	166.30
5	31771	1255.2	25.31
6	194399	2405.7	80.81
7	169999	580.2	292.98
8	104972	288.3	364.09
9	162819	348.5	467.25
10	248096	389.8	636.43
11	248048	1420.6	174.61
12	148670	1080.3	137.62
13	76772	913.5	84.04
14	230413	1369.3	168.27
15	40808	2546.6	16.02
16	99129	959.6	103.30
17	10008	447.1	22.38
18	79692	1710.4	46.59
19	19848	1366.8	14.52
20	119256	1604.7	74.32
21	132688	549.3	241.57
22	267477	870.4	307.30
23	78720	630.8	124.79
24	210752	3566.7	59.09
25	71833	1302.5	55.15
26	203984	5441.2	37.49
27	236319	3113.6	75.90
28	536201	3744.1	143.21
29	239505	2069.6	115.72
30	291078	2213.0	131.53
31	819982	6086.9	134.71
32	320912	8715.1	36.82
33	678990	5021.2	135.22
34	375343	7305.6	51.38
35	47925	6129.5	7.82
36	19043	3923.4	4.85
37	20995	18083.4	1.16
38	6010	22721.3	0.26
39	580155	5824.4	99.61
40	227837	2874.6	79.26
41	284750	7444.8	38.25
42	116040	7723.3	15.02
43	398289	3187.1	124.97
44	8601	3349.9	2.57

45	327285	3442.7	95.07
46	38361	4089.7	9.38
47	62449	4008.7	15.58
48	114504	6552.6	17.47
49	96036	56356.1	1.70
50	90158	47750.4	1.89
51	44464	9870.2	4.50
52	160278	22932.0	6.99
53	64719	7564.9	8.56
54	74126	7841.7	9.45
55	8628	20638.5	0.42
56	12420	36969.5	0.34
57	6735	27468.6	0.25
58	11833	38716.0	0.31

Table 9.5: Micro-geographic appraisals of diseases

D1 : Headache
D2 : Stress
D3 : Travel Sickness (Nausea)
D4 : Eye ailments
D5 : Tonsillitis
D6 : Chronic Flue
D7 : Chronic Cough

D08 : Hearing Loss
D09 : High Blood Pressure
D10 : High Cholesterol
D11 : High Pulse Rate
D12 : Learning Loss
D13 : Efficiency Loss
D14 : Ulcer

D15 : Throat Cancer
D16 : Lung Cancer
D17 : Birth Defects
D18 : Asthma
D19 : Other

Zone	Sample Pop.	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	Occurr - ence	Preval - ence
1	25	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	3	12.00
2	81	3	1	-	4	-	1	1	2	1	-	1	-	1	1	-	-	-	-	1	17	20.99
3	70	11	1	1	3	1	5	1	4	9	1	2	-	-	1	-	1	6	-	-	47	67.14
4	50	1	-	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	4	8.00
5	35	-	3	-	-	2	3	-	-	1	-	1	-	-	-	-	-	-	-	1	11	31.43
6	90	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4.44
7	69	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	4.35
8	49	1	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	5	10.20
9	66	1	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	5	7.58
10	61	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3.28
11	115	6	1	1	3	1	5	-	1	6	-	2	1	1	-	-	-	-	1	-	29	25.22
12	69	2	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	7	10.14
13	36	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2.78
14	107	2	-	-	-	-	1	1	-	1	-	1	-	-	-	-	-	-	-	-	6	5.61
15	19	2	-	1	-	1	-	1	-	2	-	-	-	-	-	-	-	-	-	-	7	36.84
16	46	4	1	1	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	10	21.74
17	35	1	-	2	1	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	8	22.86
18	37	-	1	2	1	-	-	-	1	2	1	-	-	-	-	-	-	-	-	1	9	24.32
19	9	2	-	-	-	-	1	2	-	1	-	-	-	-	-	-	-	-	-	-	6	66.67
20	55	-	1	1	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	5	9.09
21	62	1	1	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	4	6.45
22	124	2	-	-	4	-	3	2	1	2	-	-	-	-	-	-	-	-	-	2	16	12.90
23	37	3	-	-	1	2	-	-	-	3	-	-	-	-	-	-	-	-	-	3	12	32.43
24	98	8	-	1	2	1	1	-	1	2	-	-	-	-	-	-	-	-	-	2	18	18.37
25	45	6	2	-	1	-	1	2	1	3	1	1	2	-	-	-	1	-	1	1	23	51.11
26	95	3	-	-	1	1	1	-	-	2	-	1	-	-	-	-	-	-	-	-	9	9.47
27	111	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	2	1.80
28	249	11	1	-	-	-	7	-	1	4	2	-	1	-	-	-	-	-	2	2	31	12.45
29	111	2	1	1	-	-	4	3	1	1	-	-	-	-	-	1	-	-	-	1	15	13.51
30	135	3	3	-	2	-	-	1	1	3	1	-	-	-	-	-	-	-	1	2	17	12.59
31	372	8	1	-	1	-	6	-	2	6	2	1	1	-	-	-	-	1	-	3	32	8.60
32	149	-	-	-	1	1	1	1	1	-	-	-	1	-	-	-	-	-	-	-	6	4.03
33	306	1	2	1	1	-	3	2	-	-	1	1	-	2	-	-	-	-	-	-	14	4.58
34	98	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1.02
35	22	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4.55
36	20	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5.00
37	55	2	-	-	-	-	-	1	1	-	-	-	-	1	-	-	-	-	-	-	5	9.09
38	44	-	-	1	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	5	11.36

39	208	4	3	-	1	-	-	-	-	2	2	-	-	1	-	-	-	-	-	-	13	6.25
40	106	3	-	-	2	-	-	-	-	1	-	1	-	-	-	1	-	-	1	3	12	11.32
41	132	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	4	3.03
42	54	-	-	1	1	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	4	7.41
43	185	-	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	2.70
44	12	1	-	1	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	4	33.33
45	152	1	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	3	1.97
46	18	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	16.67
47	29	-	1	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	4	13.79
48	53	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5.66
49	75	-	-	6	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	7	9.33
50	62	1	-	1	-	1	-	-	-	-	1	-	-	1	-	2	-	-	-	-	7	11.29
51	21	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	4.76
52	75	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2.67
53	30	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	6.67
54	34	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2.94
55	10	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	10.00

Source: Data collected by the author based on questionnaire in 2001 and 2002

Table 9.6: Micro-geographic appraisals of noise distribution

LEGEND:

			Zone	Z
Mode Noise dB(A)	Working Day	Mornings	Minimum	C1
			Maximum	C2
			Range	C3
			Mean	C4
			Standard Deviation	C5
		Afternoons	Minimum	C6
			Maximum	C7
			Range	C8
			Mean	C9
			Standard Deviation	C10
		Evenings	Minimum	C11
			Maximum	C12
			Range	C13
			Mean	C14
			Standard Deviation	C15
	Weekend	Mornings	Minimum	C16
			Maximum	C17
			Range	C18
			Mean	C19
			Standard Deviation	C20
		Afternoons	Minimum	C21
			Maximum	C22
			Range	C23
			Mean	C24
			Standard Deviation	C25
		Evenings	Minimum	C26
			Maximum	C27
			Range	C28
			Mean	C29
			Standard Deviation	C30
	Weekly	Averages	Minimum	C31
			Maximum	C32
			Range	C33
			Mean	C34
			Standard Deviation	C35

		Zone	Z
Peak Noise dB(A)	Working Day Mornings	Minimum	C36
		Maximum	C37
		Range	C38
		Mean	C39
		Standard Deviation	C40
	Working Day Afternoons	Minimum	C41
		Maximum	C42
		Range	C43
		Mean	C44
		Standard Deviation	C45
	Working Day Evenings	Minimum	C46
		Maximum	C47
		Range	C48
		Mean	C49
		Standard Deviation	C50
	Weekend Mornings	Minimum	C51
		Maximum	C52
		Range	C53
		Mean	C54
		Standard Deviation	C55
	Weekend Afternoons	Minimum	C56
		Maximum	C57
		Range	C58
		Mean	C59
		Standard Deviation	C60
	Weekend Evenings	Minimum	C61
		Maximum	C62
		Range	C63
		Mean	C64
		Standard Deviation	C65
	Weekly Averages	Minimum	C66
		Maximum	C67
		Range	C68
		Mean	C69
		Standard Deviation	C70

Z	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	C35
1	79.6	84.7	5.1	82.8	0.9	73.2	79.5	6.2	76.9	1.0	80.5	85.1	4.5	83.5	0.9	74.2	81.4	7.2	78.6	1.3	65.2	73.7	8.4	70.2	1.4	75.2	82.3	7.0	79.6	1.2	76.1	80.0	3.9	78.6	0.7
2	81.3	85.1	3.8	83.3	0.8	75.4	81.2	5.8	78.0	1.1	82.3	88.9	6.6	85.2	1.1	75.2	81.5	6.3	78.5	1.5	66.0	73.6	7.6	70.5	1.4	75.7	83.1	7.4	79.4	1.6	77.3	81.1	3.9	79.2	0.9
3	78.4	84.7	6.3	82.6	1.4	72.6	80.1	7.5	77.1	1.5	79.9	88.8	8.9	84.4	2.0	74.3	80.1	5.9	77.5	1.3	65.1	73.9	8.8	70.2	1.7	75.2	81.0	5.8	78.3	1.3	75.6	80.2	4.5	78.3	1.2
4	78.2	83.6	5.3	81.5	1.1	72.5	80.1	7.6	75.8	1.5	79.4	87.2	7.8	82.5	1.6	74.4	80.2	5.8	77.6	1.4	69.0	75.6	6.7	72.0	1.4	75.0	81.5	6.5	78.5	1.4	75.4	80.6	5.3	78.0	1.1
5	77.9	84.8	6.9	82.0	1.1	71.8	79.8	7.9	76.2	1.6	76.4	86.6	10.2	82.5	2.1	71.5	81.6	10.0	77.4	1.8	63.3	74.0	10.8	69.7	2.2	72.8	82.4	9.6	78.4	1.7	72.4	80.2	7.8	77.6	1.5
6	65.3	82.9	17.6	77.6	3.6	58.9	78.6	19.6	71.5	3.9	65.8	84.0	18.2	79.1	3.6	64.0	80.4	16.4	74.7	3.7	52.6	72.6	20.0	66.8	3.8	65.2	82.3	17.2	76.1	3.7	62.2	79.3	17.1	74.3	3.5
7	81.2	83.6	2.4	82.6	0.5	76.0	78.8	2.8	76.9	0.3	81.5	84.9	3.3	83.1	0.5	76.4	80.6	4.2	78.5	0.7	67.7	72.1	4.4	70.1	0.7	77.4	81.5	4.1	79.5	0.7	77.2	79.3	2.2	78.5	0.4
8	77.6	82.7	5.1	80.9	1.3	69.2	76.9	7.7	74.7	2.0	78.0	84.5	6.5	82.5	1.6	72.5	78.4	5.9	76.1	1.5	67.7	69.9	2.2	69.0	0.4	73.5	79.4	5.9	77.1	1.5	73.9	78.4	4.5	76.8	1.1
9	82.2	83.4	1.2	82.9	0.3	76.3	77.8	1.5	77.0	0.3	83.1	84.6	1.5	84.0	0.2	77.1	79.1	1.9	78.3	0.4	67.6	70.4	2.8	69.4	0.7	78.3	80.0	1.7	79.3	0.4	77.8	79.1	1.3	78.5	0.3
10	82.8	84.1	1.3	83.4	0.2	77.1	79.2	2.1	77.9	0.4	83.3	85.4	2.2	84.5	0.5	78.3	80.2	1.8	78.9	0.4	69.6	71.5	1.9	70.6	0.4	79.1	81.3	2.2	79.7	0.4	78.5	80.3	1.8	79.2	0.4
11	70.6	85.0	14.4	80.8	3.0	66.9	81.2	14.2	75.5	3.4	72.6	87.5	14.8	81.6	3.5	63.7	81.4	17.7	75.7	3.5	57.0	74.2	17.2	66.8	3.9	64.0	83.1	19.1	76.8	3.7	67.1	81.1	14.0	76.2	3.3
12	74.1	83.9	9.8	80.8	2.1	70.4	78.7	8.4	75.8	1.7	76.4	87.6	11.2	83.0	2.1	68.3	79.6	11.3	76.0	1.9	61.1	71.9	10.9	67.8	2.6	68.8	80.5	11.7	76.9	2.0	70.1	79.7	9.5	76.7	1.9
13	74.5	84.3	9.8	80.5	2.0	69.2	80.3	11.1	75.0	2.5	73.9	86.8	12.9	81.8	2.7	71.3	81.5	10.2	76.5	2.2	66.1	77.3	11.3	71.2	2.4	72.3	83.0	10.7	77.6	2.2	71.4	81.6	10.2	77.1	2.2
14	66.3	81.1	14.8	74.7	4.2	59.5	77.4	18.0	68.5	4.2	65.5	84.3	18.8	74.6	4.5	60.3	76.8	16.5	69.4	5.0	51.9	72.9	21.0	63.0	6.3	60.5	78.4	17.9	70.4	5.2	61.5	77.7	16.2	70.1	4.7
15	67.6	83.8	16.2	78.1	2.6	62.1	78.0	15.9	72.0	2.9	69.5	84.3	14.8	78.2	3.0	64.5	77.9	13.4	73.0	2.3	55.0	71.0	16.0	64.3	3.0	64.7	78.7	14.0	74.1	2.4	65.3	77.7	12.4	73.3	2.2
16	61.9	78.0	16.1	67.6	4.5	54.9	71.8	16.8	61.9	4.3	60.5	77.5	17.0	69.2	4.5	59.9	71.8	11.9	64.7	3.2	47.4	66.9	19.4	55.9	4.5	60.9	73.1	12.2	65.7	3.1	58.5	72.6	14.0	64.3	3.8
18	77.8	85.4	7.6	82.0	1.6	70.9	84.7	13.8	76.4	2.0	79.2	91.3	12.1	85.0	2.2	71.8	81.2	9.4	76.7	1.7	60.2	71.4	11.1	66.1	2.2	72.8	82.9	10.1	77.9	1.9	72.6	81.9	9.3	77.3	1.6
19	70.5	82.4	12.0	77.3	2.6	62.5	77.5	15.0	70.6	3.0	66.6	83.8	17.1	77.7	3.5	65.2	77.9	12.6	73.0	3.2	58.4	71.2	12.8	65.4	3.1	66.1	79.3	13.1	74.1	3.3	65.9	78.1	12.2	73.1	3.0
20	70.5	84.2	13.7	79.9	3.2	62.7	79.4	16.7	73.8	3.6	66.7	85.5	18.7	80.1	3.8	65.2	81.9	16.7	75.4	4.0	58.2	75.2	16.9	66.8	4.1	66.1	83.7	17.6	76.6	4.1	66.0	80.4	14.4	75.4	3.6
21	81.1	85.8	4.7	83.8	0.9	75.7	81.0	5.3	78.5	1.0	82.7	91.7	9.0	86.7	1.9	76.0	82.9	6.9	79.6	1.5	66.7	72.4	5.7	70.0	0.9	77.3	84.7	7.4	80.8	1.7	76.8	81.5	4.8	79.8	0.9
22	77.4	83.3	6.0	80.5	1.5	71.4	79.0	7.6	75.0	1.7	78.3	86.7	8.5	82.3	2.1	71.5	78.6	7.1	75.2	1.6	63.1	72.3	9.2	68.3	2.5	73.0	79.8	6.8	76.7	1.5	72.5	79.5	6.9	76.3	1.7
23	75.7	82.3	6.7	77.9	1.0	67.2	77.0	9.8	72.1	1.3	73.2	84.1	10.9	79.0	1.5	69.7	77.5	7.7	72.0	1.6	57.2	69.7	12.5	63.3	2.3	70.9	78.8	8.0	73.6	1.7	69.9	78.0	8.2	72.9	1.2
24	69.7	80.9	11.1	75.5	2.2	62.8	76.7	13.9	70.1	2.8	70.3	86.5	16.2	77.5	3.3	63.7	77.6	13.9	70.9	2.7	53.4	75.2	21.8	63.0	3.6	64.0	78.6	14.6	71.8	2.7	65.9	77.9	12.0	71.5	2.6
25	69.1	79.2	10.1	75.6	3.0	62.9	75.2	12.3	70.6	3.6	68.6	84.4	15.8	77.6	4.3	62.1	77.5	15.4	70.9	4.3	53.3	74.8	21.6	64.1	5.1	62.8	78.5	15.6	71.8	4.3	63.0	76.5	13.5	71.7	4.1
26	69.1	85.2	16.1	79.3	2.8	61.5	78.3	16.8	73.5	3.1	66.5	84.1	17.6	78.7	2.8	61.4	82.6	21.2	73.8	3.2	48.0	74.9	27.0	65.4	3.6	62.3	83.6	21.3	74.7	3.3	61.8	80.0	18.2	74.2	2.9
27	66.7	85.2	18.6	77.0	3.2	62.0	78.3	16.3	70.6	2.8	66.6	84.1	17.5	76.2	2.6	64.4	82.6	18.2	73.0	2.9	55.2	74.4	19.2	65.3	2.9	65.3	83.7	18.4	74.0	2.9	65.7	80.0	14.3	72.7	2.6

28	74.1	83.5	9.3	79.6	1.7	67.7	80.0	12.3	74.6	2.1	74.0	89.9	15.9	81.6	3.0	68.0	80.3	12.4	75.6	1.7	58.8	72.5	13.8	66.4	2.1	68.9	81.3	12.4	76.6	1.6	69.4	79.7	10.3	75.7	1.8
29	65.0	85.6	20.6	81.7	3.4	61.3	82.4	21.2	76.5	4.2	68.8	91.6	22.8	82.5	4.6	63.2	82.3	19.1	76.6	3.2	53.5	73.6	20.1	68.4	3.2	63.3	84.0	20.7	77.6	3.5	63.8	81.5	17.6	77.2	3.4
30	62.6	81.0	18.3	74.5	4.2	54.6	75.8	21.1	66.7	4.2	61.8	84.0	22.2	74.3	4.2	58.6	77.1	18.5	69.8	3.8	44.3	67.7	23.3	60.1	4.7	59.6	77.3	17.8	70.5	3.7	58.1	76.2	18.1	69.4	3.9
31	68.5	84.0	15.5	77.7	2.8	61.8	79.3	17.5	71.6	3.3	70.5	89.6	19.2	79.6	2.7	63.5	79.2	15.8	72.3	3.0	53.2	74.8	21.6	63.8	3.9	64.6	80.3	15.7	73.4	3.1	65.8	79.9	14.1	73.1	2.9
33	71.9	85.0	13.1	78.0	2.7	66.2	79.1	12.9	72.1	2.0	72.0	89.1	17.1	78.8	2.3	66.7	83.0	16.3	74.7	3.3	58.3	74.0	15.7	66.5	3.2	67.6	84.0	16.4	75.7	3.3	68.0	80.5	12.5	74.5	2.7
39	72.9	84.0	11.1	81.5	2.0	67.4	80.0	12.6	75.1	2.1	71.2	87.0	15.8	81.0	2.1	68.0	80.2	12.1	77.2	1.9	58.3	75.0	16.7	70.2	2.7	69.2	82.0	12.8	78.6	1.9	68.7	79.7	11.0	77.3	1.9
40	71.0	80.8	9.8	75.4	2.0	64.1	76.5	12.4	68.7	1.9	67.0	86.3	19.3	75.3	3.5	66.0	80.0	14.0	70.5	2.9	54.9	75.0	20.1	61.0	3.1	66.7	82.0	15.3	71.5	3.1	65.5	78.5	13.0	70.5	2.7
41	68.0	82.2	14.2	72.8	3.1	62.0	80.5	18.5	66.5	3.2	67.0	87.1	20.1	73.5	4.3	64.0	76.6	12.6	66.7	2.5	50.0	71.5	21.5	59.2	4.9	66.0	77.7	11.7	68.0	2.5	63.0	77.9	14.9	67.6	3.1
42	74.1	82.6	8.4	78.1	2.4	66.0	80.8	14.8	70.4	3.6	70.0	86.4	16.4	74.8	4.7	66.0	79.3	13.3	72.8	5.1	63.0	75.2	12.2	65.3	2.5	66.0	80.0	14.0	73.9	5.9	67.7	79.9	12.2	72.5	3.5
43	74.5	83.9	9.4	78.2	1.6	68.2	77.7	9.4	71.9	1.4	72.0	84.6	12.6	78.6	2.1	68.0	79.0	11.0	72.9	1.9	57.8	72.5	14.6	65.0	2.3	68.6	79.5	10.9	73.8	1.7	70.6	78.1	7.5	73.4	1.3
44	60.7	83.1	22.4	72.1	4.9	52.8	76.2	23.4	65.7	5.3	60.6	82.1	21.5	72.3	5.9	52.8	80.7	28.0	65.8	5.7	46.5	68.1	21.7	56.5	5.2	52.8	81.7	28.9	66.6	5.8	55.1	77.9	22.8	66.5	5.3
45	67.4	83.1	15.6	77.1	4.3	62.8	76.8	13.9	71.3	3.4	67.4	86.4	19.1	76.2	4.0	62.3	80.9	18.5	72.6	4.5	54.5	73.0	18.5	63.5	4.4	63.1	81.9	18.8	73.7	4.6	63.7	78.4	14.7	72.4	4.0
46	69.0	83.8	14.8	78.7	2.2	66.0	80.7	14.7	72.3	2.3	69.0	88.1	19.1	78.3	3.2	65.0	80.9	15.9	74.8	2.5	56.0	78.7	22.7	68.3	4.9	66.0	81.1	15.1	75.9	2.3	66.4	80.9	14.5	74.7	2.5
47	68.0	82.0	14.0	78.5	3.6	61.6	78.0	16.4	71.9	3.5	67.6	86.0	18.4	77.1	4.0	60.2	80.0	19.8	73.4	4.9	51.0	80.0	29.0	68.0	6.8	60.8	81.0	20.2	74.3	4.9	62.0	78.7	16.7	73.9	4.2
51	67.0	82.0	15.0	74.0	4.3	58.0	79.0	21.0	68.0	5.7	69.0	88.0	19.0	73.3	3.3	65.0	74.0	9.0	68.7	2.2	59.0	69.0	10.0	62.3	1.8	65.0	74.0	9.0	69.9	3.0	64.0	74.1	10.1	69.2	3.1
52	66.9	81.5	14.6	73.2	3.5	58.0	77.1	19.1	66.3	4.1	60.8	86.3	25.5	73.5	3.9	58.7	78.1	19.4	68.4	3.6	46.5	69.0	22.5	62.1	4.8	59.7	79.0	19.3	69.3	3.5	59.4	77.7	18.3	68.8	3.4
53	65.0	89.0	24.0	75.6	7.2	56.0	79.5	23.5	67.1	6.6	60.0	89.0	29.0	74.4	8.1	55.8	77.0	21.2	65.0	5.5	49.2	71.0	21.8	61.0	6.5	56.8	85.0	28.2	70.9	9.0	57.5	79.5	22.0	69.1	6.9

Z	C36	C37	C38	C39	C40	C41	C42	C43	C44	C45	C46	C47	C48	C49	C50	C51	C52
1	92.0	98.2	6.2	96.1	1.3	84.5	101.9	17.4	94.3	2.0	92.6	96.9	4.3	95.6	0.8	88.4	97.5
2	90.7	97.9	7.2	95.1	1.5	87.1	101.1	14.0	93.6	2.1	91.2	97.6	6.4	94.5	1.4	88.6	97.2
3	88.0	98.3	10.4	93.3	2.1	77.8	102.0	24.2	92.8	3.1	86.3	96.7	10.4	93.2	2.1	88.3	97.5
4	87.9	92.6	4.7	91.0	0.8	68.3	98.0	29.7	89.7	3.2	86.2	93.7	7.6	90.3	1.3	88.9	94.8
5	89.8	97.2	7.4	93.9	1.7	85.3	102.9	17.6	93.9	2.2	89.5	97.7	8.2	94.3	1.7	88.6	97.8
6	87.0	94.9	7.8	91.6	1.7	87.0	96.0	9.0	92.8	1.7	86.5	95.0	8.5	91.9	1.6	80.7	95.6
7	91.1	97.6	6.6	95.3	1.3	90.0	98.3	8.3	94.7	0.8	90.9	96.9	6.0	94.9	1.1	90.2	96.2
8	90.2	95.3	5.2	92.2	1.3	87.0	96.0	9.0	91.8	2.1	86.5	94.7	8.2	90.9	2.1	80.8	92.9
9	92.2	96.5	4.3	95.1	1.0	90.5	95.0	4.6	93.0	1.1	91.6	95.8	4.2	94.4	0.9	88.9	94.2
10	94.0	96.9	2.9	95.9	0.5	92.5	95.6	3.1	94.2	0.6	93.6	96.2	2.5	95.2	0.5	93.1	95.1
11	86.5	95.5	9.1	92.2	1.4	81.0	101.0	20.0	89.7	2.5	83.6	94.7	11.1	91.2	1.9	80.6	97.2
12	86.5	95.5	9.0	91.2	2.1	74.0	94.9	20.9	88.9	2.6	86.1	96.2	10.2	90.7	2.1	84.9	95.7
13	86.3	93.8	7.5	89.5	2.2	85.2	96.9	11.7	90.0	1.7	84.1	93.6	9.5	89.0	2.4	82.7	96.7
14	76.6	91.2	14.6	84.8	3.2	81.0	95.0	14.0	85.1	2.7	73.9	93.7	19.9	84.0	4.3	79.0	92.1
15	78.4	97.4	19.0	89.1	2.5	73.0	101.9	28.9	89.4	3.7	79.2	97.7	18.5	89.3	2.5	78.8	97.0
16	78.4	90.1	11.7	86.9	1.9	78.4	96.0	17.6	90.1	3.1	79.2	91.8	12.6	88.1	2.2	78.8	96.0
18	87.9	94.5	6.6	90.7	1.4	82.0	100.8	18.8	88.3	2.6	87.3	94.8	7.6	90.8	1.4	81.7	92.9
19	82.7	95.2	12.6	89.5	2.7	82.9	98.9	16.1	90.2	1.9	85.0	95.9	10.9	90.1	2.4	85.1	97.1
20	82.6	95.8	13.1	91.1	2.9	82.1	99.8	17.7	91.3	2.2	84.9	95.4	10.4	91.2	2.4	85.1	97.5
21	91.7	96.0	4.3	93.4	0.7	88.1	100.9	12.8	93.5	1.5	91.3	98.2	6.9	93.8	1.3	94.6	99.2
22	89.5	96.1	6.7	93.3	1.3	89.4	96.1	6.7	93.6	1.7	89.4	96.9	7.5	94.0	1.7	88.3	96.5
23	87.1	97.9	10.8	92.9	2.1	82.9	101.0	18.1	91.5	1.7	85.4	98.4	13.0	92.4	2.5	86.8	93.9
24	85.1	97.7	12.6	91.1	2.1	80.0	100.0	19.9	89.7	2.8	83.5	98.4	14.9	91.2	2.9	80.6	99.2
25	81.1	91.0	9.9	87.2	3.1	81.5	95.5	13.9	87.5	3.6	78.6	91.1	12.5	86.0	3.9	81.7	98.1
26	78.8	96.4	17.7	90.1	1.9	77.3	96.4	19.1	87.3	2.5	77.7	94.7	16.9	88.4	2.3	81.8	100.3
27	76.3	96.6	20.2	88.5	2.8	74.1	100.0	25.9	87.9	2.5	78.7	96.4	17.7	87.5	2.4	78.7	100.4
28	84.6	97.3	12.7	90.5	2.0	82.1	99.0	16.9	90.9	2.3	84.6	97.1	12.5	90.4	2.1	79.6	97.0
29	83.9	99.4	15.5	95.3	2.7	77.0	101.0	23.9	93.6	3.7	84.7	100.8	16.1	95.7	3.0	88.6	99.2

Z	C53	C54	C55	C56	C57	C58	C59	C60	C61	C62	C63	C64	C65	C66	C67	C68	C69	C70
1	9.1	93.7	1.6	91.8	98.0	6.2	95.6	1.1	90.9	97.5	6.5	95.1	1.3	91.8	96.6	4.8	95.1	0.8
2	8.6	93.5	2.1	90.8	98.5	7.7	94.6	1.8	90.0	97.9	7.9	93.7	1.9	91.5	96.7	5.2	94.2	1.4
3	9.1	92.5	1.8	87.8	97.8	9.9	93.2	1.9	87.3	95.4	8.1	91.4	1.6	88.6	96.1	7.5	92.7	1.6
4	5.9	91.8	1.2	87.8	93.0	5.3	91.2	1.0	87.3	91.8	4.5	89.9	0.9	88.4	92.3	3.9	90.7	0.7
5	9.2	93.0	1.6	89.1	96.2	7.1	94.1	1.5	89.1	95.9	6.8	93.2	1.5	89.3	95.6	6.3	93.7	1.4
6	14.9	90.1	2.9	86.6	94.3	7.7	91.8	1.4	86.5	93.9	7.3	91.0	1.3	86.9	93.9	7.1	91.5	1.2
7	6.0	93.5	1.1	92.4	96.8	4.5	95.1	0.9	91.6	97.1	5.5	94.8	1.1	92.0	96.1	4.1	94.7	0.9
8	12.1	88.1	3.3	86.6	94.9	8.3	91.3	2.1	86.5	94.7	8.1	91.0	2.1	86.9	94.4	7.5	90.9	2.0
9	5.3	92.9	1.1	91.7	96.0	4.3	94.6	0.9	91.3	95.7	4.4	94.3	0.9	91.1	95.5	4.4	94.0	1.0
10	2.0	94.2	0.3	94.0	96.6	2.6	95.4	0.5	93.7	96.1	2.4	94.8	0.5	93.5	96.0	2.5	95.0	0.5
11	16.6	91.8	3.2	83.7	95.7	12.0	91.4	2.0	85.0	94.7	9.7	90.2	1.7	84.7	95.0	10.3	91.1	1.8
12	10.8	90.8	1.7	86.4	95.5	9.1	90.8	1.7	86.8	93.3	6.5	89.6	1.3	86.5	94.2	7.6	90.3	1.6
13	14.0	90.2	3.2	85.9	95.0	9.1	89.9	2.4	85.0	93.8	8.8	88.7	2.2	85.9	93.7	7.8	89.5	2.1
14	13.1	85.9	3.3	78.1	92.6	14.4	85.1	3.2	79.9	91.7	11.7	85.7	2.7	78.8	91.9	13.0	85.1	3.1
15	18.3	91.1	2.8	79.5	96.5	16.9	89.7	2.5	80.9	93.0	12.1	89.2	1.8	81.2	95.1	13.9	89.6	2.1
16	17.2	91.4	2.6	79.6	92.3	12.7	89.1	2.2	80.9	91.8	10.9	89.2	2.0	81.2	92.2	11.0	89.2	2.1
18	11.3	88.7	1.8	87.4	95.0	7.6	90.5	1.4	87.3	94.2	6.9	90.1	1.2	87.4	93.3	5.8	89.8	1.1
19	12.0	90.8	2.7	84.8	96.9	12.1	90.4	2.3	85.6	95.0	9.3	90.2	1.9	85.3	95.1	9.7	90.2	2.2
20	12.4	92.8	2.9	84.8	97.7	12.9	92.1	2.6	85.6	95.6	10.0	91.7	2.2	85.3	95.2	9.9	91.7	2.4
21	4.6	96.9	0.8	93.3	96.6	3.2	94.6	0.7	89.7	94.4	4.7	92.3	1.1	92.9	95.9	3.0	94.1	0.6
22	8.2	92.1	2.1	89.8	97.5	7.7	94.5	2.0	89.7	96.3	6.6	93.1	1.7	89.5	96.2	6.8	93.4	1.7
23	7.1	89.6	1.1	87.5	94.9	7.5	92.2	1.4	86.8	92.7	5.9	91.0	1.2	86.9	94.0	7.0	91.5	1.3
24	18.6	93.9	3.1	83.6	98.4	14.7	92.0	2.6	85.0	98.9	14.0	92.4	2.7	84.6	96.2	11.6	91.7	2.3
25	16.4	90.6	5.2	81.1	93.6	12.6	88.0	3.9	82.4	93.1	10.7	88.2	3.5	81.0	93.1	12.1	87.9	3.8
26	18.4	93.3	2.8	78.9	96.4	17.5	89.9	2.3	81.2	96.4	15.2	89.8	2.1	79.5	95.2	15.6	89.8	2.1
27	21.6	90.8	3.4	78.7	97.9	19.1	89.2	2.6	81.5	98.1	16.6	89.6	2.1	80.8	95.9	15.1	88.9	2.2
28	17.4	90.9	3.0	86.1	96.9	10.7	90.9	2.1	86.5	96.5	10.0	90.8	1.8	85.8	96.2	10.4	90.7	1.9
29	10.6	95.4	2.5	84.6	99.9	15.3	95.2	2.9	86.3	99.1	12.8	94.8	2.4	85.5	98.4	12.9	95.0	2.6

30	84.0	93.7	9.7	88.7	1.9	77.5	94.0	16.5	87.0	2.0	82.3	94.9	12.6	87.9	2.5	79.2	96.5	17.4	87.1	3.2	83.0	94.1	11.2	87.9	2.3	84.6	93.6	9.0	88.8	1.7	84.1	93.0	8.9	87.9	2.0
31	83.2	95.7	12.5	90.5	2.0	78.0	100.0	22.0	90.7	2.1	83.5	98.0	14.5	91.0	2.1	81.8	97.3	15.5	91.4	2.5	82.9	98.8	15.9	91.3	2.1	85.0	98.0	13.0	91.5	1.6	84.9	96.0	11.1	91.1	1.8
33	84.0	96.5	12.5	88.9	2.9	77.0	100.0	23.0	87.0	3.7	82.0	95.9	13.9	88.4	3.2	80.0	95.4	15.4	88.9	3.3	81.0	97.0	16.0	88.9	3.3	84.0	96.6	12.6	89.9	2.6	81.3	94.3	12.9	88.4	3.2
39	83.2	92.8	9.6	90.8	1.0	80.0	92.7	12.7	87.7	2.6	84.9	92.3	7.4	88.9	1.0	81.0	100.0	19.0	89.7	3.2	85.0	94.2	9.2	89.5	1.7	86.0	94.0	8.0	90.1	1.5	84.8	94.0	9.2	89.4	1.7
40	77.5	94.0	16.5	86.1	3.6	70.0	92.0	22.0	83.8	5.7	74.2	94.0	19.8	85.5	4.0	76.3	99.0	22.7	88.1	3.7	75.3	94.0	18.7	86.0	4.0	78.5	94.0	15.5	87.3	3.3	75.9	92.6	16.6	86.2	3.9
41	72.0	99.3	27.3	82.7	5.6	70.0	94.6	24.6	82.6	4.7	68.0	96.0	28.0	80.1	6.3	67.0	96.7	29.7	79.5	6.7	71.0	96.7	25.7	81.3	5.6	75.0	96.1	21.1	83.6	4.6	71.3	95.5	24.1	81.5	5.6
42	85.0	100.1	15.1	88.1	3.4	78.0	102.0	24.0	86.2	6.9	82.0	96.7	14.7	85.6	4.2	83.5	98.2	14.6	88.4	2.9	83.0	98.3	15.3	86.9	4.1	85.0	97.4	12.4	88.1	3.4	83.5	97.5	14.0	87.2	3.9
43	82.0	94.1	12.1	87.1	2.2	75.0	100.0	25.0	86.3	2.9	81.8	93.8	11.9	86.5	1.9	83.9	97.1	13.2	89.7	2.4	82.5	95.6	13.1	87.6	2.2	84.4	95.1	10.6	88.6	1.8	83.5	93.1	9.7	87.6	2.0
44	70.6	89.6	19.0	80.2	4.4	70.0	89.6	19.6	80.0	4.4	67.8	88.7	20.9	79.3	4.9	68.0	92.5	24.5	82.3	5.7	69.7	88.7	19.0	80.6	4.7	73.6	89.7	16.1	82.9	3.9	70.6	88.7	18.1	80.9	4.5
45	74.3	95.5	21.3	85.5	5.3	73.3	101.0	27.7	85.0	6.3	73.7	96.4	22.7	84.4	5.5	76.7	100.0	23.3	87.4	5.0	74.9	99.1	24.2	86.0	5.8	78.0	98.2	20.2	87.2	4.8	76.0	96.8	20.8	86.0	5.2
46	75.0	99.9	24.9	90.7	2.4	75.0	98.4	23.4	90.3	3.2	75.0	96.5	21.5	90.7	2.6	79.0	100.0	21.0	94.5	3.1	76.0	97.8	21.8	92.3	2.9	79.0	97.0	18.0	92.2	2.3	78.2	95.9	17.8	91.7	2.4
47	79.9	92.2	12.3	90.2	3.1	81.0	97.0	16.0	90.1	4.0	77.5	93.2	15.7	89.6	4.1	80.4	100.0	19.6	95.5	5.5	80.0	95.2	15.2	91.6	4.1	81.4	94.2	12.8	91.2	3.5	80.4	94.7	14.3	91.3	4.0
51	80.0	103.0	23.0	90.9	6.3	83.4	101.0	17.6	91.8	5.0	83.0	99.0	16.0	87.6	5.9	84.0	98.0	14.0	88.3	5.4	84.7	100.0	15.3	89.7	5.3	86.0	98.0	12.0	90.1	4.1	84.8	99.8	15.0	89.8	5.1
52	77.1	103.0	25.9	91.9	5.8	76.8	101.0	24.2	91.2	5.4	76.2	101.0	24.8	91.8	6.8	78.2	102.0	23.8	93.7	5.7	77.6	102.0	24.4	93.2	6.2	80.5	100.0	19.5	92.7	5.0	78.0	99.8	21.8	92.5	5.3
53	75.5	92.0	16.5	83.3	4.9	73.6	95.0	21.4	82.8	4.8	75.6	96.0	20.4	83.9	5.2	76.3	97.1	20.8	84.4	5.5	76.0	93.6	17.6	83.5	5.1	79.0	93.0	14.0	84.8	4.0	76.7	93.2	16.5	83.9	5.0

Table 9.7: Polluted Zone (by rank summation method)

Analysis Zone	Rank
Chakiwara, Kalakot	1
Ranchore Line & Ramsawami	2
Juna Market, Old Town area	3
Nawabad, Baghdadi Lane, Kharadar	4
Lea Market, Gul Mohammad Lane	5
Rizvia, Firdous Colony, Golimar	6
Saddar & Artillery Maidan	7
Civil Lines Area	8
I.I. Chundrigar Road & New Queens Road	9
Shershah, S.I.T.E. (part)	10
Korangi (Part)	11
Nazimabad, Paposhnagar	12
Naval Hospital, JPMC and Liaquat Barracks	13
Agra Taj, Bihar Colony	14
Lines Area & Khudadad Colony	15
Liaquatabad	16
Garden, Soldier Bazaar, Jamshed Quarters	17
F.C. Area and Mansoora	18
Asif, Pak Colony & T.P.I.	19
Korangi Industrial Area – East	20
Orangi, Metroville-I	21
Drigh Cantonment, 9th Mile	22
Port Area	23
Korangi Industrial Area – West	24
Gizri Area, Delhi Colony	25
Model and Malir Colonies	26
S.I.T.E. (Sindh Industrial Trading Estate)	27
North Karachi	28
Gulshan-e-Iqbal (part), P.I.B. Colony	29
Gulshan-e-Iqbal, National Cement Factory	30
Shah Latif, Deh Khanto	31
Drigh Colony & Malir	32
Akhtar & Baloch Colony, Chanesar Goth	33
Gulshan-e-Iqbal, Chandni Chowk, Society Area	34
Landhi Colony	35
Bath Island, Frere Town, Defense Society (part)	36
Defence Society	37
North Nazimabad	38
Malir Cantonment	39
Scheme 33	40
Landhi Industrial, Scheme 3 & 4	41
Karachi Airport	42
Clifton	43

Micro Geographic Appraisals
Polygonal Averages of Noise Intensities
Working Day Mornings: mode

Figure 9.2

Micro Geographic Appraisals
Polygonal Averages of Noise Intensities
Working Day Afternoons: mode

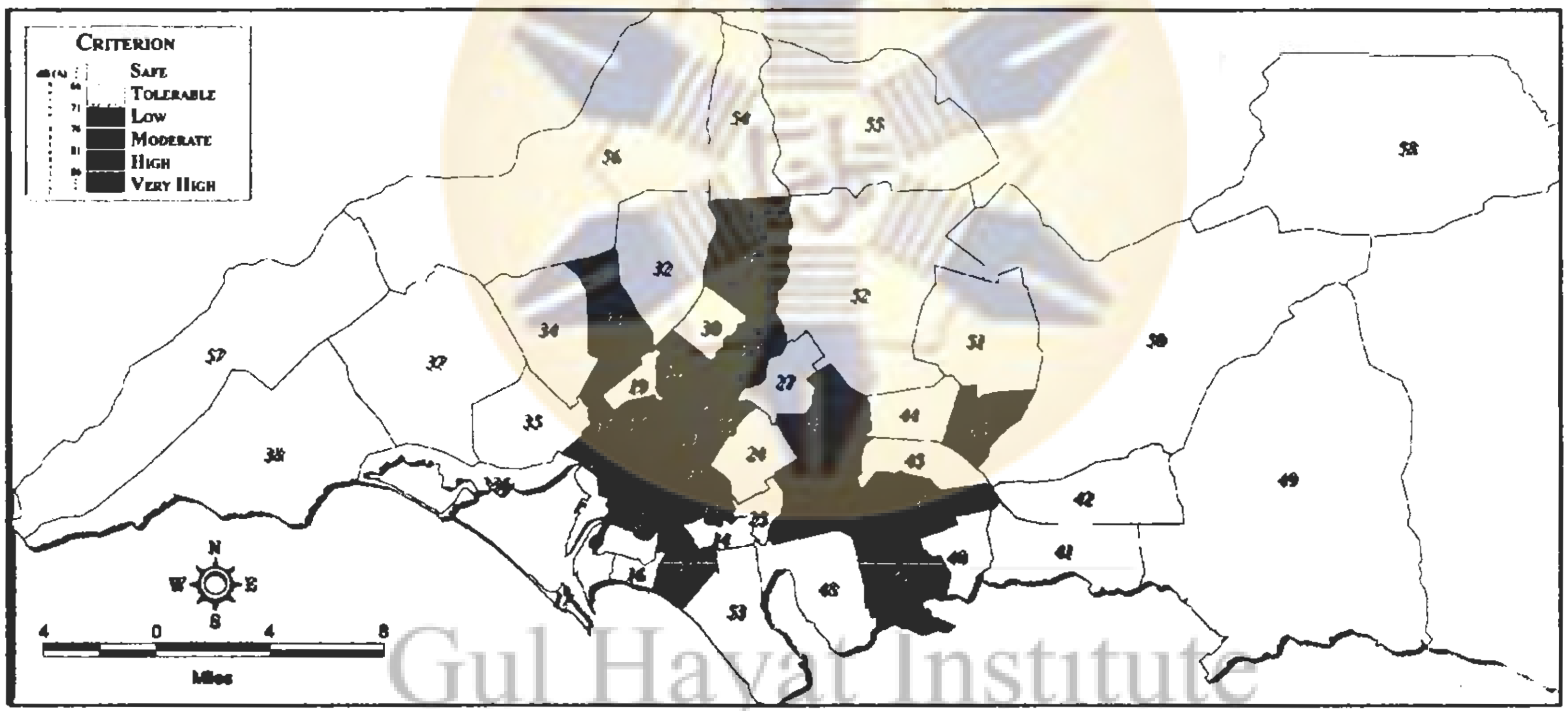


Figure 9.3

Micro Geographic Appraisals
Polygonal Averages of Noise Intensities
Working Day Evenings: mode

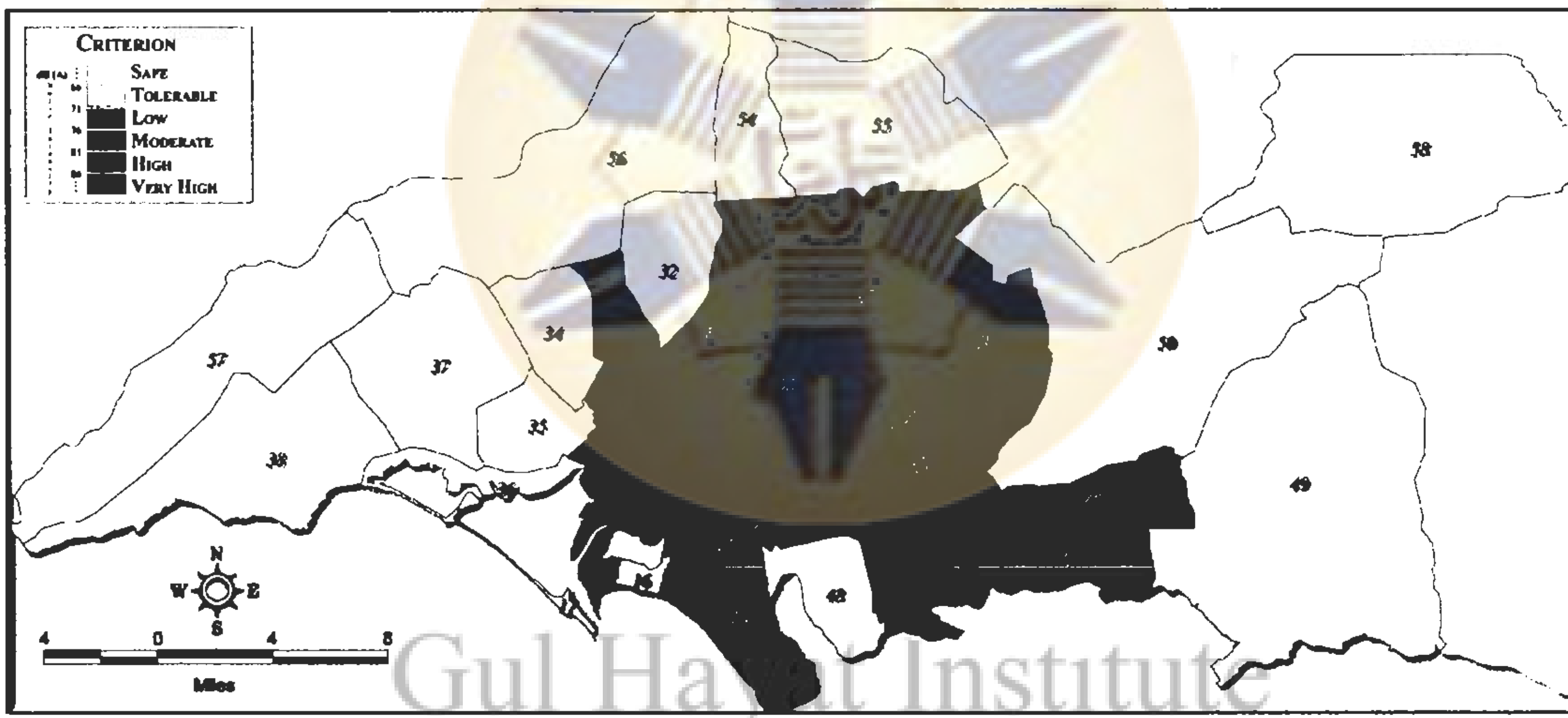


Figure 9.4

Micro Geographic Appraisals
Polygonal Averages of Noise Intensities
Weekend Mornings: mode

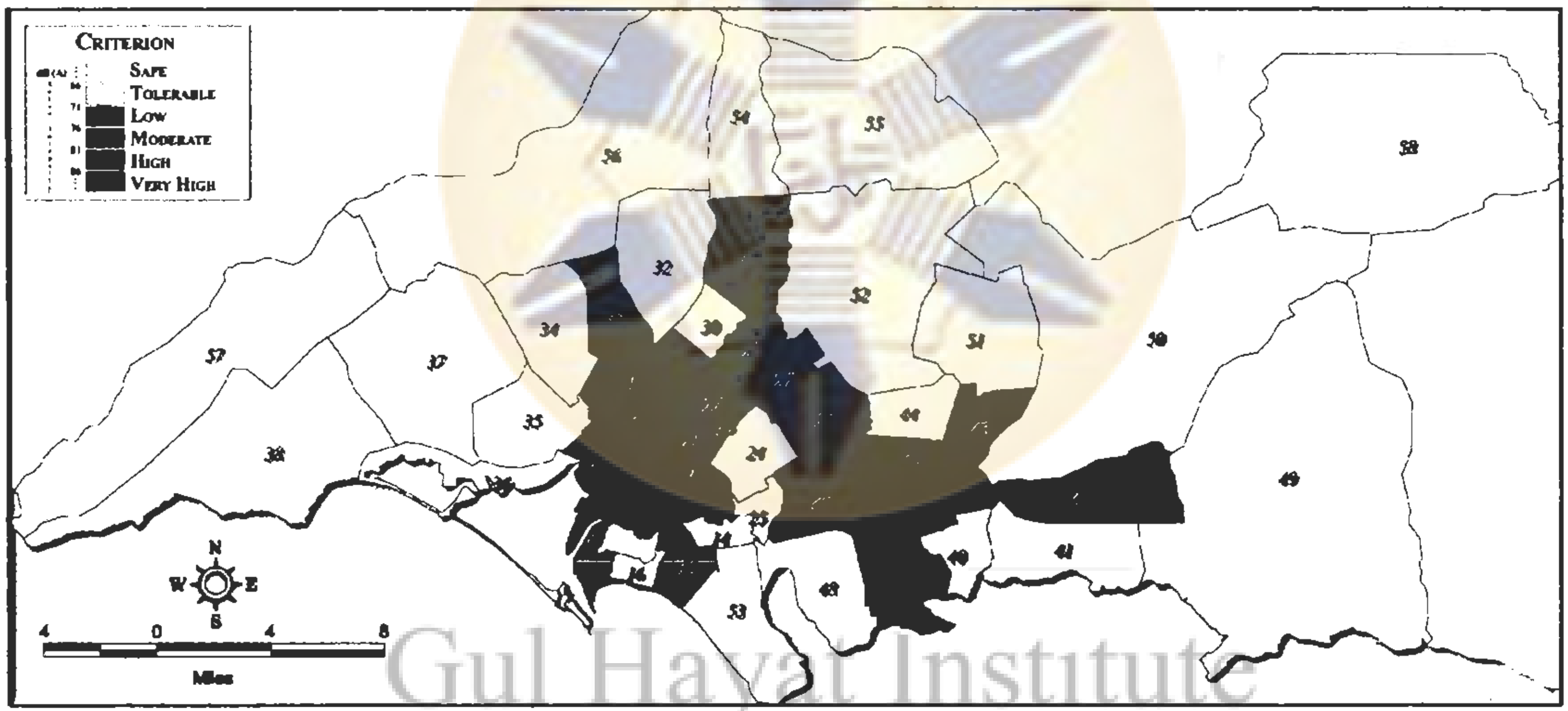


Figure 9.5

Micro Geographic Appraisals
Polygonal Averages of Noise Intensities
Weekend Afternoons: mode

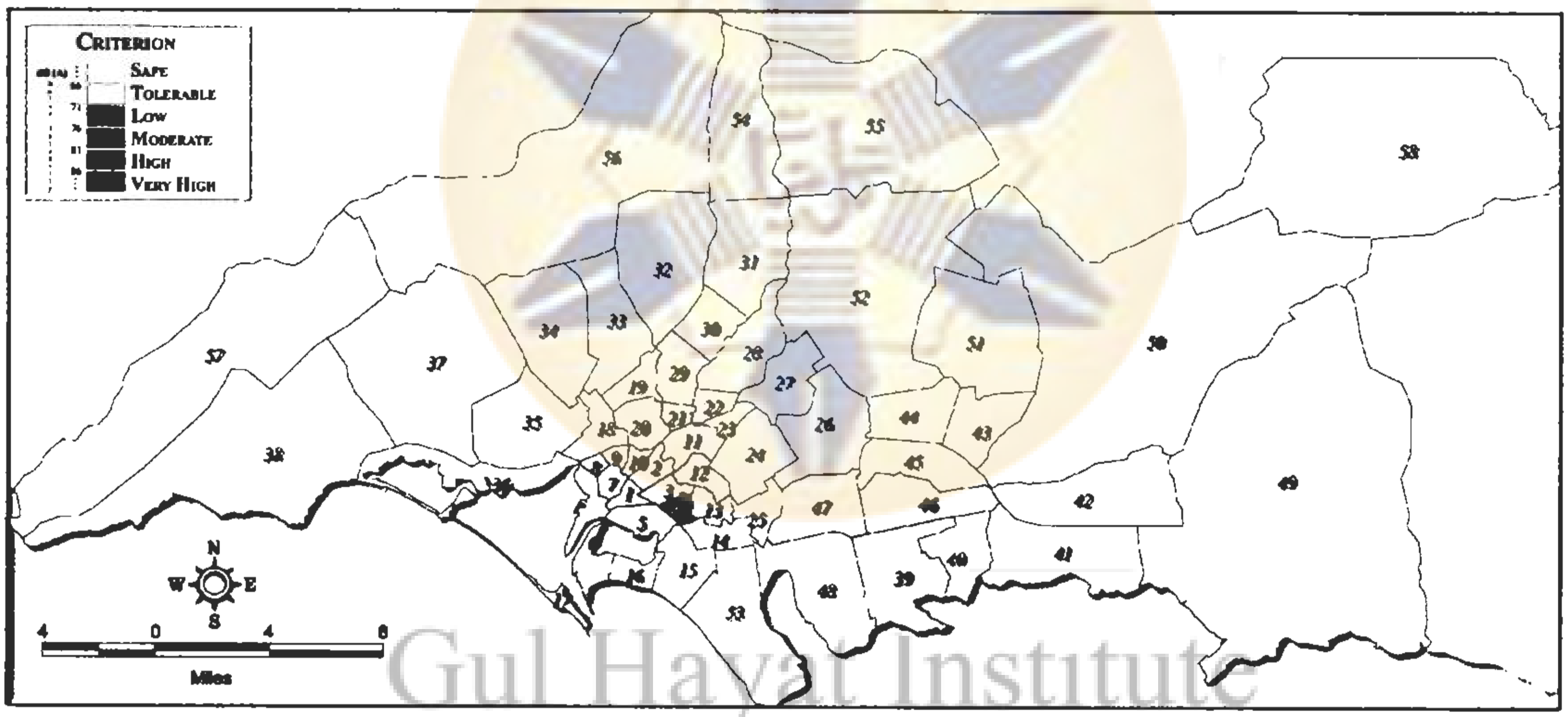


Figure 9.6

MICRO GEOGRAPHIC APPRAISALS
POLYGONAL AVERAGES OF NOISE INTENS
WEEKEND EVENINGS: MODE

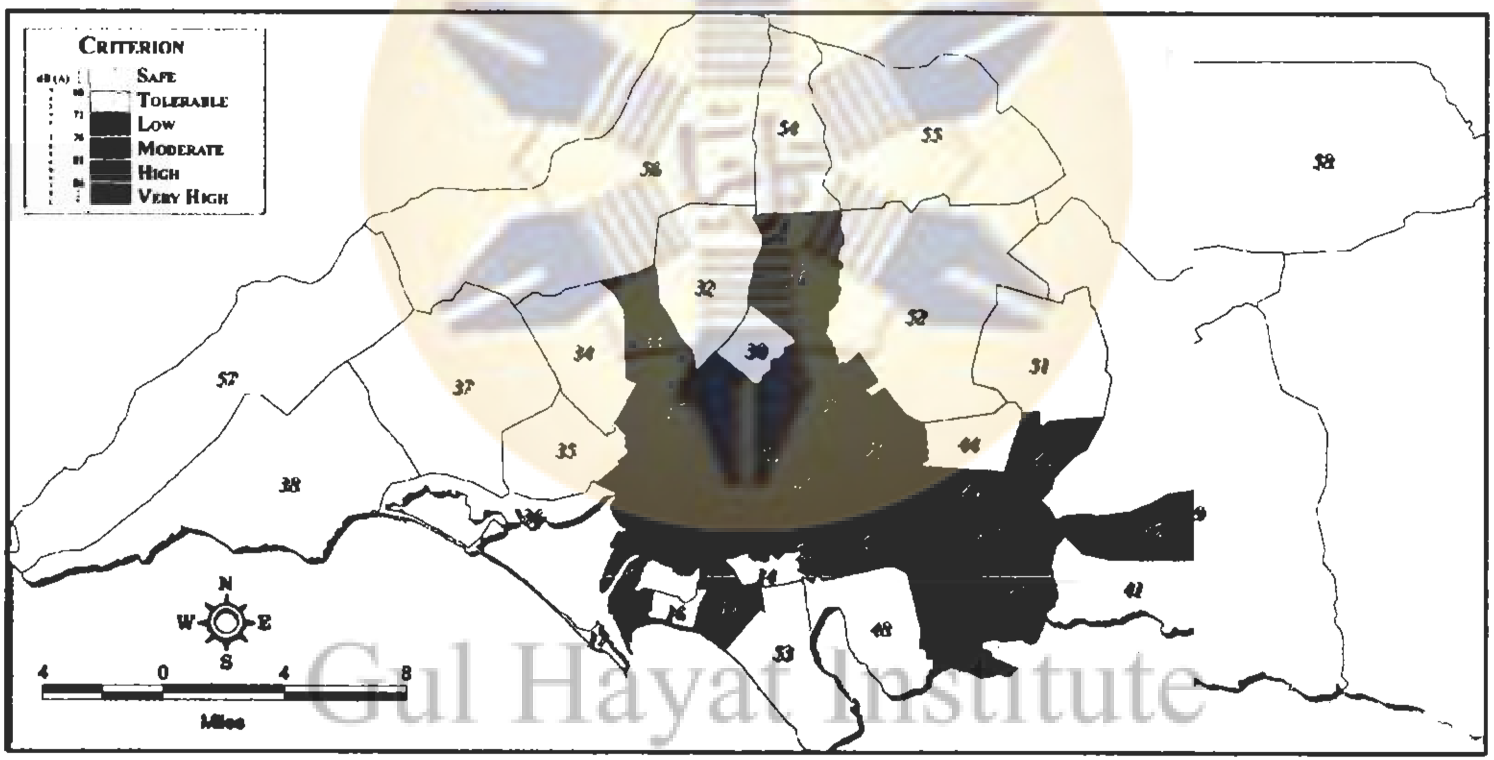


Figure 9.7

Micro Geographic Appraisals
Polygonal Averages of Noise Intensities
Weekly Averages: mode

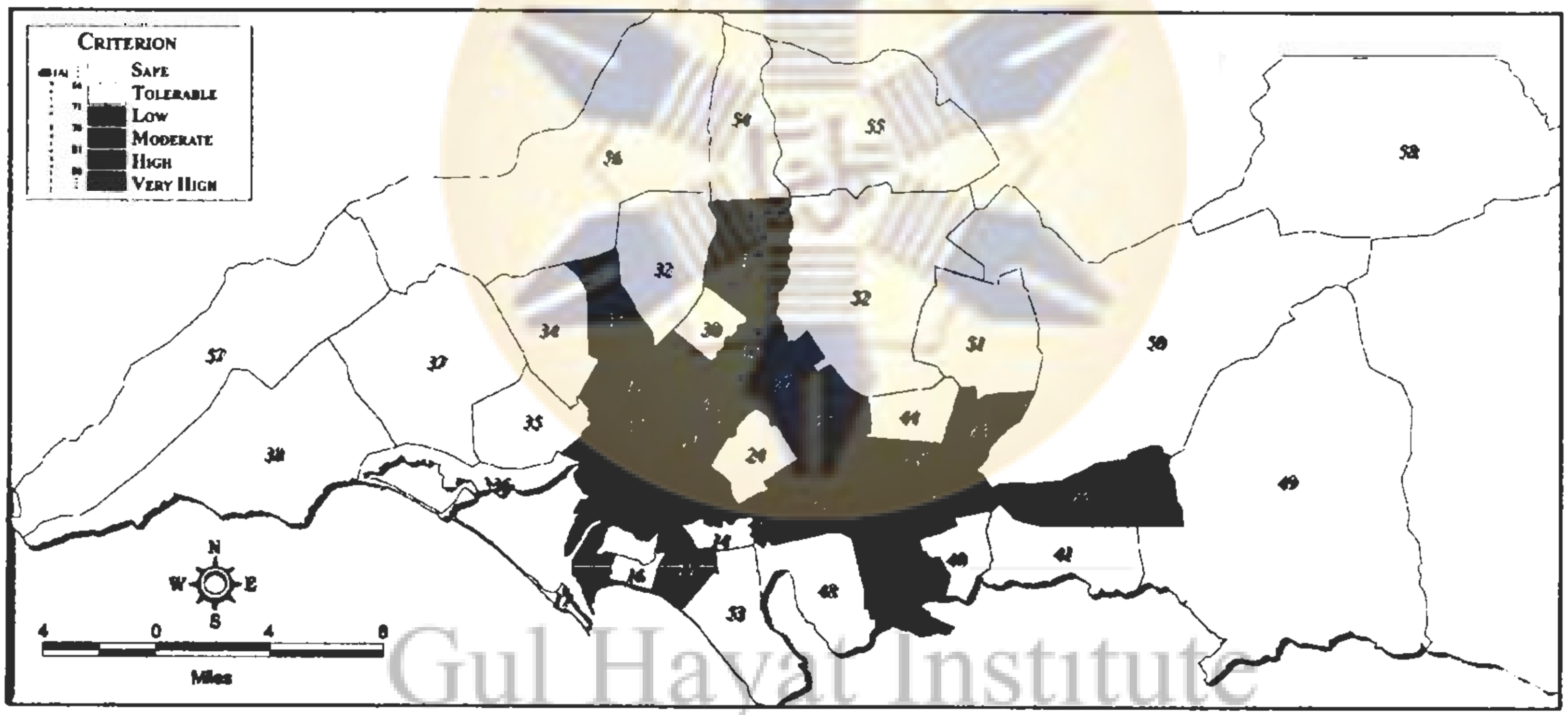


Figure 9.8

9.4 ZONAL SYNOPSIS

Area:

Largest : Steel Mill and Port Qasim (Zone # 49)

Smallest : Agra Taj, Bihar Colony (Zone # 08)

Population density:

Highest : Chakiwara, Kalakot (Zone # 10)

Lowest : Dehs in the West along Hub River (Zone # 57)

Noise:

Most Noisy : Chakiwara, Kalakot (Zone # 10)

Most Calm : Clifton (Zone # 16)

Disease prevalence:

Highest : Saddar & Artillery Maidan (Zone # 03)

Lowest : Baldia (Zone # 34)

Disease occurrence

Highest : Saddar & Artillery Maidan (Zone # 03)

Frequent Diseases:

Headache, Stress, Hypertension

Share of Densely Built-up Land cover

High : Juna Market, Old Town area (Zone # 01)
Nawabad, Baghdadi Lane, Kharadar (Zone # 07)
Lea Market, Gul Mohammad Lane (Zone # 09)

Concurrence of Military (land use) with Vegetation (land cover):

Highest : Masroor (Mauripur) (Zone # 35)

10. RISK ASSESSMENT

Today, available Geographic Information Systems offer unique opportunities to tackle more efficiently and effectively problems traditionally associated with data handling and analysis. The ultimate aim of GIS is to support spatial decision-making (Malczewski, 1999). GIS play a vital role of spatial decision-making by storing and managing a large amount of spatial data and information in both engineering and non-engineering organizations.

RISK evaluations usually require making decisions among multiple factors. GIS furnishes innovative statistical and mathematical modeling techniques. It supports a wide range of advanced functions, such as *auto-correlation, spatial interactions, location-allocation, simulation,* and *decision analysis* (Cliff and Ord, 1973; Amrhein, 1985; Anselin and Getis, 1992; Fotheringham and Rogers, 1994; Altman, 1994).

There are two methods commonly practiced to accomplish this task in GIS: a simple *overlay* and the more complicated *Multi Criteria Evaluation* (MCE). Overlay can only combine deterministic digital map information to define areas simultaneously satisfying two or more specific criteria (Carver, 1991). The integration of MCE into GIS has attracted much attention (Carver, 1991; Pereira and Ducktein, 1993; Heywood *et al.*, 1995; Jankowski, 1995). Conventional technique largely assumes spatial homogeneity within the study area (Malczewski, 1999). In the real world situation this assumption is not realistic because attributes vary across space. It is well known that the spatial data in GIS usually have properties that are difficult to handle by traditional methods, such as inaccuracy, multiple measurement scales, and interdependency among factors. Methods require prior knowledge to identify all relevant criteria, assign scores, determine the criterion preference, and select the aggregation function.

The application of digital map overlay for the purpose of identifying suitable areas is a classic application of GIS. In *raster* GIS, for example in IDRISI or in ArcView (Eastman, 1995; Lee and Wang, 2001), a suitability map is produced from a series of *Boolean* images, where each image represents all areas meeting the criterion being depicted. These images are then combined using the overlay combination procedure to yield a final map that shows the sites meeting all the specified criteria. However, overlays have limitations when dealing with information of a non-deterministic nature (Carver, 1991).

The methods for criterion importance determination and aggregation can be classified into *compensatory* and *non-compensatory* (Hwang and Yoon, 1981; Minch and Sanders, 1986; Jankowski, 1995). In a compensatory method, the high performance of an alternative achieved on one or more criteria can compensate for the weak performance of the same alternative on other criteria. *Weighted summation* is such a method (Bernhardsen, 1999). Other compensatory methods include *concordance analysis, analytical hierarchy process,* and *ideal point.* Non-compensatory techniques are the stepwise reduction of the set of alternatives without trading off their deficiencies along some evaluation measures for their strengths along other criteria.

The hypothesis formulated earlier in this study falls within the broad class of MADM (*multi-attribute decision making*). A framework for GIS based *multi-attribute decision analysis* was felt inevitable for this research.

10.1 SOURCES AND QUALITY OF DATA

The input overlays (maps) are listed below:

- *Land- cover Classification Grid **(LCCG)***
- *Population Density Grid **(PDG)***
- *Averages of Noise Mode Grid **(ANMG)***
- *Averages of Noise Peak Grid **(ANPG)***
- *Disease Prevalence Grid **(DPG)***
- *Disease Occurrence Grid **(DOG)***
- *Roads Buffers Grid **(RBG)***
- *Road Density Index Grid **(RDIG)***
- *Standard Deviation of Noise Mode Grid **(SDNMG)***
- *Standard Deviation of Noise Peak Grid **(SDNPG)***

There were some other maps (overlays) that could have been also used as input maps for this *multi-attribute analysis.* The author restricted his selection of input maps based on the sources and quality of information. It was tried utmost that the maps generated from consistent or primary sources be selected.

The land cover classification gird had been generated through the satellite imagery; population density overlay was produced by incorporating the census data into a GIS. Grids pertaining to noise pollution were basically interpolated surfaces of the primary data collected in the field, the two (2) disease maps were obtained through the instrument of 'questionnaire' filled by city dwellers while the grids related to road network were in fact the products of GIS based analytical techniques.

10.2 METHODOLOGY

Enquiries of complex spatial phenomena begin with a set of data and notions of hypotheses and theories. 'Factor analysis' may be used as a data reduction method, to reduce a dataset containing a large number of variables down to more manageable size. When many of the original variables are highly correlated, it is possible to reduce the original data from a large number of original variables to a small number of underlying factors (Foster, 2000). Miles (1998) has annotated an example of factor analysis using SPSS for a study in Human Psychology. Kazmi (1996) performed factor analysis (PCA) for investigation of the resurgence of Malaria in Pakistan.

Principal component analysis (PCA) is a transformation procedure used as a preliminary search procedure to identify variables for further monitoring and analysis (Daultrey, 1976). In this study, Principal Component Analysis (PCA) using SPSS 10.0 was applied to check the significance of the ten above-mentioned parameters and thereof weights for each layer were calculated through Weight Extraction Method. Bernhardsen (1999) has explained that kind of assignment of priority scoring using examples. The flow of weight extraction is illustrated in Figure 10.1.

The procedure of multi-attribute decision analysis (*Annexure C*) employed in a GIS environment for this research, is identical to Stevens, (1999) and can be described as follows:

"A blank overlay template is created which incorporates all of the grids, which are used in this study as components. This template is edited to assign weights and scores. Weights were assigned to each grid (layer) as an indication of the intended contribution of that grid. The scores were assigned to each class in every grid (layer) to define its suitability".

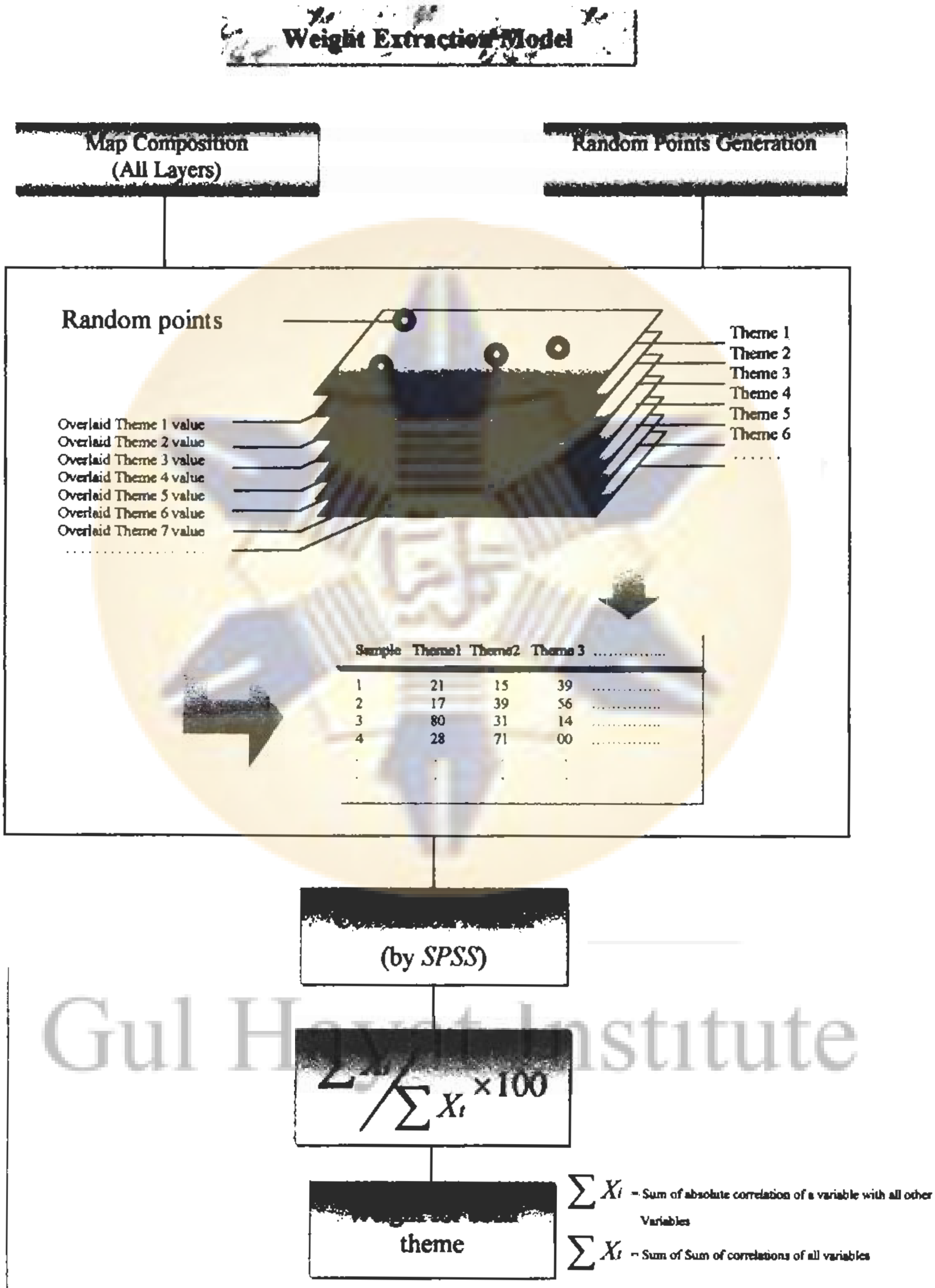


Figure 10.1 Source: Arsalan, 2002

10.3 THE FINDINGS

Most analyses explained in the preceding chapters were performed by taking up one or two variables at a time. Since the success of GIS analysis is inherent in its capabilities of handling multivariate data (Zhou and Civco, 1996), the same has been done in this study. The ultimate risk due to noise pollution in its present form is because of all other variables explained previously.

Exploration of the significance of variables is done through Principal Component Analysis (PCA). Tables 10.1, 10.2 and 10.3 are outcomes of PCA. Commonalities indicate the amount of variance in each variable that is accounted for. Initial communalities are estimates of the variance in each variable accounted for by all components or factors. For principal components analysis, this is always equal to 1.0 or the variance of the variable. Extraction communalities are estimates of the variance in each variable accounted for by the factors (or components) in the factor solution. Very small values indicate variables that do not fit well with the factor solution, and are usually dropped from the analysis. The variables based on noise data (Table 10.1) show highest extraction communalities. Factor analysis communalities indicate the amount of variance in each variable that is accounted for by the factors in the factor solution (Foster, 2000). It was reasonable to get the lowest extraction communality for the grid of road proximity since it was added as a layer in the multi-criteria analysis to acquire justified cartographic results. Further it could be observed from Table 10.2 that component one explains greater than 55 % variance and one and two cumulatively explains greater than 68 % variance. An eigenvalue (sometimes called an eigenfactor) is a measure of how important the factor is in accounting for the variance (Miles, 1998).

Table 10.1: Factor Analysis Communalities

Variables	Initial	Extraction
RBG	1.000	0.299
LCCG	1.000	0.424
PDG	1.000	0.429
DOG	1.000	0.438
DPG	1.000	0.484
RDIG	1.000	0.574
SDNMG	1.000	0.849
SDNPG	1.000	0.879
ANMG	1.000	0.939
ANPG	1.000	0.943

Extraction Method: Principal Component Analysis.

Table 10.2: Factor Analysis Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.677	55.641	55.641	6.677	55.641	55.641
2	1.486	12.381	68.022	1.486	12.381	68.022
3	.960	8.000	76.022			
4	.920	7.663	83.685			
5	.699	5.823	89.508			
6	.570	4.750	94.258			
7	.321	2.673	96.931			
8	.277	2.305	99.236			
9	7.434E-02	.619	99.856			
10	1.654E-02	.144	100.000			

Extraction Method: Principal Component Analysis.

Table 10.3 shows the component matrix carrying correlations, which could help to formulate an interpretation of the factors or components. Eight out of ten variables load highly on this component to include most of the health, environmental and demographic indicators.

Table 10.3: Factor Analysis Component Matrix

Variables	Component	
	1	2
RDIG	.580	.487
PDG	.650	7.456E-02
DOG	.536	.389
LCCG	.458	.463
ANMG	.958	-.146
ANPG	.960	-.147
SDNMG	.903	-.182
SDNPG	.913	-.214
DPG	.280	.637
RBG	-3.982E-02	-.545

Extraction Method: Principal Component Analysis.

Table 10.4: Correlation Matrix

	RDIG	PDG	DOG	LCCG	ANMG	ANPG	SDNMG	SDNPG	DPG	RBG
RDIG	1	0.397907	0.344366	-0.2380323	0.479199	0.477104	0.415813	0.4021629	0.3888884	-0.20049
PDG	0.397907	1	0.482786	-0.2736311	0.569296	0.579466	0.455407	0.5011013	-0.0194218	-0.02613
DOG	0.344366	0.482786	1	-0.2609571	0.433322	0.460598	0.330648	0.3769794	0.3408649	-0.06227
LCCG	-0.23803	-0.27363	-0.26096	1	-0.25141	-0.23454	-0.2374	-0.2235011	-0.1816015	-0.00452
ANMG	0.479199	0.569296	0.433322	-0.2514062	1	0.978588	0.841857	0.8496669	0.1890005	0.017752
ANPG	0.477104	0.579466	0.460598	-0.2345407	0.978588	1	0.83704	0.883619	0.1715274	0.007737
SDNMG	0.415813	0.455407	0.330648	-0.2373978	0.841857	0.83704	1	0.9355989	0.2269576	-0.0027
SDNPG	0.402163	0.501101	0.376979	-0.2235011	0.849667	0.883619	0.935599	1	0.1474646	-0.0067
DPG	0.388888	-0.01942	0.340865	-0.1816015	0.189001	0.171527	0.226958	0.1474646	1	-0.11634
RBG	-0.20049	-0.02613	-0.06227	-0.0045173	0.017752	0.007737	-0.0027	-0.0066954	-0.1163408	1

❖ If absolute (modulus) values are not accounted for, the sum would not reflect the strength of variable hence, Table 10.5 are the absolute values of Table 10.4.

	RDIG	PDG	DOG	LCCG	ANMG	ANPG	SDNMG	SDNPG	DPG	RBG
RDIG	1	0.397907	0.344366	0.23803227	0.479199	0.477104	0.415813	0.4021629	0.3888884	0.200488
PDG	0.397907	1	0.482786	0.27363107	0.569296	0.579466	0.455407	0.5011013	0.0194218	0.026127
DOG	0.344366	0.482786	1	0.26095713	0.433322	0.460598	0.330648	0.3769794	0.3408649	0.062267
LCCG	0.238032	0.273631	0.260957	1	0.251406	0.234541	0.237398	0.2235011	0.1816015	0.004517
ANMG	0.479199	0.569296	0.433322	0.2514062	1	0.978588	0.841857	0.8496669	0.1890005	0.017752
ANPG	0.477104	0.579466	0.460598	0.2345407	0.978588	1	0.83704	0.883619	0.1715274	0.007737
SDNMG	0.415813	0.455407	0.330648	0.23739778	0.841857	0.83704	1	0.9355989	0.2269576	0.0027
SDNPG	0.402163	0.501101	0.376979	0.22350113	0.849667	0.883619	0.935599	1	0.1474646	0.006695
DPG	0.388888	0.019422	0.340865	0.18160152	0.189001	0.171527	0.226958	0.1474646	1	0.116341
RBG	0.200488	0.026127	0.062267	0.00451725	0.017752	0.007737	0.0027	0.0066954	0.1163408	1

Table 10.5: Correlation Matrix (Modulus)

Following Table 10.6 provided the extracted 'weights' for each variable for multi criteria GIS analysis.

	Variables		$/\sum x_i$
1	*Roads Buffers (RBG)*	1.44	**3.46**
2	*Disease Prevalence (DPG)*	2.78	**6.66**
3	*Land Cover Classification (LCCG)*	2.90	**6.96**
4	*Disease Occurrence (DOG)*	4.09	**9.80**
5	*Road Density Index (RDIG)*	4.30	**10.31**
6	*Population Density (PDG)*	4.34	**10.41**
7	*Standard Deviation of Noise Mode (SDNMG)*	5.28	**12.66**
8	*Standard Deviation of Noise Peak (SDNPG)*	5.32	**12.76**
9	*Averages of Noise Mode (ANMG)*	5.61	**13.44**
10	*Averages of Noise Peak (ANPG)*	5.61	**13.44**

The disease data was not large enough but needed to be incorporated due to its environmental and public health relevance. Similarly, the land-cover overlay got lower 'weight', as a classified imagery it was quite different in nature than the other grids. Interestingly, the highest weight statistically extracted happened to be for the overlay of Noise averages.

After elucidating the importance of 'weights' of the overlays, it must be noted that each overlay has multiple classes of data; therefore, the classes are also assigned 'scores' depending upon their technical relevance and the author's professional judgement. 'Scores' are assigned on the scale of 0 to 10 where ' 0' qualitatively represents safe, and '10' represents very high risk.

Figure 10.2 illustrates the final results of the whole endeavour in the form of thematic map. It has been established that the exploration of spatial patterns of noise pollution and its risk evaluation over the whole metropolis was conducted through the integrated approach of 3-S technologies with GIS as the prime tool. This map (Figure 10.2) is able to clearly identify and demarcate the five classes of risk due to multi attributes (emphasis :noise pollution) and the population at risk, under each 'Region'. It is worth mentioning here that even the class of 'low risk' (LRR) can be not taken lightly since the outcome is involving ten variables of diverse nature.

10.3.1 Very High Risk Region (VHRR)

Area: **0.52 mile^2**

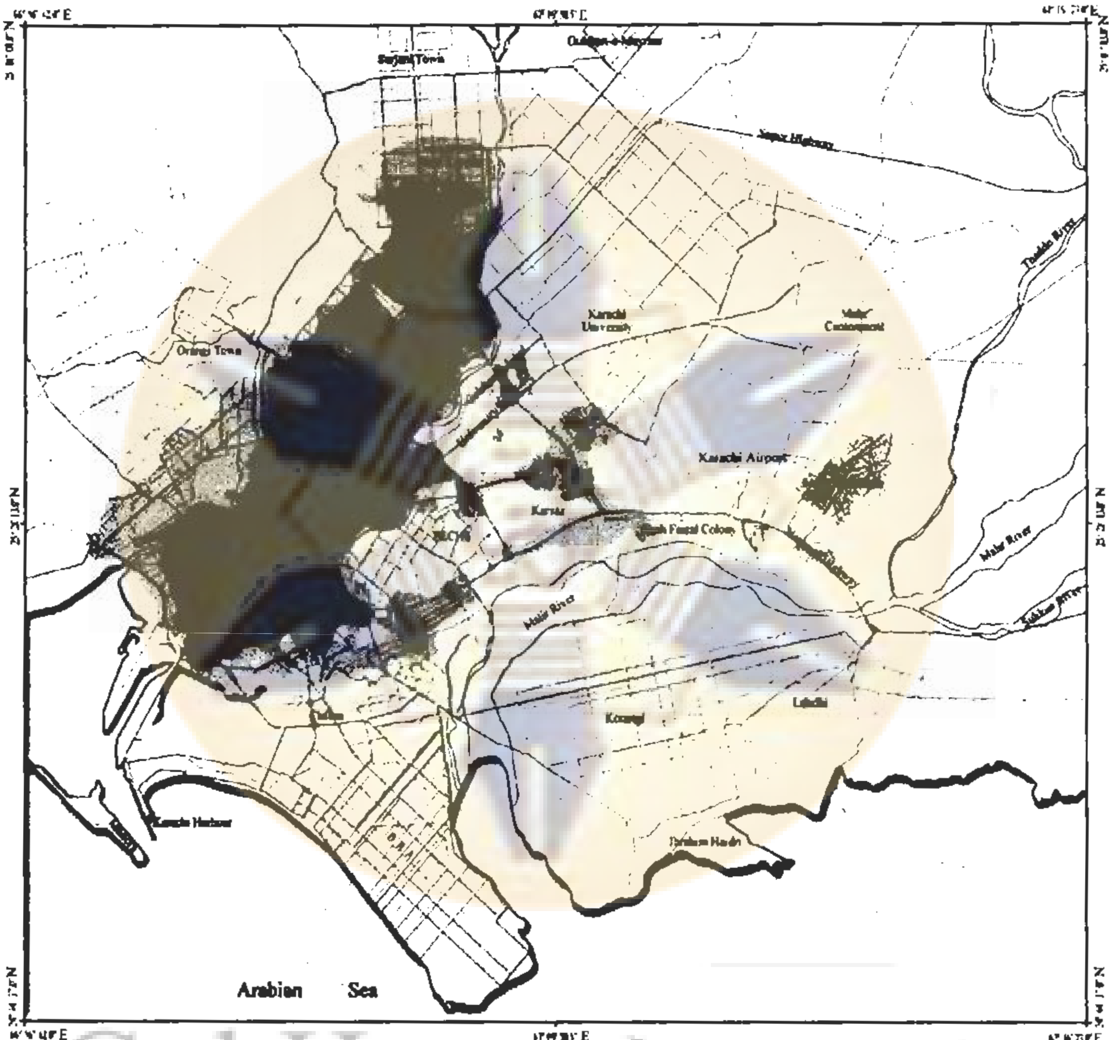
Population: **31,000 persons**

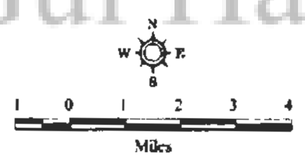
The deduced very high risk region (VHRR) comprises of several bus terminals/transfer station, dense network of roads, crowded retail markets, thousands of commuters, a lot of pedestrians, long queued vehicles, mixed land use and high-rise buildings all around. (Figure 10.2). The commercial activity of this old part of the city involves unavoidable trips, therefore, the actual human population at risk is difficult to quantify.

On the map, there are two regions of very high-risk identified as core of the Karachi (*i.e.* Saddar / Empress market) and section of M. A. Jinnah Road (from the Numaish roundabout to Robson road known as Eidgah). These have emerged as very high-risk region based on the applied criteria, counting on various parameters and not only the noise intensity. These parameters included high population density, dense road network, concentrated habitation, higher disease prevalence, and hazardous prevailing noise with low temporal variations.

For the Empress market vicinity, the appraisal of population at risk yields the figure of 18600 persons for this smaller area of 0.22 mile^2. There is no recent pedestrian data available and this study possesses the census figures of the 'resident' population only. Environmental engineers are appealed to recommend intervention measures for this peculiar very high-risk region of Karachi. The author recalls similar situations in the downtown centres of other Asian countries where *grade separation* of conflicting turning movements (overpass / underpass) have improved the traffic flow. Assignment of 'exclusive pedestrian zone' has also worked at CBDs of western cities.

Risk Assessment
Multi-Attribute Analysis





Area (mile²)	Population	Risk
0.52	31,000	Very High
6.54	768,300	High
25.28	2,375,100	Moderate
24.72	1,932,300	Low
-	-	Safe

Figure 10.2

The section of M. A. Jinnah road from the intersection of Garden Road up to Robson Road known as Eidgah is a two way traffic, section with commercial vehicles such as buses, minibuses, coaches, rickshaws *etc.*, plying with countless number of two wheeler noisy motorcycles and loading vehicles. This road is also a part of old Karachi with many factors common as in the Saddar region. The GIS analysis has figured out the population of this very high-risk region as 10,500 persons and the area as 0.12 mile^2.

10.3.2 High Risk Region (HRR)

Area: **6.54 miles^2**
Population: **768,300 persons**

It is reiterated that the risk regions have been derived due to the outcome of a combination of urban and environmental parameters endangering human potential. Reader would observe three major high-risk regions (HRRs) with some hazardous islands. The first high-risk region covers the old city areas, adjoining neighbourhoods of Nishtar road, the *Katchi-abadies* besides Layari River and borders the Karachi cantonment area (Figure 10.2). The population at risk is computed to be 436,800 persons and the area is 3.58 mile^2. The open green space of Karachi zoological garden is clearly out of high risk proving the ground reality.

Second high risk region has the jurisdiction across Liaquatabad and Federal 'B' Area. The critical arterial of Shahrah-e-Pakistan (continuation of the inter-city Super Highway), which later becomes S. M. Taufiq road, bears thousands of vehicles and people daily. The software has calculated the area of this risk region as 1.91 mile^2 and population as 250,200 persons. Six major junctions (formerly 'Roundabouts' now turned as signalised intersections) are the congested traffic sites viz. Dak khana, Liaquatabad No. 10, Karimabad, Aisha Manzil, Water Pump and Sohrab Goth (Figure 10.2). The transfer of *Subzi Mandi* to its new location on Karachi-Hyderabad Super Highway has worsened the traffic and environmental conditions of this risk region.

region. The population density here is quite high due to flats, which might have contributed in the formation of this *multi attribute* based risk region.

On the resultant map(Figure 10.2), there are two distinct spots of High Risk. One of them is the 1st Chowrangi of Nazimabad at Nawab Siddique Ali Khan road. This high-risk spot covers very small area and has the vicinity population around 3000 persons. It is a location coming in the way for a large number of commuter trips during the day. The second significant high-risk spot is seen on the intersection of Shaheed-e-Millat road and the University road (Jail Chowrangi). Analogous to Nazimabad Chawrangi, this high-risk spot also witnesses thousands of vehicles and passengers daily due to its mainstream location. This spot shown on the map wrap an area of 0.1 mile^2, bears a vicinity population of 3800 persons.

10.3.3 Moderate Risk Region (MRR)

Area: **25.28 mile^2**

Population: **2,375,100 Persons**

Administratively speaking, the two populous former districts (Karachi Central and Karachi South) are lying under moderate risk (MRR). Through GIS techniques, it has been possible to provide micro-demographic details of this risk region as the count of polygons was thirty-five. For the sake of brevity, the moderate risk region could be discussed in two folds. The agglomerated moderate risk region largely spread out over the map (Figure 10.2) and shows an elongated pattern towards the northeast direction. This agglomerated region encompasses an area of 20.69 mile^2 and a population of 2,122,600 persons at risk. This particular risk region covers a large portion of urban land and imbibes several planned, unplanned neighborhoods and squatter settlements. The figure of greater than 2 million people under risk (though moderate), by itself is a legitimate theme of environmental inquiry.

The other scattered moderate risk (MRR) spots spread on an area of 4.59 mile^2 and have a vicinity population of 252,500 persons. These locations on map are identified as Liaquat Market, Malir , Saudabad No. 15 and Malir Extension, which are densely, populated commercial areas. These locations have narrow roadway widths and traffic congestion is reported during the off peak timings as well. Other spots are the intersection of NIPA, the road section between Hassan Square and National Stadium, which lies on route for many commuter and public transport trips. The last hotspot of MRR is recognized as the intersection of Shahrah-e-Faisal and Shahrah-e-Quaideen (Figure 10.2).

10.3.4 Low Risk Region (LRR)

Area: **24.75 mile^2**
Population: **1,932,300 Persons**

As the Figure 10.2 and its legend show that there exist some low risk regions. LRRs are useful for spatial decision-makers. Adjoining the above-described moderate risk region are under low risk regions. The pattern of this region (LRR) is similar to the agglomerated moderate risk region. This particular risk region travels similarly to its adjoining moderate risk region in elongated fashion from southwest to northeast. The GIS has given the area of this region as 10.1mile^2 and it covers population of 996,800 persons.

The Rashid Minhas Road has a low risk region corridor on its both sides, which further stretches to main Shahrah-e-Faisal and Shah Faisal Colony. The T-intersection of Johar Morre at this road is the root cause in the creation of this risk region. Conflicting turning movements at the Johar Morre are made without any traffic-control device (TCD) or even without a policeman's control. This location has to be either grade separated through an Overpass or Underpass or at least be signalised. The existence of recreational parks (Aladdin and Sindbad) on left and right sides of Rashid Minhas road generates evening peak hour congestions. This low risk region (LRR) comprises of an area of 10.64 $mile^2$ and population of 495,000 persons.

Malir extensions, Quaidabad area, and parts of Shah Faisal colony make the low risk region on the eastern outskirts of the metropolis. Population of 373,600 happens to be under low risk and the area it surrounds is 4.01 $mile^2$. The grids of population density and disease prevalence might have played an important role in the formation of this low risk

The enclosed map (Figure10.2) illustrates rest of Karachi metropolis under the safe region that is only a pictorial representation of the present day situation. The rising population, in migration (Khan *et al*, 1998), increasing registration of motor vehicles , formation of new *Katchiabadies*, steady decrease in vegetation canopy suggest that sitting idle without seeking alternative solutions would turn this safe haven into a risk region in future.

11. PREDICTIVE MODELLING: CASE STUDY

One of the most fundamental problems of engineering sciences is to predict and forecast future phenomena. Using existing theories and then extending such theories by means of experimental results frequently accomplish this task. The basic problem is to develop models in analytic form so those future real world situations can be predicted with a reliable degree of accuracy. Likewise in transportation and environmental engineering, analytical models are needed to forecast urban traffic pollution that is reliable. It is the one of the objectives of this research to develop a prediction methodology for use in land use planning, which is a major component of urban transportation planning.

11.1 THE FRAMEWORK

Methodology has been developed to estimate noise pollution at intersections by collecting measurements from various types of adjacent land uses, traffic volumes, road geometry *etc.* in order to provide traffic engineers and urban planners a less expensive and fairly accurate means to facilitate critical decision making regarding pollution. This methodology is also replicable elsewhere as well by incorporating indigenous patterns (especially in the context of third world cities).

11.2 SOURCES AND QUALITY OF DATA

11.2.1 Land Use

The existing secondary data from the Master Plan and Environmental Control Department of the Karachi Development Authority (KDA) is although helpful but does not go far into looking at the micro geographic patterns of land use in various regions of Karachi.

Due to the unavailability of land use data on micro-geographic scale in Karachi, the study region was chosen as old Karachi (core area) (Figure 11.1), thus *Primary* data has been generated on land use for predictive modelling. The Old city has a unique distribution of various combinations of land use mixes, spread over the entire area. In old Karachi (core) it has been very difficult to find areas, which have a single land use category because businesses are usually found linked with residential areas. Being unplanned neighbourhoods, complex situations exist, which presents the old city area as a ease to investigate.

OLD CITY AREA OF KARACHI

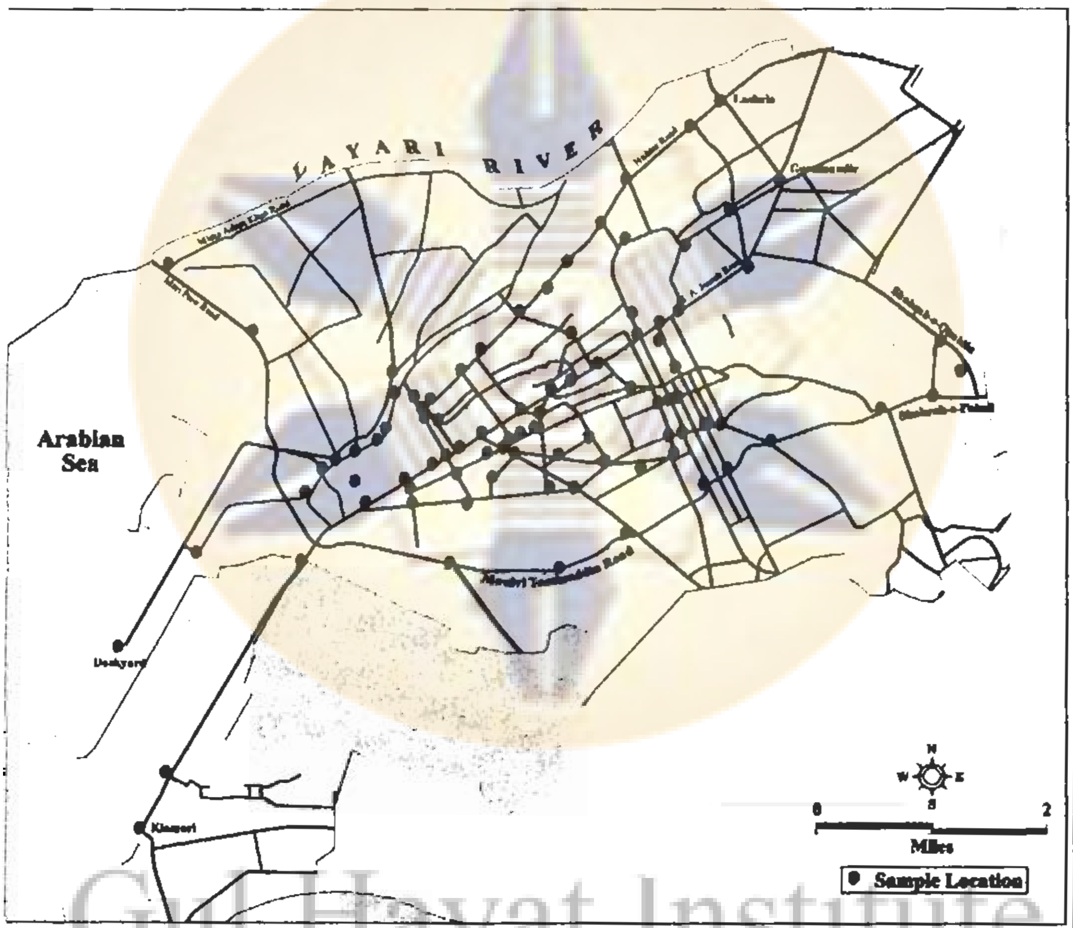


Figure 11.1

To proceed further into the study, a comprehensive data set was needed. Table 11.1 shows the list of selected locations for the collection of land use and noise pollution data. A sample size of 90 locations was considered to be large enough for statistical analysis. Attempts were made to maintain uniform data acquisition procedures. It was initially decided to acquire the details of land use for each location within a vicinity of 330-feet diameter. Physical measurements and distribution of floor area were carried out. Site-specific maps (condition diagrams) were drawn for each location. They contained land use information for the vicinity (all sides) of the location. A radius of 165 feet was superimposed on each vectorised map. Site-wise, computation of areas was done through ArcView and MS Excel.

11.2.2 Traffic

At this juncture, it was realized that efforts be made to collect current statistics. The reason of this decision was the obsoleteness and scarcity traffic data available at the traffic-engineering bureau. Hence, hourly traffic volumes at selected 90 locations of Karachi were manually recorded in the field. Table 11.1 presents the traffic volumes for 90 locations of old city (core).

After a thorough investigation, the scope of Predictive Modelling was limited to core areas (Old City) in Karachi. Since this study is un-funded research and constrained by the limited time and manpower available, the magnitude was kept to a reasonable level.

The old city (core) areas of Karachi are quite unique in nature as far as land use and traffic patterns are concerned. Simultaneous mixed activities at different floors of a single building in core Karachi calls for a model study that could provide insight on these unique situations. Photographs revealing these chaotic circumstances are illustrated as *Annexure A*.

Table 11.1: Land Use and Traffic around Monitoring Stations in Old City Area*

Name of Location	Hourly traffic count	Roadway width*	Commercial Space**	Residential Space**	Special Purpose Space**	Vacant space**	Transportation Right of Way**	Built-up Space**
Kashif Centre	2882	64.84	73785.01	5286.00	149.00	169.00	4914.00	79220.01
Native Jetty Bridge .	10974	58.52	118224.87	0.00	0.00	11616.00	13318.00	118224.87
City Station Habib Bank Plaza	3724	42.56	52871.52	0.00	4346.00	0.00	13962.00	57217.52
Numaish, M A Jinnah Road	1982	37.24	51638.55	1744.77	3357.93	652.47	14957.77	56741.25
Agha Khan Rd Roundabout	1482	42.56	50698.79	27727.00	27063.00	5930.00	15681.00	105488.79
Holy Family BYJ Rd	3422	43.81	93421.09	21665.00	27405.00	0.00	16343.00	142491.09
Queens Rd Haji Camp	5922	86.62	201516.48	0.00	23691.00	0.00	22370.00	225207.48
Intersection of M A Jinnah and Ziauddin Kutchery Rd Light House	3626	82.30	90805.24	27186.00	5106.00	293.00	22411.00	123097.24
Aram Bagh Park Side	6738	82.30	137004.98	65689.00	1638.00	0.00	22738.00	204331.98
Farooq-e-Azam Mosque, Jona Mkt, Nishtar Rd	5646	34.58	141990.07	83038.44	17597.00	0.00	22918.00	242625.51
Zoological Garden Gate	5052	31.92	137478.71	38735.00	32819.00	1370.00	23120.00	209032.71
Tayabi Dawakhana, Intersection North Napear Rd	2854	51.87	84919.94	66510.00	26594.00	0.00	24342.00	178023.94
Intersection of Burns Rd and Dr. M. Hashim Ghori Rd	8474	54.70	90785.56	81340.00	25947.00	0.00	27960.00	198072.56
Intersection of Robson Rd and Burns Rd	3210	62.68	57446.54	68407.00	30595.00	1942.00	27990.00	156448.54
Kumar Cinema Napear Rd	4544	64.84	88486.54	0.00	6987.00	0.00	29841.00	95473.54
Intersection of North Napear Rd and Nishtar Rd (Nigar Cinema)	5184	86.62	134250.85	28174.00	691.00	0.00	30236.00	163115.85
Haqqani Chowk Hasrat Mohani Rd	7324	31.92	177557.96	152128.00	2579.00	10082.00	30463.00	332264.96
Shahrah-e-Liaqat New Chali	6800	54.70	205936.78	191092.00	0.00	12577.00	31567.00	397028.78
Shoe Market, Nishtar Rd	3824	59.52	77456.42	39910.00	8329.00	0.00	32173.00	125695.42
Gaaoo Gully Agha Khan Rd	7102	87.62	204934.97	160702.00	53690.00	0.00	34357.00	419326.97
Karachi Auditorium	4890	31.92	111368.51	129184.00	3335.00	6300.00	35018.00	243887.51
Jubilee Cinema Round about	3496	51.87	90990.47	89701.00	4077.00	0.00	35973.00	184768.47
Sindhi Muslim Society Signal	2124	85.52	113386.21	78159.00	851.00	0.00	36222.00	192396.21
City Post Office	5140	51.87	118474.33	18876.00	5937.00	3270.00	36301.00	143287.33
Ranchhorre Line, Nishtar Rd	7762	92.44	124800.87	127150.34	4908.00	0.00	36480.00	256859.21
Dockyard	1244	50.00	36183.32	0.00	0.00	0.00	36501.00	36183.32
New Memon Mosque, M A Jinnah Rd	10382	58.52	246002.61	33467.00	23232.00	2245.00	36988.00	302701.61
State Life Bldg AH Rd	6974	53.20	135412.89	0.00	0.00	0.00	37094.00	135412.89
Queens Road Mai-Kolachi Intersection	3446	49.21	97673.73	20074.00	23676.00	0.00	37701.00	141423.73
Paper Market Intersection Shahrah-e-Liaqat	3410	37.24	67757.46	25094.00	0.00	9026.00	37721.00	92851.46
City Court M. A Jinnah Rd	9274	37.24	154168.72	19488.00	0.00	11196.90	38266.00	173656.72
Next to Denso Hall Stop towards Mamon Mosque M A Jinnah Rd	5292	59.52	150175.75	89300.00	0.00	2123.00	39875.00	239475.75
Intersection of Grammar School and Saghir Rd	7518	58.52	94172.68	62038.05	55380.49	14195.71	40000.00	211591.22
Lie Market Round about Location 2	8584	58.52	246751.26	48210.00	8911.00	0.00	40000.00	303872.26
Intersection of Mangho Pir Rd / Nishter Rd Near Mazar	8378	60.02	221471.10	93232.00	329.00	46131.00	40000.00	315032.10

Name of Location	Hourly traffic count	Roadway width*	Commercial Space**	Residential Space**	Special Purpose Space**	Vacant space**	Transportation Right of Way**	Built-up Space**
KMC Workshop Nishtar Rd	2588	41.23	36733.90	103101.00	0.00	0.00	40160.00	139834.90
Zaibunnisa Street near Panaorama Centre	4404	37.24	69642.00	50813.00	0.00	81414.00	40971.00	120455.00
Jang Press I I Chundrigar Rd	3484	65.00	39015.97	57081.00	0.00	7665.00	41021.00	96096.97
Regent Plaza	5414	58.52	95235.03	47076.00	0.00	0.00	41030.00	142311.03
Christ Church, Nishtar Rd	6020	58.52	126247.82	19198.00	21793.00	0.00	41173.00	167238.82
Crown Cinema Machhar Colony	2158	35.50	38614.05	797.00	4963.00	10932.00	41422.00	44374.05
Kiamari Maternity Home Railway Crossing	2712	50.54	72319.88	63636.00	4218.00	0.00	41876.00	140173.88
Arts Council	6678	53.20	155901.45	3306.00	116614.00	0.00	41894.00	275821.45
Kharadar, Intersection of Shahabdul Latif Bhitai Rd and Agha Khan Rd	3556	38.00	70848.87	28816.00	1847.00	866.00	42177.00	101511.87
IBA City Campus	2284	34.58	50058.94	0.00	118873.00	88121.14	42443.47	168931.94
Intersection of Zaibunnisa and Shahrah Iraq	4812	34.58	224546.66	0.00	0.00	10301.97	42550.98	224546.66
Zainab Market	9764	45.22	234545.64	6179.39	0.00	46855.93	42996.32	240725.02
Governor House	3084	75.00	51908.10	0.00	0.00	0.00	43580.81	51908.10
Intersection M A Jinnah Rd and Nepear Rd (Denso Hall)	17274	108.40	165332.80	98773.00	1231.00	0.00	44188.00	265336.80
Services Hospital Allahwala Mkt (Int Robson and MA Jinnah Rd)	8220	39.90	168455.64	14476.00	23842.00	0.00	45116.00	206773.64
Eid Gah Qassban Mosque M A Jinah Rd	5420	86.62	137846.60	43265.00	10906.00	0.00	45705.00	192017.60
PIDC Roundabout	9764	108.40	133704.44	6073.00	245.00	12949.00	45732.00	140022.44
Intersection of Din M Wafai and Kamal Ata Turk Rd	6382	53.20	251322.02	26726.00	15992.00	0.00	46055.00	294040.02
Hotel Avari Towers	2082	76.48	47856.62	6433.00	5938.00	2401.00	46594.00	60227.62
Bohri Bazaar	8014	43.56	232446.50	0.00	0.00	3820.27	46760.13	232446.50
Fresco Bakery Burns Rd	6694	39.90	150794.28	89978.00	0.00	0.00	46961.00	240772.28
Khadda Market	2014	71.16	94641.06	57424.00	0.00	19141.00	47222.00	152065.06
Gora Qabristan	1600	68.00	56073.17	9486.00	24370.00	0.00	47598.00	89929.17
Z-Stop, Chand Bibi Rd near Pan Bazaar	10640	26.60	176149.69	16310.00	0.00	2523.00	47682.00	192459.69
Nishter Rd, Ram Swami	4310	55.86	42551.32	89313.00	4852.00	535.00	47841.00	136716.32
Shahrah Iraq, Mehboob Market	4302	51.87	75699.28	21698.38	0.00	0.00	48824.66	97397.66
Prince Cinema Signal	2886	75.16	36819.35	0.00	18470.54	25899.00	50295.51	55289.89
Kharadar Police chowki	3400	59.52	85749.55	130784.00	8582.00	653.00	51148.00	225115.55
Empress Market	11844	75.98	148435.94	21682.29	6403.78	4091.98	51417.25	176522.01
Gulistan School Qazi Hall SMS	3418	66.34	63020.90	19821.00	4538.00	0.00	52562.00	87379.90
Shaheen Complex	6710	37.24	137277.48	5796.00	47907.00	0.00	52606.00	190980.48
Tibet Centre, M A Jinnah Rd	12610	87.12	198039.51	26403.00	9482.00	0.00	52929.00	233924.51
Sarawan Hotel	10570	100.92	180863.61	95259.00	0.00	111836.00	55419.00	276122.61
Kiamari	5716	64.84	94535.02	4634.00	19845.00	3335.00	55432.00	119014.02
Regal	12066	43.56	208461.38	42752.00	0.00	0.00	55681.00	251213.38
Intersection of MA Jinnah and Garden Rd	4416	37.24	149649.52	0.00	0.00	14667.00	55694.89	149649.52
West Wharf	1322	75.00	34316.89	0.00	0.00	1068.00	55825.00	34316.89
National Bank Main Branch, I I Chundrigar Rd	2494	74.16	41599.36	2741.00	4566.00	3618.00	56448.00	48906.36
Radio Pakistan	12548	53.20	213547.35	65447.00	30194.00	0.00	57841.00	309188.35
Solder Bazaar	4530	65.09	112694.43	13799.00	17319.00	0.00	58314.00	143812.43
SHC/ Assembly	3204	70.66	84771.29	0.00	96479.00	0.00	59473.00	181250.29
Gurumandir	8232	90.78	125797.62	62216.00	633.00	0.00	59967.00	188646.62

Name of Location	Hourly traffic count	Roadway width*	Commercial Space**	Residential Space**	Special Purpose Space**	Vacant space**	Transportation Right of Way**	Built-up Space**
Intersection of Mirza Adam Khan Rd / Mari Poor Rd	5210	59.52	130615.55	0.00	32013.00	6589.00	60989.00	162628.55
Capri Cinema Signal	6642	108.40	139797.67	11674.82	5646.78	79828.63	61967.31	157119.27
Pakistan Chowk	8738	37.24	228635.32	133570.00	0.00	0.00	61981.00	362205.32
Allah Wali Mosque, Nishter Rd Gandhi Garden	2500	45.22	34260.69	50035.00	7340.00	0.00	62629.00	91635.69
Kukri Ground, Agha Khan Rd	6182	53.20	85063.54	39983.00	0.00	0.00	64963.00	125046.54
Lie Market Round about Location 1	13784	65.84	116988.58	12547.30	0.00	0.00	65639.00	129535.89
Lasbela	8376	37.24	138526.48	4204.00	12700.00	0.00	67956.00	155430.48
Allah Wali Chowrangi, Shahrah-e-Quaideen	1858	84.48	41567.15	37327.00	705.00	3332.00	69644.00	79599.15
Lucky Star	4930	26.60	164395.80	108797.37	0.00	24626.23	69736.78	273193.16
Mereweather Tower	11844	43.89	154472.79	0.00	0.00	6109.00	86631.00	154472.79
Intersection of Zaiuddin (Kutchehri) Rd and Shahrah-e-Liaqat	14130	53.20	273631.82	161848.00	0.00	0.00	132619.00	435479.82
Intersection of G. Allana Agha Khan Jamat Khana	4058	64.84	85515.60	109336.00	220223.00	0.00	134852.00	415074.60
Café Subhani	4026	53.20	94612.64	33492.33	0.00	2514.55	208977.67	128104.97

*** Unit: feet** **** Unit: Square feet**

♠ With in 330 feet

11.3 THE TECHNIQUE

Stepwise Regression Analysis is a statistical technique, which is considered to be very effective in identifying relations between various independent and dependent variables (McCuen 1985; Gujarati, 1995). The objective of stepwise regression is to develop a prediction equation relating a criterion (dependent) variable to one or more predictor variables. Stepwise regression, in addition to calibrating a prediction equation, uses statistical criteria for selecting which of the available predictor variables will be included in the final regression equation; the multiple regression technique includes all available variables in the equation and is often plagued by irrational regression coefficients. Stepwise regression usually avoids the irrational coefficients because the statistical criteria of F-statistic(s) that are used in selecting the predictor variables usually eliminate predictor variables that have high inter-correlation (Theil, 1978; Gujarati, 1995).

The multivariate linear model structure with *p* independent explanatory variables, the regression equation is (Fomby *et al.*, 1984; McCuen, 1985; Rogerson, 2001):

$$Y = b_0 + b_1x_1 + b_2x_2 + \ldots\ldots + b_px_p \qquad (A)$$

Hameed (1990) and Ali (2000) have utilized Stepwise linear multiple regression for rural and urban transportation research. Ali (2000) in attempting to model rural travel behaviour developed probabilistic models for individual activity choice and the resulting travel using SPSS. Hameed (1990) produced three pedestrian volume prediction models using adjacent land use data at intersection through stepwise regression analysis used STEPOUT program for statistical calculations. Carter *et al.* (2002) further elaborated the utility and limitations of the technique for such studies.

Due to the inherent characteristics of land use variables (Carter *etal.* 2002), they were aggregated into major categories to keep the classification of land use for GIS and Statistical modelling to a reasonable number. The variables is shown in list and a brief description of each variable is given as follows:

1. Residential Space (X_1): indicates all space utilized for residential purposes, which includes, single family, multifamily, flats, hostels *etc.*

2. Commercial Space (X_2): refers to the space used for bazaar, petrol pumps, retail stores, shopping areas, warehouses, cottage industries, restaurants, governmental and private offices, banks, courts, *etc.*

3. Special Purpose Space (X_3): this category refers to religious institutions, medical facilities, educational institutions, social, cultural institutions, parks, cinemas, playgrounds, zoo, picnic resorts *etc.*

4. Transportation Right of Way (X_4): consist of all space used for Roadway pavement, sidewalks, all sorts of parking space, median *etc.*

5. Vacant space (X_5): designated to show all space allocated for some activity that is not utilised presently. This includes vacant plots found in different study locations.

The primary traffic variables were:

6. Hourly traffic count (X_6) and
7. Roadway width (X_7)

Later, during data screening and analysis, a new variable was computed as:

Built-up Space (X_8): consisted of all space utilized for residential, commercial or special purpose summed together. This clearly excluded the space for Vacant and Transportation/ Right of way.

11.4 THE FINDINGS

In this study, primary data on noise pollution (noise intensities), land use (floor space), traffic volume and roadway width and has been originally collected at 90 locations of old city (core) Karachi. The data review suggested that a linear model should prove to be a proper model structure (Foster, 2000). However, the independent variable data sets were examined with the help of the computer program SPSS. The results indicated that for such a data set, linear model was more suitable and appropriate.

Temporal Noise level (mode) was the dependent variable whereas roadway traffic and landuse related parameters were independent variables determined for the purpose of forecasting noise pollution in the old city centre of Karachi. Prediction models for noise pollution for the following temporal variations have been developed.

1. Working Day Mornings
2. Working Day Afternoons
3. Working Day Evenings
4. Weekend Mornings
5. Weekend Afternoons
6. Weekend Evenings
7. Weekly Averages

This was possible using the *backward elimination* procedure for estimation of linear regression models in statistical analysis software (SPSS). This procedure eliminates all non-significant coefficients such that the final model contains statistically significant coefficients only (McCuen, 1985; Gujarati, 1995; Ali, 2000).

Model parameters were estimated for equation (A). Table 11.2, summarizes the model selected on the basis of following statistical parameters:

1. The low value of intercept (constant) is statistically desirable because theoretically when there will be no traffic and land use (*i.e.* $X_1, X_2, \ldots, X_8$ all tend towards zero) then noise should also tend to zero. Therefore, intercept value should be smaller (Hameed, 1990).

2. These models were found to be statistically significant on the basis of the F-statistic (Gujarati, 1995).

3. The coefficient of multiple determinations R^2 is the proportion of variation in the dependent variable explained by the regression model (Ali, 2000). The values of R squared range from 0 to 1. Small values indicate that the model does not fit the data well. The sample R squared tends to optimistically estimate how well the models fit the population (Christ, 1966). The values of R^2 greater than 0.5 are considered to be acceptable for engineering data (McCuen, 1985).

4. If the significance value of the F statistic is small (smaller than say 0.05) then the independent variables do a good job explaining the variation in the dependent variable (Fomby *et al.*, 1984).

11.4.1 Prediction Models

The best model developed for predicting the noise in the study area (under the experimental conditions) during the selected times of week are given as follows:

Working Day Mornings

$$Y_{(\text{Working Day Mornings})} = 81.079 + 0.000381\,X_6 + 0.0000317\,X_1 + 0.0000149\,X_3 - 0.0000206\,X_5 + 0.0000163\,X_8$$

Working Day Afternoons

$$Y_{(\text{Working Day Afternoons})} = 74.669 + 0.00027\,X_6 + 0.0000377\,X_1 + 0.0000172\,X_3 + 0.0000277\,X_4 + 0.0000163\,X_8$$

Working Day Evenings

$$Y_{(\text{Working Day Evenings})} = 83.526 - 0.0195\,X_7 + 0.0000306\,X_1 - 0.0000355\,X_4 - 0.0000197\,X_5 + 0.0000117\,X_8$$

Weekend Mornings

$$Y_{(\text{Weekend Mornings})} = 76.382 + 0.000543\,X_6 + 0.0000363\,X_1 + 0.0000262\,X_3 - 0.0000187\,X_5 + 0.0000227\,X_8$$

Weekend Afternoons

$$Y_{(\text{Weekend Afternoons})} = 70.603 + 0.000565\,X_6 + 0.00004\,X_1 + 0.0000373\,X_3 - 0.0000273\,X_5 + 0.0000364\,X_8$$

Weekend Evenings

$$Y_{(\text{Weekend Evenings})} = 77.224 + 0.000512\,X_6 + 0.0000323\,X_1 + 0.0000258\,X_3 - 0.0000158\,X_5 + 0.00002\,X_8$$

Working Day Averages

$$Y_{(\text{Working Day Averages})} = 77.419 + 0.000403\,X_6 + 0.0000359\,X_1 + 0.0000234\,X_3 - 0.000018\,X_5 + 0.0000212\,X_8$$

Table 11.2: Constants and Coefficients of Predictive Models

Model Purpose	Parameter Estimates								Model Statistics		
	Constant	Traffic Count	Road Width	Residential	Special Purpose	Transportation	Vacant	Built-up	R2	F	Sig. Level
Working Days Morning1	81.079	3.81E-04		3.17E-05	1.49E-05		-2.06E-05	1.63E-05	0.878667812	1.836116203	1.29E-03
Working Days Afternoon	74.669	2.70E-04		3.77E-05	1.72E-05	2.77E-05		1.63E-05	0.832023524	1.52465435	1.91E-02
Working Days Evening	83.526		-1.95E-02	3.06E-05		3.55E-05	-1.97E-05	1.17E-05	0.659648729	1.186475575	3.23E-03
Weekend Morning2	76.382	5.43E-04		3.63E-05	2.62E-05		-1.87E-05	2.27E-05	0.805981498	1.472749828	2.07E-04
Weekend Afternoon	70.603	5.65E-04		4.00E-05	3.73E-05		-2.73E-05	3.64E-05	0.66252206	1.192010379	3.20E-02
Weekend Evening	77.224	5.12E-04		3.23E-05	2.58E-05		-1.58E-05	2.00E-05	0.72919786	1.321409288	2.63E-03
Weekly Average	77.419	4.03E-04		3.59E-05	2.34E-05		-1.80E-05	2.12E-05	0.703939345	1.272171239	2.84E-02

1 Monday, Tuesday, Wednesday and Thursday, Mode values of ten minutes at 5 feet from the source about 4 feet above the surface

2 Friday, Saturday and Sunday, Mode values of ten minutes at 5 feet from the source about 4 feet above the surface

11.4.2 Evaluation of Models

Some important aspects of the formulated models are:

- The negative coefficients for vacant space (X_5) suggest its terminating affect on the dependent variable. In other words, greater the vacant space lower would be the intensity of noise in the vicinity. In other words, in the absence of barriers and dense built environment the wind nullifies the echo effect (resonance) of noise. This is quite understandable, as lower the activity on land would translate into less noise pollution.

- All coefficients for traffic volume (X_6) bear positive sign. Higher the traffic volume, higher would be the noise pollution. These coefficients are higher in magnitude as compared to the coefficients of other variables showing positive relationship. Surprisingly, these coefficients complement the hypothesis that high level of noise pollution in an urban environment is the by-product of vehicular traffic.

- The regression analysis for almost all the seven models eliminated the variable of commercial space (X_2) in the first step.

- The coefficients for residential space (X_1) for all the seven temporal models developed carries positive sign. This could be explained by virtue of the peculiar vertical distribution of population in the case study area. The old city Karachi (Core) has significant presence of multi-family flats (apartments). Higher number of pedestrians on narrow streets is a continual hindrance in the smooth operation of traffic, which at times requires application of breaks and blowing horns causing noise pollution.

- It was realized that the results could be improved to a good extent if all the built up spaces (X_8) are added as:

$$X_8 = X_1 + X_2 + X_3$$

The relative accuracy of the models improved statistically after this modification. All the coefficients for built-up space are directly proportional to the dependent variable.

- For the model derived for working day evening mode, the variable of roadway width has interestingly played a role. Its relatively higher negative coefficient implies the inverse effect on noise pollution. It happens to be a rational aspect as hollow sound is more frequent on narrow winding roads.

- The land use category of special purpose space (X_3), functionally is a trip generator. Therefore, it increases the number of pedestrians, vehicles and vehicle-pedestrian conflicts. The driver behaviour in Karachi contributes a lot to noise pollution. The positive coefficients of special purpose space are essentially due to the inherent trip-generating characteristic of this land use category.

11.4.3 Applications of Models

The noise propagation models (*e.g.* Abou-El-Seoud, 1994; Mikkonen and Tuominen, 1998) dealt with the phenomenon of noise propagation and the air pollution dispersion models (*e.g.* Hatano *et al.*, 1989; Zannetti, 1990; USEPA, 1995; Folgert, 1997; Hodgin *et al.*, 1997; Comrie *et al.*, 1997; Cartwright *et al.*, 1997; Coe *et al.*, 1998; Dent *et al.*, 1998) dealt with pollutant dispersion. The predictive models developed in this study provide the basic input needed for the various noise propagation models found in the literature.

The models developed for predicting noise in this study lead to tremendous potential. These models have the capability of forecasting noise intensities for different temporal (diurnal, weekly) phases in Karachi. These models have practical applications in urban and transportation planning, land use control, traffic and environmental engineering. The practicality of the prediction models lies as being tool in saving time and effort compared to the cumbersome and expensive field sampling methods.

These models have another interesting future application, *i.e.*, in the areas infrastructure engineering and regional planning. Whenever a change in land use might be anticipated, it would be desirable to study its impact on noise pollution at nearby intersections in order to implement modifications and improvements. These models could be used for this purpose very efficiently.

11.4.4 Constraints of Models

Models developed in this study give a reasonable estimation of noise levels from traffic and land use variables. The limitations should also be clearly recognized.

- The data for this study were obtained from Old City (core) of Karachi. The land use patterns in the study area exempted as an important class of 'Industrial', which may be characteristic of other cities. Therefore, keeping such indigenous factors, cities may develop models for their use. In fact the models developed here should be applicable to other areas as well with slight modification with respect to local scenarios.

- These models have been developed for primarily a dense network of roads. When applying to sparse network of roads, caution should be exercised.

- The study area characterise a significant fraction of land use for 'Warehouses' (Hasan *et al.*, 1999). The results may not be consistent at locations where there is a drastic change in land use concentration *e.g.* 'warehousing' is predominant.

- Lastly, the temporal nature of regression models should be understood. The variables used in the development of these models may be changed periodically by urban renewal, change in allocation of space for various activities, future changes in transit services of Karachi such as Karachi Mass Transit Program (KMTP), construction of Layari Expressway and upgradation of Karachi Circular Railway (KCR). Catastrophic events changing landuse patterns can disturb the predictability of the derived models.

- Therefore, the predictive modelling exercise should be validated periodically and modified in order to maintain stability in the process.

12. CONCLUSIONS AND RECOMMENDATIONS

This research was about a major hazard to the environment in one of the most affected cities of the world. Decision-makers both at micro and macro levels seem to overlook urban noise pollution, traffic and land use patterns whose combination pose serious threats to human population. It is revealed from this study that this noisy phenomenon is a silent killer of the environment and its perception among local residents of Karachi is at the lowest threshold. This study discloses some of the very fascinating facts about the urban traffic pollution (noise) in Karachi and its impacts and its insight among the suffering population.

This chapter summarizes the research and gives some conclusions and suggestion for possible improvements and extensions of the research.

12.1 CONCLUSIONS

It is really a thrilling experience to study noise pollution, traffic and land use in one of the badly affected cities of the world with meagre field resources, at hand.

This investigation confirms that 3-S integrated techniques are the most reliable and expeditious technologies in monitoring urban traffic (noise) pollution. Although RS/GIS seem expensive in initial financial outlay, nevertheless, in the longer run, these are cost effective, lasting and dynamically adaptable in any part of the world.

It is revealed through this study that human behaviour is the key in creating urban transport pollution and that it should not be combated only through technological solutions. Rather a balanced modification in human perceptions would come up with more concrete remedial measures. It is with this basic intention that parallel physical and perception studies have been initiated to achieve the main objective of the study, which has been outlined in the hypothesis:

"The high level of noise pollution is associated with the geographical agglomeration of land use and traffic volume which resulted in high incidence of noise induced diseases and the population close to those areas are on vulnerable risk."

The developed GIS evaluation combined the data sets, various analyses and the resultant maps with the capability to integrate further parameters for future risk assessments. Multi-attribute decision analysis in the GIS environment was successfully employed probably first ever in Pakistan.

Micro-geographic appraisals of the metropolis were performed by considering 58 analysis zones outlined by the local development authority. Each assessment included area, population density, distribution of land cover classes; split of land use categories, frequency and prevalence scenario of noise induced diseases, and finally the temporal variations in noise intensities within the analysis zone.

Multiple regression models for predicting the noise levels at the olden regions of Karachi metropolis have been formulated in which traffic and land use parameters act as independent variables.

Further conclusions and suggestions concerning the general flow of the study within RS/GIS framework and the specific aspects of epidemiology and public discernment in Karachi are listed point wise:

- The satellite image processing has yielded the thematic product that is able to give, in quantitative terms, the geographical spread of major land covers throughout the metropolis (Chapter # 2).

- Another RS/GIS integrated technique of *change detection* has illustrated the historical growth of human settlements and the future expansion potentials available (Chapter # 2).

- This study also successfully demonstrated the advanced capabilities of Remote Sensing (RS) and Geographic Information Systems (GIS) for simulating the parameters and variables that happened to be the causes and effects of noise pollution respectively.

- Spatial demographic patterns have been monitored on micro geographic scale of *analysis zones*. Computer Assisted Cartography (CAC) provided a combination of demographic themes on which author has briefly tried to reflect with a socio-economic viewpoint (Chapter # 4).

- The study investigated the land use scenario of this mega-city and has furnished the first ever development of a statistical and geocoded database on explicit land use types and functions for Karachi, which has also raised some issues requiring further studies (Chapter # 3).

- It has been firmly established that GIS and GPS enabled the researcher to render temporal assessment of traffic and spatial variations of the road network across the city. (Chapter # 5).

- Noise pollution monitoring has been ventured for investigating spatial patterns. Recently collected field data by the author have been used for GIS *Interpolation* and transformation of point observation into continuous *surface*. (Chapter # 6).

- Ground truthing was endeavoured for unsafe noise. Out of 308 stations monitored, more than 54% sites exceeded the 75 dB (A) limit for six (6) temporal variations (Annexure B and Table 6.1)

Techniques such as *Map Algebra, Density computation, and Surface development* produced the outcomes that effectively integrated to generate risk maps (Chapter # 6)

- Effects of noise pollution on the human health within the study area have been investigated by means of conventional tools. The study has gone further to measure the epidemiological indicators of *disease occurrence* and *point prevalence* at the micro scale of *Analysis Zone* (Chapter # 8 and # 9).

  Base line public health information pertaining to *Morbidity, noise induced disease frequency* and *Intensity of occurrence* has been computed by the author (Chapter # 8).

  The linkage between noise pollution and subsequent diseases has been evaluated through a critique of experiences of the physicians practising in Karachi (Chapter # 8).

- The research focused on the community participation and awareness aspect of the population at risk. Pathetic public attitude towards an important societal problem was concluded. Findings of perception survey on noise pollution, traffic and housing indicate jeopardy at the community level (Chapter # 7).

12.2 FURTHER RESEARCH AVENUES

The products of this enquiry have created many possibilities for further research and provide a unique research agenda for engineers, environmentalists and urban managers:

- Landsat 5 image, which was adopted in this study for the extraction of land cover themes, had a spatial resolution of 30 meters that suits better to large-scale investigations. Today's world offers a host of high-resolution commercial satellite imageries like *Quick Bird, IKONOS, DK1* and *KVR*, having spatial resolution are in the range of 2.0 to 0.60 meters. Urban investigations require detailed topography for modelling *etc.* in the form of Digital Elevation Model (DEM). Further research applications in Pakistan can be conducted on similar lines provided the availability of stereo pairs of low altitude *aerial photographs* and/or high-resolution digital imageries.

- Satellite Remote Sensing (SRS) has been employed worldwide for time-lapse monitoring of land covers. Developing countries such as Pakistan could watch for specifics *e.g.* vegetation, environmental quality, settlement patterns and desertification. This work has provided a footing for building on these inquiries.

- As presented in this work, urban parameters are drastically different from that of developed countries, which has put forward environmental implications (ESCAP, 1990). Interrelationships among categories of land use in the metropolitan cities of developing countries in Asia are interesting research areas. Karachi deserves in depth autopsy in this regard.

  Studies' identifying gradual land use changes at the neighbourhood level and its consequent impacts on environmental deterioration are an avenue of future investigation for Karachi and like South Asian cities.

- Further comprehensive simulated models embedding meteorological parameters (vertical and horizontal temperatures; moisture; field, direction and velocity of wind), which could evaluate / animate the changes in noise (pollution) levels, seasonally and their effects henceforth.

- Risk assessment studies incorporating age and gender information of the affected population could be carried out as outlined in this thesis.

- Pakistan lacks in vivo as well in vitro epidemiological studies establishing indigenous linkage between environmental pollution and subsequent upshots on human health. Causation and Correlation of diseases *incidence* and pollution levels have to be inferred through recurrent community based studies.

  The suggested clinical studies should be spatially widespread and imbibe socio-economic and ethnic clues of the focus population.

- Cross-sectional studies should be taken to evaluate the perceptions about the understanding of such important environmental problems and the psychological desires to abate them. These studies may provide the perspicacity variations among the various socio-economic and ethnic target groups.

developing countries.

12.3 RECOMMENDATIONS

- Technological innovation, institutional development, and co-operation by all levels of government and industry have proven to be successful strategy for abating noise pollution in the developed nations. Keeping in view the monetary constraints of developing countries like Pakistan, concurrent endeavours by all the stakeholders, incorporating educational (ethical), engineering and enforcement (legislation) measures are recommended.

- Although the population data for Pakistan are spatially managed at the level of districts, it has not been able to deliver goods at the micro levels. Detailed demographic and socio-economic households' information is required to be maintained on GIS at smaller local entities.

- The quality of data on land use in the study area had not been excellent as it consisted of many approximations. There is a dire need of developing a comprehensive *cadastral* database in the GIS framework for the metropolitan city of Karachi. The beneficiaries of such MAGIS (Metropolitan Area Geographic Information Systems) would not only be planners and researchers but also utility and services providers; law enforcement agencies and revenue departments of the federal, provincial and local governments.

- It is suggested that a metropolis-wide *traffic volume* count program be launched to ascertain the current magnitudes. The storing and computing power of GIS and its analysis tools provide potential for more detailed descriptions and analysis of roadway and traffic data. In this region, Abu Dhabi Municipality is successfully using it. There is no doubt that traffic management in Karachi could greatly be enhanced by GIS technology due to its visualising, analyses, simulating and modelling capacities.

- This research has exposed another public health requirement of the society. *Vital statistics* are largely managed on GIS worldwide. Steps towards this direction need initiation in Pakistan.

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Annexure A

Visual assessment of the Problem

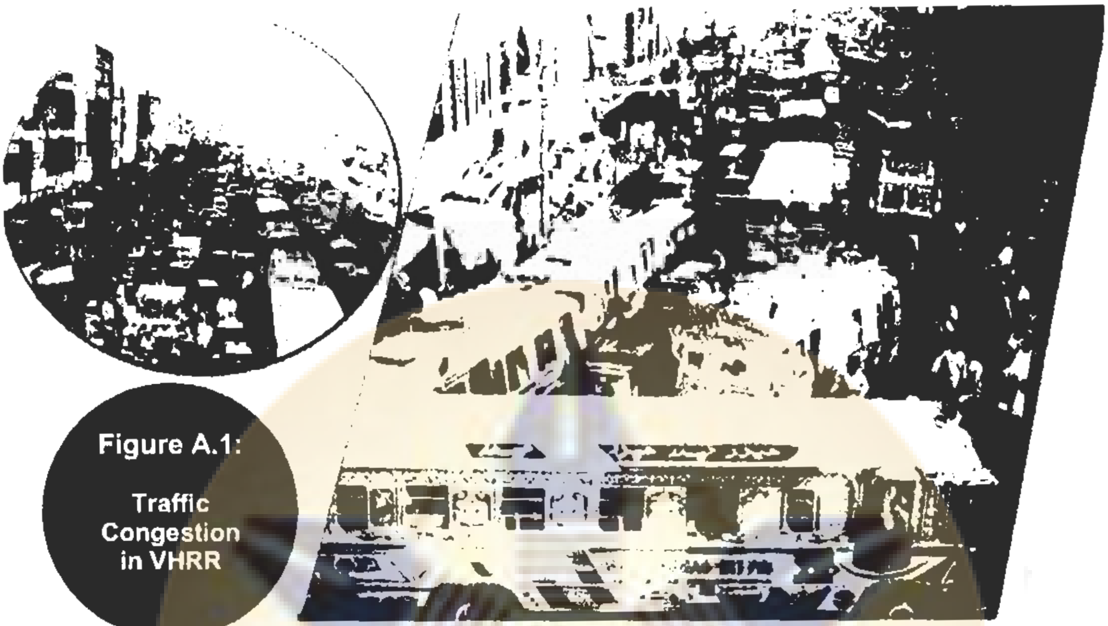


Figure A.1: Traffic Congestion in VHRR

Figure A.2: Congestion Problem nearby Empress Market (VHRR), Old City Karachi (Core), Analysis Zone 3

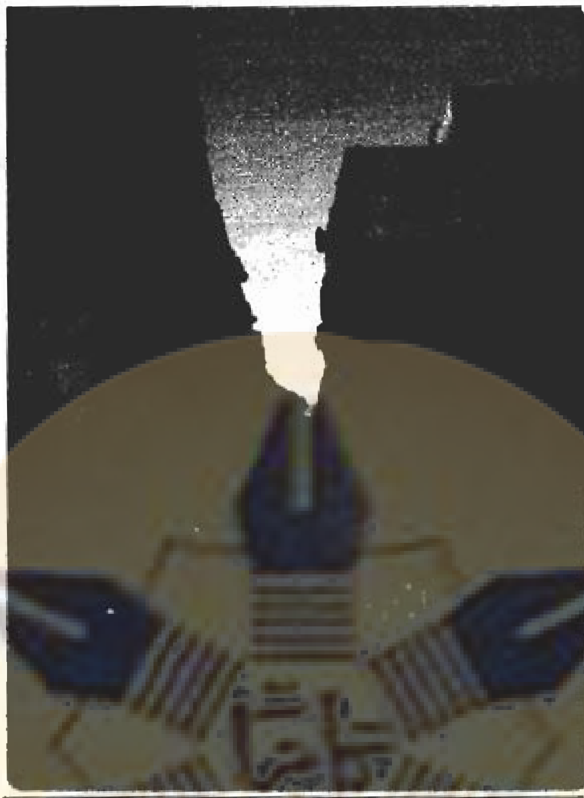


Figure A.3: Rickshaw, noisy transport mode passing across Typical Old City Housing (HRR), Analysis Zone 2

Figure A.4: Human Resource at Vulnarable Risk

Annexure B

Questionnaires (English Translation)

B-Q1. Filled by Health Professionals **B-Q2. Filled by General Public**

B-Q1

Name: ☐ **Sex:** ☐ **Age:** ☐

Specialization: ☐ **Experience:** ☐ *years*

Practicing Locality: ☐ ☐ ☐ ☐

- **Mark the diseases frequent in your practicing area (Noise pollution based):**

S. No.		Symptoms and Diseases	S. No.		Symptoms and Diseases
01	☐	Tinnitus	13	☐	Palpitation
02	☐	Hearing Loss	14	☐	Hypertension
03	☐	Ulcer	15	☐	Efficiency Loss
04	☐	Aural Pain	16	☐	Nausea
05	☐	Reduced Muscular Control	17	☐	Colitis
06	☐	Elevated Cholesterol	18	☐	Birth Defects
07	☐	Stress	19	☐	Learning Loss
08	☐	Anxiety	20	☐	Headaches
09	☐	Irritability	21	☐	Sleeplessness
10	☐	Brain impairments	22	☐	Arteriosclerosis and coronary heart disease
11	☐	Nerve impairments and ataxia (irregular movements)	23	☐	Muscular impairments
12	☐	Liver malfunctions	24	☐	Kidney malfunctions

- **List three most prevalent diseases from the above-mentioned in your practice area:**

1. ☐ 2. ☐ 3. ☐

100%	*Just only because of Noise Pollution,*	**50%**	*Moderately Significant factor*
75%	*Noise Pollution is a Significant Factor*	**25%**	*Less Significant Factor*
		0 %	*Not Significant*

100 %	75 %	50 %	25 %	0 %	Symptoms and Diseases	100 %	75 %	50 %	25 %	0 %	Symptoms and Diseases
☐	☐	☐	☐	☐	Tinnitus	☐	☐	☐	☐	☐	Palpitation
☐	☐	☐	☐	☐	Hearing Loss	☐	☐	☐	☐	☐	Hypertension
☐	☐	☐	☐	☐	Ulcer	☐	☐	☐	☐	☐	Efficiency Loss
☐	☐	☐	☐	☐	Aural Pain	☐	☐	☐	☐	☐	Nausea
☐	☐	☐	☐	☐	Reduced Muscular Control	☐	☐	☐	☐	☐	Colitis
☐	☐	☐	☐	☐	Elevated Cholesterol	☐	☐	☐	☐	☐	Birth Defects
☐	☐	☐	☐	☐	Stress	☐	☐	☐	☐	☐	Learning Loss
☐	☐	☐	☐	☐	Anxiety	☐	☐	☐	☐	☐	Headaches
☐	☐	☐	☐	☐	Irritability	☐	☐	☐	☐	☐	Sleeplessness
☐	☐	☐	☐	☐	Brain impairments	☐	☐	☐	☐	☐	Arteriosclerosis and coronary heart disease
☐	☐	☐	☐	☐	Nerve impairments and ataxia (irregular movements)	☐	☐	☐	☐	☐	Muscular impairments
☐	☐	☐	☐	☐	Liver malfunctions	☐	☐	☐	☐	☐	Kidney malfunctions

Questionnaire #: [ ] **Name:** [ ] **Age:** [ ] **Sex:** [ ] **B.Q2**

Present Address: [ ] **Working Place Address:** [ ]

Duration of work *(at present address)*: [ ] **Occupation:** [ ] **Education:** [ ]

House Hold: < 02 yrs old [ ], 2 - 12 yrs old [ ], 12 - 27 yrs old [ ], 27 - 40 yrs old [ ], 40 - 60 yrs old [ ]

> 60 yrs old [ ]

Social Status: *(Monthly Income)* < 2000 Rs. [ ] 2000 - 5000 Rs. [ ] 5000 - 10000 Rs. [ ] 10000 - 15000 Rs. [ ] > 15000 Rs. [ ]

How much time do you spent outside *(in hours)*: During Working days [ ] Weekends / off days [ ]

Travel Time *(Daily average)*: [ ]

Most Frequently Used Transportation Mode:

Bus / Minibus	[ ]	Coach	[ ]	Rickshaw	[ ]
Taxi/ School Van/ Contract Bus	[ ]	Cycle or Motor Bike	[ ]	Metro Bus (A.C)	[ ]
Metro Bus (Non A.C)	[ ]	Car (A.C)	[ ]	Car (Non A.C)	[ ]
Animal Drawn	[ ]	By foot	[ ]	Other	[ ]

During what hours, the traffic remains high at the nearest street to your work place?

From [ ] hours to [ ] hours, From [ ] hours to [ ] hours, From [ ] hours to [ ] hours

What is the operating speed at the nearest road at the high traffic times?

Ever High [ ] High at congestion times only [ ] Medium [ ] Slow at congestion times only [ ] Ever Solw [ ]

If traffic speed is slow nearby you: Reasons for slow operating speed.

High traffic volume [ ] Roadway condition [ ] Encroachments / Parking in the vicinity [ ]

Does this road have traffic jams? Yes [ ] No [ ] Only temporarily [ ]

In your opinion, what are the adverse affects of the Traffic present at the nearby street to yourself and your work place? [ ]

Is there any factory or industrial unit near your work place/house? Yes [ ] No [ ] **If yes, how far?** [ ]

In your opinion, what adverse affect does it have on you? [ ]

Is there another source of noise nearby your work place / house?

Yes [ ] No [ ] **If yes how far?** [ ]

Do you think Growing population is the main cause of environmental degradation? Yes ☐ No ☐

Do you think environmental noise is a threat? Yes ☐ No ☐

Has anyone from your family members been affected by any of the following disorders:

Disease Symptom	Age	Sex	Duration	Current status	Reasons
Head ache					
Stress					
Nausea					
Eye ailments					
Tonsillitis					
Chronic Flue					
Chronic Cough					
Hearing Loss					
Hypertension					
Elevated Cholesterol					
Palpitation					
Learning Loss					
Efficiency Loss					
Ulcer					
Throat Disease					
Chest Disease					
Birth Defects					
Asthma					
Other					

How would you rate noise pollution in your neighborhood?

Very High ☐ High ☐ Moderate ☐ Low ☐ Very Low ☐

Do you consider that noise pollution affects human health? Yes ☐ No ☐
If yes, at what extent?
Very High ☐ High ☐ Moderate ☐ Low ☐ Very Low ☐
Do you have any remedial measures for the prevention of noise pollution?

1. ☐, 2. ☐, 3. ☐, 4. ☐, 5. ☐

Which place do you perceive to be clear of noise pollution?

Home ☐ Office ☐ Educational Place ☐ Place of worship ☐ Recreational Place ☐

Annexure C

Multi-Attribute Analysis Template

New MapID & Title : MultiCri Noise Risk Multi Attribute

No of Input Maps : 10
Input Maps (Id Max Color)
LandCoverClassification1998 7 *PopulationDensity* 10 *AverrageNoiseMode* 6 *AverrageNoisePeak* 6 *DiseasePrevalence* 5 *DiseaseOccurrence* 5 *RoadsBuffers* 5 *RoadDensityIndex* 10 *StdDeviationNoiseMode* 4 *StdDeviationNoisePeak* 4

Format = Weight Map ID

6.96 *LandCoverClassification1998 (LCCG)*

	Null	- 0:	0
1	Water	- 1:	0
2	Vegetation	- 2:	01
3	Urban Veg. (Mix)	- 4:	05
4	Medium Built up	- 5:	08
5	Densely Built up	- 6:	10
6	Low Built up	- 7:	05
7	Open Land	- 8:	0

10.41 *PopulationDensity (PDG)*

	Null			- 0:	0
1	54	-	467	- 1:	01
2	467	-	1113	- 2:	02
3	1113	-	2359	- 3:	03
4	2359	-	7246	- 4:	04
5	7246	-	12859	- 5:	05
6	12859	-	19205	- 6:	06
7	19205	-	22724	- 7:	07
8	22724	-	46610	- 8:	08
9	46610	-	103108	- 9:	09
10	103108	-	143588	- 10:	10

13.44 *AverrageNoiseMode (ANMG)*

Null	- 0:	0
< 66	- 1:	01
66 - 71	- 2:	02
71 - 76	- 3:	03
76 - 81	- 4:	05
81 - 86	- 5:	07
> 86	- 6:	08

13.44 *AverrageNoisePeakt (ANPG)*

Null	- 0:	0
< 66	- 1:	01
66 - 71	- 2:	02
71 - 76	- 3:	03
76 - 81	- 4:	05
81 - 86	- 5:	07
> 86	- 6:	08

6.66 *DiseasePrevalence (DPG)*

Null	- 0:	0
1 - 14	- 1:	01
14 - 27	- 2:	02
27 - 41	- 3:	05
41 - 54	- 4:	08
54 - 67	- 5:	10

9.80 *DiseaseOccurrence (DOG)*

Null	- 0:	0
1 - 3	- 1:	01
4 - 8	- 2:	02
9 - 14	- 3:	05
15 - 23	- 4:	08
24 - 47	- 5:	10

3.46 *RoadsBuffers (RBG)*

Null	- 0:	0
1 - 50	- 1:	10
51 - 100	- 2:	08
101 - 500	- 3:	05
501 - 1000	- 4:	02
> 1001	- 5:	01

10.31 *RoadDensityIndex (RDIG)*

Null	- 0:	0
1 - 86	- 1:	01
86 - 173	- 2:	02
173 - 259	- 3:	03
259 - 346	- 4:	04
346 - 432	- 5:	05
432 - 519	- 6:	06
519 - 605	- 7:	07
605 - 691	- 8:	08
691 - 778	- 9:	09
778 - 864	- 10:	10

12.66 *StdDeviationNoiseMode (SDNMG)*

		Null	- 0:	0
1	-	03	- 1:	05
03	-	05	- 2:	05
05	-	07	- 3:	03
07	-	10	- 4:	03

12.76 *StdDeviationNoisePeak (SDNPG)*

		Null	- 0:	0
1	-	03	- 1:	05
03	-	05	- 2:	05
05	-	07	- 3:	03
07	-	10	- 4:	03

Annexure D

Monitoring Sample Locations around Karachi Metropolis

Location No.	Name of Location	GPS Coordinates X (Long.)	GPS Coordinates Y (Lat.)
1	Nazimabad Chowrangi	67.03111	24.90222
2	Golimar	67.03083	24.89861
3	Lasbela	67.03333	24.88722
4	Gurumandir	67.03889	24.87972
5	Kala Pul	67.05472	24.84722
6	CSD Super Market	67.05222	24.85333
7	Gora Qabristan	67.04944	24.85861
8	Lucky Star,Fleet Club	67.03333	24.85694
9	Café Subhani	67.03167	24.85694
10	Sarawan Hotel	67.03167	24.85694
11	Zaibunnisa Street near Panaorama Center	67.02944	24.85611
12	Zainab Market	67.02806	24.85583
13	State Life, Abdullah Haroon Road (Survey of Pakistan)	67.02861	24.85417
14	Shahrah Iraq Mehboob Market	67.02694	24.85889
15	Intersection of Zaibunnisa Street and Shahrah Iraq	67.02806	24.85917
16	Bohri Bazaar	67.02889	24.85944
17	Hasan Square	67.07333	24.90167
18	New Town, University Road	67.06000	24.88806
19	Intersection of University Road and Shaheed Millat Road	67.05583	24.88528
20	Jamshed Road	67.05278	24.88722
21	Soldier Bazar	67.03389	24.87694
22	Holy Family hospital, BYJ Road	67.02944	24.87361
23	IBA City Campus	67.02417	24.86722
24	Zoological Garden (gate)	67.02333	24.87417
25	Intersection of M. A. Jinnah and Garden Road	67.02472	24.86528
26	Empress Market	67.02861	24.86222
27	Intersection of Karachi Grammar School and Saghir Road	67.02694	24.86472
28	Hotel Avari Towers	67.03167	24.85139
29	Hotel Regent Plaza	67.03861	24.85528
30	Karimabad	67.05472	24.86028
31	Aisha Manzil	67.06472	24.92722
32	Water Pump F B Area	67.07639	24.93750
33	Sohrab Goth	67.08361	24.94333
34	Shafiq Morre	67.07639	24.95639
35	Nagan Chowrangi	67.06639	24.96500
36	U.P. Morre	67.06611	24.97306
37	North Karachi Power House	67.06500	24.98556
38	Do Minute Chowrangi	67.06500	25.00000
39	Surjani Chowrangi	67.06389	25.00611
40	Gulberg F B Area	67.07083	24.94222
41	Peoples Chowrangi	67.06528	24.94806
42	Sakhi Hasan	67.05778	24.95333
43	Tahir Villa	67.05944	24.93194
44	Numaish, M A Jinnah Road	67.03583	24.87167
45	Capri Cinema (Signal)	67.02889	24.86750
46	Prince Cinema (Signal)	67.02694	24.86639
47	Radio Pakistan	67.01806	24.86083
48	Kaimari	66.97528	24.81833

Location No.	Name of Location	GPS Coordinates X (Long.)	Y (Lat.)
49	Kaimari Maternity Home Railway Crossing	66.97778	24.82361
50	Native Jetty Bridge	66.99111	24.84361
51	Dockyard	66.97278	24.83528
52	West Wharf	66.98056	24.84417
53	Agha Khan Road Roundabout	66.99139	24.85000
54	Corner of Aga Khan Jamat Khana at G. Allana Road	66.99306	24.85222
55	Khada Market	66.99444	24.85306
56	Kharadar Police Chowki	66.99639	24.85111
57	Mereweather Tower	66.99750	24.84917
58	Queens Road Haji Camp	67.01722	24.84333
59	Queens Road Mai-Kolachi Intersection	67.00611	24.84361
60	PIDC Roundabout	67.02389	24.84667
61	Shaheen Complex	67.01861	24.85083
62	Arts Council	67.02167	24.85333
63	Sind High Court / Assembly	67.02000	24.85556
64	Governor House	67.02528	24.85278
65	Kashif Centre	67.03417	24.85222
66	Cantt Station	67.03944	24.84333
67	Sindhi Muslim Society Signal	67.05444	24.85972
68	Nursery	67.06000	24.86000
69	Chanesar Halt Shahrah-e-Faisal	67.06472	24.86111
70	Fine House Shahrah-e-Faisal	67.07639	24.86528
71	Baloch Colony Flyover Shahrah-e-Faisal	67.08278	24.86722
72	Lal Qila Shahrah-e-Faisal	67.09028	24.87167
73	Karsaz Roundabout Shahrah Faisal	67.09583	24.87500
74	PAF Shahrah-e-Faisal	67.11639	24.88444
75	Drigh Road Shahrah-e-Faisal	67.12500	24.88722
76	Labour Square Rashid Minhas Road	67.11611	24.90083
77	Johar Morre Rashid Minhas Road	67.14694	24.90417
78	Johar Square	67.12528	24.91250
79	Safura Morre University Road	67.15639	24.93944
80	Suparco Morro Mosamyat University Road	67.14056	24.93611
81	KU Campus Gate University Road	67.14611	24.93389
82	Safari More University Road	67.11222	24.92806
83	NIPA Chowrangi	67.09639	24.91806
84	Gulshan Chowrangi	67.09111	24.92389
85	Intersection of Shabbir Usmani and Sehba Akhtar Road	67.08194	24.91667
86	Intersection of Shabbir Usmani Road	67.08667	24.92056
87	Rab hospital	67.08833	24.92222
88	Gulshan Block 1 Abid Town	67.08389	24.92333
89	Basera Morre,Gulshan	67.08722	24.92528
90	Moti Mahal	67.08889	24.92667
91	Fazal Mill	67.08556	24.93222
92	Al-Asif Square	67.09083	24.94083
93	Maymar Complex	67.09750	24.95444
94	Bara Board,Manghopir Road	67.01750	24.90361
95	Noras Chowrangi	67.01667	24.90556
96	Habib Bank DC West office	67.01444	24.91028
97	Social Security SITE Hospital	67.01528	24.92694
98	Valika Stop, Manghopir Road SITE	67.01472	24.91944
99	Dakkhana Stop SITE	67.00944	24.90861
100	Siemens Chowrangi SITE	67.00278	24.90306

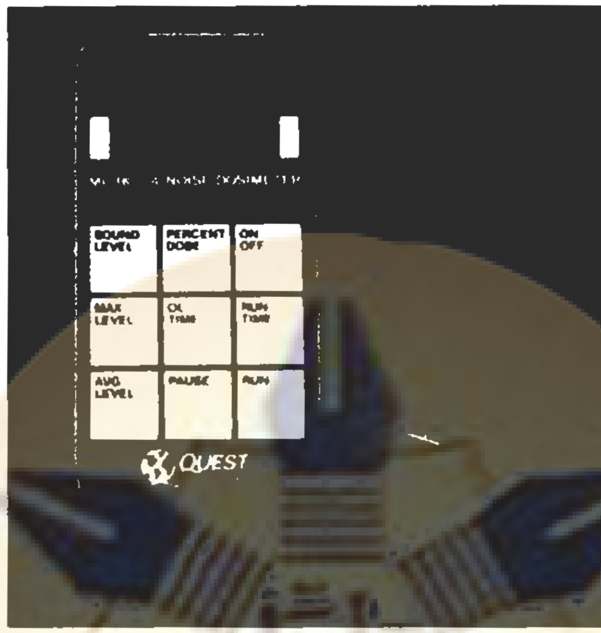
Location No.	Name of Location	GPS Coordinates X (Long.)	GPS Coordinates Y (Lat.)
101	Johnsons and Philips Factory SITE	67.00417	24.90417
102	South Avenue Awami Kanta SITE	66.99611	24.89861
103	Ghani Chowrangi Traffic Signal SITE	66.98944	24.89361
104	Sher Shah Chowrangi	66.98528	24.89056
105	Dalda Stop, Maripur Road opp. Lever Br. Factory	66.97917	24.89139
106	Paracha Chowk Signal (Sher Shah)	66.98278	24.88889
107	PAF Base Masroor	66.96389	24.87833
108	Gul Bai	66.96778	24.87611
109	Intersection of Mirza Adam Khan Road and Maripur Rd	66.97722	24.87111
110	Crown Cinema, Machhar Colony	66.98583	24.86500
111	Mi-Kolachi Bypass	67.01417	24.83500
112	Boat Basin Khayaban-e-Sadi	67.02583	24.82667
113	Intersection of Khayaban-i- Sadi and Khayaban-i-Firdosi	67.02083	24.81389
114	Ziauddin University Shireen Jinnah No. 1	67.00667	24.81667
115	Oil Terminal Shireen Jinnah Colony	67.00222	24.81778
116	Clifton, end of Khayaban-i- Sadi	67.01778	24.80917
117	Clifton main resort	67.02333	24.80722
118	Helipad / play land Clifton	67.02778	24.81361
119	Mazar Abdullah Shah Ghazi Gate	67.03167	24.81028
120	Intersection of 24th Street and Khayaban-i-Shamsheer	67.04028	24.80556
121	Intersection Sea View Avenue and Khayaban-i-Shamsheer	67.03500	24.79972
122	Kinara Resturent (Sea view Avenue)	67.04139	24.79306
123	Intersection of Khayaban-i-Ittihad and Sea View Avenue (Village)	67.05472	24.77861
124	Sea shore corner behind Village Rest.	67.05306	24.77611
125	Intersection of Khayaban-i-Ittihad and Khayaban-i-Hafiz	67.07389	24.79889
126	Intersection of Khayaban-i-Hafiz and Khayaban-i-Rahat	67.06528	24.80556
127	Intersection of Khayaban-i-Behria and Khyaban-i-Hafiz (M. Sultan)	67.05861	24.81361
128	Intersection of Khayaban-i-Hafiz and Khayaban-i-Shamsher	67.05167	24.81639
129	Gizri (Mubarak Mosque)	67.04639	24.82139
130	Intersection of Khayaban-i-Jami and Ch. Khaliquzzaman Road	67.04333	24.82861
131	Schon Circle	67.03528	24.82750
132	Do Talwar (Shahrah-e-Iran, Zamzama Boulevard)	67.03444	24.82139
133	Intersection of Zamzama Boulevard and 5th Commercial Lane	67.04139	24.81694
134	Mohatta Palace Hatim Alvi Road	67.03278	24.81500
135	Madina Mosque Main Clifton	67.02889	24.81250
136	Teen Talwar Signal	67.03361	24.83333
137	Clifton Bridge	67.03278	24.84083
138	Intersection of Ch. Khaliq-uzzaman and CA Avenue	67.03694	24.83528
139	Intersection of Khayaban-i-Hafiz and Khayaban-i-Roomi	67.04250	24.82861
140	Intersection of Gizri Avenue and Gizri Boulevard	67.05194	24.82389
141	Intersection of Gizri Boulevard, Khayaban-i-Shamsher	67.05278	24.81806
142	Intersection of II South Street and Sun Set Boulevard	67.06278	24.76639
143	Intersection of Sun Set Boulevard and Korangi Road	67.06750	24.83694
144	National Bank Korangi Road Signal	67.06000	24.84083
145	Gulistan School Qazi Hall SMS	67.05750	24.86222
146	Allah Wali Chowrangi Shahrah-e-Quaideen	67.05528	24.86500
147	Intersection of Tariq Road and Allama Iqbal Road	67.05972	24.87167
148	Intersection of Khalid Bin Waleed Road and Allama Iqbal Road	67.05667	24.87361
149	Intersection of Kashmir Road Allama Iqbal Road	67.05139	24.87583
150	Intersection of Khalid Bin Waleed Road and Sir Syed Road	67.05861	24.87722
151	Intersection of Tariq Road and Sir Syed Road	67.06194	24.87556
152	National Institute of Cardiovascular Diseases	67.04083	24.85417

Location No.	Name of Location	GPS Coordinates X (Long.)	Y (Lat.)
153	Jang Press I I Chundrigar Road	67.01611	24.85083
154	City Station Habib Bank Plaza	67.00778	24.84917
155	National Bank Main Branch I I Chundrigar Road	67.00222	24.84917
156	Shahrah-e-Liaqat New Chali	67.00667	24.85194
157	Haqqani Chowk Hasrat Mohani Road	67.01028	24.85167
158	Pakistan Chowk	67.01250	24.85389
159	Intersection of Zaiuddin (Kutchery Road and Shahrah-e-Liaqat)	67.01139	24.85444
160	Light House Intersection of M A Jinah and Ziauddin (Kutchery) Road	67.00917	24.85583
161	Aram Bagh Park Side	67.01306	24.85583
162	Fresco Bakery Burns Road	67.01444	24.85639
163	Intersection of Robson Road and Burns Road	67.01500	24.85778
164	Services Hospital Allahwala Market, M A Jinnah Road	67.01306	24.85806
165	Intersection of Burns Road and Dr. M. Hashim Ghori Road	67.01194	24.85528
166	Intersection of D M Wafai and Kamal Ata Turk Road	67.01694	24.85389
167	Regal Chowk	67.02417	24.86028
168	Tibet Center M A Jinnah Road	67.02083	24.86250
169	Eid Gah Qasaban Mosque M A Jinah Road	67.01611	24.86000
170	Jubilee Cinema Roundabout	67.01806	24.86528
171	Nishter Road Ram Swami	67.01556	24.86944
172	Allah Wali Mosque Lawrence Road Gandhi Garden	67.02083	24.87556
173	Intersection of Mangho Pir Road / Nishter Road Near Mazar	67.02333	24.87972
174	Karachi Auditorium	67.02972	24.88472
175	Pital Gali Golimar	67.03083	24.89306
176	Bundo Khan Bridge Super Highway	67.12139	24.97667
177	Gulshan-e-Maymar Morre Super Highway	67.13556	24.99167
178	New Subzi Mandi Entrance Super Highway	67.15667	24.99333
179	Suchal Rangers Head Quarter Super Highway	67.20444	24.98639
180	Intersection Malir Cantt Rd and Super Highway (Toll Plaza)	67.21278	24.98500
181	Model Colony Morre, Jinnah Avenue	67.18250	24.90306
182	9-C Stop Model Colony	67.19028	24.90222
183	Model Colony Railway Station	67.19417	24.90139
184	Malir Bridge National Highway	67.20361	24.86639
185	Quaidabad Intersection National Highway	67.21139	24.85556
186	Dawood Chowrangi	67.20750	24.85056
187	Future Colony Morre	67.20222	24.85500
188	Murtaza Chowrangi, Shahrah-e-Darul Uloom Korangi	67.18139	24.85028
189	Darul Uloom Karachi and OGDC Korangi	67.16611	24.84750
190	Single Chowrangi Korangi	67.16028	24.84611
191	Bilal Chowrangi Korangi	67.14222	24.84250
192	Grace Marriage Hall Korangi	67.14639	24.82500
193	Korangi Poly Clinic	67.15417	24.82639
194	Chishtia Bus Stop Korangi	67.15806	24.82750
195	KDA Civic Center Korangi	67.16417	24.82889
196	Korangi No.6	67.16972	24.82944
197	Landhi No.6	67.17306	24.83167
198	DSP Office Landhi Police Thana	67.18167	24.83806
199	Landhi No. 1	67.20472	24.84611
200	Babar Market	67.19222	24.84056
201	2 way traffic Morre, Landhi	67.18667	24.84083
202	Bus Stop 89 Landhi	67.20472	24.84639
203	DMC Office Malir	67.22639	24.84222
204	Hospital Chowrangi, Landhi	67.22556	24.83778

Location No.	Name of Location	GPS Coordinates X (Long.)	GPS Coordinates Y (Lat.)
205	Zafar Town Railway Crossing, Landhi	67.22694	24.84444
206	Bhains Colony Morre, Landhi	67.22889	24.85472
207	Razzaqabad PMTF Entrance	67.25861	24.85611
208	Port Qasim Morre, Zulfiqarabad	67.30028	24.86639
209	Malir Mandir	67.19361	24.87500
210	Malir 15 No. National Highway	67.18972	24.87806
211	Malir Kala Board National Highway	67.18278	24.88194
212	Malir Halt National Highway	67.17556	24.88444
213	Mohabbat Nagar Malir	67.19222	24.88333
214	Jinnah Square Malir	67.19750	24.89000
215	Liaqat Market Malir	67.19528	24.89389
216	Urdu Chowk Malir	67.19806	24.89833
217	Saudabad No. 15 Malir	67.20806	24.90611
218	Khokarapar No. 2 1/2 Malir	67.21778	24.93028
219	Malir Token Bus Stop	67.19972	24.90306
220	RCD Ground Malir	67.19583	24.90056
221	Malir Dak Khana Lal Masjid	67.19167	24.89528
222	Madina Mosque Malir Buraf Khana	67.18528	24.88583
223	Jinnah Terminal	67.16750	24.89639
224	Jinnah Terminal approaching Signal	67.16833	24.89583
225	PIA Motor Transport Building Entrance	67.14833	24.89944
226	PIA Transport & Road from Colony Gate	67.14417	24.89833
227	Rufi Shopping Centre Gulistan-e-Johar	67.13889	24.90583
228	NED University Gate, University Rd	67.11361	24.92889
229	Silver Jubilee Gate KU University Rd	67.11833	24.93083
230	Sindhi Hotel	67.12194	24.93194
231	PIA Planetarium (Inside)	67.07722	24.90333
232	Safari Park Gate	67.11000	24.92694
233	Alladin Park Gate	67.10611	24.91056
234	Sindbad Park Gate	67.09917	24.91556
235	Lundi Kotal	67.05528	24.93667
236	KMDC North Nazimabad	67.06056	24.94139
237	Bhayani Center 2K Stop	67.05333	24.94889
238	Ship Owners College North Nazimabad	67.04056	24.94833
239	Asghar Ali Stadium North Nazimabad	67.02972	24.93722
240	KDA Roundabout Saifee Hospital North Nazimabad	67.06111	24.92778
241	Ziauddin Hospital North Nazimabad	67.04528	24.92528
242	Mukka Chowk F. B. Area	67.06833	24.92333
243	CMA / Comprehensive School F B Area	67.07083	24.92056
244	Tall Wala Stop, Razia Hospital F B Area	67.07306	24.92694
245	Javed Nihari House F B Area	67.07583	24.93167
246	Education College F B Area	67.08000	24.93250
247	Dhoraji Morre Gulshan-e-Iqbal	67.09444	24.93250
248	Disco Bakery Gulshan-e-Iqbal	67.09750	24.92917
249	Sarafa Bazar New Karachi	67.07167	24.97278
250	3 No. New Karachi	67.07028	24.98861
251	Kala School Shahrah-e-M A Johar New Karachi	67.06944	25.00028
252	D Morre New Karachi	67.07750	25.00028
253	Sindhi Hotel New Karachi	67.07778	24.99667
254	5 No. New Karachi	67.07833	24.98722
255	Nala Stop New Karachi	67.07889	24.97667
256	Godhra Stop	67.07972	24.96556

Location No.	Name of Location	GPS Coordinates X (Long.)	Y (Lat.)
257	Al Noor Morre F B Area	67.08111	24.94972
258	Babul Ilm North Nazimabad	67.04694	24.94306
259	Banaras/ Bacha Khan Chowk	67.01528	24.93250
260	Police Station Orangi Town	67.00611	24.93806
261	5 No. Stop Orangi Town	67.00083	24.94056
262	12 No. Stop Orangi Town	66.99667	24.94306
263	Telephone Exchange Orangi Town	66.99917	24.93722
264	10 No. Market Orangi Town	66.99194	24.94111
265	Metro Cinema Signal Orangi Town	67.00944	24.93611
266	Abdullah College North Nazaimabad	67.02417	24.92917
267	Paposh Nagar Nazimabad	67.02472	24.92250
268	Chandni Chowk Nazimabad	67.02139	24.92167
269	Chhota Maidan Nazimabad	67.02194	24.91444
270	1 No. Stop Nazimabad	67.02222	24.91111
271	Petrol Pump Chowrangi Nazimabad	67.03111	24.91083
272	Khamosh Colony Stop Near Liaqatabad	67.03250	24.90139
273	Abbasi Shaheed Hospital Nazimabad	67.02861	24.92000
274	7 No. Nazimabad	67.03111	24.91889
275	Board Office (Matric) North Nazimabad	67.03139	24.92444
276	Anda More Mangho Pir Road	67.05389	24.96472
277	Qalandria Chowk North Karachi	67.05028	24.95944
278	Town Municipal Office Purana Golimar Mangho Pir Road	67.02028	24.89111
279	Shoe Market, Nishtar Road	67.01750	24.87194
280	Ranchhorre Line, Nishtar Road	67.01278	24.86722
281	KMC Workshop Nishtar Road	67.00889	24.86361
282	Christ Church, Nishtar Road	67.00694	24.86167
283	Farooq-e-Azam Mosque, Jona Mkt, Nishtar Road	67.00389	24.85889
284	Intersection of North Napear Road and Nishtar Road (Nigar Cenima)	67.00306	24.85806
285	Tayabi Dawakhana, Intersection North Napear Road	67.00333	24.85722
286	Z stop, Chand Bibi Road Near Pan Bazaar	67.00472	24.85694
287	City Court M. A Jinnah Road	67.00694	24.85444
288	Intersection of M A Jinnah Road and Nepear Road (Denso Hall)	67.00556	24.85361
289	Next to Denso Hall Stop towards Mamon Mosque M A Jinnah Road	67.00417	24.85278
290	New Memon Mosque, M A Jinnah Road	67.00139	24.85139
291	City Post Office, Intersection of S L Bhitai Road and A Khan Road	67.00194	24.85056
292	Main Kharadar Bus Stop	66.99639	24.85389
293	Gaaoo Gully Agha Khan Road	66.99861	24.85500
294	Kukri Ground Agha Khan Road	66.99944	24.85611
295	Lee Market Round about Location 1	67.00028	24.85944
296	Lee Market Round about Location 2	67.00000	24.86139
297	Kumar Cinema Nipear Road	67.00222	24.85917
298	Paper Market Intersection Shahrah-e-Liaqat	67.00972	24.85389
299	National Stadium, Stadium Road	67.08222	24.89250
300	Dhoraji Society Intersection	67.07778	24.89139
301	Mohammad Ali Housing Society Roundabout	67.08833	24.87528
302	Makka Masjid Tipo Sultan Road	67.08528	24.87556
303	Intrersection of Tipo Sultan Road and Shaheed-e-Millat Road	67.07972	24.87139
304	Hill Park Entrance Gate	67.07194	24.87083
305	Gulistan Shadi Hall Hill Park	67.07083	24.87528
306	Intrsection of Sirajuddola Road and Shaheed-e-Millat Road	67.06889	24.87889
307	Main Bahadurabad Roundabout	67.06750	24.88194
308	Bahadurabad Roundabout Shaheed-e-Millat Road	67.06556	24.87972

Annexure E Noise Meter



Noise Dosimeter
Quest Technologies
Model: Micro-14
Made in USA
Oconomowoc, Wisconsin
Approved by:
United States Department of Labour
Mine Society and Health Administation