A Handbook for Socio-economic Impact Assessment (SEIA) of Future Urban Transport (FUT) Projects

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Transportation Research and Injury Prevention Programme

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TRIPP

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Contents

Introduction

Transport plays a critical role in social and economic development. The need to understand and to accommodate the interests, perceptions and needs of target populations and other key stakeholders is paramount in the design of projects and programs aimed at social and economic development.

The involvement of local stakeholders (user groups, transport service providers, academia, government, private sector groups, NGOs) in the fact-finding and decision-making processes has been central to improving the responsiveness of transport planning to a broad set of users, as well as making the best use of limited public resources. These interests range from such traditional concerns as mobility and congestion to a wide range of non-traditional concerns such as social equity, economic development and competitiveness, institutional effects, and environmental costs.

In spite of these advances in transport and development, there remains a critical need for new assessment and evaluation regimes that better articulate the effects of transport investments and their alternatives, and better plan for the goals of social equity and inclusion. Theoretical analyses that link transport influences to social and economic change require more complex models that go beyond the general and aggregate levels of data collection.

Thus far, few studies of transport have addressed the consequences of social change or derived predictive models to deal with this set of issues. Moreover, there has not been sufficient examination of transport's impact on social issues within a qualitative framework. For example, in many instances only economic criteria are applied to the analysis of “improved accessibility.” It is important to also consider the flow of social capital[1] in the form of information, news, or job opportunities facilitated through transport networks. The role of transport in facilitating or limiting social capital expands economic criteria models when measuring the impact of transport projects.

The benefits of improving transport infrastructure have traditionally been measured by performance criteria, like improved connectivity, travel time, speeds and fuel savings. The costs of improvements in transport infrastructure are classically defined as construction cost, ongoing operations and maintenance cost. These criteria form the basis of the cost-benefit analyses, which judge the feasibility of these projects. According to the ASCE (1999) definition, the Benefit to Cost (B/C) Ratio is calculated as present value of project benefit divided by the present value of project cost. While in theory, any project with a B/C ratio exceeding 1 is worthwhile, most agencies have recognized that there is some uncertainty associated with both the benefit and the cost estimates. Accordingly, it is not uncommon for agencies to desire a threshold of B/C exceeding 1.5 for large new projects, and 1.3 for incremental projects (in which uncertainty is less.)

However, transport is a derived demand, i.e. transport is used only when the need to move exists, and the need to move is dictated by socio-economic requirements of the users. This implies that the necessity for movement, hence the use of transport infrastructure, is need/goal based; i.e. people do not move for the sake of moving, they move to get to work, education, recreation, health etc which will finally enable them to improve their social and economic well being. At the same time, the “users” are a heterogeneous mix of people of different socio-economic classes, with different needs and desires and differing needs of movement. These differential concerns make the task of assessing the feasibility of a project more complex - some users may benefit, some may not, and some may not be affected at all.

Also, there may be a category of non-users of the project - people who are not the target group or the stakeholders - who may experience an indirect impact of the project. This indirect impact is an externality of the project which is not included in the standard cost benefit analysis. The externality can be negative or positive depending on the nature of indirect impact. In both cases this externality needs to be understood for the transport projects. If the externality is positive then the project can build in methods to capitalize on that eternality. If the externality is negative then mitigation and compensation measures too need to be built in the project. The classical cost-benefit analysis, then, needs to be replaced by a socio-economic impact assessment methodology (SEIA) to get a measure of expected benefits and costs to different groups.

1. **Social capital** is the set of norms, networks, and organizations through which people gain access to power and resources, and through which decision-making and policy formulation occurs (Grootaert C., 1998.)

International funding agencies like the World Bank (WB), Asian Development Bank (ADB), and Department for International Development (DFID), U.K., advocate inclusion of social assessment in transportation projects and prioritize poverty alleviation as an objective. The projects funded by them have also focused on mobility and access needs of the poor. The policy documents of these agencies bring out the following areas where work needs to be carried out:

1. The understanding of a community as a disaggregated mass (differentiated by income, occupation, gender, age, ethnicity, etc.) specifically in the Indian context.
2. The gap between access availability (transport infrastructure) and mobility issues (ability of different groups to utilize the infrastructure) and their correlation with poverty (especially with respect to livelihood opportunities).
3. A methodological framework or model for ensuring the inclusion of socio-economic issues of transport planning in policies and projects in India.

Hence the evaluation of transport projects from the perspective of social development goals becomes important, especially for large projects where the impacts are spatially and temporally extensive. With differential social impacts over a different user groups, it becomes important to not only understand how the users benefit from new transport projects but if the community benefits, especially its vulnerable sections the urban poor.

This handbook is based on the PhD dissertation work of Anvita Arora, titled “Socio-Economic Impact Assessment (SEIA) Methodology for Urban Transport Projects: Case Study Delhi Metro”, carried out under the supervision of Dr. Geetam Tiwari, both being the co-authors of this handbook. The objective of handbook is to assess the impact of large transport projects on the urban poor and to propose a socio-economic impact assessment methodology (SEIA) which can be integrated in the impact assessment studies of such projects. The handbook presents a methodology to understand the impact of accessibility and mobility on socio-economic well-being (SEWB) of the urban poor. It uses household survey based primary data to derive indicators of accessibility, mobility and SEWB. The indicators are then aggregated into indices of accessibility, mobility and SEWB. The change in indicators and indices in the before and after project scenarios is used to assess the significance of the impact of the project on the urban poor.

The handbook is divided into 3 units:

UNIT 1: SEIA - current practices
UNIT 2: Key Concepts, Definitions and Indicators
UNIT 3: The SEIA Method

The handbook wraps up with a concluding note and a listing of common problems and errors.

UNIT 1
SEIA - Current Practices

- The Funding Agencies' Approach
  - The World Bank
  - The Asian Development Bank
- The SCOPE Framework
- Implementing Agencies' Guidelines
  - The FDOT Handbook
- The NGOs' Perspective
  - The FYCC Approach
- Discussion
- Conclusion

UNIT 1 : SEIA - Current Practices

The process of assessing the impact of a transportation project on a community has been referred to in different ways by different authors - community impact assessment, social impact assessment, economic impact assessment, and sometimes as a subset of environmental impact assessment. These terms have a substantial overlap in meaning but are not necessarily completely synonymous. And hence, a review of the methodologies followed in all these processes is necessary to comprehensively formulate a method that would contribute to the objective of assessing impact. Where some of the methodologies directly focus on the impact of transportation processes, others talk about infrastructure projects or development projects in general and thus have a more generic and broad-based approach. The methodologies reviewed in this unit are:

- **The funding agencies' approach**
- **The SCOPE framework**
- **The implementing agencies' guidelines**
- **The NGOs' perspective**

The Funding Agencies' Approach

Transport projects, especially in developing countries, are often funded by international agencies. The stated agenda also is to reduce poverty and social inequities by improving access. The World Bank, the Asian Development bank, DFID etc. are some agencies involved in this work. Most of these agencies have a social impact assessment method of some kind built into their project objectives. The SIA methods of two of these have been extracted from their published literature and discussed in this section.

The World Bank

According to World Bank, social assessment is relevant to any World Bank initiative that aims to reduce poverty. The broad objectives of social impact assessment are to ensure that World Bank investment programs contribute to poverty alleviation by sharpening project objectives to focus on poor, vulnerable, and other marginalized and excluded groups. Social assessment, as an approach, provides a dynamic, research process and a framework for identifying and integrating the key social and institutional issues that should be addressed in the project cycle.

Social assessments are expected to contribute to development effectiveness by:

- Focusing on the poor, vulnerable and other marginalized and excluded groups;
- Identifying key social development objectives and institutional arrangements;
- Creating a participatory framework which enhances the inclusion of stakeholders in processes and decisions that affect them;
- Building ownership and capacity for policies and investments, and
- Mitigating adverse social impacts of development initiatives.

In the World Bank's use of the term, a social assessment (SA) is not an abstract study or a set of discussions, but an integral part of project planning and implementation. Key criteria for a good social assessment would therefore be the extent to which it has analytical value (how it contributes to understanding key social issues required for social preparation and implementation); its operational value (whether it provides instruments, mechanisms, and action plans that are integrated in the project

as a whole; and its process value (how well it mainstreams participation and capacity value).

Social Assessment involves four primary steps or pillars. These are:

1. **Identify Key Social Development and Participation Issues**

   SA strengthens transport projects by:

   - Facilitating the identification of the social dimensions of spatial and transport planning. By highlighting needs and priorities of stakeholders, SA identifies complementary policies and investments to maximize intended outcomes of transport sector interventions and to increase social returns of projects.
   - Identifying the differential needs, priorities, and constraints of particular social groups (for example, urban/rural, men/women) resulting in more responsive and appropriately designed transport strategies and programs aimed at providing the poor with better access to employment, education and health services.
   - Supporting an objective evaluation of the anticipated distribution of benefits and how best to ensure that benefits reach the intended beneficiaries equitably.

2. **Analyze Institutional and Organizational Issues**

   SA strengthens transport projects by evaluating institutional arrangements and mechanisms for sustaining the participation of beneficiaries and communities in the maintenance of transport infrastructure.

3. **Formulate a Participation Framework**

   SA strengthens transport projects by instituting consultative mechanisms to ensure the participation of key user groups, including the poor, local communities, NGOs and the private sector in the selection, planning, design, and implementation of infrastructure improvements.

4. **Establish Mechanisms for Monitoring and Evaluation**

   SA strengthens transport projects by monitoring distributional impacts of transport investments and develops indicators for participatory monitoring of social development objectives.

These four pillars are useful for understanding how transport and social development intersect with one another. They also provide a holistic way of viewing transport projects within a specific socio-economic context, without undermining the traditional economic and financial requirements of such projects. Each pillar of the SA requires a number of steps, which are detailed in the World Bank Document (World Bank (b). 1999). Where appropriate, each pillar must also address the need to mitigate any adverse social impacts. This is accomplished by identifying the impacts, assessing the institutional capacity to mitigate them, ensuring stakeholder participation in the mitigation plan, and, integrating the monitoring of the mitigation measures into the overall project monitoring framework.

The Asian Development Bank

The ADB (ADB India, 2002a) has formulated a comprehensive project implementation guideline referred to as Public Works Directives (PWD) for use of agencies implementing central-level and district level projects. The objective is to provide a set of understandable, effective, efficient and practical directives to the kingdom of Nepal, though the application is generic to the South Asian region. According to them, social and environmental assessments are required at the feasibility stage of a project. These may be incorporated into the feasibility study, or they may be conducted as separate components depending on the complexity of issues. In either case, there is a need to ensure that that any social/environmental mitigation actions are incorporated into a project's design, implementation plan and cost estimates. The chapter on Social Assessment (ADB India, 2002b) gives

1. The definition and objectives of Social Assessment
2. The types of projects where Social Assessment is required
3. Social Assessment in the Project Cycle
4. The Steps in Social Assessment

5. Resources for Social Assessment

The steps prescribed for the Social Assessment process are listed below.

1. Create socio-economic profile
2. Identify client population
3. Create socio-economic profiles for sub-groups
4. Assess needs of client population
5. Assess demand for proposed project
6. Assess absorptive capacity of sub-groups
7. Address gender issues
8. Address impacts on vulnerable groups
9. Identify target beneficiaries and targeting mechanisms
10. Participatory development process
11. Modulate implementation modalities
12. Resettlement action plan
13. Determine Benefit monitoring and evaluation procedures
14. Social Assessment Reports

Detailed discussion on these steps, the responsible people and the estimated time period are available in the document for perusal. For a Central level project, the social assessment process is expected to take up to 12 months to complete.

The SCOPE Framework

The Scientific Committee on Problems of the Environment (SCOPE) is an interdisciplinary body of natural and social science expertise focused on global environmental issues, operating at the interface between scientific and decision-making instances. It is a France based Institution created by, the International Council for Science, in 1969. This section studies socio-economic assessment, as a part of the environmental impact assessment, as detailed by the SCOPE Working Group proceeding, at Toronto 1977 (SCOPE 5, 1977). The social environment is a composite of numerous interrelated factors. Although these items may be identified from checklists, interviews, etc., the inter-relationships are generally poorly understood and have largely been ignored in project planning. A general list of socio-economic impact categories is as follows:

1. **Demographic impacts:** rural depopulation; suburban growth; etc.
2. **Economic impacts:** income, employment, and taxes; the affected parties; impacts on business and large property owners; increased short-term and long-term employment; the 'boom and bust' pattern of project construction; problems of local inflation and short-term changes in supply and demand patterns;
3. **Impacts on social values and attitudes:**
   a. Community cohesion: the social integration of the community and the mechanisms by which individuals and groups within a defined area maintain functional ties with one another;
   b. Life style: a perceptual and behavioral dimension, referring to accepted values and day-to-day behavior in the affected communities, as well as to outsiders' views of these values and behavior.

According to SCOPE 5 (1977) “social profiling” of the target groups needs to be carried out by gathering the required socio-economic information. The methods advocated for collecting such data are categorized as using existing data, asking questions, and direct and indirect observations

The methods that can be used for socio-economic prediction are classified by the document with the objective to predict changes in the main features of the social profile over the next few years, with and without action. The principal sub-division is between extrapolative and normative methods. In the former

case, a prediction is made that is consistent with past and present socio-economic data, e.g., a prediction based on the linear extrapolation of current trends. A normative method, on the other band, is one in which desired socio-economic goals are specified, and an attempt is made to project the social environment backward in time to the present to examine whether existing or planned resources and environmental programs are adequate to meet the goals. These methods are discussed in some detail in the SCOPE document (SCOPE 5, 1977).

Implementing Agencies' Guidelines

The agencies responsible for implementing the transportation projects are also concerned with their social impacts. Some transport departments, especially in the developed countries, sometimes have prescribed guidelines to deal with these issues. The handbook (Florida Department of Transportation (FDOT). 2000) used by the Florida Transportation Department has been discussed in this section.

The FDOT Handbook

The approach suggested by Kramer and Williams (2000) for assessing and addressing potential land use impacts of transportation projects draws from a Handbook (Florida Department of Transportation (FDOT). 2000), prepared for the Florida Department of Transportation (FDOT) by the Center for Urban Transportation Research (CUTR) at the University of South Florida in Tampa as a supplemental guide to the FDOT's Project Development & Environment (PD&E) Manual. The Handbook is intended to provide practical, cost-effective, and simple to implement guidance to FDOT Environmental Management staff in the preparation of environmental documents relative to the assessment of potential social and economic impacts of transportation projects on communities and neighborhoods.

According to the Handbook community impact assessment is a fluid and iterative process that occurs throughout the life of a transportation project - from planning through construction and monitoring. The basic steps of the process are listed below. Public involvement is an integral part of each of these steps.

1. Determine the nature of the project and define the study area.
2. Develop a community profile to gain a thorough understanding of the study area, including any issues surrounding the project. This information provides a baseline for analysis and is used to understand what would happen in the community with and without the project.
3. Analyze each project alternative and identify any potential impacts and the magnitude of those potential impacts.
4. Identify potential solutions to identified potential adverse impacts.
5. Document the findings of the assessment process, including any commitments made.

The level of effort involved in each step is a function of the size and complexity of the project, the level of controversy involved, and the potential for significant community impacts. If a project requires preparation of an environmental impact statement, it will also require a more detailed community impact assessment. If an issue surfaces that is of considerable concern to an affected community, it should be assessed regardless of the nature of the project. This assures that the issue will be adequately addressed.

According to the Handbook, urban planning programs rely on reasonable consistency between transportation and land use plans and projects. Without that consistency, it is difficult to accomplish desired objectives. The purpose of the consistency determination is to assure that the final project conforms to and supports, as much as feasible, the planning objectives of the affected area. Because land use and transportation are interdependent, the consistency determination will involve both land use and transportation plans and issues in the affected area. Making a consistency determination is fairly subjective and requires a combination of common sense and some working knowledge of transportation

and growth management issues. In addition, because it is essentially a policy determination, the determination of consistency must be made in the context of the local political and socio-economic environment. Below is a general process set forth for transportation agencies to determine the consistency of the transportation project with local and regional growth management plans. Of course, the process would need to be modified as necessary to accommodate local circumstances.

1. Work with local government and regional planning staff to identify current adopted plans for each affected jurisdiction.
2. Consider the nature of the proposed project and review the identified plans to identify potential consistency issues.
3. Summarize findings by briefly describing the type of plan reviewed and any potential consistency issues that arose through the review or discussion with agency staff.
4. Review the draft consistency determination with agency staff and study area stakeholders and revise the draft accordingly.

The Handbook then instructs analysts that where project alternatives are determined to be consistent, no more action is required beyond documenting the process and findings. However, where the project alternatives are determined to be clearly inconsistent, the handbook advises that strategies to either make the project alternatives consistent or to address their potential adverse impacts must be developed.

The determination of growth inducement establishes whether project alternatives will induce growth or alter the planned pattern of development. There are three general categories of induced growth related to transportation projects:

1. Projects serving specific land development, such as a highway interchange for a theme park,
2. Projects that would likely stimulate complementary land development, such as the development of a hotel near a large airport, and
3. Projects that would likely influence regional land development location decisions, such as a new highway providing convenient access to developable land on the fringe of a metropolitan area. If the potential for growth inducement is largely consistent with local future land use plans, the Handbook advises that no further action is required beyond documenting the process and findings. If the potential exists for growth inducement that is significantly inconsistent with local comprehensive plans or that could adversely affect the transportation investment, the Handbook states that the next step is to then consider alternative strategies for addressing potential growth impacts.

The NGOs' Perspective

The fourth type of agency concerned with the impact of transportation projects on communities are the non-governmental organizations working at the grass root level. Some of these organizations have developed their own methodologies to determine impacts, one of which has been elucidated in this section.

The FYCC Approach

The reference document by Families, Youth and Community Care (2000), Australia provides guidance and essential information about how social impact assessment processes should be undertaken according to an NGO and does not represent government policy. The approach outlined in this section is generic in its scope but can be applied to Transportation projects with ease. According to this document the SIA methodology is delineated as follows:

1. **Scoping:** Identify potentially affected groups and individuals and their issues of concern and the nature of the likely impact what might happen where and to whom.
2. **Profiling:** Identify the nature of the groups and individuals likely to be affected. Do they have the

capacity to cope with the likely impact? Are they particularly vulnerable to the development? Profiling techniques include literature review, secondary data analysis, social indicators analysis (e.g. Census data, Socio Economic Indicators for Areas, Community Sensitivity Indices), survey research, Community involvement process, community observation, inventories and community needs assessment.

3. **Prediction:** What are the social impacts associated with the options of scenarios for change? Proposals will often present a number of scenarios to be considered by the impact assessment study. Prediction should be summarized in to core social impacts and include the type of impacts magnitude of impacts, direction of impacts, location of impacts, community level impacts, direct and indirect impacts, Impacts can be presented in tables, matrices, and with the use of geographical information systems.
4. **Assessment:** Are these impacts significant given the priorities, policies and programs of Government? Assessment will include weighing the positive and negative impacts of each scenario. The results of the prediction stage may indicate one or two preferred scenarios.
5. **Evaluation:** Are there alternative ways to meet the objectives of the development without causing the identified potential impacts? This stage should include innovative scenario development or perhaps combinations of scenarios. Better outcomes are often achieved when stakeholders are included in the development of options.
6. **Management, mitigation, monitoring and review:** How can we best manage the potential impacts of this development that we have identified? What strategies might help to get the best out of the development and manage the negative impacts? Issues identified in the preceding stages, in particular issues highlighted through consultation with stakeholders, should be addressed in the management and review of the project. The project's environmental management plan should include practical strategies that will ensure social impacts are monitored and managed.
7. **Recommendations:** What recommended strategies and actions will produce the best outcomes for the groups or individuals potentially impacted by the development?

Discussion

The methodologies chosen for review represent the approaches of a variety of policy-making bodies from the funding agencies, international expert forums, government bodies, and NGOs and consequently differ in their emphases.

The World Bank approach addresses issues of a larger policy framework with generic applicability. The focus invariably is on institutional mechanisms and community participation but it is an objective framework imposed upon a community. The ADB document is fairly comprehensive in its delineation of the SIA process. It is, however, generic in its application and therefore does not include the special problems of transportation projects.

The SCOPE framework discusses the formulation of a socio-economic framework of a community. It exhaustively lists various methods of data collection and analysis. It also approaches the community in an objective fashion with emphasis on the need to quantify all parameters listed. However, it does not correlate these parameters into a holistic assessment design.

The focus of the FDOT Guidelines is on land use impacts of transportation projects and seems only remotely related to social impact assessment. It has been discussed in this handbook primarily because it introduces the temporal and spatial dimensions of the Social Impact Assessment process a reminder that communities influence the use of land and vice-versa and transportation projects influence both in a correlated manner; and that communities change with time and response to a transportation project can never be instantaneous.

The FYCC approach, very obviously, is an approach of an NGO working at the community level, and emphasizes heavily on people and their need and reactions. It actually talks of concepts like community

sensitivity indices and the vulnerable community groups.

Conclusion

The social development challenges facing transport are daunting. To address such issues effectively, requires systematic quantitative and qualitative research, highly participatory processes, inter-sectoral cooperation, and refined monitoring and evaluation tools. SEIA is a comprehensive approach toward meeting these challenges, and inherently expects that the development initiatives contribute to poverty alleviation, enhance inclusionary practices, increase social capital, build ownership, and avoid adverse social impacts. SEIA needs to become an integral part of project feasibility analyses. It complements economic, financial, technical and environmental analyses and is used to refine and direct investment programs toward more effective and socially sustainable development objectives. What is perhaps obvious from this review is that most social impact assessment methodologies have a piece-meal approach to the whole issue of how a community can be affected by the introduction of a transport project in its area. The need, then, is to design a SEIA methodology, specifically for transportation projects, with specific tools to quantify the affect on the poor. This can be integrated with the traditional cost-benefit techniques.

In summary, the SEIA of a transportation project must answer the following questions:

1. What is the impact area of the transport project? This would include the area immediately affected and the area where the impact spreads over time.
2. Who is affected by the project? This would include the targeted beneficiaries and the others affected without benefiting from the project. Of the targeted group, the further questions are:
   - What is their socio-economic structure?
   - What are their needs?
   - What are their demands?
   - What is their absorptive capacity?
3. Which are the vulnerable groups? Specific questions to identify these groups would be:
   - What is the income differential in mobility and accessibility?
   - What is the gender differential in mobility and accessibility?
   - What is the socio-cultural differential in mobility and accessibility?
4. What is the existing transport system? This would include not only the existing road network and the formal transport services in the region, but also the informal/intermediate transport that is currently catering to the mobility needs.
5. What are the potential adverse impacts? This would anticipate adverse impacts and thus give clues to formulation and inclusion of mitigation strategies within the scope of the transportation project

UNIT 2

Key Concepts, Definitions and Indicators

- Influence zone and target groups
  - Spatial Characteristics
  - Temporal Framework
- Population Characteristics
  - Target groups
- Urban Transport and poverty
- Accessibility and Mobility : Concepts and Definitions
  - Defining accessibility
  - Defining mobility
- Socio-economic Well-being : Concepts and Definitions
  - Defining Socio-economic Well-being
- Indicators of Accessibility, Mobility and SEWB
  - Accessibility Indicators
  - Mobility Indicators
  - Socio-Economic Well-being Indicators
- Impact of Transport Project
  - Impact Assessment

UNIT 2 : Key Concepts, Definitions and Indicators

This unit presents the concepts used to develop the SEIA method. It reviews the current discussions on the concepts and develops definitions to be used for this handbook. It also structures the defined concepts into indicators used to develop the model. The concepts discussed in this unit are

Influence zone and target groups
Urban transport and poverty
Accessibility and Mobility : concepts and definition
Socio-economic well being (SEWB) : concepts and definition
Indicators of Accessibility, Mobility and SEWB
Impact of transport projects

Influence Zone and Target Groups

The first step in any impact assessment study would be the process of identifying the study area and its contents, or defining the influence zone. The aim of this element of the preliminary evaluation is to define the focus of the assessment studies, including what can and cannot be accomplished. The influence zone has the following components:

1. The spatial limits of the study
2. Time factors to be considered in the study and impact analysis
3. The population set that would be affected by the project

Defining the components would enable the team to identify the baseline characteristics for a comprehensive impact assessment study. The factors listed above are in no way mutually exclusive and it is their overlap that would help to define the influence zone of the project.

Spatial Characteristics

The geographic area subject to the potential impact needs to be clearly defined prior to the beginning of the assessment study. A new transport project in a city can have citywide impact or localized to a specific area depending on the nature of the project. The spatial limits of the affected area can be defined on the basis of:

1. Type and scale of project
2. Diversity of land uses
3. Sensitivity of the proposed surroundings

For example, a new subway can have localized nodal impact, a flyover will affect the immediate network and the land uses around the intersection, a new mass transit system will affect all areas which have access to the system.

Temporal Framework

The temporal framework needs to be understood in two aspects

1. The time required to conduct the impact assessment study
2. The impact of the project over time

The time requirements for the study depend on whether:

The studies require investigation during special periods of the year.

The fields to be studied are numerous and the results must be integrated

The required information is available for existing resources, such as government agencies, or will involve considerable site investigation work.

The impact of the project over time can be studied as:

Short term or immediate impact,

Medium term impact, or

Long term impact.

The impact over time will depend on both the spatial characteristics of the impacted area and the population characteristics

Population Characteristics

The relevant human environment for impact assessment of transport project is a dispersed collection of interested and affected publics, interest groups, organizations and institutions. The generic set of dimensions for investigation listed below includes the following aspects of the human environment for construction projects and geographically-located programs and policies:

1. Relationships with the biophysical environment, including aspects of the environment seen as resources or problems; areas having economic, recreational, aesthetic or symbolic significance to specific people; residential arrangements and living patterns, including relationships among communities and social organizations.
2. Historical background, including initial settlement and subsequent shifts in population; developmental events and eras, including experience with boom-bust effects, as well as discussion of broader employment trends; past or ongoing community controversies, particularly those involving technology or transport; and other experiences likely to affect the level of distribution of the impacts on local receptivity or proposed action.
3. Political and social resources, including distribution of power and authority; the capacities of relevant systems or institutions (e.g. the school system); friendship networks and patterns of cleavage or cooperation among potentially affected groups; levels of residential stability; distributions of socio-demo-graphic characteristics such as age and ethnicity; presence of distinctive or potentially vulnerable groups (e.g. low income); and linkages among geo-political units (federal, state, county, local and inter-local).
4. Culture, attitudes and social-psychological conditions, including attitudes toward the proposed action; trust in political and social institutions, perceptions or risks; relevant psychological coping and adjustment capacity; cultural cognition of society and environment; assessed quality of life; and improvement values that may be relevant to or affected by the proposed action.
5. Population characteristics including demographics of relevant groups (including all significant stakeholders and sensitive populations and groups); major economic activities; future prospects; the labor markets and available work force; unemployment and underemployment; population and expected changes; availability of housing, infrastructure and services; and size and age structure of households

The level of effort that is devoted to the description of the human environment should be commensurate with the size, cost and degree of expected impacts of the proposed action. At a minimum, the existing literature on comparable or analogous events, knowledgeable experts, and readily available documents such as government reports should be consulted. On-site investigations and the use of previous field studies and surveys are recommended, as well as rapid appraisals and mini-surveys.

Target Groups

Target group would refer to the specific subset of the influence zone on which the SEIA would be conducted. This target group is well defined in terms of spatial and population characteristics and the temporal framework of the study is realistic in terms of resources available.

The identification of the target group would depend on:

1. Interests of the organization conducting the SEIA
2. Nature of the impact to be studied

Urban Transport and Poverty

Transport policies and projects have implicit or explicit affects on the quality of life, especially of the poor. The literature review on this subject highlights the various aspects of this issue and raises two problems.

> The conceptualization of poverty is difficult. The World Bank (1999a) conceptualizes poverty as "a multidimensional phenomenon, encompassing inability to satisfy basic needs, lack of control over resources, lack of education and skill, poor health, malnutrition, lack of shelter, poor access to water and sanitation, vulnerability to shocks, violence and crime, lack of political freedom and voice".
>
> Tracing the poverty impacts of transport interventions is complex because transport is an intermediate service - transport improvements reduce poverty not through increased consumption of transport per se but through improving the quality and security of access to work, markets, and services, and through release of scarce resources for consumption and production. Decisions on transport investment can easily overlook needs and concerns of poor groups especially in low income countries, where the resources are limited and there are several competing projects in both physical and social infrastructure sectors that make decisions of resource allocation difficult.

Transport policy must therefore explicitly address the distributional effects of efficiency interventions, and vice versa. For example, an efficiency-focus leads to a bias towards "strategic" infrastructure, higher-speed, longer-distance links and projects that "save time" for motor vehicle users. This is at the expense of pedestrian and NMV facilities. Enhancements and projects that enhance local, low-speed accessibility have a much greater direct positive impact upon the lives of the poor (Dimitriou, 1993). Good transport policy contributes to poverty reduction by enhancing efficiency and equity (Gannon, C., et al, 2001). Improvements in transport infrastructure may accrue different level of direct benefits to different sections of society and it is the socio-economic status that defines the absorptive capacity of a people; i.e. the ability to benefit from a development project. The need assessment of the poor - in terms of where they live, what transport modes they use and what are their problems - is usually not comprehensive. Apart from being users of transport, the poor are also employed in the transport sector for construction and services.

Understanding of gender issues in the transport context is of vital relevance too, since women are estimated to account for 70% of those living in poverty worldwide (UNDP, 1995). The growing literature on women and transport has also clearly shown that they tend to have different travel needs deriving from the multiple tasks they must perform in their households and in their communities (Greico and Turner, 1997). Adverse environmental impacts of transport effect the urban poor particularly severely, since they are the least able to avoid or seek protection from them (UNDP 1998). Similarly, road accidents and street crime disproportionately affect poor groups. In developing countries, where many people do not have access to motorized vehicles, more than 50 percent of road accident victims (injuries and fatalities) are pedestrians, motorcyclists, bicyclists and other non-motorized vehicles (NMV) occupants. Some explicit adverse impacts of transport projects on the urban poor can be highlighted here:

1. Displacement of a transport mode that is popularly used by poor people and other vulnerable groups to make way for another;
2. Disruption/partitioning of low-income neighborhoods due to road construction;
3. Involuntary resettlement;
4. Excessive regulatory control of transport services, especially entry barriers to the informal sector;
5. Transport tariff increases as a result of removal of a subsidy;
6. Traffic accidents, especially for pedestrians;
7. Environmental pollution emission concentrations and noise from vehicles;
8. Labor redundancy caused by restructuring, commercialization, and privatization of state owned transport enterprises.

There is a shelter-transport-livelihood link for the urban poor. High densities and intense mixing of land uses allow for many daily trips to be very short and thus able to be made by foot or by non-motorised vehicles (NMV). Increasing motorization and investments in high-speed, high-capacity roads, and increasing sub-urbanization, results in increasing trip distances and exclusion of the NMVs. Access to affordable transport is one of the most important factors in determining livelihoods for the urban poor. The urban poor have very limited mobility, hence increasing accessibility and affordable mobility would allow them to upgrade their quality of life.

Most rural and urban poor take recourse in informally organizing their own transportation supply. This may take the form of intermediate form of local transport, primarily non-motorized. These non-motorized users are in majority in Sub-Saharan Africa (on foot) and Southeast Asia and South Asia (bicycles, cycle rickshaws, bullock carts, and traditional country boats on the inland waterways). However, they are often neglected in the design and modernization of transportation infrastructure.

The transport needs of the poor can be better met by facilitating the informal sector. There are two issues of particular relevance here - one is of transportation services provided by the authorities for the poor and the other is of transportation services used/ provided by the informal sector. The poor confront everyday problems related to mobility such as access to employment, social services, educational opportunities and domestic tasks. If the mass transport services in the city/area are physically and financially inaccessible to the poor, they contribute in reinforcing their poverty.

Accessibility and Mobility : Concepts and Definition

In any discussion on urban and transport planning, the concepts of mobility and accessibility play a central role. Their definitions have changed over time and they are often interchangeably used. Where the earlier urban development models were mobility based - increasing movement and speed of movement seen as a sign of progress - the current discourses of sustainable development advocate accessibility-based models, ensuring that the desired destinations and services are within reach of people. The increasing 'automobility' (Cervero, 1997) due to the focus on increasing mobility has, of late, led researchers to query whether increasing accessibility rather than increasing mobility should be the ultimate aim of transport policies.

According to Vivier (2001) “Access to urban activities for a population presupposes the existence of a public transport service offering all city dwellers, whatever their income level, age or handicaps, the possibility of getting to work or school, going shopping and enjoying themselves. This aspect of the question is often obscured by transport professionals, who focus on what is measured in transport surveys, i.e. recorded mobility and travel times, not the lack of mobility caused by the simple fact that no means of transport are available.” Vivier (2001) defines mobility as “motorized mobility, measured by average annual distances traveled by city dwellers in automobiles, motorized two-wheeled vehicles, taxis and public transport”. According to him “Accessibility is good when density is high because distances to be covered are low and when public transport is fast… In low density cities where the automobile dominates, one travels quickly and a great deal, but the daily travel times are high and city

dwellers, who do not have an automobile to get around in, are excluded from urban activities." According to his discussions then, mobility is dependent on having recourse to a motorized transport mode and accessibility is dependent on dense urban planning and provision of public transport.

Ross (2000) defines mobility as the "amount of travel people undertake" and measures it by per capita vehicle kilometers traveled. He shows that "a positive relationship exists between mobility and such indicators as transport energy use, motor vehicle ownership and use, journey to work distance, journey to work speed and general car speed." According to him, accessibility is far more difficult, if not impossible, to measure. "Often understood as the ease of access to destinations, amongst other parameters it encompasses ideas of costs in time and money; extent, comfort and frequency of the public transport system; and the distance to be negotiated to reach destinations such as shops, work places and schools." He shows (Ross, 2000) that accessibility and mobility have a relationship of reciprocity and if planners aim to increase accessibility then car use and personal mobility must be restricted.

Both Vivier's and Ross's definitions give rise to the several negative consequences of promoting mobility. The first negative consequence is the high cost of motorized mobility (especially private modes). According to Vivier (2001) the journeys by the motorized city dwellers in mobility based urban and transport systems are "expensive for the community, consume large amounts of non-renewable energy, and generate major emissions of green-house gases". In the same vein Ross says that "mobility contributes nothing to wealth, can be wasteful of resources, damages communities, and contributes to air, water and noise pollution." The second negative consequence is social exclusion. Vivier (2001) states that "mobility, like all consumption of goods and services, is very unequally distributed amongst city dwellers. One can even say that the growth of urban mobility has been accompanied by a worsening of the phenomenon of exclusion, due to the development of low-density peripheral quarters which are devoid of stores and local services and are poorly served by public transport. In the absence of adequate public transport, those excluded from the automobile are thus also more or less excluded from employment, services and leisure activities." Obviously then, the processes of suburbanization, and more importantly forced relocation, engender social exclusion by expecting increased mobility and decreasing accessibility.

The next step in the discussion on the definitions of mobility and accessibility is to check their applicability to the developing countries. Since mobility, as defined by both Vivier and Ross, is dependent on having access to motorized modes, it definitely engenders social exclusion, especially since it does not consider movement by public transport, non-motorized modes and walking as mobility. With regard to their concepts of accessibility too the argument that provision of better public transport would mean better access to services and employment for the poor becomes inapplicable in the context of the developing countries because (a) the poor often cannot afford the public transport services, and (b) non-motorized modes and walking, which are the transport means of the poor, are still not considered.

Black (1981) writes that accessibility is a function of land-use intensity and transport supply. According to Black (1992), accessibility is "a description of how conveniently land-uses are located in relation to each other… and how easy or difficult it is to reach these land use activities via the transport network of both public and private transport modes."

While Roberts (1988) sees mobility as the number of kilometers traveled, he measures accessibility as the number of trips made. Further he argues that the "number of, and/or the ease of making journeys" are more related to accessibility (Roberts, 1990). He notes that fewer kilometers traveled (that is, less mobility) equates to a higher quality of life.

Litman (2003a), defines mobility as "the movement of people or goods. It assumes 'travel' means person-or-ton-miles, 'trip' means person-or-freight-vehicle trip. It assumes that that any increase in travel mileage or speed benefits society… This perspective considers automobiles most important, it values, transit, ridesharing and cycling where there is sufficient demand, such as downtowns and college campuses, and so justifies devoting a portion of transport funding to transit, HOV and cycling

facilities… The mobility perspective defines transportation problems in terms of constraints on physical movement, and so favors solutions that increase motor vehicle system capacity and speed… it gives little consideration to walking and cycling except where they provide access to motorized modes". According to Litman, 2003a, accessibility "refers to the ability to reach desired goods, services, activities and destination (collectively called opportunities). Access is the ultimate goal of most transportation…This perspective considers all access options as potentially important, including motorized and non-motorized modes… It values modes according to their ability to meet users' needs, and does not necessarily favor longer trips or faster modes if shorter trips and slower modes provide adequate access… From this perspective… solutions can include traffic improvements, mobility improvements, mobility substitutes such as telecommuting or delivery services, and more accessible landuse." According to Litman, 2003a, then, mobility is a subset of accessibility and the latter is a more comprehensive and inclusive definition of the transportation needs of the society. An important point made in the TDM Encyclopedia (Litman, 2003b) is regarding the impact of accessibility on equity. "The quality of a persons or group's access determines their opportunity to engage in economic and social activities. Policies that favour access for one group over others can be considered horizontally inequitable. Policies that favour advantaged groups over disadvantaged groups (such as wealthy over poor or motorists over non-motorists) can be considered vertically inequitable."

Defining Accessibility

The review of literature on accessibility shows that different researchers have used the words access and accessibility in different ways. Keeping in mind that the primary goal of transportation is to access 'opportunities' (Litman, 2003a), these different perspectives have been combined under two headings of land use accessibility and transport accessibility. However, for the same transport system in a city, the accessibility for different user groups is different, and herein comes the question of equity. The definition of accessibility in this handbook considers the accessibility of and for the urban poor (using different modes).

ACCESSIBILITY

Accessibility is a description of the proximity of destinations of choice and the facilitation offered by the transport systems (including public transport and non-motorized modes) to reach them.

Landuse accessibility: geographical allocation of opportunities, dependent on urban planning and land use distribution and is represented by the distance to opportunities.

Transport accessibility: how the transport system facilitates access to opportunities and is dependent on the quality of the transport system (civil infrastructure and transport modes available).

Defining Mobility

Based on the literature review, the word mobility can mean several things: it can mean either the ability to move, or the amount of movement. The standard transport planning definitions relate to the latter meaning - the amount of movement. Hence, mobility is measured by distance traveled, time spent in traveling and the cost incurred. This gives rise to the several negatives of increased mobility. The increase in the amount of movement comes at a cost to the society - social, economic and environmental. Also clearly, 'forced mobility' due to spread-out landuse, forced relocation and unsustainable growth of the cities, is undesirable. However, if the first meaning - ability to move is seen as the definition of mobility, then the arguments change drastically. This definition, is infact, the more commonly used definition in both natural and social sciences. A major difference between plants and animals is the ability of the latter to move in search of food and better environments - mobility places

them higher in the evolutionary scale. Similarly, in the context of the ideals of socialism and democracy today, mobility is closely linked with personal and individual freedom, and lack of mobility is often associated with the repression of basic freedoms and even human rights (Ekeh, 1974). Women, too, have several constraints on mobility, which are a result of their socio-economic conditions. According to Grieco and Turner (1997), "women's greater domestic responsibilities coupled with their weaker access to household resources have significant consequences for their transport and travel status. The lower the income of a household the more probable it is that women will experience greater transport-deprivation as compared to men." In addition to these economic constraints, the mobility situation of women in India is worsened by the social constraints of caste and class. This disabled mobility or 'forced immobility' is as negative as 'forced mobility'.

Clearly, if mobility is defined only as the amount of movement, then it assumes that the user group is homogeneous. The special needs of people with constrained mobility - the poor, the women, the elderly, and the physically disabled - are ignored by this definition. Policies that reduce amount of movement may or may not benefit these disadvantaged groups, and may in fact seriously dis-benefit them. For example, if only one car is allowed per household as a policy, then only the male member of the family will have access to it, disabling the movement of the women. Another example is that the optimization of public transport according to time-of-day will increase the number of buses/trains in the peak hours and reduce them in the off-peak hours, disadvantaging the women and the elderly who travel in the off-peak hours.

On the other hand, if the definition of mobility also includes the ability to move then it is possible to include desegregated user groups and assess the differential impact of transport projects and policies on them. It also allows for the inclusion of the socio-economic parameters in the transport planning paradigm. Since this handbook is looking at the social impact of transport projects, it is important to define mobility both as the ability to move and the amount of movement.

MOBILITY

Mobility is both the ability to travel to destinations of choice and the amount of movement necessary to do so.

Amount of movement is negative and has social, economic and environmental costs. Also "Forced mobility" due to suburbanization and relocation is another negative aspect.

Ability to move is positive. It is the difference between plants and animals and an expression of freedom. It also denotes ability to move for better opportunities. Also, "Forced immobility" of poor, women, elderly, disabled is negative hence the ability to move is important.

Socio-economic Well-being : Concepts and Definition

The term socio-economic well being has three components that that are used separately or in combination by different social analysts; these are 'social', 'economic' and 'well-being'. Well-being is also understood as 'welfare' and socio-economic well being has a direct correlation with 'development'. It is difficult to separate completely the term 'social' from 'economic' because "social demands are subject to economic restraints and because economic processes are linked to their social and societal environment… At most we can say that economic indicators deal mainly with things and money while social indicators are more concerned with people" (Horn, 1993). This section presents the various discourses on socio-economic well being.

The term 'social indicators' has long been used for statistics that are relevant for the analysis of the situation in a particular social field or for society as a whole (Horn 1993). Applications of social indicators have now been extended from the narrowly defined area of social problems to urban planning, international development and the quality of life; and from description and measurement of social conditions to comparison over time and place and to policy planning. The general functions of social

indicators can be fitted into a systematic sequence from observation and assessment to prognosis, to policy planning and the monitoring of plan performance. The distinctive roles of social indicators are reflected in definitions given by various authors:

> *Social indicators… are statistics, statistical series, and all other forms of evidence that enable us to assess where we stand and are going with respect to our values and goals, and to evaluate specific programs and determine their impact*. (Bauer, 1966)
>
> *Social indicators are constructs, based on observation and usually quantitative which tell us something about the aspect of life in which we are interested or about changes in it. Such information may be objective … to show the position or changes, or subjective to show how they are regarded by the community or constituent groups*. (United Nations Statistical office, F/18. 1975)
>
> *Social indicators are facts about society in a quantitative form. They involve … interpretation of advance and retrogression against some norm*. (Hauser, 1975)

Social indicators are used extensively in several fields like health, education, culture, human rights, war and peace, politics, etc. However their use in trans-disciplinary studies, like environment, urban studies and infrastructure, is still at a nascent stage.

Economic indicators[2] relevant to this handbook are those that have been used to measure development by different agencies. According to Horn (1993) "Economic and social development can be broadly distinguished but usually interact and should preferably be considered together. Social development cannot be separated from the economic limitations imposed by scarce resources… Social implications of the distribution of income and wealth, or of the impact of national welfare and the environment, are never far below the surface of economic analysis."

National level economic development indicators commonly used are Gross National Product (GNP = national income +/- net income paid overseas + depreciation allowances) and Gross Domestic product (GDP = GNP +/- net factor income from abroad). Others are National accounts Systems and Income distribution (Horn 1993). The past decade has seen the evolution of economic development indicators from objective fiscal measures to subjective community based welfare indices like 'levels of living', 'human development', and 'quality of life'. These have been discussed in some length in the following paragraphs.

Socio-economic wellbeing has been a subject of research for development agencies and states all over the world and a literature shows definitions and measures at different scales ranging from the Human Development Index for each country developed by the UNDP to Community well-being and individual well being. The definitions differ, to some extent, for urban and rural context too. Also a lot of work has been done on the subjective aspects of well being like the Quality of Life (QOL) or subjective well being (SWB) by organizations like WHO. This section presents a review of some of the definitions and measures popularly used in the cross-national and national development contexts.

Probably the best known composite index of social and economic well-being is the Human Development Index (HDI), developed by the United Nations Development Program (UNDP, 1990). The index was first published in 1990. The index is composed of three indicators: longevity as measured by life expectancy at birth; educational attainment, as measured by a combination of adult literacy (two-thirds weight) and the combined first, second, and third level gross enrolment ratio (two-thirds weight); and the standard of living, as measured by real GDP per capita (purchasing power parity dollars).

The UNDP has also developed a Human Poverty Index (HPI). For developing countries, the HPI-1 concentrates on deprivations in three essential dimensions of human life already reflected in the HDI longevity, knowledge and a decent standard of living. The first deprivation relates to survival the vulnerability to death at a relatively early age. The second relates to knowledge being excluded from the world of reading and communication. The third relates to a decent standard of living in terms of overall economic provisioning. The deprivation in longevity is represented by the proportion of the population not expected to survive to age 40. The deprivation of knowledge is represented by the proportion of the population who are illiterate. The deprivation of a decent standard of living is represented by three variables the proportion of the population without access to safe water, the proportion without access to

2. Economic indicators, are often used in business and to discuss economic progress, can be listed as production, consumption, investment, income, manpower, finance, trade, transportation, public sector etc. However, these are not relevant in the context of this dissertation.

health services, and the proportion of moderately and severely underweight children under five.

Ed Diener (1995), has developed an index of the quality of life (QOL) based on a universal set of values. He constructs two indexes, one called the Basic QOL Index, which is particularly relevant for developing countries, and the Advanced QOL Index for developed countries. The Basic QOL Index includes seven variables: purchasing power, homicide rate, fulfillment of basic needs, suicide rate, literacy rate, gross human rights violations, and deforestation. The Advanced QOL Index also includes seven variables: physicians per capita, savings rate, per capita income, subjective well-being, college enrollment rate, income inequality, and environmental treaties signed. According to Diener, combining the two indices produces a reliable measure of QOL that systematically covers diverse human values.

Several efforts have been made to translate macro indices like HDI and QOL to the community level. Malcolm Shookner (1998) of the Ontario Social Development Council has developed a community-based Quality of Life Index (QLI) for Ontario. The following indicators were included in the Quality of Life Index:

Social: Children in care of Children's Aid Societies; social assistance recipients; public housing waiting lists.

Health: Low birth weight babies; elderly waiting for placement in long-term care facilities; suicide rates.

Economic: Number of people unemployed; number of people working; bankruptcies.

Environmental: Hours of poor air quality; environmental spills; tonnes diverted from landfill to blue boxes.

The Community Well-being Index (CWB) published by another Canadian agency (INAC, 2004) is composed of for indicators - education, labour force, income, and housing, where education includes 'functional literacy' and 'high school plus', labor force includes 'participation in labor force' and 'employed labor force participants', income is measured per capita and “is indicative of one's ability to purchase the necessities, comforts and conveniences that, cumulatively, enhance one's quality of life” , and housing includes both 'housing quantity' and 'housing quality'.

Based on the above discussion, the next section develops definitions and indicators of the SEWB.

Defining Socio-economic Well-being

The review of definitions and measures of SEWB in the preceding section forms the basis for the formulation of the definition and indicators of SEWB for this handbook. The context for the development of definition is specified as follows:

1. At a geographic scale this handbook looks at the socio-economic well-being of a household. The advantage of taking this unit lies in the fact that, one, the interdependencies of individuals within a household get included in this and , two, it can be linked to the well being of the community too
2. Since the handbook focuses on impacts on the urban poor, the social well being needs to be defined in that background both 'urban' and 'poor' need to be seen as the context.
3. Specifically, the handbook looks at those aspects of socio-economic well being that are affected by transportation.

SOCIO-ECONOMIC WELL BEING (SEWB)

Socio-economic well-being is defined as the status of a household where the basic social and economic needs for survival are fulfilled and the household has the capacity to improve its quality of life.

SEWB can be measured with the parameters of literacy and education, employment, income and consumption, shelter and urban services, health and nutrition, environmental concerns, safety and security, time use and availability.

Indicators of Accessibility, Mobility and SEWB

Using the definitions and measures of accessibility, mobility and SEWB developed in the preceding sub-sections, this section quantifies the indicators of accessibility, mobility and SEWB that can be used to measure the impact of urban transport projects. The indicators are quantified in the context of the urban poor who are affected by the introduction a new transport project.

Accessibility Indicators

The introduction of a new transport system should improve accessibility and according to this handbook, "accessibility is a description of the proximity of destinations of choice and the facilitation offered by the transport systems (including public transport and non-motorized modes) to reach them". This is described, in this handbook, by the distance to educational services, health services and other urban services like vegetable markets, daily need shops and larger shopping areas. It is also described by the accessibility to the public transport system distance to the bus stop, frequency of bus services. The indicators of accessibility are derived from household surveys and are illustrated in table 1.

Table 1: Indicators of Accessibility

Indicator Type	Indicator	Indication
Accessibility (A) (unit = indicator per Household)	$SD_{education}$, where SD is spatial distance	Lower value gives better accessibility
	SD_{health} , where SD is spatial distance	Lower value gives better accessibility
	$SD_{services}$, where SD is spatial distance	Lower value gives better accessibility
	$SD_{bus\text{-}stop}$, where SD is spatial distance	Lower value gives better accessibility
	S_{bus} , where S is time gap between two successive buses	Lower value gives better accessibility

Mobility Indicators

By definition, the ability to travel of the household is seen as positive mobility from the socio-economic perspective because indicates that people are traveling for work, education and other purposes thus enabling value addition to the households and denoted by the per capita trip rate (PCTR) of the household for these purposes. The utilization of non motorized vehicles (NMV) by the households for their mobility is also seen as positive mobility and is expressed as the ratio of use of NMVs to all modes used.

On the other hand the amount of movement is seen as negative mobility from the socio-economic perspective because it uses resources of the household, like time and money, which could have been better utilized to upgrade the quality of life of the household. It is denoted by the indicators of distance, time and cost of travel for the purposes of work, education and others.

The positive mobility is termed as household mobility (M_{HH}) and the negative mobility as personal mobility (M_P). The indicators of Mobility are derived from the household surveys of low-income settlements and are illustrated in table 2.

Table 2: Indicators of Mobility

Indicator Type	Indicator	Indication
Household (+) Mobility (M_{HH}) (unit = indicator per Household)	$PCTR_{work}$, where PCTR is the average per capita trip rate HH	Higher value higher mobility of HH
	$PCTR_{education}$, where PCTR is the average per capita trip rate of HH	Higher value higher mobility of HH
	$PCTR_{others}$, where PCTR is the average per capita trip rate of HH	Higher value higher mobility of HH
	$\frac{M_{NMV}}{M_{all}}$, where M is modes	Higher value higher mobility of HH
Personal (-) Mobility (M_P) (unit = indicator per Household)	D_{work}, where D is daily travel distance	Higher value higher mobility
	$D_{education}$, where D is daily travel distance	Higher value higher mobility
	D_{others}, where D is daily travel Distance	Higher value higher mobility
	T_{work}, where T is daily travel time	Higher value higher Mobility
	$T_{education}$, where T is daily travel time	Higher value higher mobility
	T_{others}, where T is daily travel time	Higher value shows higher mobility
	C_{work}, where C is daily travel cost	Higher value higher Mobility
	$C_{education}$, where C is daily travel cost	Higher value higher mobility
	C_{others}, where C is daily travel cost	Higher value higher mobility

Socio-economic Well-being Indicators

The SEWB is measured in two components, social well-being and economic well-being. The indicators for both have been developed as follows:

1. **Social Well being (WB_S):** This includes indicators of literacy, status of women, infrastructural facilities available, and tenure available to upgrade quality of life. Literacy has been measured as the ratio of adults educated more than the 5^{th} grade to all adults in the household; status of women has been measured as the ratio of the girls in school to the girls of school-going age in the household; infrastructural facilities are measured as an Infrastructure rank score describing the availability of infrastructure like electricity, water-supply and toilets. The ratio of the years spent in the low-income settlement to the years spent in the city gives a measure of the time the household has spent upgrading its quality of life and networking in the location.
2. **Economic Well Being (WB_E):** This includes indicators of employment, income and assets. Employment is measured by number of people on the workforce versus all members of the

household, Income is measured as per capita income of the household and assets are measured as per capita vehicle ownership of the household (including bicycles and other NMVs).

The indicators of SEWB developed are illustrated in table 3.

Table 3: Indicators of Socio-economic Well Being (SEWB)

Indicator Type	Indicator	Indication
Social Well-being (WB_S) (unit = indicator per Household)	$\frac{NG_{inschool}}{NG_{schoolage}}$, where NG is no. of girls	Higher value shows higher social well being
	$\frac{NA_{literate\ (>5grade),}}{NA_{all}}$ where NA is no. of adults	Higher value shows higher social well being
	Infrastructure rank score * (Electricity, water, toilet)	Higher value shows higher social well being
	$\frac{Y_{low\text{-}income\ settlement}}{Y_{city}}$, where NA is no. of years	Higher value shows higher social well being
Economic Well-being (WB_E) (unit = indicator per Household)	$\frac{N_{working}}{N_{all}}$, where N is no. people	Higher value shows higher economic well being
	$\frac{I_{total}}{N_{all}}$, where I is income	Higher value shows higher economic well being
	$\frac{Veh_{all}}{N_{all}}$, where Veh is no. of vehicles	Higher value shows higher economic well being

Notes:

* Infrastructure rank score refers to the additive score of the types of services where the service which is formally provided and operational is given a value of 2, that which is self obtained has a value of 1, and that which is not available is given a value of 0

Impact of Transport Project

The impact of a transport project can be understood by the change in the indicators due to the introduction of the project.

Change in Accessibility: The change in Accessibility (A) is measured as

1. Direct impact by the change in indicators of A of households in the vicinity of the project.
2. Indirect impact by the change in indicators of A of households relocated due to the project.

Change in Mobility: The change in Mobility (M) is measured as

1. Direct impact by the change in indicators of Household Mobility (M_{HH}) and Personal Mobility (M_P)of households in the vicinity of project.
2. Indirect impact by the change in indicators of M_{HH} and M_P of households relocated

Change in SEWB: The change in SEWB is measured as

1. Direct impact by the change in indicators of Social Well-being (WB_S) and Economic Well being (WB_E) of households in the vicinity of the projrct (HH_V)
2. Indirect impact by the change in indicators of WB_S and WB_E of households relocated due to the project (HH_R)

Impact Assessment

The change in indicators and indices is used to test the two hypotheses - the introduction of the transport project has changed accessibility for the urban poor, and, the change in accessibility has changed their mobility profile and the SEWB. Subsequently, the correlations between accessibility, mobility and SEWB are modeled to understand the impact of:

1. Accessibility on Mobility
2. Accessibility on SEWB
3. Accessibility and Mobility on SEWB

UNIT 3

The SEIA Method

- Step I : Problem Formulation
  - Key Hypotheses
  - Theoretical Framework
- Step II : Project Description
- Step III : Identifying the Target Group
- Step IV : Data Collection
  - Survey Design
  - Locations Identified
  - Sample Size and Strategy
  - Questionnaire Design
  - Administration of Survey
- Step V : Profiling the Target Group
  - Households in the Vicinity of the Metro
  - Households Relocated due to the Metro
  - Discussion
- Step VI : Estimating the Indicators of Accessibility, Mobility and SEWB
  - Accessibility
  - Mobility
  - Socio-economic Well-being
  - Testing the Hypotheses
  - Discussion
- Step VII: Combining the Indicators into Indices
  - Accessibility
  - Mobility
  - Socio-economic Well-being
  - Testing the Hypotheses
  - Discussion
- Step VIII: Developing the SEIA Model
  - Linear Correlation
  - Linear Regression

UNIT 3 : The SEIA Method

This unit develops a step by step method to carry out a SEIA of a transport project on the urban poor. To illustrate the method for SEIA, the Delhi metro rail has been selected as a case study of a transport system to understand the impacts on the accessibility, mobility and socio-economic well being of the urban poor. It is the single largest transport intervention in Delhi, India in the last decade, especially in terms of capital investment. It has all the requisite elements of a large transport project, including land acquisition, infrastructure and system development, and widespread influence area including key areas in the city with high density population.

The SEIA of a project is carried out in 8 steps.

STEP I: **Problem Formulation**
STEP II: **Project description**
STEP III: **Identifying the target group**
STEP IV: **Data collection**
STEP V: **Profiling the target group**
STEP VI: **Estimating the indicators of accessibility, mobility and SEWB**
STEP VII: **Combining the indicators into indices**
STEP VIII: **Developing the SEIA Model**

STEP I : Problem Formulation

The first step in carrying out the SEIA is to formulate the problem which requires assessment. This handbook essentially addresses the problem of impact assessment of large transport projects on the urban poor who may or may not be the actual users of the new system. The hypothesis of the assessment and the theoretical framework need to be clarified at the outset to guide the SEIA process.

Key Hypotheses

H1: **First Hypothesis:** Introduction of a new transport system changes the accessibility for the urban poor.

H1-0: Null Hypothesis: Introduction of a new transport system **improves** the accessibility for the urban poor.

Alternate Hypotheses:

H1-a1: Introduction of a new transport system **worsens** the accessibility for the urban poor

H1-a2: Introduction of a new transport system has **no impact** on the accessibility for the urban poor.

H2: **Second Hypothesis:** Change in accessibility changes the mobility profile and the socio-economic well-being of the urban poor.

H2-0: Null Hypothesis: Change in accessibility has **improved** the mobility profile and **improved** the socio-economic well-being of the urban poor.

Alternate Hypotheses:

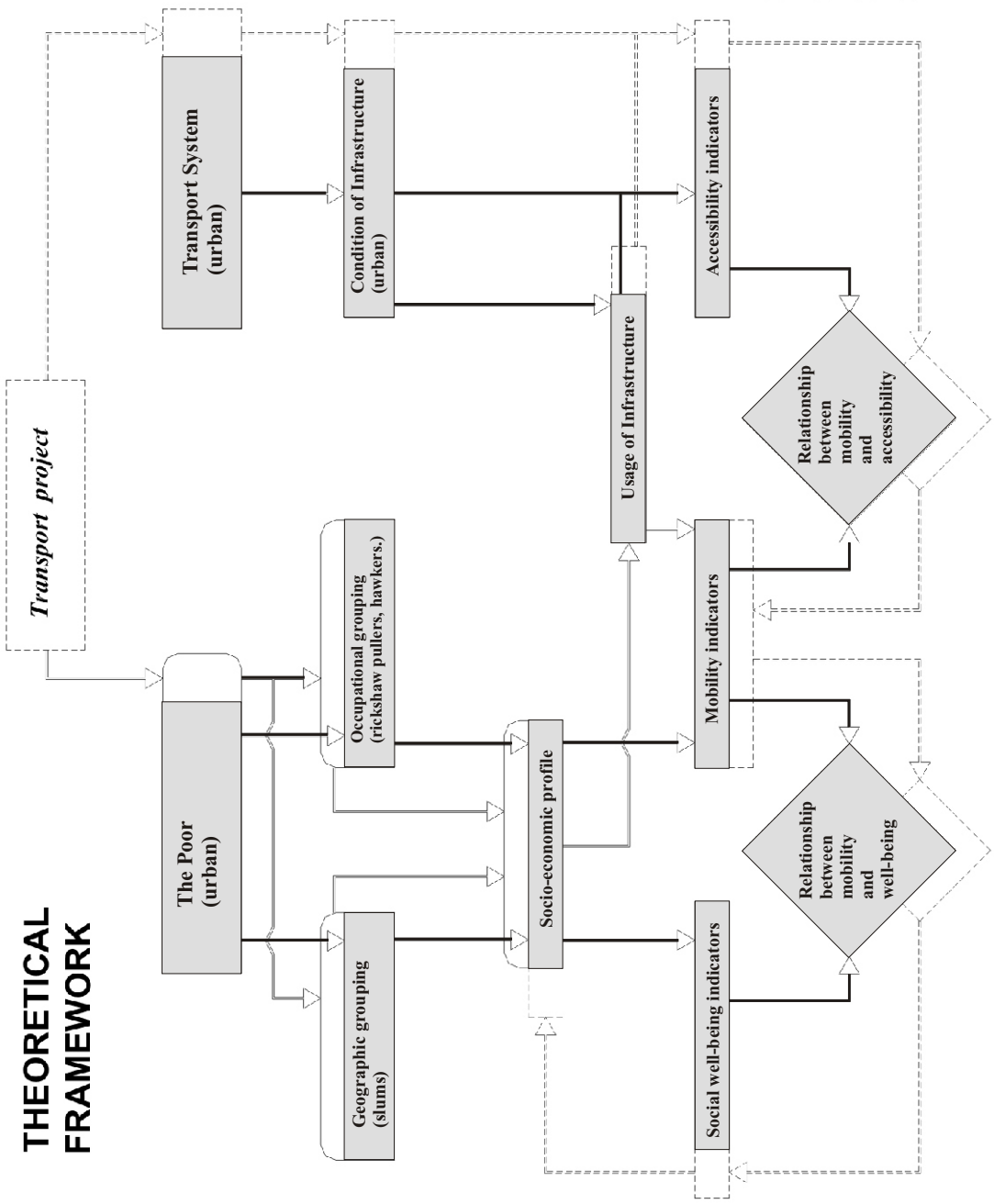
H2-a1: Change in accessibility has **deteriorated** the mobility profile and **deteriorated** the socio-economic well-being of the urban poor.

H2-a2: Change in accessibility has had **no impact** the mobility profile and **no impact** on the socio-economic well-being of the urban poor.

Theoretical Framework

The theoretical framework establishes the linkages between the urban poor and the urban transport system based on the extensive review of the issues. It also postulates an indicative process of impact of new transport projects.

1. The baseline consists of two components The Urban Poor and the Transport System.
   a. The **urban poor** can be studied as communities and/or livelihood types. Since the impact of the transport system and the changes therein are of concern for this dissertation, the urban poor targeted need to be within the influence area of the transport system. The urban poor are described in terms of their **socio-economic profile**, which is quantified into socio-economic well-being indicators in this dissertation.
   b. The **transport system** is described by the condition of the transport infrastructure, i.e. the civil infrastructure and the public transport services. The transport infrastructure is quantified into accessibility indicators.
   c. The manner in which the urban poor use the transport infrastructure gives rise to mobility indicators.
   d. The relationship between well-being, mobility and accessibility indicators needs to be modeled.
2. Any intervention made in the transport system (like the introduction of a new transport project) will have direct and indirect impacts on the baseline framework described above and changes the indicators formulated
   a. **Direct Impact**: The change in the condition of Infrastructure changes the accessibility indicators, mobility indicators and hence the indicators of socio-economic well-being.
   b. **Indirect Impact**: It may be caused by relocation and/or change in livelihood, changing the accessibility status and/or the socio-economic profile.


THEORETICAL FRAMEWORK
Transport project
The Poor (urban)
Transport System (urban)
Condition of Infrastructure (urban)
Accessibility indicators
Occupational grouping (rickshaw pullers, hawkers.)
Geographic grouping (slums)
Socio-economic profile
Usage of Infrastructure
Mobility indicators
Social well-being indicators
Relationship between mobility and accessibility
Relationship between mobility and well-being
LEGEND
Existing System
Direct Impact
Indirect Impact

STEP II : Project Description

The second step in the assessing the impact of the transport project is to understand the design of project itself. This needs to include the following information about the project:

1. The planning history
2. Justification
3. Demand assessment
4. Financial plan
5. Expected usage
6. Expected benefits
7. Identified externalities, if any

The source of this data can be planning documents, government websites, feasibility reports, tender documents for financial bids and other documentation of the pre-project implementation phase.

The project description of the Delhi Metro Rail has been taken up as the case-study illustration for this handbook. The Delhi metro rail was first proposed by the Central Road Research Institute (CRRI, 1970) to meet the projected travel demand for 1981. It was incorporated by the DDA in its Master plan for Delhi for 2001 (DDA, 1990) as a part of a recommended multimodal transport system for Delhi. The Urban Arts Commission suggested some modifications to the proposal of DDA and recommended for the development of the existing Ring Railway with three radial underground MRT corridors. RITES (1990) recommended for three-component system comprising of Rail corridors, Metro corridors and dedicated bus way totaling to 184.5 Km and further addition of 14 km increased to 198.5 km. The total network contains 16 sections to be implemented in phases based on passenger kilometer carried per kilometer length of each section.

Though the metro rail was conceived as a part of a multimodal transport system, for its implementation, an independent body called the Delhi Metro Rail Corporation was constituted. For the

Figure 1: Proposed alignments for Phase I and II of the Metro Rail
Source: website http://www.mapsofindia.com/maps/delhi/delhi-metro-map.html

first phase, 64% of the total funds (total cost INR 1057 billion) were solicited from Japan Bank for International Corporation (JBIC) and the remainder from the Government of India (14%) and the Government of National Capital Territory of Delhi (14%); with 3% to be generated from property development. The first phase has a network of 32.1 Km and the second phase is proposed to have network of 121.11 Km in length (illustrated in figure 1). The estimated number of originating passengers per day in the year 2011 for Phase I and Phase II corridors is 2.6 million.

The first phase, completed in November 2006, covers a distance 62.16 km with 59 stations. It was constructed at a cost of INR1057 billion. It expected ridership is 1.5 million passengers per day. In July 2005, after completion of 50% of the project, the ridership was 0.37 million passengers per day. Details of the project, including the kind of facilities for commuters, are available on the DMRC website http://www.delhimetrorail.com

The first phase has three lines - the Shahadra-Rithala line, The Central Secratariat-Vishvavidyalaya line and the Indraprastha-Dwarka line. A section of the first line[3] - the Shahadra to Tri-nagar (later Inderlok) corridor of the first phase, with 18 stations has been taken as case study (figure 2). This line cuts across varying land-uses and some important land marks in the city. Shahadra metro station is located in conjunction with an intercity railway station and is surrounded by middle and low income residential areas. This residential character continues till Shastri Park station after which the line crosses the Yamuna River and enters the main city of Delhi. The Kashmere Gate station is located in conjunction with an Interstate Bus Terminus (ISBT) and is the change station for the second metro line too. Tis Hazari station serves important landuses like the district courts, hospitals and office/commercial areas. After Pul Bangesh up to Tri nagar (Inderlok), the character of the land use is again low income residential areas.

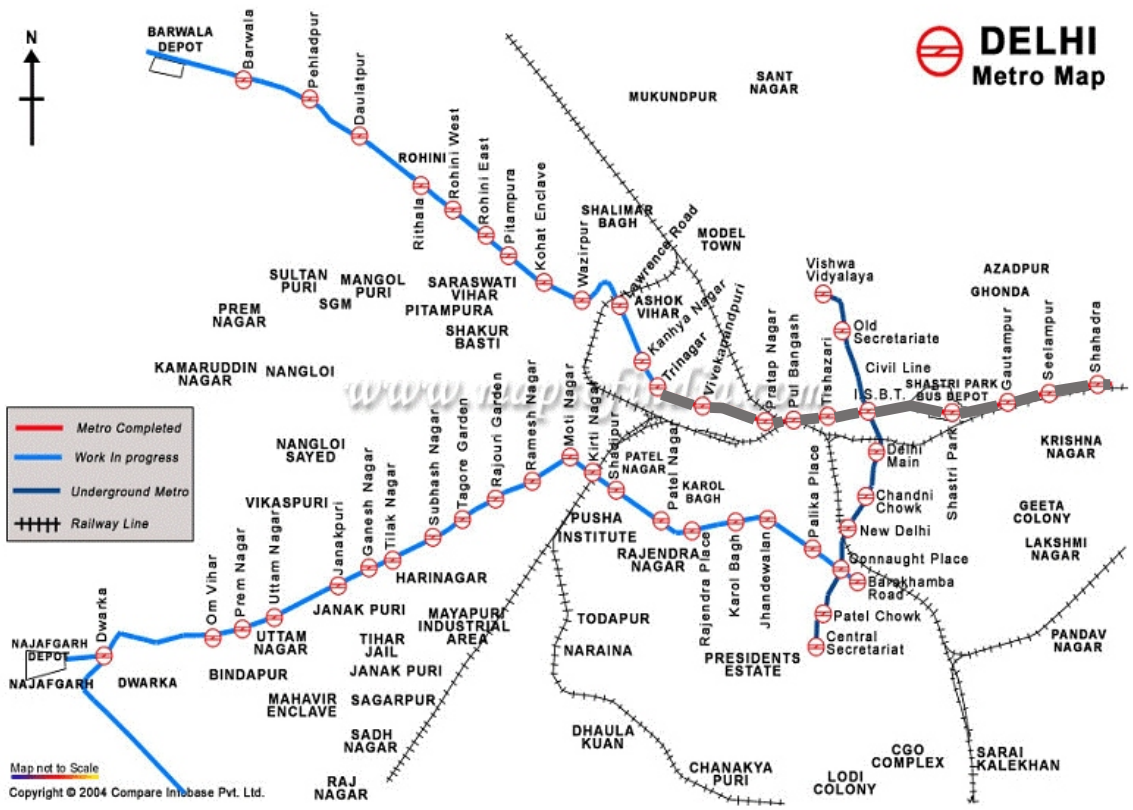


Figure 2: Alignment of the existing metro line with case-study line
Source: http://www.delhiindia.com/wiki-Delhi_Metro

3. This part of the line was operational when the survey was conducted in 2004; the Inderlok-Rithala part of the line became operational subsequently

STEP III : Identifying the Target Group

The third step is to identify the target groups for impact assessment. The target groups identified are based on the understanding of the influence zone of the project (refer Unit 2, *ibid*). This would include

1. Geographic location of the target group
2. Time and resource allocation for the target group study
3. Population characteristics of communities targeted

The objective of the case study of the Delhi Metro Rail was to understand the impact of the Delhi metro on the urban poor and, hence, the target groups identified were (a) the urban poor living in low-income settlements along the metro line, and (b) urban poor relocated due to the metro. The first target group comprised of low-income communities living in the vicinity of the metro-line (Rajiv Gandhi colony in Kailash Nagar and Sukhdev Nagar in Wazirpur Industrial area) and those relocated (Metro Vihar in Holambikalan resettlement colony) due to the construction of the Metro. (refer figure 3)

STEP IV : Data Collection

The fourth step in the SEIA process is collect relevant data to assess impact. The data collection process leads to the profiling of the target group to generate a base understanding of the issue and the data is then used to estimate the values of the indicators of accessibility, mobility and SEWB. The data collection has three processes

1. Secondary literature sources review
2. Observation survey
3. Primary data collection using face-to-face survey techniques.

If the target groups are unfamiliar to the surveyors then focus group discussions with the target groups need to precede the primary data collection to clarify the intent of the survey. For the case study illustrated in this handbook, the help to the community based organizations (CBOs) already active with the target group was taken to administer the survey. The primary data collection process used for the case study of the Delhi metro rail is illustrated below.

Survey Design

At the conceptual level this handbook identifies impacts at two levels - direct and indirect. Direct impact would refer to a change in the travel patterns due to introduction of the Metro and any resulting change in the socio-economic profile of the low-income settlements around the metro. Indirect impact would refer to change in travel patterns and socio-economic profiles as a side effect of the installation of the system - in this case eviction and relocation of the urban poor. For this purpose 2 low-income settlements along the metro line were selected to study change in travel and socio-economic profiles of poor households due to the introduction of the metro; and 1 resettlement colony was selected where the households relocated due to the construction of the metro were resettled by the government agencies.

Locations Identified

Locations for survey are identified based on the understanding of the influence zone.
For the case study, the identified locations were:

Low-income settlements near metro: Rajiv Gandhi colony in Kailash Nagar low-income and Shahid Sukhdev Nagar low-income in Wazirpur Industrial area near the Shastri Park and Keshavpuram stations at both ends of the metro line.

Urban poor relocated due to metro: Metro Vihar in Holambikalan resettlement colony beyond Narela and Bawana areas on the North-West corner of Delhi.

Figure 3 show the identified locations.

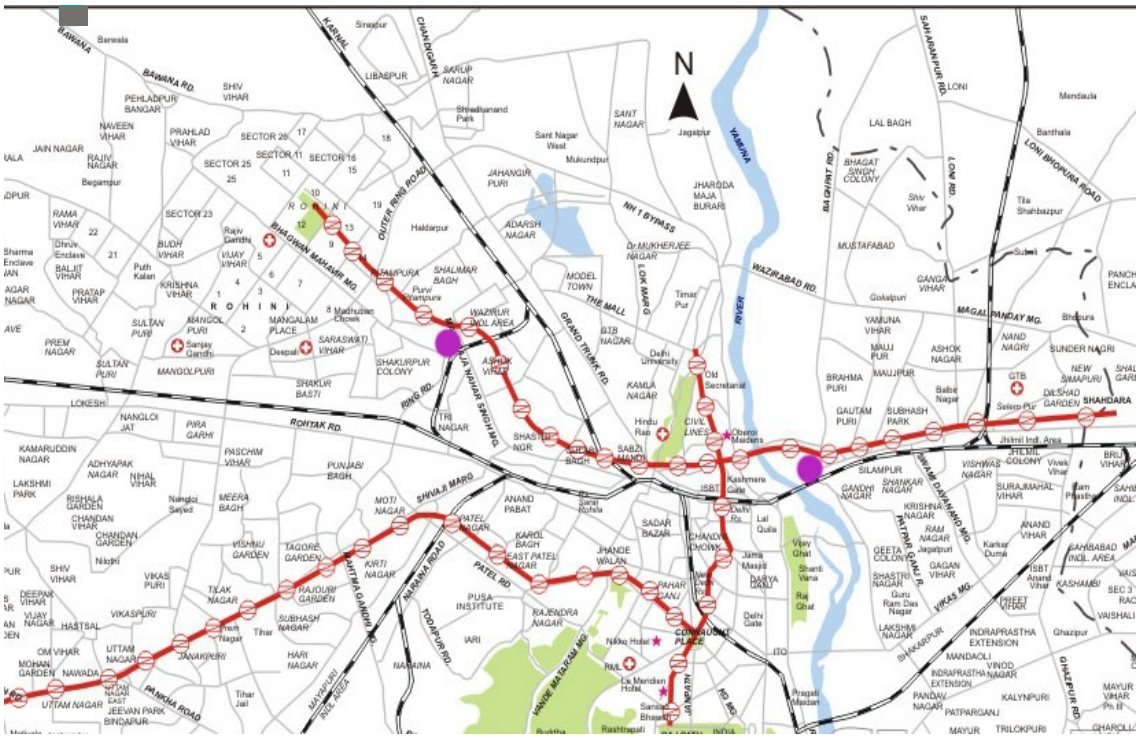


Figure 3: Part map of Delhi showing Case Study locations of household survey

Source: http://www.mapsofindia.com/maps/delhi/delhi-large.html

Sample Size and Strategy

The selection of the sample size depends on the size of the target group.
For the case study the sample size was defined as follows:

Household surveys in low-income settlements in vicinity of Metro line: In Kailash Nagar the total number of households was approximately 780 and in Sukhdev Nagar the total was approximately 1250. A sample of 10% was selected from both settlements. The choice of the households was based on the respondents' willingness to answer the survey with the proviso that the sample was evenly distributed throughout the site.

Household surveys in resettlement site: In Metro Vihar the total number of households living here were approximately 2010 though 3000 plots had been allocated. A sample of 10% was selected from the inhabited households. The choice of the households was based on the respondents' willingness to answer the survey with the proviso that the sample was evenly distributed throughout the site.

Questionnaire Design

The information needed in the interviews was both quantitative and qualitative to understand the depth of the concerns. Accordingly, the questions designed were of both the close-ended and open-ended type. In the definition of McBurney (2002) a close-ended question is one that limits the respondents to certain alternatives and an open-ended question is one that the respondents answer on their own. Using

open-ended questions makes it more likely that the questionnaire will discover something not anticipated by its designers, but they are harder to code and analyze for a large sample so were used sparingly. Also, for some questions the open-ended questions in the pilot survey were made close-ended depended on the types of answers of the respondents.

The following points were kept in mind while designing the questionnaire to avoid problems at the data analysis stage:

Address a single issue per item: Each item addressed only a single question and did so in a clear and unambiguous manner.

Avoid bias: The next consideration was to write the question in such a way that it would not bias the result.

Make alternatives clear: There was a particular need to write close-ended questions in such a way that the options were distinctly different from one another and they covered all possibilities the answers needed to be mutually exclusive and exhaustive. By definition (McBurney, 2002) categories are mutually exclusive if no individual case could belong to more than one category at a time; and for the categories to be exhaustive, all cases must fall into one of the alternatives.

Beware of the social desirability tendency: According to McBurney, 2002, bias often enters when the respondents perceive on alternative as more socially acceptable than the other a phenomenon called social desirability. The questionnaire avoided this problem by wording questions so that each alternative appeared equally socially desirable.

Determine the format of the item: the formats of the answers were pre-decided to avoid confusion during the administration of the survey. This included the units, numerical / alpha numeric, tick the right item etc.

Sequence the items: Care was taken in sequencing the items in the questionnaires since answers to some questions could have been biased if they were to come after some others.

Determine how the data will be analyzed: Data entry and analysis techniques, including the software to be used were considered during the construction of the questionnaire.

The answers were not pre-coded. This ensured that errors did not arise due to incorrect entry during filling out the questionnaires and data entry. This policy has the disadvantage of making the post-entry coding work tedious and time consuming but has the advantage of being error free and giving more options at the analysis stage.

For the case study the questionnaires were translated in Hindi (local language) before administration of the survey and the translation checked rigorously against the original. This was done to avoid loss of meaning by surveyors due to impromptu translation on site. The questionnaires used are reproduced in the Annexure in English.

Administration of Survey

The questionnaire was administered as personal (face-to-face) interviews. This method has the following advantages:

1. The interviewers can establish a rapport with the people being interviewed and direct the attention of the respondents to the material.
2. They are able to notice when the respondents seem to misunderstand the question and explain its meaning.
3. They can probe for more complete answers when the respondents answer in a manner that does not fully respond to the question.

This is the only realistic option for the household interviews in low-income settlements. In fact, the survey team may need to pay several preliminary visits to the sites and have informal discussions with some key people before starting the survey so that the respondents will be willing to answer correctly and comprehensively.

STEP V : Profiling the Target Group

The next step in the SEIA process is to collate and analyze the results of the primary surveys conducted to understand the issues and trends shown by the data. This data is used to develop indicators of accessibility, mobility and SEWB.

The data regarding the socio-economic, accessibility and travel profile of the households residing in the vicinity of the metro line and the households relocated due to the construction of the metro was analyzed. The status of change due to the introduction of the metro has been illustrated by some results summarized in this subsection.

Households in the Vicinity of the Metro

SOCIO-ECONOMIC PROFILE

1. Approximately 85% of the households have 6 or less members residing in them with approximately 60% having 4-6 members. The average family size is of 5 members.
2. Approximately 66 % of the respondent families are from Uttar Pradesh and 25% are from Bihar, and on an average they have been in Delhi for over 20 years and in the surveyed settlements for over 16 years. Almost 50% came to the settlement 15-25 years ago but there has been a steady inflow in the last 15 years too. The trend shows continuous immigration and growth of the settlements in the last 25 years. Almost 98% of the household heads came to Delhi to look for jobs indicating that they are first generation migrants.
3. Approximately 13% of the people interviewed were less than the school age of 5+ years, 37% belong to the school going age of over 5 years and upto 18 years, and 59% of the respondents belong to the working age of over 18 years and upto 60 years of age. Approximately 47% of the respondents are illiterate and there is no change in literacy rate after the introduction of the metro.
4. The work participation rate is 33% which does not change with the introduction of the metro.
5. The change in household income shows that for 66% of the households the income has not changed with the construction of the metro, for 10% it has decreased and for 24% it has increased. The average household income has increased by INR175 after the coming of the metro.
6. 74% of the households do not own a vehicle and 21% own cycles. The status remains unchanged.
7. Electricity is available to every household in both the communities. With the coming of the metro some households have experienced a formalization of the electricity connection. 10% have shifted to a metered connection and 2% to rent system from informal hooking on existing lines.
8. The water supply status shows an increase in self obtained supply of water, like tankers and decrease in community water supply like taps and hand pumps.
9. The use of toilets in households has changed from informal open area to paid toilets for 7% of the households.

ACCESSIBILITY

1. The bus route availability and frequency has reduced after the metro for the community. Few buses are available to the households staying in the vicinity of the metro as shown in Table 1 for 65% of the households 1-2 buses are available to their destinations of choice, and the number decreases to 43% after the coming of the metro. For 32% of the households, buses have become non-available to their destinations of choice. Frequency of the bus service has decreased for the high frequency buses but has remained the same for the low frequency (over 20 min) buses.

Table 1: Change in number of bus routes available after Metro

No. of Buses	Before Metro		After Metro	
	Number	%	Number	%
0	10	4.93%	76	37.44%
1	85	41.87%	63	31.03%
2	48	23.65%	24	11.82%
3	37	18.23%	25	12.32%
4	21	10.34%	13	6.40%
5	2	0.99%	2	0.99%
Grand Total	**203**	**100.00%**	**203**	**100.00%**

2. The RTV (informal mini-buses which run on same routes as the formal buses) routes' availability to the households have increased by 33% after the coming of the metro
3. The average distances to bus-stop, school (primary and secondary) and urban services are 1 Km, 1.41 Km and 1.2 Km respectively and the status does not change significantly for most households. The urban services include doctor, chemist, vegetable market, daily needs shop and large shopping centers.
4. The respondents were also asked if they had ever used the metro since they lived in its vicinity approximately 87% of the respondents had never used the metro; of the remaining 13%, 7.5% had used the metro to see it as a tourist attraction. And only 2% had used it to go to work occasionally. Very few women have been on the metro, even to just see it as a tourist attraction.

TRAVEL PROFILE

The introduction of the metro shows no significant change in the number of daily trips, daily travel distance, daily travel time and daily travel costs. Table 2 presents the change in travel parameters after the introduction of the metro.

Table 2: Change in travel parameters due to introduction of Metro

Travel parameter	Before Metro	After Metro
Average daily trips	4.3	4.2
Average daily travel distance (Km)	6.2	6.4
Average daily travel time (min)	68.6	68.3
Average daily travel cost (INR)	2.6	2.5

The results of T-test to study the significance of change with the introduction of the metro are summarized in Table 3.

Table 3: Significance of change for the households in the vicinity of the metro

Results of T-tests (paired two sample for means)		
Change in parameter after metro	**At 95% confidence level**	**At 99% confidence level**
HH Income	significant	not significant
Distance to amenities	not significant	not significant
Travel Distance	not significant	not significant
Travel Time	not significant	not significant
Travel Cost	not significant	not significant

Households Relocated Due to the Metro

Several households from different low-income settlements have been relocated due to construction of the metro line. All of them have been relocated to a designated resettlement colony called Holambikalan, located at the North-West periphery of Delhi. In fact, within Holambikalan all relocatees due to Delhi Metro have been relocated to a particular sector in Holambikalan called the Metro Vihar.

SOCIO-ECONOMIC PROFILE

1. The average family size for a household is 5 members. A majority (approximately 55%) of the households have 4-6 members in their family. Approximately 66 % of the respondent families are from Uttar Pradesh and 24% are from Bihar, and on an average they have been in Delhi for over 24 years and in the surveyed settlements for 3 years. Approximately 50% of the households came to Delhi 20-30 years back and 36% came 10-20 years back. 10 % came to Delhi 30-40 years back accounting for almost the entire sample. Approximately 92% of the household heads came to Delhi looking for a job and the remaining 8% because they had relatives in Delhi. All of the families came to this low-income 3 years back and were relocated from their earlier houses in Delhi due to the construction of the metro.
2. Approximately 16% of the people interviewed were less than the school age of 5+ years, 40% belong to the school going age of over 5 years and upto 18 years, and 41% of the respondents belong to the working age of over 18 years and upto 60 years of age. Approximately 59% of the respondents are illiterate and there is no change in literacy levels after relocation.
3. The work participation rate has increased from 24.4% to 26.25% after relocation.
4. The average household income has reduced from INR 3145 to INR 2514 after relocation. There is a significant shift of household incomes from the higher income to lower income categories. Twenty five percent households in the monthly income category of 3000-5000 rupees reduced to 14% after relocation and the 21% in the 1000-2000 rupees category increased to 42%. The change in household income shows that for 19% of the households the income has not changed after relocation, for 66% it has decreased and for 15% it has increased.
5. Approximately 75% of the households did not own a vehicle and 21% owned cycles before relocation. After relocation the number of households not owning vehicles increased to 79% and the numbers owning bicycles decreased to 17%.
6. The households had self obtained electricity by illegally hooking to the main supply before relocation. After relocation 91% of them have metered connection while 8% have no electricity.
7. The number of households getting community tap water supply from the Municipal Corporation of Delhi (MCD) has reduced from 83% to 53% after relocation, whereas the dependence on water tankers has increased from 11% to 31%.
8. The number of households using paid toilet facilities has increased from 73% to 92%. The 8% households, who do not use the paid facility, use the fields. There is no option of free built facility available to the households after relocation.

ACCESSIBILITY

1. The bus route availability and frequency has reduced after relocation due to the metro with average frequency reducing from 5 min to 63 min (13 times). The average number of routes available to a household has reduced from 3 to 2 after relocation.
2. Ninety nine percent of the households did not have availability/need of using RTVs for access before relocation, but all households use RTV to travel after relocation. The frequency of RTVs for 80% of the households in between 20-60 minutes interval.
3. Cycle-rickshaws were available to 93% of the households before relocation. After relocation cycle rickshaws are available to 28% of the households.
4. The average distance to bus-stop, school and urban services was 0.1 Km, 0.7 Km and 1.8 Km respectively and the status changed to 0.3 Km, 0.62 Km and 6 Km.

TRAVEL PROFILE

1. The number of trip segments made daily shows (figure 4) a shift to higher trip categories after relocation with the average increasing from 3.8 to 4.2 trip segments.

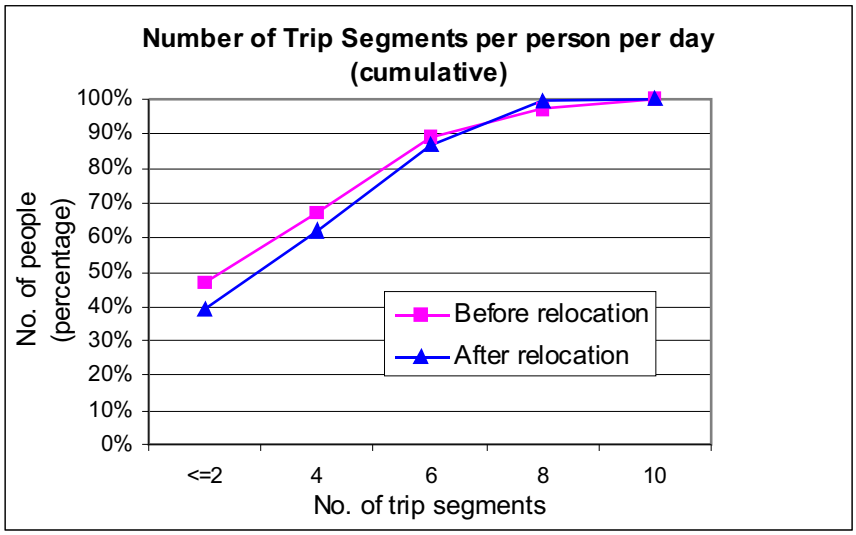


Figure 4: Trip segment frequency before and after relocation

2. The daily travel distance shows (figure 5) a shift to higher categories after relocation with the average increasing from 4.4 Km to 15.4 Km.

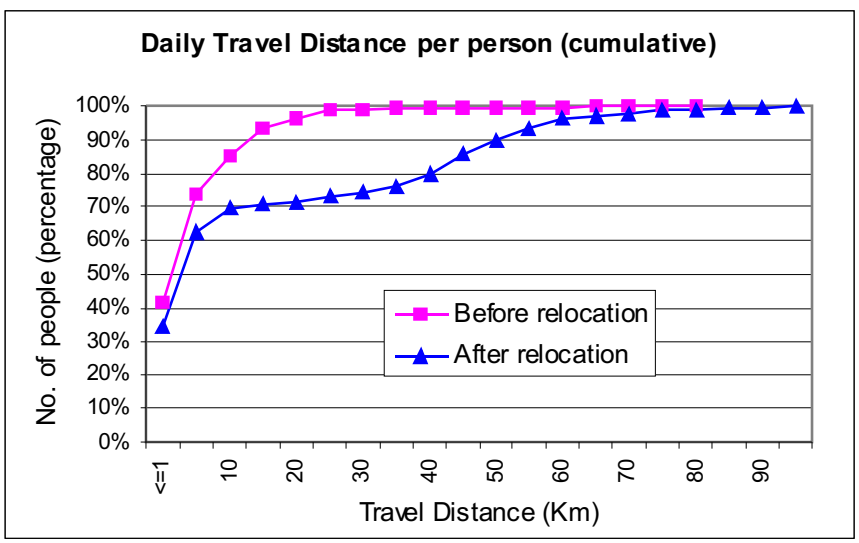


Figure 5: Trip length frequency before and after relocation

3. The daily travel time shows (figure 6) a shift to higher categories after relocation with the average increasing from 32 min to 77 min.

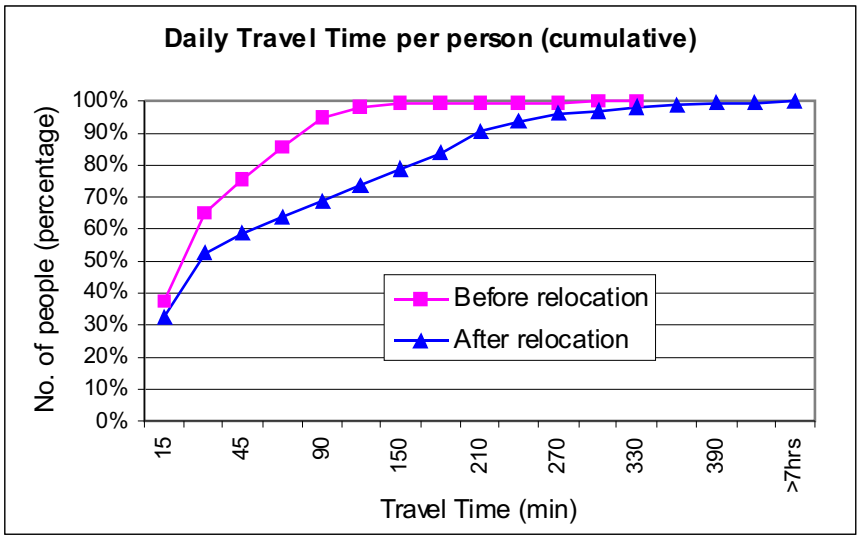


Figure 6: Travel time frequency before and after relocation

4. The daily travel cost shows (in figure 7) a shift to higher categories after relocation with the average increasing from INR 2 to INR 7.

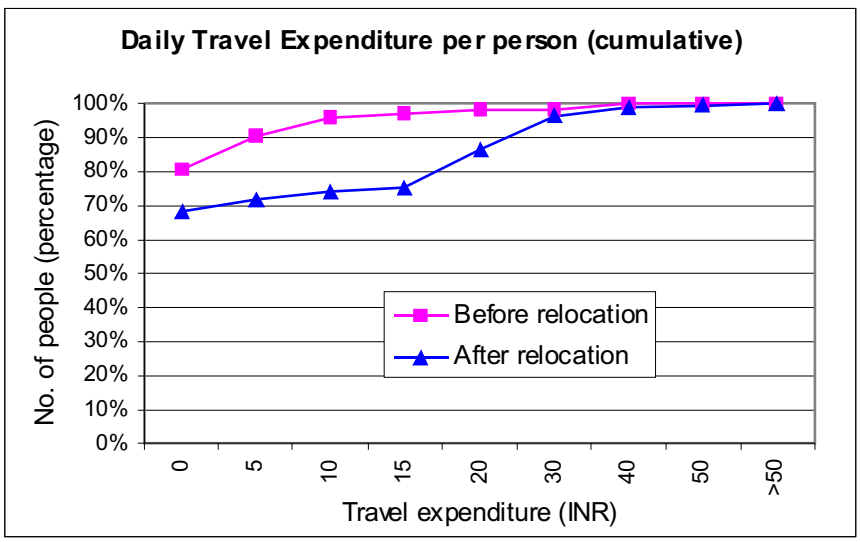


Figure 7: Travel expenditure frequency before and after relocation

The results of T-test to study the significance of change with the introduction of the metro are summarized in Table 4.

Table 4: Significance of change for the households relocated due to the metro

Results of T-tests (paired two sample for means)		
Change in parameter after metro	**At 95% confidence level**	**At 99% confidence level**
HH Income	significant	significant
Distance to amenities	significant	significant
Distance to ISBT & Rail station	significant	significant
Frequency of buses	significant	significant
Travel Distance	significant	significant
Travel Time	significant	significant
Travel Cost	significant	significant

Discussion

The primary survey results indicate that for the poor households residing along the metro-line, the metro has had no significant impact on their socio-economic and travel profile. It has only served to decrease the availability of buses since several bus-routes were realigned by policy to improve metro ridership. A few of the respondents have boarded the metro as tourist attraction but do not use it to travel. Considering that only 8% of their trips are on bus and 77% by walk, 4% by cycle and 6% by rickshaw, it is unlikely that these trips will be replaced by metro trips.

For the poor households relocated because of the construction of the metro, there has been a significant change in their accessibility and travel profile and income. The increasing distance, time and cost of daily travel, along with reduced incomes has had an extremely negative impact on the households. Their relocation has also put most urban services beyond their access and the significantly reduced bus service has further reduced their accessibility status.

STEP VI : Estimating the Indicators of Accessibility, Mobility and SEWB

This section is the first step in the SEIA model formulation and lists out the values of indicators, their change and significance of change due to the introduction of the transport project.

1. The values for the indicators developed in unit 2 for Accessibility, Mobility and SEWB are calculated using the case-study data.
2. The change in the values of indicators due to the project are calculated
3. Hypotheses 1 and 2, as stated in step 1 are tested, using t-test paired two sample for means
   a. The change in indicators of accessibility are used to test the hypothesis 1
   b. The change in indicators of mobility and SEWB are used to test hypothesis 2

Accessibility (A)

This subsection describes the indicators of accessibility and the change in them for both data sets - HH in the vicinity of metro and HH relocated due to the metro. Tables 5 and 6 summarize the percentage change in A_{st} indicators for households in the vicinity of the metro line and for households relocated due to the metro line, respectively.

Table 5 shows that, for the households living in the vicinity of the metro line, there has been little change in the indicators of $D_{education}$ and D_{health}, indicating that the location of schools, dispensaries and chemist services, in relation to the households, have not been affected by the coming of the metro. However the distance to services ($D_{services}$) like vegetable markets, daily needs shops and larger shops has increased for 23.6% of the households. This is borne out by the fact that several informal vendor

markets have been shifted or banned after the construction of the metro. Similarly, the distance to the bus stops ($D_{busstops}$) has increased for 19% of the households, and infact several bus stops have been shifted after the construction of the metro. The bus service time-gap (S_{bus}) has decreased for 34% of households of which it has decreased to the point of non-existence now for 33% making this a negative change, corroborated by the fact that several buses were rerouted to increase ridership of metro.

Table 5: Percentage change in Accessibility indicators for households in the vicinity of the metro line

Change Category	$D_{education}$ (diff)	D_{health} (diff)	$D_{services}$ (diff)	$D_{busstop}$ (diff)	S_{bus} (diff)
Total Decrease	0.0%	3.0%	4.9%	0.5%	34.5%
upto -100%	0.0%	0.0%	0.0%	0.0%	33.0%
>-100% upto -75%	0.0%	0.0%	0.5%	0.0%	0.0%
>-75% upto -50%	0.0%	0.0%	0.5%	0.0%	1.0%
>-50% upto -25%	0.0%	1.5%	1.0%	0.5%	0.5%
>-25% upto <0%	0.0%	1.5%	3.0%	0.0%	0.0%
No change	98.0%	93.1%	71.4%	80.3%	65.0%
>0% upto 25%	0.5%	0.0%	8.4%	0.0%	0.0%
>25% upto 50%	0.5%	1.5%	6.9%	0.5%	0.5%
>50% upto 75%	0.0%	0.0%	3.9%	0.0%	0.0%
>75% upto 100%	0.5%	1.0%	3.0%	1.0%	0.0%
>100%	0.5%	1.5%	1.5%	17.7%	0.0%
Total Increase	2.0%	3.9%	23.6%	19.2%	0.5%

Table 6 shows that, for the households relocated due to the construction of the metro, the value of all the indicators have changed for the majority of the households. The distance to schools ($D_{education}$) has increased for 52% of the households but decreased for 41% of the households. Similarly, the distance to health services (D_{health}) has increased for 63% of the households and decreased for 34% of the households. Also, the distance to urban services ($D_{services}$) has increased for 52% of the households and decreased for 36% of the households. The highest impact is seen in the indicators discussing access to bus system the distance to the bus stop ($D_{busstops}$) has increased for 72% of the households and the time gap between successive buses (S_{bus}) has increased by more than 100% for 98% of the households.

Table 6: Percentage change in Accessibility indicators for households relocated due to the metro line

Change Category	$D_{education}$ (diff)	D_{health} (diff)	$D_{services}$ (diff)	$D_{busstop}$ (diff)	S_{bus} (diff)
Total Decrease	40.8%	33.8%	36.3%	13.9%	1.5%
upto -100%	0.0%	0.0%	0.0%	0.5%	1.5%
>-100% upto -75%	10.4%	11.4%	13.4%	1.0%	0.0%
>-75% upto -50%	12.9%	12.9%	7.5%	3.5%	0.0%
>-50% upto -25%	12.4%	5.5%	12.4%	6.5%	0.0%
>-25% upto <0%	5.0%	4.0%	3.0%	2.5%	0.0%
No change	7.5%	3.5%	11.9%	14.4%	0.0%
>0% upto 25%	9.5%	13.9%	3.5%	8.0%	0.0%
>25% upto 50%	8.5%	5.0%	1.5%	9.5%	0.0%
>50% upto 75%	8.0%	15.4%	2.0%	3.5%	0.0%
>75% upto 100%	15.9%	13.9%	1.0%	6.0%	0.5%
>100%	10.0%	14.4%	43.8%	44.8%	98.0%
Total Increase	51.7%	62.7%	51.7%	71.6%	98.5%

Mobility

This subsection describes the indicators of mobility and the change in them for both data sets - HH in the vicinity of metro and HH relocated due to the metro. Tables 7 and 9 summarize the percentage change in M_{hh} indicators for households in the vicinity of the metro line and for households relocated due to the metro line, respectively; and tables 8 and 10 summarize the percentage change in M_p indicators for households in the vicinity of the metro line and for households relocated due to the metro line, respectively.

The table 7 shows that, for the households living in the vicinity of the metro line, there is some change in the indicators of per capita trip rate (PCTR) for work (there is no change for 78% of the households and it increases for 13% of the households) and other (there is no change for 82% of the households and it decreases for 14%) purposes but little change in the PCTR for education (there is no change for 91% of the households. The share of NMVs in the modes used for travel in households does not change for 87% of the households, increases for 7% and decreases for 5% of the households

Table 7: Percentage change in M_{HH} indicators for households in the vicinity of the metro line

Change category	$PCTR_{work}$ (diff)	$PCTR_{edu}$(diff)	$PCTR_{others}$(diff)	M_{nmv}/M_{all}(diff)
Total Decrease	9.4%	3.9%	13.8%	5.4%
upto -100%	0.0%	2.5%	2.0%	0.0%
>-100% upto -75%	0.5%	0.5%	0.0%	0.0%
>-75% upto -50%	2.0%	0.5%	3.0%	0.0%
>-50% upto -25%	3.0%	0.5%	6.4%	0.5%
>-25% upto <0%	3.9%	0.0%	2.5%	4.9%
No change	77.8%	91.1%	81.8%	87.2%
>0% upto 25%	1.5%	0.0%	1.0%	6.9%
>25% upto 50%	4.4%	0.5%	1.5%	0.5%
>50% upto 75%	1.5%	0.5%	0.0%	0.0%
>75% upto 100%	3.9%	3.9%	1.5%	0.0%
>100%	1.5%	0.0%	0.5%	0.0%
Total Increase	12.8%	4.9%	4.4%	7.4%

Following the trend of table 7, the table 8 shows minimum change in the mobility indicators regarding travel for education (distance, time, cost). The distance to work, the time to work and the cost has not changed for 73%, 72% and 91% households respectively and has increased for 17%, 17% and 5% households respectively. For trips made for other purposes, the distance, time and cost indicators have not changed for 72%, 72% and 93% households respectively, and have decreased for 15%, 16% and 4% households respectively.

Table 8: Percentage change in M_p indicators for households in the vicinity of the metro line

Change category	D_{work} (Diff)	$D_{education}$ (diff)	D_{others} (diff)	T_{work} (diff)	$T_{education}$ (diff)	T_{others} (diff)	C_{work} (diff)	$C_{education}$ (diff)	C_{others} (diff)
Total Decrease	10.3%	3.9%	15.3%	13.8%	4.4%	16.3%	3.4%	0.0%	4.4%
upto -100%	0.00%	2.46%	1.97%	0.00%	2.46%	1.48%	1.97%	0.00%	2.46%
>-100% upto -75%	0.99%	0.00%	2.46%	1.48%	0.00%	2.96%	0.00%	0.00%	0.49%
>-75% upto -50%	1.97%	0.49%	3.45%	1.48%	0.49%	2.46%	0.99%	0.00%	0.99%
>-50% upto -25%	3.94%	0.49%	5.42%	4.93%	1.48%	6.40%	0.49%	0.00%	0.49%
>-25% upto <0%	3.45%	0.49%	1.97%	5.91%	0.00%	2.96%	0.00%	0.00%	0.00%
No change	72.91%	90.64%	72.41%	69.46%	88.67%	71.92%	91.13%	100.00%	93.60%
>0% upto 25%	6.40%	1.97%	2.96%	6.40%	3.45%	2.96%	0.99%	0.00%	0.00%
>25% upto 50%	1.97%	0.49%	2.46%	2.46%	0.49%	2.46%	0.00%	0.00%	0.00%
>50% upto 75%	0.99%	0.00%	0.99%	0.49%	0.00%	0.99%	0.49%	0.00%	0.00%
>75% upto 100%	1.48%	1.48%	0.49%	1.97%	0.99%	1.97%	0.49%	0.00%	0.00%
>100%	5.91%	1.48%	5.42%	5.42%	1.97%	3.45%	3.45%	0.00%	1.97%
Total Increase	16.7%	5.4%	12.3%	16.7%	6.9%	11.8%	5.4%	0.0%	2.0%

Table 9 and 10 show that, for the households relocated due to the construction of the metro, the value of all the mobility indicators have changed for the majority of the households. Table 9 indicates that for 49% households, the PCTR for work has increased and for 30% of the households it has decreased. For 71% of households, the PCTR for education does not change it increases for 19% and decreases for 10% of the households. The PCTR for other purpose has increased for 35% of the households and decreased for the same percent of households. The share of NMVs in the mode used has decreased for 59% of the households.

Table 9: Percentage change in M_{HH} indicators for households relocated due to the metro

Change category	$PCTR_{work}$ (diff)	$PCTR_{edu}$(diff)	$PCTR_{others}$(diff)	M_{nmv}/M_{all}(diff)
Total Decrease	29.9%	10.4%	35.3%	58.7%
upto -100%	3.48%	6.47%	3.98%	2.99%
>-100% upto -75%	2.49%	0.00%	0.50%	0.00%
>-75% upto -50%	7.46%	2.99%	4.98%	3.98%
>-50% upto -25%	9.95%	1.00%	14.93%	15.42%
>-25% upto <0%	6.47%	0.00%	10.95%	36.32%
No change	21.39%	70.65%	29.35%	21.89%
>0% upto 25%	4.98%	0.00%	6.47%	14.43%
>25% upto 50%	8.96%	1.00%	9.95%	3.48%
>50% upto 75%	3.98%	1.49%	4.98%	0.50%
>75% upto 100%	19.40%	13.43%	8.96%	1.00%
>100%	11.44%	2.99%	4.98%	0.00%
Total Increase	48.8%	18.9%	35.3%	19.4%

The table 10 shows that the mobility indicators for travel to work distance, time and cost have increased for 83%, 82% and 61% of the households respectively. The distance, time and cost for education have not changed for 43%, 43% and 94% of the households respectively and have increased for 34%, 35% and 4% of households respectively. Regarding travel for other purposes, there is a decrease of distance and time for 58% and 52% households respectively but no change in cost for 65% of households.

Table 10: Percentage change in M_p indicators for households relocated due to the metro line

Change category	D_{work} (Diff)	$D_{education}$ (diff)	D_{others} (diff)	T_{work} (diff)	$T_{education}$ (diff)	T_{others} (diff)	C_{work} (diff)	$C_{education}$ (diff)	C_{others} (diff)
Total Decrease	14.9%	22.9%	58.2%	14.4%	21.9%	52.2%	10.4%	2.5%	12.4%
upto -100%	3.48%	6.47%	5.47%	3.48%	6.47%	3.48%	7.96%	2.49%	10.95%
>-100% upto -75%	4.48%	2.99%	17.91%	2.99%	1.99%	8.46%	0.00%	0.00%	0.50%
>-75% upto -50%	1.99%	6.47%	18.91%	1.49%	6.47%	20.90%	1.00%	0.00%	1.00%
>-50% upto -25%	2.49%	5.47%	11.94%	2.99%	5.47%	11.94%	1.49%	0.00%	0.00%
>-25% upto <0%	2.49%	1.49%	3.98%	3.48%	1.49%	7.46%	0.00%	0.00%	0.00%
No change	2.49%	43.28%	8.96%	3.48%	42.79%	7.96%	28.36%	93.53%	65.17%
>0% upto 25%	1.00%	1.99%	4.98%	2.99%	1.49%	5.97%	1.49%	0.00%	0.50%
>25% upto 50%	1.49%	0.50%	1.99%	2.49%	4.48%	3.48%	2.99%	0.00%	0.00%
>50% upto 75%	3.48%	0.50%	1.49%	1.49%	1.49%	4.98%	1.00%	0.00%	0.00%
>75% upto 100%	0.50%	5.47%	2.49%	2.49%	1.49%	2.49%	2.49%	0.00%	1.00%
>100%	76.12%	25.37%	21.89%	72.64%	26.37%	22.89%	53.23%	3.98%	20.90%
Total Increase	82.6%	33.8%	32.8%	82.1%	35.3%	39.8%	61.2%	4.0%	22.4%

Socio-economic Well-being

This subsection describes the indicators of socio-economic well-being (SEWB) and the change in them for both data sets - HH in the vicinity of metro and HH relocated due to the metro. Tables 11 and 12 summarize the percentage change in SEWB indicators for households in the vicinity of the metro line and for households relocated due to the metro line, respectively.

The table 11 shows that, for the households located in the vicinity of the metro line, there is no change in the indicators of female literacy, adult literacy ($N_{Adults>=5}$/ N_{adults}), residency ($Y_{low\text{-}income}$/ Y_{delhi}), employment and vehicle ownership. Of the seven indicators of SEWB, only two show change with the introduction of the metro. The infrastructure rank score has not changed for 79% of the households and become better for 18% of the households. The household income available per person has not changed for 66% of the households and has become better for 24% and worsened for 10%.

Table 11: Percentage change in SEWB indicators for households in the vicinity of the metro line

Change category	$\frac{Ng_{inschl}}{NG_{schage}}$ (diff)	$\frac{N_{Adults>=5}}{N_{adults}}$ (diff)	IRS (diff)	$\frac{Y_{low\text{-}income}}{Y_{delhi}}$ (diff)	W/N (diff)	I/N (diff)	V/N (diff)
Total Decrease	0.0%	0.0%	3.4%	0.0%	0.0%	9.9%	0.0%
upto -100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
>-100% upto -75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
>-75% upto -50%	0.00%	0.00%	0.49%	0.00%	0.00%	1.48%	0.00%
>-50% upto -25%	0.00%	0.00%	1.97%	0.00%	0.00%	4.43%	0.00%
>-25% upto <0%	0.00%	0.00%	0.99%	0.00%	0.00%	3.94%	0.00%
No change	55.67%	100.00%	78.33%	100.00%	100.00%	66.01%	100.00%
>0% upto 25%	0.00%	0.00%	6.90%	0.00%	0.00%	6.40%	0.00%
>25% upto 50%	0.00%	0.00%	1.97%	0.00%	0.00%	7.88%	0.00%
>50% upto 75%	0.00%	0.00%	0.99%	0.00%	0.00%	3.94%	0.00%
>75% upto 100%	0.00%	0.00%	2.96%	0.00%	0.00%	3.45%	0.00%
>100%	0.00%	0.00%	5.42%	0.00%	0.00%	2.46%	0.00%
Total Increase	0.0%	0.0%	18.2%	0.0%	0.0%	24.1%	0.0%
NA	44.33%						

Table 12 shows that, for the households relocated due to the construction of the metro, the value of all the SEWB indicators have changed for the majority of the households. The indicators most affected are female literacy (21% decrease), residency (100% decrease), Household income per person (66% decrease), Infrastructure rank score (33% decrease and 61% increase), and employment (8% decrease and 14% increase). The indicators of adult literacy and vehicle ownership show least change with 82% and 94% respectively in the no change category.

Table 12: Percentage change in SEWB indicators for households relocated due to the metro line

Change category	$\frac{N_{ginschl}}{Ng_{schage}}$ (diff)	$\frac{N_{Adults>=5}}{N_{adults}}$ (diff)	IRS (diff)	$\frac{Y_{low\text{-}income}}{Y_{delhi}}$ (diff)	W/N (diff)	I/N (diff)	V/N (diff)
Total Decrease	20.9%	3.5%	32.8%	100.0%	8.0%	65.7%	5.0%
upto -100%	14.93%	0.00%	0.00%	0.00%	0.50%	0.00%	4.98%
>-100% upto -75%	0.50%	0.00%	0.00%	98.51%	0.00%	0.50%	0.00%
>-75% upto -50%	3.48%	0.50%	4.48%	1.49%	5.97%	18.91%	0.00%
>-50% upto -25%	1.99%	0.50%	4.98%	0.00%	1.00%	31.34%	0.00%
>-25% upto <0%	0.00%	2.49%	23.38%	0.00%	0.50%	14.93%	0.00%
No change	41.79%	82.09%	5.97%	0.00%	78.11%	19.40%	94.53%
>0% upto 25%	0.00%	1.99%	50.75%	0.00%	0.00%	2.49%	0.00%
>25% upto 50%	0.00%	5.97%	0.50%	0.00%	0.00%	3.98%	0.00%
>50% upto 75%	0.00%	0.50%	5.47%	0.00%	0.50%	4.48%	0.00%
>75% upto 100%	4.48%	5.97%	0.00%	0.00%	11.44%	1.49%	0.50%
>100%	0.00%	0.00%	4.48%	0.00%	1.99%	2.49%	0.00%
Total Increase	4.5%	14.4%	61.2%	0.0%	13.9%	14.9%	0.5%
NA	32.84%						

Testing the Hypotheses

Hypotheses 1 and 2, as stated in Step 1 are tested for all the indicators, using t-tests paired two-sample for means and the results are summarized in table 13. The results show that:

1. For the households living in the vicinity of the metro line there has been significant change in the accessibility provided by the bus transport system, and the status of the physical infrastructure;
2. For the households relocated due to the metro line there has been significant change in the accessibility to urban services and the frequency of bus services amongst the accessibility indicators, use of NMVs and the work trip profile amongst the mobility indicators, and all indicators of SEWB except employment.

Table 13: Significance of change in indicators due to introduction of metro

No.	Type of Indicators	Indicators	Significance of change for HH in metro vicinity		Significance of change for HH relocated	
			At 5% confidence Level	At 1% confidence level	At 5% confidence level	At 1% confidence level
1	Accessibility	$D_{education}$	Not significant	Not significant	Not significant	Not significant
2		D_{health}	Not significant	Not significant	Not significant	Not significant
3		$D_{services}$	Not significant	Not significant	Significant	Significant
4		$D_{busstop}$	Significant	Significant	Significant	Not significant
5		S_{bus}	Significant	Significant	Significant	Significant
6	Mobility	$PCTR_{work}$	Not significant	Not significant	Not significant	Not significant
7		$PCTR_{edu}$	Not significant	Not significant	Not significant	Not significant
8		$PCTR_{others}$	Not significant	Not significant	Not significant	Not significant
9		M_{nmv}/M_{all}	Not significant	Not significant	Significant	Significant
10		D_{work}	Not significant	Not significant	Significant	Significant
11		$D_{education}$	Not significant	Not significant	Significant	Not significant
12		D_{others}	Significant	Not significant	Not significant	Not significant
13		T_{work}	Not significant	Not significant	Significant	Significant
14		$T_{education}$	Not significant	Not significant	Significant	Significant
15		T_{others}	Significant	Not significant	Not significant	Not significant
16		C_{work}	Not significant	Not significant	Significant	Significant
17		$C_{education}$	Not significant	Not significant	Not significant	Not significant
18		C_{others}	Not significant	Not significant	Significant	Not significant
19	SEWB	NG_{inschl}/ NG_{schage}	Not significant	Not significant	Significant	Significant
20		$N_{adults>=5}/ N_{adults}$	Not significant	Not significant	Significant	Significant
21		IRS	Significant	Significant	Significant	Significant
22		$Y_{low-income}/ Y_{delhi}$	Not significant	Not significant	Significant	Significant
23		W/N	Not significant	Not significant	Not significant	Not significant
24		I/N	Not significant	Not significant	Significant	Significant
25		V/N	Not significant	Not significant	Significant	Significant

Discussion

This step answers the question - what aspects of accessibility, mobility and SEWB are affected by a new project? The indicators developed in Unit 2 for accessibility, mobility and SEWB are based on generic theoretical understanding and the definitions developed after extensive review. In this step the indicators are quantified based on the data. However, based on the results of step V, one can add more indicators at this step (or delete some). The change in these indicators is the first step towards quantifying the impact of the project

STEP VII: Combining the Indicators into Indices

In this step the indicators of accessibility, mobility and SEWB are aggregated using the Principal Component Analysis (PCA) technique to develop indices of accessibility, mobility and SEWB. The PCA is used to assign weights to the indicators before aggregating them into indices. The method used for index construction is as follows:

1. Principal components are calculated using PCA
2. Different rotations are tried to maximize loading on the principal components (PC1, PC2,…PCn) so that they explain maximum percent of the total variance. Theoretically the 'varimax' rotation maximizes variance explained while increasing the large loading and decreasing the smaller loadings. The higher loadings in each PC are retained and the smaller loadings are discarded in a manner so that each PC clubs together similar/ correlated indicators in a logical manner. Each PC becomes a type of factor explaining the aggregate index and each PC is independent of the others.
3. The loadings of the retained variables in each PC are taken as indicative weights for the indicators and calculated as a fraction of 1.
4. The 'variance explained'[4] are taken as relative weights for each PC to aggregate them as an index.
5. The value of the index is calculated for each household.
6. The change in the value of indices due to introduction of the project is calculated. Hypotheses 1 and 2, as stated in chapter 4 are tested, using t-test paired two sample for means
   a. The change in index of accessibility are used to test the hypothesis 1
   b. The change in indices of mobility and SEWB are used to test hypothesis 2

Accessibility

The accessibility index developed by the method described above is shown by equation 1 (a to d). The steps used to derive the equation using the results of PCA are as follows:

$$\mathbf{A_{st} = E_1(PC1) + E_2(PC2)}$$

Where E1 and E2 are the eigenvalues

And $PC1 = d(D_{busstop}) + e(S_{bus})$

$PC2 = a(D_{ed}) + b(D_{health}) + c(D_{ser})$

Where a, b …e are component loadings.

The PCA aggregates correlated variables into one factor. The PC1 explains accessibility provided by the bus system and the PC2 explains the landuse accessibility. The PC1 and PC2 explain approximately 55% (average) of the total variance.

Box 1 illustrates the Principal component method of factor analysis applied to the accessibility indicators of the low-income settlements residing in the vicinity of the metro line before introduction of the metro to develop an index of accessibility.

4. The 'variance explained' and 'eigen values' are the same for a non-rotated matrix used for PCA. The 'variance explained' changes with rotations because the component loading change. This new 'variance explained is taken as relative weight of the principal component.

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	PC 2
D_ED	0.076	**0.555**
D_HEALTH	0.184	**0.646**
D_SER	0.337	**0.707**
D_BUSSTOP	**0.881**	0.169
S_BUS	**0.870**	0.054

"Variance" Explained by Rotated Components

PC 1	PC 2
1.686	**1.257**

Percent of Total Variance Explained

PC 1	PC 2
33.716	**25.139**

Indicators	**From PCA**		**Scaled to fraction of 1**		**Multiplied by weights (variance explained)**	
	PC1	**PC2**	**PC1**	**PC2**	**PC1**	**PC2**
$D_{education}$		0.555		0.29		0.49
D_{health}		0.646		0.34		0.57
$D_{services}$		0.707		0.37		0.62
$D_{busstop}$	0.881		0.50		0.63	
S_{bus}	0.870		0.50		0.62	

Box 1: Accessibility Index (A) calculation using PCA for dataset in Vicinity-before metro

Box 2 illustrates the principal component method of factor analysis applied to the accessibility indicators of the low-income settlements residing in the vicinity of the metro line after the introduction of metro to develop an index of accessibility.

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	PC 2
D_ED	0.014	**0.959**
D_HEALTH	0.085	**0.149**
D_SER	0.281	**0.312**
D_BUSSTOP	**0.857**	0.001
S_BUS	**0.872**	0.021

"Variance" Explained by Rotated Components

PC 1	PC 2
1.582	**1.040**

Percent of Total Variance Explained

PC 1	PC 2
31.639	**20.794**

Indicators	**From PCA**		**Scaled to fraction of 1**		**Multiplied by weights (Variance explained)**	
	PC1	**PC2**	**PC1**	**PC2**	**PC1**	**PC2**
$D_{education}$		0.959		0.68		1.07
D_{health}		0.149		0.10		0.17
$D_{services}$		0.312		0.22		0.35
$D_{busstop}$	0.857		0.50		0.52	
S_{bus}	0.872		0.50		0.52	

Box 2: Accessibility Index (A) calculation using PCA for dataset in Vicinity-after metro

The comparison of the coefficients (weights) of indicators generated for the before and after metro scenario for the households residing in the vicinity of the metro line, as illustrated by Boxes 7.1 and 7.2, shows that the distance to education becomes more important and the distance to health services and other urban services becomes less important after the introduction of the metro. There is no significant change in the contribution of the distance to bus-stop and the services provided by the bus after the introduction of the metro the contribution of the bus system (including location of bus stop and frequency of buses) in explaining accessibility remains high regardless of the introduction of the metro.

Box 3 illustrates the PCA applied to the accessibility indicators of the low-income settlements relocated due to the metro line before the introduction of the metro to develop an index of accessibility.

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	PC 2
D_ED	0.075	**0.876**
D_HEALTH	0.201	**0.264**
D_SER	0.250	**0.470**
D_BUSSTOP	**0.896**	0.015
S_BUS	**0.874**	0.000

"Variance" Explained by Rotated Components

PC 1	PC 2
1.675	**1.058**

Percent of Total Variance Explained

PC 1	PC 2
33.496	**21.152**

Indicators	**From PCA**		**Scaled to fraction of 1**		**Multiplied by weights (variance explained)**	
	PC1	**PC2**	**PC1**	**PC2**	**PC1**	**PC2**
$\mathbf{D}_{education}$		0.876		0.54		0.91
$\mathbf{D}_{health}$		0.264		0.16		0.27
$\mathbf{D}_{services}$		0.470		0.29		0.49
$\mathbf{D}_{busstop}$	0.896		0.51		0.54	
$\mathbf{S}_{bus}$	0.874		0.49		0.52	

Box 3: Accessibility Index (A) calculation using PCA for dataset Relocated-before metro

Box 4 illustrates the PCA applied to the accessibility indicators of the households relocated due to the metro line after introduction of the metro to develop an index of accessibility.

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	PC 2
D_ED	0.622	0.**504**
D_HEALTH	0.346	0.**582**
D_SER	0.085	0.**789**
D_BUSSTOP	0.**716**	0.043
S_BUS	0.**494**	0.085

"Variance" Explained by Rotated Components

PC 1	PC 2
1.270	**1.224**

Percent of Total Variance Explained

PC 1	PC 2
25.407	**24.489**

Indicators	**From PCA**		**Scaled to fraction of 1**		**Multiplied by weights (Variance explained)**	
	PC1	**PC2**	**PC1**	**PC2**	**PC1**	**PC2**
$\mathbf{D}_{education}$		0.502		0.27		0.34
$\mathbf{D}_{health}$		0.582		0.31		0.39
$\mathbf{D}_{services}$		0.789		0.42		0.53
$\mathbf{D}_{busstop}$	0.716		0.59		0.72	
$\mathbf{S}_{bus}$	0.494		0.41		0.50	

Box 4: Accessibility Index (A) calculation using PCA for dataset Relocated-after metro

The comparison of the coefficients (weights) of indicators generated for the before and after metro scenario for the households relocated due to the metro line, as illustrated by Boxes 3 and 4, shows that the distance to education becomes less important and the distance to health services becomes more important after the introduction of the metro. The distance to bus-stop becomes a more significant contributor in explaining accessibility after relocation while the contribution of services provided by the bus after relocation becomes less important.
The aggregated index reads as follows for the 4 data sets:

In Vicinity-before metro
$$\mathbf{A = 0.49(D_{ed}) + 0.57(D_{health}) + 0.62(D_{ser}) + 0.63(D_{busstop}) + 0.62(S_{bus})} \ldots\ldots\ldots 1\text{-a}$$

In Vicinity-after metro
$$\mathbf{A = 1.07(D_{ed}) + 0.17(D_{health}) + 0.35(D_{ser}) + 0.52(D_{busstop}) + 0.52(S_{bus})} \ldots\ldots\ldots 1\text{-b}$$

Relocated-before metro
$$\mathbf{A = 0.91(D_{ed}) + 0.27(D_{health}) + 0.49(D_{ser}) + 0.54(D_{busstop}) + 0.52(S_{bus})} \ldots\ldots\ldots 1\text{-c}$$

Relocated - after metro
$$\mathbf{A = 0.34(D_{ed}) + 0.39(D_{health}) + 0.53(D_{ser}) + 0.72(D_{busstop}) + 0.50(S_{bus})} \ldots\ldots\ldots 1\text{-d}$$

According to the index, the distance to the bus stop and bus frequency, and distance to urban services (vegetable market, daily need shops and larger shopping areas) affect accessibility maximally, while the land use accessibility like distance to schools and health services affects it to a lesser extent.

The value of A is calculated for each household and the change in the value after the introduction of the metro is analyzed. T-tests (paired-two-sample for means) are conducted to the index values to see if the change is significant in table 14.

Mobility

The mobility index developed by the method described above reads as equation 2(a to d). The steps used to derive the equation using the results of PCA are described below

$$\mathbf{M = E_1\,(PC1) + E_2\,(PC2) + E_3\,(PC3) + E_4\,(PC4)}$$

Where E1,E2, E3 and E4 are the eigenvalues

And
$$PC1 = b(PCTR_{education}) + e(D_{ed}) + h(T_{ed}) + k(C_{ed})$$
$$PC2 = c(PCTR_{others}) + f(D_{others}) + i(T_{others}) + l(C_{others})$$
$$PC3 = a(PCTR_{work}) + d(D_{work}) + g(T_{work}) + j(C_{work})$$
$$PC4 = M_{nmv}/M_{all}$$

Where a, b, ….l are component loadings.

The PCA aggregates correlated variables into one factor. The PC1 explains the trip for education, PC2 explains the trip for other purposes like social, health, religious and PC3 explains the trip to work and PC4 explains only a single indicator of use of non-motorized modes. The sequence of the PC may vary for different datasets but the logic of aggregation is consistent. The 4 components explain, on an average, approximately 65% of the total variance.

Box 5 illustrates the PCA applied to the mobility indicators of the low-income settlements residing in the vicinity of the metro line before introduction of the metro to develop an index of mobility (M).

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC1	PC2	PC3	PC4	PC5
PCTR_WORK	0.121	0.161	**0.698**	0.262	0.103
PCTR_EDU	0.034	**0.876**	0.024	0.028	0.142
PCTR_OTHERS	**0.660**	0.032	0.051	0.009	0.566
M_NMV/M_ALL	0.220	0.041	0.127	0.100	**0.807**
D_WORK	0.094	0.070	**0.862**	0.145	0.228
D_ED	0.062	**0.950**	0.036	0.189	0.033
D_OTHERS	**0.878**	0.090	0.130	0.079	0.133
T_WORK	0.079	0.045	**0.813**	0.058	0.052
T_ED	0.079	**0.950**	0.015	0.006	0.054
T_OTHERS	**0.895**	0.105	0.075	0.015	0.070
C_WORK	0.109	0.007	**0.327**	0.751	0.155
C_ED	0.040	**0.191**	0.007	0.854	0.019
C_OTHERS	**0.754**	0.020	0.094	0.016	0.237

"Variance" Explained by Rotated Components

PC1	PC2	PC3	PC4	PC5
2.679	**2.664**	**2.050**	1.441	**1.675**

Percent of Total Variance Explained

PC1	PC2	PC3	PC4	PC5
20.606	**20.489**	**15.772**	11.083	**8.959**

Components' aggregation: other education work share NMV

Indicators	**From PCA**				**Scaled to fraction of 1**				**Multiplied by weights (Variance explained)**			
	PC1	**PC2**	**PC3**	**PC5**	**PC1**	**PC2**	**PC3**	**PC5**	**PC1**	**PC2**	**PC3**	**PC5**
$PCTR_{work}$			0.70				0.26				0.53	
$PCTR_{education}$		0.88				0.30				0.79		
$PCTR_{others}$	0.66				0.21				0.55			
$M_{nmv}/_{Mall}$				0.81				0.81				1.68
D_{work}			0.86				0.32				0.65	
$D_{education}$		0.95				0.32				0.85		
D_{others}	0.88				0.28				0.74			
T_{work}			0.81				0.30				0.62	
$T_{education}$		0.95				0.32				0.85		
T_{others}	0.90				0.28				0.75			
C_{work}			0.33				0.12				0.25	
$C_{education}$		0.19				0.06				0.17		
C_{others}	0.75				0.24				0.63			

Box 5: Mobility Index (M) calculation using PCA for dataset in Vicinity-before metro

Box 6 illustrates the PCA applied to the mobility indicators of the low-income settlements residing in the vicinity of the metro line after introduction of the metro to develop an index of mobility (M).

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC1	PC2	PC3	PC4
PCTR_WORK	0.153	0.077	**0.696**	0.171
PCTR_EDU	**0.876**	0.057	0.006	0.138
PCTR_OTHERS	0.005	**0.805**	0.027	0.352
M_NMV/M_ALL	0.092	0.090	0.179	**0.747**
D_WORK	0.009	0.048	**0.842**	0.277
D_ED	**0.950**	0.030	0.071	0.053
D_OTHERS	0.040	**0.826**	0.077	0.387
T_WORK	0.030	0.044	**0.819**	0.044
T_ED	**0.951**	0.033	0.034	0.060
T_OTHERS	0.067	**0.875**	0.065	0.067
C_WORK	0.020	0.059	**0.334**	0.070
C_ED	**0.196**	0.047	0.070	0.047
C_OTHERS	0.098	**0.485**	0.091	0.643

"Variance" Explained by Rotated Components

PC1	PC2	PC3	PC4
2.663	**2.359**	**2.038**	**1.389**

Percent of Total Variance Explained

PC1	PC2	PC3	PC4
20.486	**18.143**	**15.676**	**10.687**

Components' aggregation: education other work share NMV

Indicators	**From PCA**				**Scaled to fraction of 1**				**Multiplied by weights (variance explained)**			
	PC1	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**	**PC4**
$PCTR_{work}$			0.70				0.26				0.53	
$PCTR_{education}$	0.88				0.29				0.78			
$PCTR_{others}$		0.81				0.27				0.63		
$M_{nmv/Mall}$				0.75				1.0				1.39
D_{work}			0.84				0.31				0.64	
$D_{education}$	0.95				0.32				0.85			
D_{others}		0.83				0.28				0.65		
T_{work}			0.82				0.30				0.62	
$T_{education}$	0.95				0.32				0.85			
T_{others}		0.88				0.29				0.69		
C_{work}			0.33				0.12				0.25	
$C_{education}$	0.20				0.07				0.18			
C_{others}		0.49				0.16				0.38		

Box 6: Mobility Index (M) calculation using PCA for dataset in Vicinity-after metro

The comparison of the coefficients (weights) of indicators generated for the before and after metro scenario for the households in the vicinity of the metro line, as illustrated by Boxes 5 and 6, shows that the education trips contribute more to the index of mobility after the construction of the metro replacing other purpose trip as PC1.

Box 7 illustrates the PCA applied to the mobility indicators of the low-income settlements relocated due to the metro line before relocation to develop an index of mobility (M).

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC1	PC2	PC3	PC4
PCTR_WORK	**0.790**	0.133	0.027	0.094
PCTR_EDU	0.108	**0.861**	0.030	0.092
PCTR_OTHERS	0.068	0.168	**0.709**	0.279
M_NMV/M_ALL	0.363	0.159	0.142	**0.638**
D_WORK	**0.869**	0.020	0.065	0.251
D_ED	0.064	**0.917**	0.031	0.085
D_OTHERS	0.103	0.015	**0.784**	0.389
T_WORK	**0.855**	0.024	0.094	0.060
T_ED	0.012	**0.915**	0.050	0.086
T_OTHERS	0.036	0.104	**0.901**	0.010
C_WORK	**0.624**	0.116	0.023	0.513
C_ED	0.116	**0.255**	0.175	0.334
C_OTHERS	0.026	0.056	**0.398**	0.686

"Variance" Explained by Rotated Components

PC1	PC2	PC3	PC4
2.676	**2.584**	**2.157**	**1.581**

Percent of Total Variance Explained

PC1	PC2	PC3	PC4
20.585	**19.873**	**16.589**	**12.158**

Components' aggregation: work education other share NMV

Indicators	**From PCA**				**Scaled to fraction of 1**				**Multiplied by weights (variance explained)**			
	PC1	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**	**PC4**
$PCTR_{work}$	0.79				0.25				0.67			
$PCTR_{education}$		0.86				0.29				0.75		
$PCTR_{others}$			0.71				0.25				0.55	
M_{nmv}/M_{all}				0.64				1.0				1.58
D_{work}	0.87				0.28				0.74			
$D_{education}$		0.92				0.31				0.80		
D_{others}			0.78				0.28				0.61	
T_{work}	0.86				0.27				0.73			
$T_{education}$		0.92				0.31				0.80		
T_{others}		0.90					0.32				0.70	
C_{work}	0.62				0.20				0.53			
$C_{education}$		0.26				0.09				0.22		
C_{others}			0.40				0.14				0.31	

Box 7: Mobility Index (M) calculation using PCA for dataset Relocated-before metro

Box 8 illustrates the PCA applied to the mobility indicators of the low-income settlements relocated due to the metro line before relocation to develop an index of mobility (M).

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC1	PC2	PC3	PC4
PCTR_WORK	**0.770**	0.015	0.091	0.328
PCTR_EDU	0.198	**0.619**	0.051	0.022
PCTR_OTHERS	0.040	0.120	**0.311**	0.836
M_NMV1M_ALL	0.516	0.006	0.239	**0.573**
D_WORK	**0.881**	0.047	0.061	0.147
D_ED	0.032	**0.961**	0.062	0.037
D_OTHERS	0.060	0.016	**0.969**	0.020
T_WORK	**0.826**	0.040	0.063	0.091
T_ED	0.040	**0.916**	0.021	0.035
T_OTHERS	0.098	0.024	**0.937**	0.110
C_WORK	**0.890**	0.065	0.017	0.205
C_ED	0.077	**0.894**	0.116	0.044
C_OTHERS	0.004	0.050	**0.942**	0.045

"Variance" Explained by Rotated Components

PC1	PC2	PC3	PC4
3.173	**2.972**	**2.894**	**1.228**

Percent of Total Variance Explained

PC1	PC2	PC3	PC4
24.406	**22.865**	**22.260**	**9.442**

Components' aggregation: work education other share NMV

Indicators	**From PCA**				**Scaled to fraction of 1**				**Multiplied by weights (variance explained)**			
	PC1	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**	**PC4**	**PC1**	**PC2**	**PC3**	**PC4**
$PCTR_{work}$	0.77				0.23				0.73			
$PCTR_{education}$		0.62				0.18				0.54		
$PCTR_{others}$			0.31				0.10				0.28	
M_{nmv}/M_{all}				0.57				1.0				1.23
D_{work}	0.88				0.26				0.83			
$D_{education}$		0.96				0.28				0.84		
D_{others}			0.97				0.31				0.89	
T_{work}	0.83				0.25				0.78			
$T_{education}$		0.92				0.27				0.80		
T_{others}			0.94				0.30				0.86	
C_{work}	0.89				0.26				0.84			
$C_{education}$		0.89				0.26				0.78		
C_{others}			0.94				0.30				0.86	

Box 8: Mobility Index (M) calculation using PCA for dataset Relocated-after metro

The comparison of the coefficients (weights) of indicators generated for the before and after metro scenario for the households relocated due to the metro line, as illustrated by Boxes 7 and 8, shows that the cost of trips (of all purposes) contribute very little to the loadings of the principal components before relocation but become significant contributors after relocation of the households.

Since $\mathbf{M_{hh}}$ indicators are seen as desirable mobility and $\mathbf{M_p}$ as undesirable mobility they are ascribed opposing signs in the index. Hence the mobility index reads as:

In Vicinity-before metro

$$\mathbf{M = [0.53(PCTR_{work}) + 0.79(PCTR_{education}) + 0.55(PCTR_{others}) + 1.68\ (M_{nmv}/M_{all})]}$$
$$\mathbf{-[0.65(D_{work}) + 0.85(D_{ed}) + 0.74(D_{others}) + 0.62(T_{work}) + 0.85(T_{ed})}$$
$$\mathbf{+ 0.75(T_{others}) + 0.25(C_{work}) + 0.17(C_{ed}) + 0.63(C_{others})]} \quad \ldots\ldots\ldots\ldots \text{ 2-a}$$

In Vicinity-after metro

$$\mathbf{M = [0.53(PCTR_{work}) + 0.78(PCTR_{education}) + 0.63(PCTR_{others}) + 1.39(M_{nmv}/M_{all})]}$$
$$\mathbf{- [0.64(D_{work}) + 0.85(D_{ed}) + 0.65(D_{others}) + 0.62(T_{work}) + 0.85(T_{ed})}$$
$$\mathbf{+ 0.69(T_{others}) + 0.25(C_{work}) + 0.18(C_{ed}) + 0.38(C_{others})} \quad \ldots\ldots\ldots\ldots \text{ 2-b}$$

Relocated-before metro

$$\mathbf{M = [0.67(PCTR_{work}) + 0.75(PCTR_{education}) + 0.55(PCTR_{others}) + 1.58\ (M_{nmv}/M_{all})]}$$
$$\mathbf{- [0.74(D_{work}) + 0.80(D_{ed}) + 0.61(D_{others}) + 0.73(T_{work}) + 0.80(T_{ed})}$$
$$\mathbf{+ 0.70(T_{others}) + 0.53(C_{work}) + 0.22(C_{ed}) + 0.31(C_{others})} \quad \ldots\ldots\ldots\ldots \text{ 2-c}$$

Relocated-after metro

$$\mathbf{M = [0.73(PCTR_{work}) + 0.54(PCTR_{education}) + 0.28(PCTR_{others}) + 1.23\ (M_{nmv}/M_{all})]}$$
$$\mathbf{- [0.83(D_{work}) + 0.84(D_{ed}) + 0.89(D_{others}) + 0.78(T_{work}) + 0.80(T_{ed})}$$
$$\mathbf{+ 0.86(T_{others}) + 0.84(C_{work}) + 0.78(C_{ed}) + 0.86(C_{others}} \quad \ldots\ldots\ldots\ldots \text{ 2-d}$$

The coefficients of the PCs imply that the trip for education and other reasons like buying daily need supplies would have a higher impact on the mobility index than the work trips, though the difference is not significant. For mobility explained by different purposes, the cost of trips is the least important contributor.

The value of M is calculated for each household and the change in the value after the introduction of the metro is analyzed. T-tests (paired two sample for means) are conducted to the index values to see if the change is significant in table 14.

Socio-economic Well-being

The SEWB index developed using the method described above is in Equation 3 (a to d). The steps used to derive the equation using the results of PCA are described below

SEWB = E1 (PC1) + E2 (PC2) + E3 (PC3)

Where, E1, E2 and E3 are the eigenvalues

And $PC1 = e(W/N) + f(I/N) + g(V/N)$

$PC2 = c(IRS) + d(Y_{low\text{-}income}/Y_{delhi})$

$PC3 = a(NG_{inschl}/ NG_{schage}) + b(N_{adults>=5}/ N_{adults})$

Where a, b, …. g are component loadings

PC1 explains economic well-being, PC2 explains condition of physical infrastructure and PC3 explains social well-being. Together, the three principal components, on an average, explain 60% of the variance.

Box 9 illustrates the PCA applied to the SEWB indicators of the low-income settlements residing in the vicinity of the metro line before introduction of the metro to develop an index of SEWB (S).

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	**PC 2**	**PC 3**
NG_SCH	0.208	0.270	**0.473**
N_ADULTS_LIT	0.042	0.631	**0.328**
IRS	0.214	**0.767**	0.063
Y_RES	0.234	**0.567**	0.209
WORKERS	**0.887**	0.115	0.086
INCOME	**0.874**	0.128	0.055
VEHICLE	**0.189**	0.164	0.799

"Variance" Explained by Rotated Components

PC 1	**PC 2**	**PC 3**
1.732	**1.438**	**1.028**

Percent of Total Variance Explained

PC 1	**PC 2**	**PC 3**
24.743	**20.537**	**14.683**

Indicators	**From PCA**			**Scaled to fraction of 1**			**Multiplied by weights (variance explained)**		
	PC1	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
NG_{inschl}/ NG_{schage}			0.47			0.59			0.61
N_{adults}>=5/ N_{adults}			0.33			0.41			0.42
IRS		0.77			0.57			0.83	
$Y_{low-income}/Y_{delhi}$		0.57			0.43			0.61	
W/N	0.89			0.45			0.66		
I/N	0.87			0.45			0.65		
V/N	0.19			0.10			0.14		

Box 9: SEWB Index (S) calculation using PCA for dataset in Vicinity-before metro

Box 10 illustrates the PCA applied to the SEWB indicators of the low-income settlements residing in the vicinity of the metro line after introduction of the metro to develop an index of SEWB (S).

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	**PC 2**	**PC 3**
NG_SCH	0.208	0.273	**0.534**
N_ADULTS_LIT	0.024	0.615	**0.425**
IRS	0.245	**0.700**	0.066
Y_RES	0.218	**0.611**	0.172
WORKERS	**0.895**	0.056	0.031
INCOME	**0.894**	0.019	0.031
VEHICLE	**0.265**	0.109	0.725

"Variance" Explained by Rotated Components

PC 1	**PC 2**	**PC 3**
1.821	**1.331**	**1.027**

Percent of Total Variance Explained

PC 1	**PC 2**	**PC 3**
26.009	**19.017**	**14.676**

Indicators	**From PCA**			**Scaled to fraction of 1**			**Multiplied by weights (variance explained)**		
	PC1	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
NG_{inschl}/ NG_{schage}			0.53			0.56			0.57
N_{adults}>=5/ N_{adults}			0.43			0.44			0.46
IRS		0.70			0.53			0.71	
$Y_{low-income}$/Y_{delhi}		0.61			0.47			0.62	
W/N	0.90			0.44			0.63		
I/N	0.89			0.44			0.63		
V/N	0.27			0.13			0.19		

Box 10: SEWB Index (S) calculation using PCA for dataset in Vicinity-after metro

The comparison of the coefficients (weights) of indicators generated for the before and after metro scenario for the households in the vicinity of the metro line, as illustrated by Boxes 9 and 10, shows no significant change indicating that the indicators of SEWB and their contribution to the index of SEWB are not affected by the introduction of the metro for these households.

Box 11 illustrates the PCA applied to the SEWB indicators of the low-income settlements relocated due to the metro line before introduction of the metro to develop an index of SEWB (S).

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	PC 2	PC 3
NG_SCH	0.092	**0.796**	0.152
N_ADULTS_LIT	0.091	**0.802**	0.053
IRS	0.016	0.096	**0.934**
Y_RES	0.177	0.151	**0.144**
WORKERS	**0.827**	0.132	0.256
INCOME	**0.825**	0.127	0.242
VEHICLE	**0.291**	0.119	0.163

"Variance" Explained by Rotated Components

PC 1	PC 2	PC 3
1.497	**1.357**	**1.071**

Percent of Total Variance Explained

PC 1	PC 2	PC 3
21.388	**19.390**	**15.293**

Indicators	**From PCA**			**Scaled to fraction of 1**			**Multiplied by weights (variance explained)**		
	PC1	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
NG_{inschl}/ NG_{schage}		0.80			0.50			0.68	
N_{adults}>=5/ N_{adults}		0.80			0.50			0.68	
IRS			0.93			0.87			0.93
$Y_{low-income}/Y_{delhi}$			0.14			0.13			0.14
W/N	0.83			0.43			0.62		
I/N	0.83			0.42			0.62		
V/N	0.29			0.15			0.22		

Box 11: SEWB Index (S) calculation using PCA for Relocated-before metro

Box 12 illustrates the PCA applied to the SEWB indicators of the low-income settlements relocated due to the metro line after introduction of the metro.

Component Loadings using Rotated Loading Matrix (VARIMAX)

	PC 1	PC 2	PC 3
NG_SCH	0.096	**0.790**	0.097
N_ADULTS_LIT	0.212	**0.761**	0.011
IRS	0.020	0.100	**0.673**
Y_RES	0.003	0.207	**0.732**
WORKERS	**0.893**	0.097	0.052
INCOME	**0.829**	0.228	0.179
VEHICLE	**0.071**	0.162	0.465

"Variance" Explained by Rotated Components

PC 1	PC 2	PC 3
1.545	**1.343**	**1.250**

Percent of Total Variance Explained

PC 1	PC 2	PC 3
22.067	**19.192**	**17.856**

Indicators	**From PCA**			**Scaled to fraction of 1**			**Multiplied by weights (variance explained)**		
	PC1	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
NG_{inschl}/ NG_{schage}		0.79			0.51			0.68	
$N_{adults>=5}$/ N_{adults}		0.76			0.49			0.66	
IRS			0.67			0.48			0.60
$Y_{low-income}/Y_{delhi}$			0.73			0.52			0.65
W/N	0.89			0.50			0.72		
I/N	0.83			0.46			0.67		
V/N	0.07			0.04			0.06		

Box 12: SEWB Index (S) calculation using PCA for dataset Relocated-after metro

The comparison of the coefficients (weights) of indicators generated for the before and after relocation scenario for the households relocated due to the metro line, as illustrated by Boxes 11 and 12, shows no significant change in the social indicators of literacy and education of girls; significant change in the physical infrastructure indicators with decrease in the contribution of the IRS and increase in the contribution of residency status; and significant decrease in the importance of vehicle ownership in the economic indicators.

Aggregating the indicators to the index with the coefficients for each dataset, the SEWB index reads as:

In Vicinity-before metro

$$SEWB = 0.61(NG_{inschl}/ NG_{schage}) + 0.42(N_{adults>=5}/ N_{adults}) + 0.83(IRS) + 0.61(Y_{low-income}/Y_{delhi}) + 0.66(W/N) + 0.65(I/N) + 0.14(V/N) \quad \text{..... ....3-a}$$

In Vicinity-after metro

$$SEWB = 0.57(NG_{inschl}/ NG_{schage}) + 0.46(N_{adults>=5}/ N_{adults}) + 0.71(IRS) + 0.62(Y_{low-income}/Y_{delhi}) + 0.63(W/N) + 0.63(I/N) + 0.19(V/N) \text{..... ....3-b}$$

Relocated-before metro

$$SEWB = 0.68(NG_{inschl}/ NG_{schage}) + 0.68(N_{adults>=5}/ N_{adults}) + 0.93(IRS) + 0.14(Y_{low-income}/Y_{delhi}) + 0.62(W/N) + 0.62(I/N) + 0.22(V/N) \text{..... 3-c}$$

Relocated-after metro

$$\mathbf{SEWB = 0.68(NG_{inschl}/\ NG_{schage}) + 0.66(N_{adults>=5}/\ N_{adults}) + 0.60(IRS) + 0.65(Y_{low\text{-}income}/Y_{delhi}) + 0.72(W/N) + 0.67(I/N) + 0.06(V/N)}$$ 3-d

The value of SEWB is calculated for each household and the change in the value after the introduction of the metro is analysed. T-tests (paired two sample for means) are conducted to the index values to see if the change is significant in table 14.

Testing the Hypotheses

The values of the indices are calculated for each household and T-tests (paired two-sample for means) are applied to the index values to see if the change is significant.

Table 14 shows that for the households residing in the vicinity of the metro-line, the accessibility index has changed significantly due to the introduction of the metro but there has been no significant change in the mobility and SEWB indices. However, for the households relocated due to the metro line, there has been significant change in all the indices of accessibility, mobility and SEWB.

Table 14: Significance of change in indices due to introduction of metro

No.	Indices	Significance of change for HH in metro vicinity		Significance of change for HH relocated	
		At 5% l confidence Level	At 1% confidence level	At 5% confidence level	At 1% confidence level
1	Accessibility	Significant	Significant	Significant	Significant
2	Mobility	Not significant	Not significant	Significant	Significant
3	SEWB	Not significant	Not significant	Significant	Significant

Discussion

This step answers the question of how do each of the different indicators contribute respectively to indices of accessibility, mobility and SEWB? The change in the value of the indices assesses the impact of the project on accessibility mobility and SEWB.

It combines the indicators into indices of Accessibility, Mobility and SEWB by assigning them weights using the PCA technique. The weight/coefficient of each indicator, i.e. its contribution to the index, will vary for different datasets.

STEP VIII: Developing the SEIA Model

The focus of this handbook is to understand the correlation between Accessibility, Mobility and SEWB. Correlation between Accessibility, Mobility and SEWB is modeled in two ways

1. The dependence of SEWB on the indices of accessibility and mobility is estimated using the linear correlation method.
2. The dependence of the index of mobility on the indicators of accessibility and the dependence of the index of SEWB on the indicators of accessibility and mobility is estimated using linear regression method.

Linear Correlation

To model the correlation between indices of accessibility, mobility and SEWB, their values calculated using the PCA technique in step 7 are used. This correlation is carried out using both parametric and non-parametric methods and their R^2 values have been compared. The methods used for the linear correlation are as follows:

1. Parametric method using Pearson correlation has been used since the dataset is continuous.
2. Non-parametric method using Spearman's correlation has been used by assuming that the data is normative and rank order is assigned to it.

The R^2 values from both methods for the case study are listed in the Table 15

Table 15: R^2 values of correlation between Indices of Accessibility (A), Mobility (M) and SEWB (S)

Data Set	Correlation A & M		Correlation M & S		Correlation A & S	
	Pearson's	Spearman	Pearson's	Spearman	Pearson's	Spearman
In Vicinity- before metro	-0.001	0.004	0.176	0.180	0.035	0.084
In Vicinity- after metro	0.128	0.108	0.112	0.089	0.277	0.280
In Vicinity- change	-0.157	-0.202	0.014	0.114	-0.170	-0.177
Relocated- before metro	-0.034	0.055	0.169	0.134	0.057	0.140
Relocated- after metro	0.001	-0.049	-0.039	-0.090	-0.065	-0.125
Relocated- change	0.026	-0.027	-0.219	-0.229	0.016	0.045
TOTAL	-0.223	-0.335	0.122	0.115	0.020	0.034

Table 15 shows that:

1. There is no significant difference in the correlation modeled by parametric and non-parametric methods
2. Accessibility and Mobility have no correlation according to individual datasets. However, when the data is combined then accessibility and mobility show a reciprocal correlation increase in accessibility will decrease mobility.
3. Mobility and SEWB have no correlation according to the different datasets except in the case of change in indices due to relocation where mobility and SEWB have a reciprocal correlation increase in mobility will decrease SEWB.
4. Accessibility and SEWB have no correlation except for the households in the vicinity of the metro (after introduction of the metro) where accessibility and SEWB are positively correlated increase in accessibility will increase SEWB.

Linear Regression

In this section the model is developed using the ordinary least square (OLS) regression technique to understand the relationship between indices of accessibility, mobility and SEWB with appropriate indicators of accessibility, mobility and SEWB. The impact of different indicators on indices is modeled for all 4 data sets (all repeated for each set). This has been tried for the following equations:

1. Index of mobility (dependent variable) and indicators of accessibility (AI)
   $$\mathbf{M = a + b(AI_i) + c(AI_j) + \ldots + x(AI_n)} \quad \ldots\ldots\ldots\ldots\ldots(4)$$

2. Index of SEWB (dependent variable) and indicators of mobility (MI)
   $$\mathbf{S = a + b(MI_i) + c(MI_j) + \ldots + x(MI_n)} \quad \ldots\ldots\ldots\ldots\ldots(5)$$

3. Index of SEWB (dependent variable) and indicators of accessibility (AI)
   $$\mathbf{S = a + b(AI_i) + c(AI_j) + \ldots + x(AI_n)} \quad \ldots\ldots\ldots\ldots\ldots(6)$$

4. Index of SEWB (dependent variable) and indicators of both accessibility and mobility
   $S = a + [b(AI_i) + c(AI_j) + \ldots + x(AI_n)] + [b(MI_i) + c(MI_j) + \ldots + x(MI_n)]$.....(7)

Where, M = Index of Mobility
S = Index of SEWB
AI_i ,AI_j , … AI_n = Indicators of Accessibility
MI_i ,MI_j , … MI_n = Indicators of Mobility
a = constant
b, c, … x = coefficients of the indicators

These linear regressions have been run for all 4 data sets (before and after metro in the vicinity of the line and those relocated due to the metro). Table 16 illustrates the values of R^2 and the P value for the F-test to check the significance of the coefficients.

Table 16: Summary of results of linear regression

No.	Model used	Data set	R^2 value	P value for F-test
1	Equation 4	In Vicinity- before metro	0.022	0.49
2		In Vicinity- after metro	0.020	0.55
3		Relocated- before metro	0.025	0.43
4		Relocated- after metro	0.051	0.07
5		TOTAL	0.103	0.00
6	Equation 5	In Vicinity- before metro	0.283	0.00
7		In Vicinity- after metro	0.257	0.00
8		Relocated- before metro	0.200	0.00
9		Relocated- after metro	0.283	0.00
10		TOTAL	0.202	0.00
11	Equation 6	In Vicinity- before metro	0.157	0.00
12		In Vicinity- after metro	0.130	0.00
13		Relocated- before metro	0.011	0.83
14		Relocated- after metro	0.012	0.81
15		TOTAL	0.037	0.00
16	Equation 7	In Vicinity- before metro	0.361	0.00
17		In Vicinity- after metro	0.331	0.00
18		Relocated- before metro	0.231	0.00
19		Relocated- after metro	0.295	0.00
20		TOTAL	0.234	0.00

Note: The results with P value nearing to zero have been highlighted as the coefficients are significant for those and they can be discussed as possible models.

The results shown in the Table 16 can be described as follows:

1. Results of Equation 4 show that there is no significant correlation between the index of mobility and the indicators of accessibility for individual datasets. However, when the data is combined then accessibility and mobility have a significant correlation albeit with a low R^2 value. Four of the five coefficients of the indicators of accessibility have a negative sign, as does the constant, indicating a reciprocal relationship between accessibility and mobility.
2. Results of Equation 5 show that there is a significant correlation between the index of SEWB and the

indicators of mobility, implying that mobility affects SEWB significantly. A in the case of all datasets, majority of the indicators have negative coefficients implying a reciprocal relationship between SEWB and mobility.

3. Results of Equation 6 show that there is a significant correlation between the index of SEWB and the indicators of accessibility for the households residing in the vicinity of the metro line but the correlation is not significant for the households relocated.
4. Results of Equation 7 show that there is a significant correlation between the index of SEWB and the combined indicators of accessibility and mobility, implying that accessibility and mobility affect SEWB significantly.
5. Comparing the R^2 values of all the models, the best results are given by Equation 7, implying that the SEWB is explained best when the affects/contributions of indicators of both accessibility and mobility are considered. However, it is observed that the R^2 values change for the households after the introduction of the metro. For the households located in the vicinity, the affects of accessibility and mobility on SEWB become less significant after the metro and for the households relocated due to the metro line, they become more significant.

For all 4 datasets, the model of Equation 7 was run and the coefficients derived along with t-test results illustrating their significance are compiled in Table 17.

Table 17: Coefficients of indicators of accessibility and mobility and their significance for each dataset

Indicator	Description	In Vicinity-b4 metro		In Vicinity-aft metro		Relocated-b4 metro		Relocated-aft metro	
		Coeff	P (2Tail)	Coeff	P (2Tail)	Coeff	P (2Tail)	Coeff	P (2Tail)
CONST		435.2	0.006	308.1	0.019	318.2	0.013	515.5	0
A1	$SD_{education}$	-81.3	0.041	-43.8	0.123	-2.6	0.812	-10.7	0.736
A2	SD_{health}	-15.7	0.353	-23.0	0.153	-27.3	0.059	-11.0	0.484
A3	$SD_{services}$	-69.9	0	-17.6	0.477	-1.1	0.958	-4.6	0.238
A4	$SD_{bus\text{-}stop}$	65.6	0.118	30.9	0.037	295.9	0.088	5.3	0.704
A5	S_{bus}	-0.1	0.929	1.0	0.099	4.1	0.51	-0.2	0.57
M1	$PCTR_{work}$	102.5	0	89.7	0	126.4	0	105.6	0
M2	$PCTR_{education}$	45.3	0.151	54.0	0.068	53.5	0.344	-1.4	0.966
M3	$PCTR_{others}$	31.9	0.224	45.8	0.054	56.2	0.004	31.0	0.042
M4	M_{NMV}/M_{all}	59.3	0.675	25.0	0.831	-37.9	0.746	-280.3	0
M5	D_{work}	-4.7	0.013	-2.7	0.063	-1.8	0.426	0.3	0.581
M6	$D_{education}$	2.5	0.814	4.0	0.704	-16.2	0.323	4.3	0.567
M7	D_{others}	-1.5	0.721	-2.3	0.62	-3.3	0.454	6.4	0.005
M8	T_{work}	0.0	0.909	0.0	0.88	-0.8	0.038	0.0	0.844
M9	$T_{education}$	-0.6	0.29	-0.6	0.274	0.1	0.912	-0.3	0.479
M10	T_{others}	-0.4	0.371	-0.4	0.443	-0.8	0.28	-0.9	0.038
M11	C_{work}	-0.9	0.558	-2.0	0.135	-1.6	0.364	-3.0	0.012
M12	$C_{education}$	1.1	0.9	1.5	0.861	7.7	0.631	-9.1	0.485
M13	C_{others}	1.2	0.594	2.1	0.619	3.3	0.384	-6.0	0.045

Note : The indicator coefficients with P value significant at 90% confidence levels have been highlighted as the coefficients are significant can be included in the models.

Comparative study of the coefficients shown in Table 17 shows that:

1. Different coefficients contribute to the model significantly for different data sets.
2. The number of significant coefficients increases after the introduction of the metro in the households both living in the vicinity and relocated due to the metro.
3. The PCTR for work is the only indicator that is significantly consistent across the board.
4. The cost of travel has no significance in explaining SEWB before relocation but it becomes significant when they are relocated.
5. A study of the coefficients of the combined dataset to get an overview of whether the coefficients are +ve or ve shows that approximately 90% of the significant indicators and 72%of all indicators are correlated to the SEWB index in accordance with the empirically observed behavior (expected indications specified in chapter 5)

   The final equations derived from the application of Equation 7 using significant indicators from Table 17 are illustrated below:

In Vicinity-before metro

$$\mathbf{S_{Vb4} = 435.2 - 81.3(SD_{education}) - 69.9(SD_{services}) + 102.5(PCTR_{work}) - 4.7(D_{work})} \quad \text{..... (8-a)}$$

$R^2 = 0.32$

In Vicinity-after metro

$$\mathbf{S_{Vaft} = 308.1 + 30.9\,(SD_{bus\text{-}stop}) + 1.0\,(S_{bus}) + 89.7(PCTR_{work}) + 54.0(PCTR_{education}) + 45.8(PCTR_{others}) - 2.7(D_{work})} \quad \text{..... (8-b)}$$

$R^2 = 0.28$

Relocated-before metro

$$\mathbf{S_{Rb4} = 318.2 - 27.3(SD_{health}) - 295.9(SD_{bus\text{-}stop}) + 126.4(PCTR_{work}) + 56.2(PCTR_{others}) - 0.8\,(T_{work})} \quad \text{..... (8-c)}$$

$R^2 = 0.19$

Relocated-after metro

$$\mathbf{S_{Raft} = 515.5 + 105.6\,(PCTR_{work}) + 31.0\,(PCTR_{others}) - 280.3\,(M_{NMV}/M_{all}) + 6.4\,(D_{others}) - 0.9(T_{others}) - 3.0(C_{work}) - 6.0\,(C_{others})} \quad \text{..... (8-d)}$$

$R^2 = 0.27$

The equations 8-a and 8-b illustrate the indicators affecting socio-economic well being of the households living in the vicinity of the metro line, before and after the introduction of the metro. According to these equations, the PCTR to work has the maximum contribution to SEWB of the households both before and after the metro; however, after the metro the PCTR for education and other trips also become contributors to SEWB. The service offered by the bus system becomes a contributor to SEWB after the introduction of the metro. The distance to education, work and other services have a negative affect on SEWB according to equation 8-a. After introduction of the metro, the distance to work continues to have a negative impact on the SEWB while the distance to the bus stop has a positive affect. The equations 8-a and 8-b, studied together, show that:

1. The PCTR for work is consistently the most important positive determinant of SEWB. This implies the trips to work made by a household ensure the SEWB, and the increase in number of employed people commuting to work will improve the SEWB of the household.
2. The distance to work is consistently a negative indicator for households implying that increase in distance to work will negatively affect SEWB.
3. The introduction of the metro changes the indicators which affect SEWB. Also, more numbers of indicators have a significant impact on SEWB after the introduction of the metro. This implies that the introduction of a new transport system restructures the determinants of SEWB, making the households more vulnerable by increasing the number of significant indicators.

4. Since bus routes and services have been affected by the introduction of the metro, they become significant indicators affecting SEWB. This implies that the introduction of a new transport system makes the existing transport system important in determining SEWB.

The equations 8-c and 8-d illustrate the indicators affecting socio-economic well being of the households relocated due to the metro line, before and after the introduction of the metro. According to these equations (following the pattern of 8-a and 8-b) the PCTR to work has the maximum contribution to SEWB of the households both before and after the metro. The PCTR for other trips also remains a determinant of SEWB. The spatial distance to health services and the bus stop and the travel time to work negatively affect the SEWB of households according to equation 8-c. After introduction of the metro, the cost of work trips, and the distance, time and cost of trips for purposes other than work and education have a significant negative impact on SEWB of the households. The ratio of NMV use to all modes used has a significant negative impact on the SEWB of households relocated due to the metro. The equations 8-c and 8-d, studied together, show that:

1. The PCTR for work is consistently the most important positive determinant of SEWB. This implies the trips to work made by a household ensure the SEWB, and the increase in number of employed people commuting to work will improve the SEWB of the household..
2. The introduction of the metro changes the indicators which affect SEWB. Also, more numbers of indicators have a significant impact on SEWB after the introduction of the metro. This implies that the introduction of a new transport system restructures the determinants of SEWB, making the households more vulnerable by increasing the number of significant indicators.
3. The presence of the indicators of distance, time and cost of other trips in equation 8-d implies that travel for purposes other than work and education is affected by the relocation. While the distance for these trips contributes positively to SEWB, the time and cost of these trips contributes negatively to it. Since these trips include trips made for shopping and social reasons, we conclude that there is a time and cost factor which gets built in due to relocation and affects the SEWB of the households negatively.
4. The presence of the indicator of cost of work trips in equation 8-d implies that while the commuting cost had no significant correlation with SEWB before relocation, after relocation it has a significant negative impact on SEWB of the households.
5. The presence of the indicator of the ratio of NMV to all modes used in a household in equation 8-d implies that this has become a significant indicator after relocation. The high negative value of this indicator implies that the reduction in this ratio (implying reduction in use of NMV in the household) has a severe negative impact on the SEWB of the households. Since the process of relocation has increased distances to destinations of choice for the household, beyond comfortable NMV distances, this indicator implies that the modal shift from NMV to motorized modes has had a negative impact on the SEWB of the relocated households.

Discussion

This step answers the questions:

- **What is the correlation between accessibility, mobility and SEWB?**
- **How does accessibility and mobility affect SEWB?**
- **How does the change in accessibility and mobility affect SEWB?**

It models the correlation between accessibility, mobility and SEWB in different ways, concluding that the equation explaining the affect of the indicators of accessibility and mobility on the index of SEWB is the best model of the phenomenon.

Conclusions

The case study used in this handbook to exemplify the SEIA method has illustrated the impact of a large transport project like the Delhi metro on the urban poor, who are not expected beneficiaries of the project. The impact on the urban poor is studied for two settlements of low-income households residing within the vicinity of the metro line and for a resettlement colony where approximately one-third of the households, evicted due to the construction of the metro, have been relocated.

The impact of the metro project on the poor households has been analyzed in the Unit 3 of this handbook in three steps VI, VII and VIII. Step VI estimates the values of the indicators and studies the change in the identified indicators of accessibility, mobility and socio-economic well being (SEWB) to illustrate the impact. The results of the step show that for the poor households in the vicinity of the metro line there is no significant impact on the indicators of SEWB and mobility while for those relocated due to the metro there has been a significant negative impact on the SEWB of the poor households.

Step VII combines the indicators of accessibility, mobility and SEWB respectively into indices and studies the impact of the new project by assessing the change in the value of the indicators. The results of this step show that for the households living in the vicinity of the project, there has been a significant change in accessibility but no change in mobility and SEWB of the household, while for the relocated household, there has been a significant change in all three indices.

The step VIII illustrates how the change in accessibility and mobility has changed the SEWB by modeling the correlation of SEWB to accessibility and mobility. The results indicate that SEWB is affected by indicators of both accessibility and mobility. SEWB is negatively correlated to the spatial distance to education health and other urban services. The model indicates that SEWB is positively correlated to PCTR for work, education and other purposes and it is negatively correlated to travel distance, time and cost. The significance of indicators changes with change in situation like introduction of the new metro line and relocation due to it. The study shows that the PCTR for work is positively correlated with SEWB and has the highest coefficient in all datasets, indicating the mobility for work is important in ensuring their SEWB, whatever is their situation. Also, the cost of travel has no significance in explaining SEWB of the urban poor but it becomes significant when they are relocated and now have to pay heavily for the travel.

The results of the different steps in this method may differ with different data-sets with differences in projects and different target groups. However, this method can be used to study impact of transport projects on the urban poor regardless of the changed input of data. The handbook has modeled how SEWB is affected by accessibility and mobility and, in doing so, has formulated a generic methodology of SEIA which is applicable in understanding the impact of large urban transport projects like expressways, flyovers etc on the urban poor. This model can be used by urban transport practioners to generate scenarios to assess how the proposed interventions in the urban transport system will impact the urban poor. Different intervention scenarios can be compared for their impacts and mitigation measures planned accordingly. This would lead to internalizing the external cost of the impact of transport projects on the urban poor.

Generically, the case-study illustrates that though the urban poor are not expected users of the metro, their accessibility and mobility and hence their socio-economic well-being is affected by its introduction in the urban transport system as an unaccounted for externality. While they may not be expected beneficiaries of the project, the dis-benefits accrued to them due to the project need to be assessed. The project then needs to be optimized over a larger target group. The impact on SEWB of the urban poor measured by this method can be integrated either by being internalized by the project by building in compensation measures or optimized by building in mitigation measures Hence, it is important to conduct SEIA studies for a new project over disaggregated groups, specifically including impacts on the most vulnerable group - the urban poor.

Common Problems and Errors in SEIA Studies

The SEIA methodology described in this unit has the potential of different types of errors and biases at every step. Some of these are discussed below:

STEP I : Problem Formulation

The formulation of the problem including stating the objectives and hypothesis and delineating the theoretical framework need to be specific and coherent. Any ambiguity at this stage will lead to confusions while data collection - which will be either too much or too less - leading to either wasted resources or insufficient data for analysis. Also, this step is iteratively modified till step 4, since the description of project, identification of target groups and resource allocation for data collection may modify the objectives.

STEP II : Project description

The design of the project needs to be understood in depth and all possible documents and sources of information need to be reviewed at this stage. Insufficient work at this step would lead to:

- Lack of clarity of the base line
- Duplication of efforts as others may have the data already
- Errors in identifying the influence area and the target groups

STEP III : Identifying the target group

Identification of the target group is important to collect data which fulfills the identified objectives. Incorrect identification of the target group will lead to:

- Gap between data collected and objectives
- Data analysis not giving conclusive results
- Skewed assessment of the impacts

STEP IV : Data collection

This step is the most crucial and most prone to errors. Since this step has several components, errors at any level will lead to additive errors and skewed results.

- The selection of sample size needs to balance the resource constraints of data collection with statistical necessity of a sufficient sample size. It needs to be adequately representative of the population otherwise the results will not have enough statistical significance to run the model.
- The locations identified should be in the influence area while also being amenable to survey. Sometimes the ideal locations for study may have no contact NGO group or have communities hostile to survey. A non-cooperative respondent set will lead to indifferent results.
- The preparation of the questionnaire requires several revisions before it is taken on ground. The common problems in the preparation of a questionnaire are:
    - o Language of the questionnaire not descriptive enough hence open to interpretation.
    - o Questionnaire too long hence the respondents lose interest.
    - o The sequencing of the questions not being logical, requiring the interviewers to repeat questions which were answered earlier during the interview.
    - o The questions guide the answers, whether by the phrasing or by giving only specific

answer options.
- o Questions offensive to the respondents, for example, questions on religion, caste or income.
- o The translated version (into local language) does not say the same thing as the original version.

Most of these errors can be avoided by:
- o Discussing the phrasing of the questions to see if they are concise without being ambiguous and specific without guiding answers.
- o Having an initial focus group discussions with community to understand that none of the questions be offensive.
- o Meetings with interviewers to discuss intent of survey.
- o Pilot survey in community to check for errors and time taken

STEP V : Profiling the target group

The profile of the target group is generated by the primary data analysis. The common errors at this level are:

- Standard errors in data entry not verified and cross checked for.
- Standard spreadsheet errors of copy-paste of formulas etc. not checked for.
- Incorrect identification of categories for analysis leading to meaningless analysis.
- Discarding results which are counter intuitive / not questioning them.

STEP VI : Estimating the indicators of accessibility, mobility and SEWB

The indicators developed in this handbook are indicative only. Based on the different communities, projects, and focus of the impact assessment study indicators can be added on or discarded by the assessment team.

STEP VII : Combining the indicators into indices

Significance of different indicators for the indices may vary for different communities, projects, and objectives of the impact assessment study.

STEP VIII : Developing the SEIA Model

The model developed in this handbook uses a specific case-study for demonstration. Different data-sets will change the significance of different indicators leading to different equations. However, the final equation will be a statistical representation of how change in accessibility and mobility affect the socio-economic well being of the community.

Annexure : Questionnaires

- Metro Users' Survey
- Bus Users' Survey
- Households in Vicinity of the Metro Line
- Households Relocated due to the Metro

Delhi Metro rail - users' survey

Name of Station **Surveyor** **Date**

Gender M/F

Age yrs

Where do you live?

Do you own a vehicle? **Y/ N** **If yes, which one?**

Where are you coming from?

Where are you going?

What is the purpose of this trip you are about to make?

Details of a typical weekday trip

Trip Segment	Origin (colony name)	Destination (colony name)	Purpose	Mode	Distance Km	Time Min	Cost Rs
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Since when have you been using the metro? _____

What mode did you use before the metro came? _____

Why did you start using the metro? _____

When using the metro do you buy anything from

1 The hawkers outside Y/N
2 Kiosks inside and outside station Y/N
3 Shops on station premises Y/N

Have you ever been in a road accident in your life? Y/N

If yes Place
Your mode during accident
Fall of hit by which type of vehicle

Delhi Metro rail - Bus users' survey

Name of Station **Surveyor** **Date**

Gender M/F

Age yrs

Where do you live?

Do you own a vehicle? **Y/ N** **If yes, which one?**

Where are you coming from?

Where are you going?

What is the purpose of this trip you are about to make?

Details of a typical weekday trip

Trip Segment	Origin (colony name)	Destination (colony name)	Purpose	Mode	Distance Km	Time Min	Cost Rs
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Have you ever been on the metrorail? **Y / N**
If yes, for what purpose?

Why are you not using the metro instead of the bus? (tick as many as appropriate)
1. Fare of metro more than bus for my trip
2. Would have to take bus/rickshaw anyway to reach the final destination after metro station
3. Too much walking to reach the metro station
4. Station environment uncomfortable (specify)
5. Other (elaborate)

How has the coming of the metro affected your daily travel pattern or other aspects of using the road?

When using the bus-stop do you buy anything from

1	The hawkers outside aroud the bus-stop	Y/N
2	Kiosks inside and outside metro station	Y/N
3	Shops on metro station premises	Y/N

Have you ever been in a road accident in your life? Y/N

If yes Place
Your mode during accident
Fall of hit by which type of vehicle

Household survey for Basti in vicinity of Metro line

Name of Settlement **Surveyor** **Date** **Time**

HOUSEHOLD LEVEL SURVEY

1 Name of interviewee _____

2 Address _____

3 No. of people in household _____

4 Where are you originally from _____

5 When did you come to Delhi _____

6 Why _____

_____

7 When did you come to this Basti _____

8 Why _____

_____

9 Did you live somewhere else in Delhi before coming here

10 If yes, Where _____

11 For how long _____

	Before Metro	After Metro
12 Household Income		
13 Vehicle/s owned		

14	**Status of Facilities before Metro**	**Available (Y/N)**	**Operational (Y/N)**	**Type (describe)**
	Electricity			
	Water			
	Toilet			
	Sewerage			

15	**Status of Facilities after Metro**	**Available (Y/N)**	**Operational (Y/N)**	**Type (describe)**
	Electricity			
	Water			
	Toilet			
	Sewerage			

16	Transport services	Before Metro	After Metro	Remarks
	Bus Routes operating			
	Frequency of buses			
	RTVs			
	Frequency of RTVs			
	Rickshaws			
	other (specify)			

	17 Distance to Amenities	Before Metro	After Metro	Remarks
a)	Bus-stop			
b)	Primary School			
c)	Secendory School			
d)	Dispensary/ Doctor			
e)	Chemist			
f)	Vegetable Market			
g)	Daily Needs Shop			
h)	Shopping Center			

INDIVIDUAL LEVEL SURVEY

pers No	Relation to HOH	Gender	Age	Education	Occupation	Income	Vehicle owned
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

WORK PROFILES

pers No	Type of work	Working since?	This work since?	What work did you do before this?	Type of employment (formal/informal)	Wage paid (daily/ weekly/monthly)
1						
2						
3						
4						

IMPACT OF METRO

Has anybody in the household travelled by the metro rail

If yes, give details

pers No	Origin	Destination	Purpose	Distance	Time	Cost	problems faced

What has been the impact of the metro (to be answered by 1 male and 1 female of HH, preferably working)

pers No		during construction phase	after operationalization
	a) on your daily work trip		
	b) on other trips		
	c) availability of amenities like shops		
	d) other impacts (specify)		

pers No		during construction phase	after operationalization
	a) on your daily work trip		
	b) on other trips		
	c) availability of amenities like shops		
	d) other impacts (specify)		

TRIP LEVEL SURVEY

(to be answered for all persons listed in individual survey) Person No.

[Before metro]

Trip Number	Origin	Destination	Purpose	Mode	Distance	Time	Cost	problems faced
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

[After metro]

Trip Number	Origin	Destination	Purpose	Mode	Distance	Time	Cost	problems faced
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Household survey for Relocated Settlement

Name of Settlement **Surveyor** **Date** **Time**

HOUSEHOLD LEVEL SURVEY

1 Name of interviewee _____

2 Address _____

3 No. of people in household _____

4 Where are you originally from _____

5 When did you come to Delhi _____

6 Why _____

_____

7 When did you come to this Basti _____

8 Why _____

_____

9 Where have you been relocated from _____

10 Why _____

_____

	Before relocation	After Relocation
11 Household Income	_____	_____
12 Vehicle/s owned	_____	_____

13

Status of Facilities Before Relocation	Available (Y/N)	Operational (Y/N)	Type (describe)
Electricity			
Water			
Toilet			
Sewerage			

14

Status of Facilities After Relocation	Available (Y/N)	Operational (Y/N)	Type (describe)
Electricity			
Water			
Toilet			
Sewerage			

15	Transport services	Before Relocation	After Relocation	Remarks
	Bus Routes operating			
	Frequency of buses			
	RTVs			
	Frequency of RTVs			
	Rickshaws			
	other (specify)			

16	Distance to Amenities	Before Relocation	After Relocation	Remarks
a)	Main Road (>3o m ROW)			
b)	Bus-stop			
c)	Primary School			
d)	Secendory School			
e)	Dispensary/ Doctor			
f)	Chemist			
g)	Vegetable Market			
h)	Daily Needs Shop			
i)	Shopping Center			
j)	Post-office			
k)	ISBT			
l)	Rly Station			

INDIVIDUAL LEVEL SURVEY

pers No	Relation to HOH	Gender	Age	Education	Occupation	Income	Vehicle owned
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

WORK PROFILES

pers No	Type of work before relocation	Location of workplace	Working since?	This work since?	What work did you do before this?	Type of employment (formal/informal)	Wage paid (daily/ weekly/monthly)
1							
2							
3							
4							

per No	Type of work after relocation	Location of workplace	This work since?	Type of employment (formal/informal)	Wage paid (daily/ weekly/monthly)	Impact of relocation on work (remarks)
1						
2						
3						
4						

IMPACT OF METRO

Has anybody in the household travelled by the metro rail _____

If yes, give details

per No	Origin	Destination	Purpose	Distance	Time	Cost	problems faced

What has been the impact of the metro (to be answered by 1 male and 1 female of HH, preferably working)

		Person No. _____	Person No. _____
a)	on your daily work trip		
b)	on other trips		
c)	availability of amenities like shops		
d)	other impacts (specify)		

TRIP LEVEL SURVEY

(to be answered for all persons listed in individual survey) Person No. _____

[Before relocation]

Trip Number	Origin	Destination	Purpose	Mode	Distance	Time	Cost	problems faced
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

[After relocation]

Trip Number	Origin	Destination	Purpose	Mode	Distance	Time	Cost	problems faced
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

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