Successfulness of Bus Rapid Transit systems in Asia

Ex-post evaluation

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Preface

This thesis is the outcome of the research, which I conducted in the context of a final master's research project for the Centre of Energy and Environmental studies (IVEM), University of Groningen. This research has been conducted during my internship at the Energy Research Centre of the Netherlands (ECN), Policy Studies department, International Energy and Climate Issues Group.

I would like to thank all people who were involved in this project, who have enabled me to perform my research at ECN and have assisted me during this process. This research was a part of the project 'Comparative international review of third country measures to reduce the climate impact of transport' which ECN was performing for DG-environment of the European Commission, led by the Transport Research Laboratory in collaboration with four other research institutions from Europe, Latin America and Asia.

At first, I would like to thank my supervisor at ECN, Stefan Bakker, for allowing me to join the project, his supervision and deep dedication to this work. His support with valuable comments, feedbacks and suggestions have guided me though my research from the early beginning until the end. Particularly I am thankful for the brainstorm sessions we frequently had, which gave me new ideas and showed the actual challenge of this research subject.

Furthermore, I would like to express my gratitude to my first supervisor, Henk Moll, particularly emphasizing his scientific contribution to this research. Hi always supported me with valuable advices, which was a crucial part of this research from the proposal development till the end of report writing.

I would also like to thank Sandra Bellekom for being the second supervisor of this research and her valuable comments.

Also, I am very thankful to Heleen de Coninck, who is the leader of the International Energy and Climate Issues Group, for her valuable advice at the critical moment of my research, when the decision upon the main research line had to be made. I also thank her for giving me a possibility of being a part of the International Energy and Climate Issues Group during my internship at ECN.

I would like to thank Ko Sakamoto as well, who is the Senior Consultant at Transport Research Laboratory (TRL), for sharing his knowledge and experience in transportation field with me.

Besides, I would also like to thank Indira Darmonoyon from the Institute for Transport and Development Policy for her remarks and advices, particularly on Jakarta BRT case study.

At last, I would like to thank all interesting people who I came across during my internship at ECN, who had inspired me with new ideas.

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Contents

Summary

Bus Rapid Transit (BRT) can be defined as “a bus-based mass transit system that delivers fast, comfortable, and cost-effective urban mobility”. It offers the opportunity to create a high-quality mass transit system at affordable costs, which is particularly important for developing countries, since the majority of the population in those countries is highly reliant on public transport. Nevertheless, the service of public transportation in those countries in general can be characterised as deteriorating, slow, unsafe and uncomfortable. There are many BRT systems implemented in various cities in the developing world. However, no scientific evaluation of these systems on their successfulness was performed so far.

The main goal of this research was to gain insight in BRT system functioning in large Asian cities and identify how knowledge from these system operation can be applied on future BRT system planning/implementation processes with the intension to make BRT systems more successful. In order to perform an evaluation of the selected BRT systems on their successfulness, a new evaluation methodology was developed in this research, since no methodology applicable for such an evaluation existed. According to the developed methodology, a BRT system was considered successful when it showed a high contribution to the sustainable development of the selected city. This contribution was evaluated using nine indicators on three sustainability dimensions: environment, society and economics.

This research consisted of four main blocks, respectively, ‘definition’, ‘description of the case studies’, ‘evaluation of each case study’ and ‘result analysis’. In the first block, behavioural theories for analysis of transport behaviour of people were studied. Next, a theoretical framework was selected and the new methodology for BRT system evaluation was developed. In the following blocks, based on the literature study, the selected BRT case studies were described and later evaluated by applying the new developed methodology. During the evaluation, the main factors which impeded/facilitated the success of each BRT system were determined. In the last block, results obtained within each case study were analysed. Each BRT case study in this research was conducted separately.

The general findings of this research are the following. Integration of BRT systems in Jakarta, Delhi and Beijing was an important step towards more sustainable transport in those cities. In general, the new BRT systems improved the functioning of the transport system, ensuring a faster transfer of a majority of inhabitants and reducing the environmental impacts of the transport sector. Based on the results from BRT system evaluation, two out of three systems, i.e. TransJakarta and Beijing BRT were defined as successful. All three evaluated BRT systems improved traffic speed for bus transit, reduced travel time for bus commuters and increased road safety on BRT corridors. However, all these systems have a common problem, respectively, the lack of system capacity. A major barrier of this research was data availability on the selected BRT systems, leading to low certainty of the evaluation results. The main success factors of BRT systems were also determined, respectively, BRT support from government and international organisations, scrutinised planning stage of a new BRT system and the implementation of BRT systems together with other policies. Last, but not least, the new developed methodology was valid to measure the success of BRT systems in Asia. It was applicable for the evaluation of the selected BRT cases and can be also applied in the future for the evaluation of other BRT systems.

1. Introduction

In order to keep climate change at stabilised level (below 2°C), IPCC (2007) states that by the year 2050, developing countries will have to reduce their greenhouse gas (GHG) emissions up to 50% while the reduction of over 80% will be required in developed countries. These goals represent a particular challenge for transport sector which is one of the largest sectors responsible for GHG emissions. Currently it accounts for 13 percent of globally emitted GHG, which can be translated into 18 percent of global CO_2 emissions (IPCC, 2007; IEA, 2006). Besides significant contribution to climate change, the transport sector, especially in developing countries, usually causes local and national problems such as congestion, atmospheric pollution, endangered safety of inhabitants, and others, in this way affecting the overall quality of life, health and sustainable development of the country and its society.

Transport sector in developing countries, particular in Asian countries, such as India, China and Indonesia, can be characterised with rapid motorisation, constantly increasing private car ownership and deteriorating public transit systems (Ernst, 2009; Soehodo, 2010). However, the major part of population of these countries, especially its poor part, still travel by the use of public transport, NMT (non-motorised transport, i.e. cycling and walking) and motorcycles (IEA, 2009). This indicates that in these countries more attention has to be put on the improvement of public transport sector and infrastructure for NMT transport, rather than on construction of new roads and flyovers to accommodate the increasing amount of cars (Bhatia & Jain, 2009). One of the options for the improvement of public transport system functioning and the quality of this service is so-called Bus Rapid Transit (BRT), which is usually integrated into transportation system of the city together with several support measures, such as new (renovated) infrastructure for NMT transport (IEA, 2009; Wright & Fulton, 2005).

BRT offers the opportunity for developing cities to create a high-quality mass transit system at affordable costs (Wright, 2005). BRT can be defined as “a bus-based mass transit system that delivers fast, comfortable, and cost-effective urban mobility” (Wright, 2005). At present, according to VTPI (2010), BRT systems are also considered as a more affordable alternative to a rail-based system, such as metro or light rail. In the core of BRT operation are the segregated bus lanes that set a priority for a rapid movement of buses. BRT can be seen as a system that incorporates the infrastructure (bus lanes, station, terminals, and buses) with its organised operation in order to provide a higher quality service than traditional bus system and attract travellers who would otherwise drive personal cars on congested urban roads (Caldes et al., 2007). Consequently, the reduction of the amount of cars on the roads would result in general decrease of congestion level in the city centre together with the decrease of GHG gases and local pollutants.

Despite the growing popularity of BRT systems in developing countries, there is a relative lack of detailed research on the successfulness of these systems that would reveal at which circumstances BRT systems show high performance and at which circumstances these systems has to be improved/changed in order to ensure their better functioning. BRT systems, which is one particular type of transport policy, can be potentially evaluated on their successfulness by using so-called ex-post evaluation method. The main objective of ex-post evaluation is learning. Lessons from the past considering implementation of such a system could potentially improve the quality of future decision making process, effecting the evaluation and planning of current/future BRT projects (Berveling et al., 2009). Besides this, ex-post evaluation of BRT systems on their successfulness, particularly in largest cities of Asia, could also fill a significant gap as in science.

2. Research methodology

The overall aim of this research is to:

> *Gain insight in BRT system functioning in large Asian cities and identify how the knowledge from these system operation can be applied on the current/future BRT system planning/implementation process with an intension to make these BRT systems more successful from environmental, social and economic perspectives.*

The main research question to be answered in this research is:

> *Under which conditions BRT systems could be successfully applied in large Asian cities in the 21th century?*

The term 'success' can be defined as an achievement of something desired planned or attempted (The FD, 2010). However, it is rather difficult to measure a success in the objective science as there is no uniform and commonly accepted method existing for the evaluation of success. In this research, therefore, it is important to define first what is a successful transport policy, particularly a successful BRT system, which was chosen for the evaluation from a variety of existing transport polices.

In this research, a BRT system will be considered successful, when it shows a high contribution to the sustainable development of a selected city. This contribution will be evaluated on three main sustainability dimensions, respectively, environment, society and economics. The application of these sustainability dimensions for a policy evaluation is reported in Campos et al., (2009); Joumard, R. & Nicolas, (2010); Vickerman, (2000); Neij & Astrand, (2006). These sustainability dimensions are also known as a 'triple bottom line'[1] (Wayne & MacDonald, 2003; UNEP, 2009). More specific definition and guidelines on how and when the BRT system will be evaluated as 'successful' is given in Paragraph 4.2.
There were three BRT systems selected for the evaluation in this research, respectively, TransJakarta BRT, Delhi BRT and Beijing BRT. The reasons for a selection of particularly these systems are discussed in Chapter 5.

Policy evaluation is an important step for an enhanced understanding of policy performance. Identification, understanding and learning of changes and effects made by certain policy implementation are essential for an improvement of future policy making process (Neij & Astrand, 2006). Evaluation of implemented policy with the main objective of learning can be performed by using *ex post* evaluation. This method mainly involves the evaluation of policy outcomes after the policy implementation, assessing to which extent policy objectives were reached (Berveling et al., 2009)[2].

This research will be focused on *ex post* evaluation of several BRT systems on its successfulness, and it is going to be performed according to the methodology as shown in Figure 2.1.

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1 "The triple bottom line, also known as 'people, planet, profit' or 'the three pillars' is an attempt to describe the social and environmental impact of an activity, in a measurable way, to its economic performance in order to show improvement or to make evaluation more in-depth" (Wayne & MacDonald, 2003; UNEP, 2009).

2 The other possible policy evaluation method is so-called *ex ante*. *Ex ante* evaluation is usually applied in policy design and implementation stage. This evaluation is aiming at improving the quality of the policy and to foresee (in terms of several scenarios) the outcomes from the policy implementation (Crabbé & Leroy, 2008).

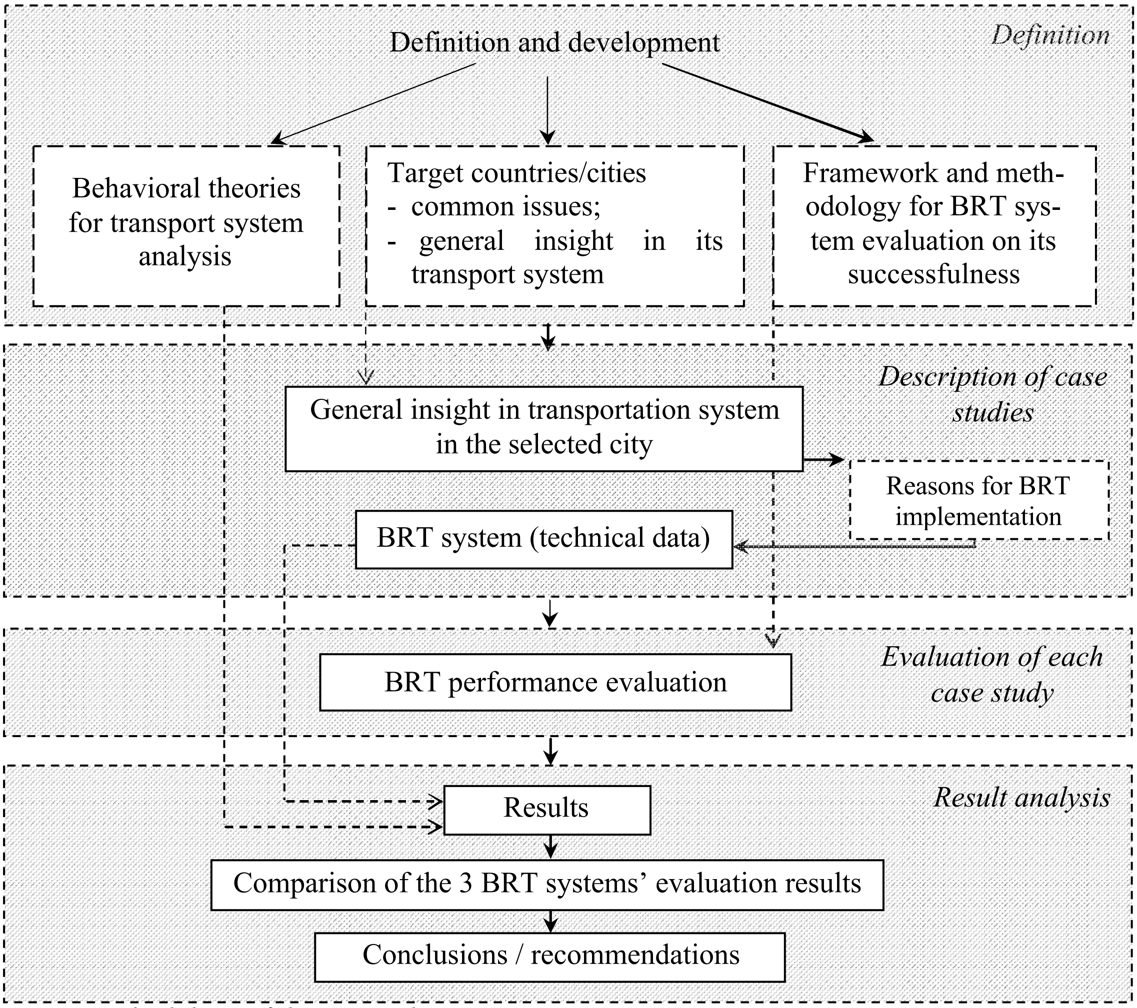

Figure 2.1 *Methodology of the research*

Figure 2.1 shows that the current research consists of four main blocks, respectively, *'definition'*, '*description of the case studies*', '*evaluation of each case study*' and '*result analysis*'.

Before a short description of each block, it has to be mentioned that the evaluation of each BRT system selected within this research is going to be performed by a separated case study (see more discussion in Section 4.1). Therefore two out of four blocks contain an expression 'case study'.

The '*definition*' block of the research is going to be used as a base for the performance and evaluation of BRT case studies. In this block, three main elements are going to be defined: 'behavioural theories', 'framework and methodology for BRT system evaluation' and 'target countries for BRT evaluation'.

First, behavioural theories for transport system analysis are going to be described and analysed (see Chapter 2). These theories will give an explanation why people travel and why a particular way/mode of transportation is chosen in particular circumstances. These theories are going to be applied in 'result analysis' block for the explanation of BRT system evaluation results.

Second, a theoretical framework for transport policy evaluation needs to be defined. The evaluation of each BRT case study is going to be performed within this defined framework (Section 4.1 and 4.3). Next to this, for the evaluation of transport policy on its successfulness, a new evaluation methodology needs to be developed, since no methodology applicable for this study exists. In Section 4.2, a uniform methodology for transport policy evaluation on policy successfulness is going to be developed and this methodology will be identically applied particularly for BRT policy evaluation.

Third, the selection of BRT case studies will be described. In this step, the main characteristics (common/different issues) of the target countries will be discussed, as well as the main insight in general transport system characteristics of these countries will be provided (Chapter 5).This will be used as a contextual information for the BRT case studies. Based on this information, it will be decided to what extent the evaluation results of each BRT case study can be compared with each other.

In the '*case study description'* and '*case study evaluation'* blocks, the selected BRT case studies will be conducted (Chapter 6,7 and 8). Each case study will be conducted separately from each other (see Paragraph 4.1.1 for explanation). The main steps, which will be undertaken within these blocks, are described in details in Section 4.3.

In the last '*result analysis*' block, the results of each BRT case study evaluation will be analysed and compared[3], taking into consideration the main characteristics of each transportation system evaluated. The conclusions and recommendations for the further research will be given.

This research (master thesis) is performed at ECN, Policy Study department in Amsterdam under the supervision of Stefan Bakker. The research is a part of the project 'Comparative international review of third country measures to reduce the climate impact of transport' which ECN is performing for DG-environment of the European Commission, led by the Transport Research Laboratory in collaboration with four other research institutions from Europe, Latin America and Asia.

Boundary setting
This research is performed based on a broad literature study. Information in scientific publications is given a highest priority. No site-visits or stakeholder's interviews are planned to be performed due to time and financial constraints.

This research is focused on the evaluation of bus rapid transit systems, which is one type of transport policies. This means that no other transport policies are evaluated in this.

The results of the evaluation represent a general 'picture' of the BRT systems performance from the moment of system's opening until present. No predictions or scenarios for these BRT systems' performances in the future are conducted in this research.

3 To what extent these results can be compared with each other will be defined in the third step of the '*definition block*'.

3. Behavioural theories

3.1 Transport system analysis. Transportation and social organisation

The design of a built environment and the organisation of a social system can be outlined by its three fundamental structures, which are often viewed as interrelated systems. These systems are: a production system, a societal system and an infrastructure service system (Figure 3.1), (Michaels, 1981).

A production system, according to Michaels (1981), is viewed as a set of functional units, producing socially useful and desirable goods from raw materials through the use of machines and people (e.g. factories).

A societal system consists of institutions that provide goods and services to customers (e.g. supermarkets, hospitals, schools).

The third, *the infrastructure service system,* can be viewed as a linkage between production and societal systems, providing the basic resources that both systems need to function. These sources can be, for example, energy, water, raw materials, etcetera. However, the central element of this system is transportation itself, involving the transportation of basic resources and the transportation of people.

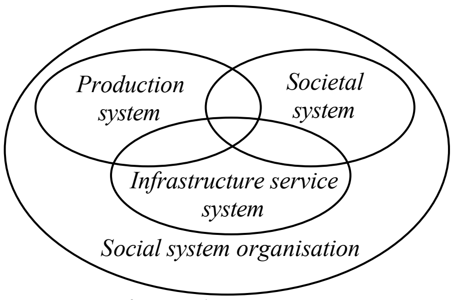

Figure 3.1 *Fundamental structure of social system organisation (adapted from Michaels, 1981)*

The integration between these three systems (Figure 3.1) determine the general wealth, the quality of life of society and the design of its built environment. Industrial cities, for example, were mainly developed around the production system. The primary focus of these cities has been on providing technologies, labour and infrastructure to satisfy the requirement of the production system (Michaels, 1981). For this reason, the infrastructure service system in these cities, in which transportation played a major role, was developed and organised by the production system's requirements. For public transportation, mass transfer systems (e.g. metro, bus and tram systems) were designed and heavy infrastructure systems for raw material transportation were developed (railways, highways, etc.). The way in which these cities were developed and organised has determined the demand and importance of the transportation sector.

The understanding the driving forces behind city/country development can be applied for the analysis of the transport system design in a particular city/country. In this research, the description and analysis of the transportation system of a particular country is conducted under the 'description block' (see Figure 2.1).

Personal transportation within the societal system organisation is considered as a part of the infrastructure service system (mentioned above). According to Michaels (1981), the term 'travel' can be defined as follows: "mediating activity between the needs of the individuals and the sources of their satisfaction, which are distributed in the space". This definition clarifies that travel and personal transportation are the linkages between people's needs and satisfiers of these needs, which can be found in the societal system. A need, for instance, can be to remedy a tooth ache; a satisfier in this case would be a tooth cure by a doctor (in the hospital). In order to satisfy this need, a person has to travel from one destination to another.

In order to understand transportation demand, i.e. why people travel and choose a particular transportation mode, destination and time, it is important to analyse people's behaviour and their motivation and decision-making process with regard to transportation issues. A general model that can be deployed for understanding what drives people's motivation and behaviour, the so-called 'needs-opportunities-abilities (NOA) model', is discussed in the following section.

3.2 Behaviour theories: The Needs-Opportunities-Abilities (NOA) model of people behaviour analysis

The NOA model was developed at the end of the 1990's as a conceptual framework for describing and understanding the motivations behind customer consumption patterns and customer behaviour (OECD, 2002; Schenk et al., 2007). In the NOA model, according to OECD (2002), "consumer motivation to act in a specific way results from certain consumer needs and opportunities and abilities to fulfil those needs." According to this model, people buy goods and travel for satisfaction of their needs and not for the process itself. The schematic overview of NOA model is represented in Figure 3.2.

Needs of people in NOA model are often referred to "a set of objectives that an individual wants/pursues to achieve in order to maintain and improve his/her quality of life and well-being" (OECD, 2002; Schenk et al., 2007). This set of objectives can be education, work, money, social status, etcetera (see Figure 3.2). However, all needs, which are indicated in the 'need box' in Figure 3.2, are primary created as a combination of a person's physiological, safety, belongingness, esteem and self-actualisation needs, as described by Maslow (1943). Understanding these primary human needs is a basic step for the analysis of people behaviour (see Section 3.3).

Opportunities are often described as a set of conditions that can influence people's decisions on how, where and when they are going to satisfy their needs. In general, the opportunities can be, for instance, the availability of goods and services, their accessibility and diversity (e.g. different transportation modes), prices, relevant available information, etcetera.

Abilities, on the other hand, are the limitation factors in people's needs satisfaction. These limitations include financial (income level), spatial (distance to travel from one destination to another), temporal (free time availability, e.g. to go on holiday), cognitive and physical skills (culture, education, favourite destinations, health, permits, etc.).

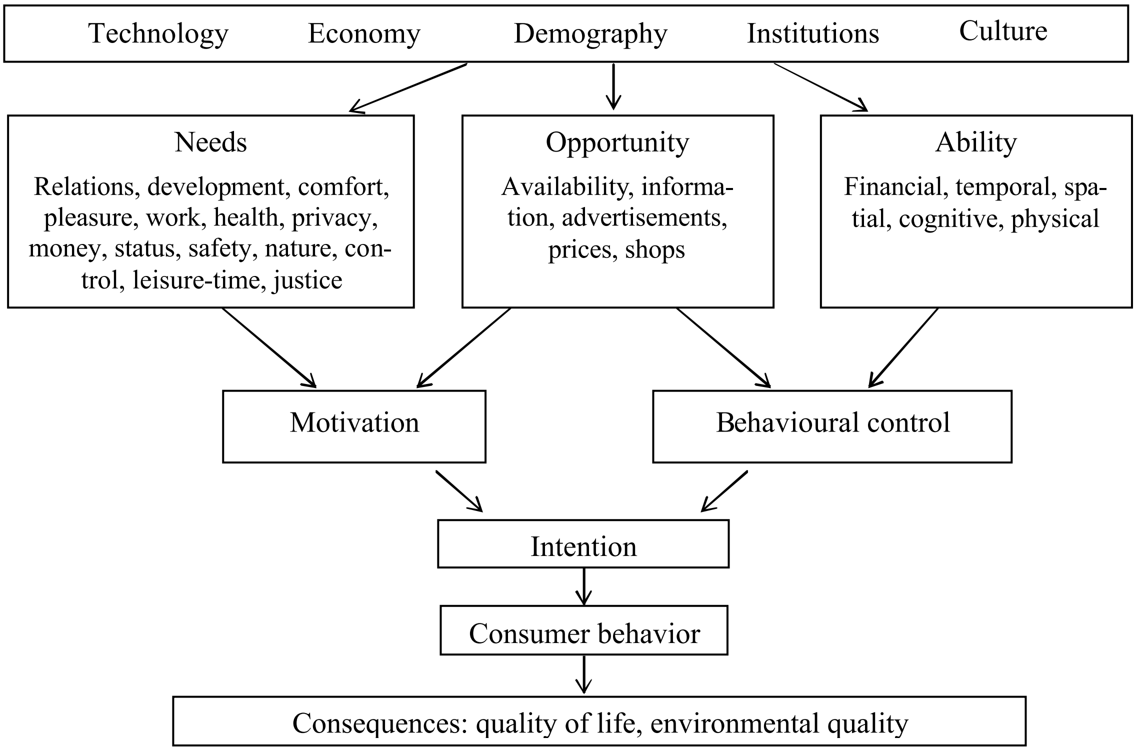

Figure 3.2 *Need-opportunity-ability (NOA) model of consumer behaviour*
Source: OECD, 2002; Schenk et al., 2007

The schematic representation of the NOA model in Figure 3.2 shows that on the one hand, needs and opportunities together comprise the *motivatio*n of people 'to do things'. For example, hunger, which creates a person's need for food, and availability of a supermarket in the neighbourhood both create a person's motivation to go to that particular supermarket and buy food. On the other hand, a person's financial situation and the location of the supermarket can significantly influence a person's decision to choose for this location or an alternative location to buy food. In the NOA model, this influence is defined as the *behaviour control*, which comprises both opportunities and abilities (see Figure 3.2). From this analysis it can be concluded that, in principle, consumer behaviour (how, where and when they buy food) is guided by personal needs and behaviour control to satisfy these needs. However, Figure 3.2 also shows that, in addition to the needs-opportunities-abilities model, there are five external factors that can also influence consumer behaviour, which, according to OECD, (2002), Schenk et al., (2007) and EEA, (2008), are:
- *Economic*: e.g. level of income, taxes, GDP, prices for goods and services, subsidies, etc.
- *Socio-demographic/spatial*: e.g. household size, age distribution, ethnicity, migration, population density, land use, etc.
- *Institutional*: refers to permissions, governmental regime, etc.
- *Cultural*: e.g. attitudes, lifestyle and values, etc.
- *Technological*: e.g. development in information technologies, etc.

The interaction of these factors and their influence on customer needs, opportunities and abilities is important when analysing people's transportation behaviour.

3.3 Maslow's hierarchy of human needs

In the previous section, the needs of customers were briefly introduced. It is rather important though to get a deeper insight in basic human needs to understand what motivates people to act in a certain way. Based on this knowledge, the analysis of a person's behaviour (involving transportation issues), can be performed.

The hierarchy of needs, developed by the American psychologist Abraham Maslow in 1943, is considered as a fundamental theory for understanding the basic human needs that motivate a person for a particular action and for personality development (Maslow, 1943). The hierarchy of needs is usually presented as a pyramid, depicting the levels (in total five basic levels) of human psychological and physical needs. The theory behind this hierarchy is that a person does not feel a second (higher) need until the first, most basic need is satisfied (Maslow, 1943). The same way, the third level of needs emerges only when the needs of the second level are satisfied and so on.

According to Maslow (1943), the five basic levels of human needs are as follows:
- *Physiological needs*. These are the most basics needs for survival, such as the need for water and food, located at the lowest (basic) level of the hierarchy. The physiological needs are ones that have to be satisfied first. All other needs become less important until the physiological level of needs is satisfied.
- *Security needs* are placed on the second hierarchical level. Security needs are also important for survival. However, these needs are not emerging before physiological needs. Examples of security needs can be a need for a good house, health insurance, steady employment, a safe neighbourhood, etc.
- *Social needs*. This level includes needs for belonging, love and affection, involving both giving and receiving these needs. Relationships such as family, friends and romantic attachment are usually fulfilling social needs.
- *Esteem (Ego) needs*. After satisfaction of the first three levels of needs, esteem becomes important. This level includes a need for things that reflect on esteem (personal and received from others), personal worth, social recognition, etc. When these needs are satisfied, a person becomes self-confident as opposed to frustrated, weak and helpless.
- *Self- actualisation needs*. This is the last level of needs hierarchy. Self-actualisation is a need of a person to be 'what he can be'. For a musician it is making music; for an artist it is painting. These needs can drive a person to "become everything that one is capable of becoming" and fulfil their potential. One individual can experience self-actualisation as a need to become an ideal mother; others may want to express themselves in painting, inventions, etc.

From the description of the five basic levels of human needs it can be seen that transportation as such is not included in these needs. This can be seen as the main conclusion of this section. According to the NOA model (see Section 3.2), people travel to satisfy their needs (e.g. going to shops for buying food and clothes, going to work and schools) and not for the travelling process itself. However, it is important to realise that the places people travel/go to and the things people do are unconsciously guided by basic human needs, as described by Maslow. For example, people travelling to work, applying Maslow's hierarchy of needs, can be explained as satisfaction of their basic security and social levels of needs. In other words, people's need to go to work emerges from the necessity of e.g.: (1) having financial security and (2) feeling a social belonging.

Considering travel to be a connection between human needs and their satisfiers, the NOA model, which was initially designed for understanding customer behaviour, can also be applied for the analysis of human transportation behaviour. This NOA application is discussed in the next section.

3.4 Application of NOA model for human transportation behaviour analysis

As discussed in the previous section, there is always a need behind personal transportation. In order to satisfy the five levels of needs, people go shopping for food and cloths (basic physiological needs), they travel to hospitals for medical care, ensuring their security needs. Moreover, people get education and work (security and social needs satisfaction), as a result of which they have to travel as well, in order to reach these establishments. In terms of social needs, people go on holiday and visit friends. These examples reflect the important role of transportation as a mean for needs satisfaction in a person's everyday life.

According to EEA (2008), people's needs satisfiers can be found in several 'sectors', i.e. domestic/housing, education, health (hospital), industry, retail shopping, business and leisure/tourism (see Figure 3.3). The distribution of these sectors' establishments (e.g. shops, hospitals, schools, etc) in the city mainly determines the opportunities and abilities of people to satisfy their needs. For example, if the city hospital is located far away from a person who needs medical care, the abilities of this person to reach the hospital can be limited by travel distance and other factors (e.g. availability of a car, financial situation, time, etc).

However, the needs, opportunities and abilities of people are often influenced by different external factors, such as economic, socio-demographical, institutional, cultural and technological factors (as discussed in Section 3.2). The complex interactions of sectors and factors discussed determine the demand for transportation (see Figure 3.3), transport model choice, the distance travelled, etc.

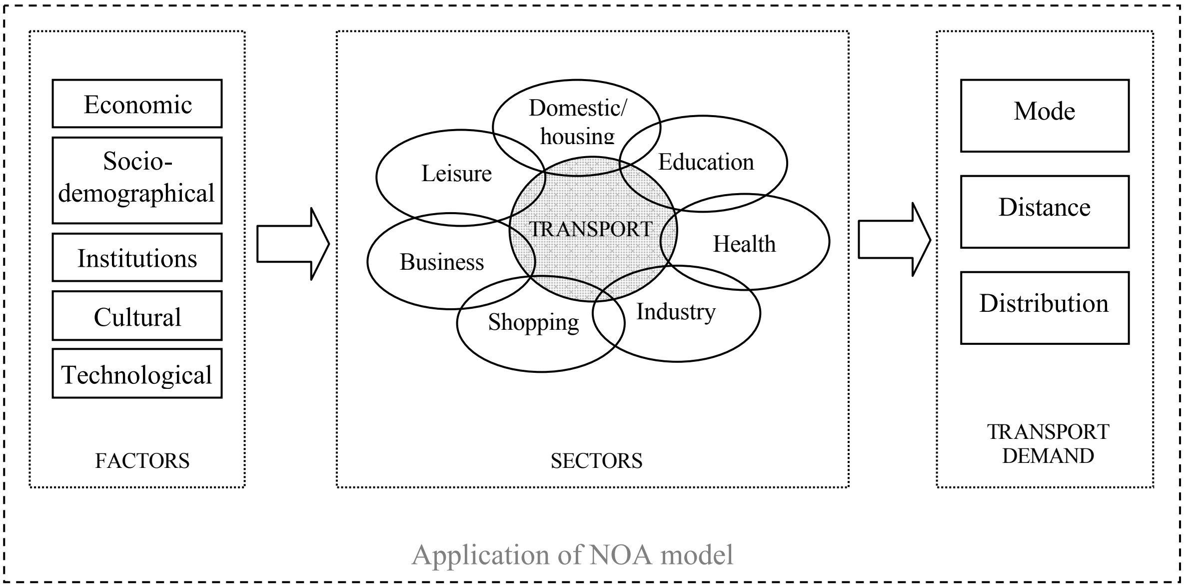

Figure 3.3 *Application of NOA model for transport demand analysis (adapted from EEA, 2008)*

The discussion above generally represented the integration of the NOA model into the analysis of human transportation behaviour, which results in a particular transportation demand. It was shown that, in order to understand the demand for transportation and issues related to that, it is first important to understand people's needs, existing opportunities and abilities.

For a better understanding of Figure 3.3, it will be practically analysed in a specific example. A person's travelling for leisure purposes is chosen for this particular analysis. As shown in Figure 3.3, the leisure sector is one of the components determining a person's needs, resulting in his/her motivation and choice for transportation. The practical application of the NOA model to the travel for leisure (holiday) example is shown in Figure 3.4.

Factors

Technology (tourism infrastructure, transport modes); **Economy** (integration, globalisation, etc); **Policy** (regulations, information, visa); **Demographics** (retirement age, employment, family structure); **Culture** (destination choice, leisure-time spending choice)

↓

Leisure sector

Needs	Opportunities	Abilities
↓	↓	↓
Entertainment, relaxation and variety	Tourism travel prices Tourism products and services Advertising and information	Per capita income Working time and paid leave Vocation time availability

↓

Transport demand

Transportation mode, destinations and frequency of travel

Figure 3.4 *NOA model application to leisure travel example (adapted from OECD, 2002)*

A person's needs for leisure travel (holidays) can find its motivation in seeking for e.g. relaxation, recreation, comfort (sunny and warm weather), distraction from the working environment, etc. On the global travel market, plenty of holiday opportunities are offered by travel agencies, depending on personal preferences. The abilities of how when and where a person goes on holidays can be determined by several factors, such as preferred destinations and type of holiday (depending on the lifestyle of a traveller). For instance, whether a person has more interests in nature (sunny weather, attractive beaches, sky-high mountains) or in culture (historical cities, interesting architecture, unique local culture). Besides type of holiday, factors such as availability of money and time to be spent on holiday, as well as family and work situation (has impact on the frequency and duration of holiday) also are major determinants.

As discussed above, several external factors can also influence the holiday travel choice. These could be, e.g. the culture of a traveller, possibilities to get to a particular destination (e.g., visa permit), and many other factors. The final choice for a holiday destination, transportation mode and consequently the environmental impacts from tourism travel will depend on the interaction of needs-opportunities-abilities and the external factors (OECD, 2002; Sauermann, 2005).

The holiday travel example discussed above gave a short overview of how the NOA model can be applied to transportation behaviour analysis. However, besides all factors mentioned, there is one important factor that needs to be analysed in more detail: a person's cognitive perception, which can have a significant influence on a person's motivation, transportation behaviour, transportation demand and transportation mode choice.

3.5 Psychological factors influencing the choice and demand for transportation

The discussion in the previous sections indicated that the demand for transportation can be established depending on a person's needs, opportunities and abilities, influenced by interaction of different external factors. However, the final decision of where and how to travel usually also depends on a person's psychological factors.

Because satisfiers' locations of people's needs are geographically scattered (in societal system), according to Michaels (1981), individuals have to develop a so-called 'cognitive understanding' of their environment.

Michaels (1981) indicates that "the distribution of a trip in the space is a consequence of the interaction between cognitive organisation and the means of access of the space". For example, people who are willing to buy new cloths, would select stores which they are aware of. The selection of these stores, according to Michaels (1981), is usually made from a subset of different possibilities that are determined by a person's knowledge (where to buy a particular piece of clothing) and their ability to locate alternatives (different stores) in the space. This selected subset of different options is further reduced by accessibility, which can be determined by the transportation system itself (e.g. availability of routes by which the desired location can be reached, possibility of reaching the selected location by public transport vs. by passenger car, etc).

To summarise the discussion above, the final set of possibilities for a person's need satisfaction can be reduced because of: (1) individual cognitive perception of the alternatives and (2) by the transportation issues of how the chosen alternatives can be reached.

Considering the second issue (transportation), factors such as travel time, costs and comfort are the most important ones to be considered. According to Michaels (1981), there are also other factors to take into consideration, which can determine the overall decision to travel and the choice of a particular transportation mode. These factors are: trip frequency, trip reliability, trip length and trip urgency. However, in general, people tend to choose for the shortest, least expensive and most comfortable way of transportation (Michaels, 1981). The significance of these three factors and their influence on a traveller's decision (e.g. student vs. retired person's transportation behaviour) depends on a person's needs, opportunities and abilities (NOA model).

Besides individual cognitive perception, another important factor has to be considered when discussing people transportation behaviour. The selection of alternatives by a person is based not only on a person's rational considerations (such as costs and time), but also on individual preferences, values and attitudes (Michaels, 1981; Sauermann, 2005). These qualitative and emotional dimensions are also very significant (together with individual cognitive factors) in determining where, when and how people will travel for their need satisfaction. For example, if a person possesses a 'luxurious' car, other people may have a perception that this person has a high social status[4] (Pucher, 1995; Hook, 1999; White, 1979).

This section gave an overview of two important psychological factors, which, besides needs-opportunities and abilities, can significantly influence individual transportation behaviour. However, on top of all the factors discussed, the motivation and behaviour of people, determining how, when and where they are going to travel in order to satisfy their needs, can also be influenced and controlled by various regulations. A theory that is commonly applied as a base for these regulations (e.g. policies) for people behavioural control is so-called reinforcement theory, which is discussed in the following section.

3.6 Reinforcement theory

Reinforcement theory, as reported by Everett (1981), was developed with the purpose of shaping people's behaviour by controlling the consequences of their behaviour. This theory had been successfully applied (tested) for modification of people's behaviour in clinical, educational and correctional institutions. Since the 1980s, the application of this theory is also found in changing

[4] Personal auto became an important symbol of freedom and social status in eastern Europe after the World War II. Demand in automobiles in Eastern Europe (Poland, Hungary, etc), far exceeded "what is actually necessary to meet mobility. The very possession of a western automobile has become so important for displaying one's social and economic status that is also could be called auto-mania". In eastern Europe people with modest income have purchased cars even though they couldn't really afford them, because it was essential to show that one doesn't belong to lower class of society (Pucher,1995).

people's behaviour related to energy consumption, environmental pollution and transportation patterns.

There are two central concepts in reinforcement theory, i.e. reinforcement and punishment. This theory suggests that the consequences of a particular behaviour influence and/or determine the probability and frequency of such behaviour to occur in the future (Everett, 1981; Barnett, 2010). If the consequences of a person's behaviour increase the probability of such behaviour to occur again, it refers to reinforcement concept of the theory (reinforcement of desired behaviour). For example, if an individual completes a piece of work, such as a painting, and receives a large amount of money for this painting, the person would be motivated to paint more; as a result the probability and frequency of this behaviour (painting) would also increase.

The second concept of the theory is punishment, which, opposite to the reinforcement concept, tries to decrease the frequency and probability of a particular behaviour to occur. In other words, punishment is applied to eliminate undesirable behaviour. A good example of punishment concept application in practice (by means of regulations) could be e.g. tickets for speeding. According to Everett (1981) and Barnett (2010), punishment is the most commonly used concept of reinforcement theory, but, in principle it should be used only if the reinforcement concept cannot be applied.

The stronger effects of reinforcement incentives were proven by E.L. Thorndike back in 1911, known as the 'law of effects'. This law basically states that "while all other things remain equal, responses to stimuli that are followed by satisfaction will be strengthened and responses that are followed by discomfort - weakened" (Barnett, 2010). The research of Everett (1981) and Barnett (2010) suggests that, in principle, reinforcement/punishment occurring directly after a particular behaviour has a much stronger impact on strengthening/weakening of this behaviour in comparison to when reinforcement/punishment is delayed (e.g. when a person receives a speed ticket by post at home a couple of month after the speeding incident).

The application of the reinforcement theory in the NOA model offers the most optimal possibilities for behaviour control in the 'opportunity' part of the model. The needs of people are determined by the people themselves and therefore cannot be entirely controlled by external factors and regulations. The ability of people to satisfy their needs is also determined by their circumstances, attitude and social level (income level, health (e.g. handicapped people have less abilities than healthy people), time availability, etcetera), which are rather complicated to control by means of regulations. The 'opportunity' part of the model defines existing options for people to travel from one destination to another.

Applying reinforcement theory in this part of the model, transportation behaviour and the choice of a particular mode can be controlled. For example, 'reinforcement' for car driving (what motivates person to choose for this transportation mode) could be: short travel times, prestige, arrival/departure flexibilities, privacy, route selection possibility, etc (Everett, 1981); 'punishers' for the car driving (demotivates a person for the use of personal car) could be i.e. congestion, fuel and car maintenance costs, parking, etc. Making these 'punishers' stronger than 'reinforcements' (or vice versa), by means of regulation, in general can guide person to a particular transportation mode choice. This is, regulations in the transportation sector, such as bans of cars in the city centres, introduction of the road pricing systems, fuel taxation, speed tickets, etcetera, are all oriented towards 'opportunities' and are applied for making car driving 'punishers' stronger. The reduction of personal car use can be expected as a possible outcome of these regulations, leading to a switch from this transportation mode towards other alternatives, such as public transit.

However, in this example, in order to perform a successful transportation mode switch from personal cars to the use of public transit modes (i.e. a bus), the 'punishers' for a car driving have to be stronger in comparison to the 'punishers' for the use a bus. The 'punishers' for the use of buses (that can be influenced by various policies) can be: discomfort, noise, dirt, exposure to weather, danger of crime (at the stops), crowdedness, unpredictability, long travel times, low prestige, limited route selection, waiting times (schedules), etc (Everett, 1981). For the promotion of public transportation modes it is also important to pay attention and emphasise its reinforcements, i.e. freedom from: (1) a car ownership, (2) driving responsibility and (3) search/costs for a parking place.

The description of the reinforcement theory, which was presented in this section, is important for understanding of why the regulations (i.e. transport policies) are applied, and in which particular part of NOA model its application is the most optimal. The discussion of this section mainly provides a base for a further analysis of transport policies and successfulness of their implementation.

4. Transport policy evaluation

4.1 Theoretical framework

In this research, a general transport policy evaluation framework needs to be developed, which can be identically applicable for the evaluation of the selected transport polices. From various transport policies existing in developing countries, in this research BRT systems in Asia region were selected and therefore the new developed framework is going to be applied for the evaluation of the selected BRT systems.

There are several different approaches existing for policy evaluation (Crabbé & Leroy, 2008). Within this research, eleven different approaches for *environmental policy evaluation*, reported by Crabbé & Leroy, (2008), were analysed and evaluated on their applicability to be used for the *transport policy evaluation*. These approaches are: needs analysis; program theory evaluation; case study evaluation: case study research; experiment and quasi-experiment; formative/developmental evaluation; goal-free evaluation; impact assessment; cost-effectiveness analysis and cost-benefit analysis; logframe method/logical framework approach; multi-criteria analysis and realistic evaluation.

All approaches mentioned could be applied to greater or lesser extent for transport policy evaluation. However, when particularly *ex post* assessment is considered, several approaches (e.g. needs analysis) become non-practical, as being used mainly *ex ante* (Crabbé & Leroy, 2008). From all eleven approaches analysed I found out that *ex post* transport policy evaluation, particularly BRT system evaluation on its successfulness[5] in the developing Asian countries, can contain elements of three different evaluation approaches, which are: case study evaluation, goal-free evaluation and multi-criteria analysis. All selected approaches are going to be shortly described as follows.

4.1.1 Case study evaluation

Case study evaluation (CSE) is a general research method, which can be applied for the evaluation purposes. According to Crabbé & Leroy (2008) CSE application can explain how and why a certain policy has worked. “By scrutinising policy, within the boundaries of a case, the evaluator acquires insight into how policy is functioning and why”. On the basis of these findings, the evaluator then can assess the policy.

Case study evaluation can be applied as an in-depth research, which allows a performance of a separate study on a specific subject[6] within its context (Crabbé & Leroy, 2008). There are four main steps in case study evaluation, which are: 1) design of the case study; 2) data collection; 3) analysis of the collected data and 4) report on findings. These four steps of CSE provide a suitable framework for BRT systems’ evaluation, as each BRT system selected, respectively, TransJakarta BRT, Beijing BRT and Delhi BRT, can be assessed as an independent case. Therefore, the performance of the selected BRT systems will be studied partly based on the ‘case-study evaluation’ approach.

4.1.2 Goal-free evaluation

According to Crabbé & Leroy (2008), goal-free evaluation approach can be applied for an assessment of policy effects. It aims to evaluate “what the policy actually does rather what it is

5 Definition of success was given in the introduction.
6 In this case these are selected BRT systems.

expected to do", therefore for goal-free evaluation is not important to know the goal/objectives of the policy[7]. The evaluation of policy effects has to be based on several evaluation criteria and it is required to keep a broad evaluation scope (Crabbé & Leroy, 2008) in order to cover direct and indirect effects[8] of the policy. Therefore, as mentioned in Chapter 2, BRT systems are going to be evaluated on three sustainability dimensions: environment, society and economics. The application of these sustainability dimensions for policy evaluation is reported in Campos et al. (2009), Vickerman (2000) and Neij & Astrand (2006).

Goal-free evaluation approach includes four main steps. First, it includes a description of data collection and analysis techniques (a way in which data are going to be collected and analysed). The second step involves selection of the evaluator, a person to perform the evaluation. The third step is an actual study or evaluation and the forth step is a formulation of recommendations (based on the evaluation outcomes) (Crabbé & Leroy, 2008). It can be seen, that these steps are rather similar to '*case study evaluation*' (see Section 4.1.1) and therefore this evaluation approach fits into the selected framework. Goal-free evaluation makes this framework more specific; during the data search/collection stage, there is no need to define objectives of the BRT policy implemented.

As mentioned before, goal-free evaluation suggests using different evaluation criteria, which can represent the outcome of the policy. However, there is no uniform set of criteria existing for transport policy evaluation, especially for BRT system. Applying the goal-free evaluation approach, the evaluator is allowed to independently make a selection of criteria for the evaluation (see Section 4.2). This step involves elements of '*multi-criteria analysis',* as described below.

4.1.3 Multi-criteria analysis

Multi-criteria analysis (MCA) is a method which is mostly used for a comparison of various policy alternatives. The general idea of this evaluation method is the assessment of various policy actions against selected criteria in order to determine the best alternative. Usually, each criterion in this evaluation is given a score, allowing further comparison of the alternatives. As a result of this analysis, a ranking of alternatives takes place, revealing the best option (Crabbé & Leroy, 2008).

Multi-criteria analysis is mainly applied *ex ante* in policy planning phase. However, there is an element of this method that is applicable for this research, which is the selection of indicators for the evaluation of one particular criterion.

In this stage it is important to distinguish the difference between criterion and indicator:

- Criteria represent the outcome of the policy and can be evaluated by the use of indicators.
- Indicators are usually values that can be measured[9]. For instance, indicators can be: CO_2 emission reduction (gCO_2/km), speed of motorised vehicles (km/h), time saving for transportation (min/day), etc. Based on the values of selected indicators, the evaluation of a particular criterion can be made (see Section 4.2).

In this research, the evaluation of a particular criterion[10] is going to be based on a set of indicators. The selection of the evaluation criteria as well as of these indicators is going to be per-

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7 In goal-free evaluation it is not required to identify and evaluate policy objectives (to which extent the objectives of the policy were reached), instead, more attention should be paid to the evaluation of policy (side)effects (Crabbé & Leroy, 2008).

8 Direct effect form BRT policy implementation can be, for instance, congestion reduction. The reduction of congestion level in the city, as the result of BRT policy, can lead to the improvement of local air quality. In this case, the improvement of local air quality is indirect effect of the BRT policy implementation.

9 There are quantitative and qualitative indicators existing (see paragraph 4.2.2).

10 There are several criteria to be selected in this research for the evaluation of BRT systems on their successfulness (see Paragraph 4.2.3).

formed based on the elements of 'goal free evaluation' and 'multi-criteria analysis' approaches, as discussed above. However, the general evaluation of BRT system performance is going to be performed within the broader framework of 'case-study' evaluation.

4.2 Transport policy evaluation methodology

In this section, the methodology for BRT systems evaluation on its successfulness is going to be developed. This methodology only concerns the evaluation step itself and is it going to be equally applied for the evaluation of each selected BRT system (see Figure 2.1). In order to understand how the evaluation of transport policy can be performed and which types of indicators should be selected for the evaluation, it is important to get a general insight on policy implementation cycle.

4.2.1 Policy implementation cycle

The policy implementation cycle[11] involves five main steps, which are 'objective', 'input', 'output', 'outcome' and 'impact' (see Figure 4.1). Depending on the goal of the evaluation, each of these steps can be evaluated by the use of appropriate indicators.

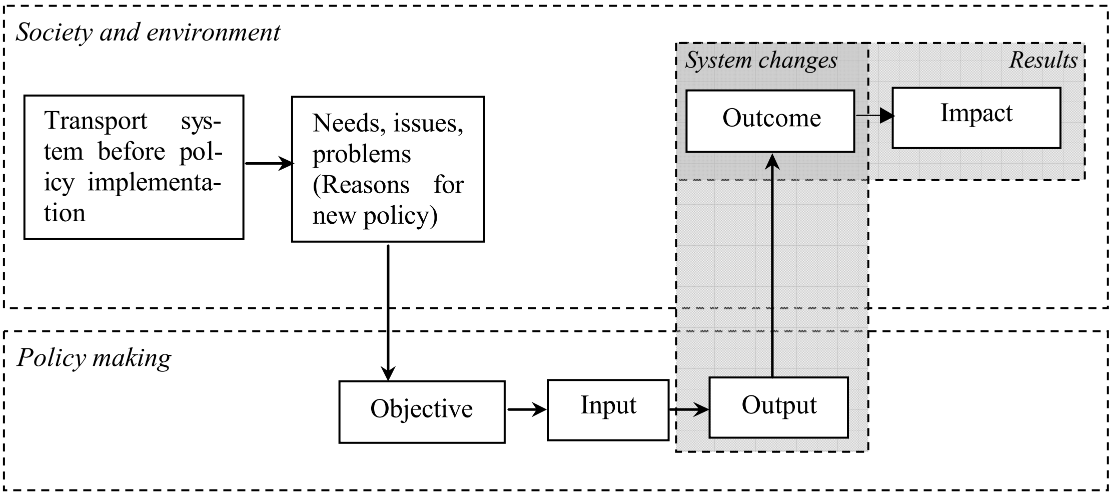

Figure 4.1 *(Transport) policy implementation cycle (adapted from Neij & Astrand, 2006)*

From Figure 4.1 can be seen that in general, policy implementation is occurring on two different levels, respectively, societal level (involving society and environment) and policy making level, where the policy is mainly been designed.

The reasons for a new policy design and implementation are found in the societal level. The functioning of a system (in this case transport system) can cause several problems and create additional needs in the society. These problems and needs indicate the desired changes in the system, and these are the main reasons for a new policy development (Segnestam, 2002; Boker, 2005). Defining the objectives of the new policy is the first step in the cycle (see Figure 4.1).

In goal-free policy evaluation it is less important to know the objectives of the policy (see Section 4.1.2). However, it is still essential to have a description of the transportation system before

[11] Transport policy implementation complies with the general policy implementation cycle (concluded by the author of the research based on the literature study).

the policy implementation, since it can be used as a reference point for the analysis of the changes in the system caused by the implementation of the new policy[12].

The second step is policy input (Segnestam, 2002; Boker, 2005). Inputs are the resources that are invested in policy implementation (e.g. investment, equipment, labour, etc). Considering transport policy, this can be a level of funding spent on construction of new roads and stations, etc. For monitoring this step, input indicators are used.

The third step is defined as policy outputs. After policy implementation there are quantitative direct results, e.g. number of installed air quality measure station, number of new busses, km of new sidewalks, etc. In order to measure these results output indicators are used[13].These indicators, though, give an insight only in system improvement but still not on its' functioning (Segnestam, 2002; Boker, 2005), since this step is taking place in policy making level[14]. Therefore these indicators can be seen as contextual factors or technical data of the evaluated system. The literature study performed shows that these indicators are easy to define and measure, and therefore they can be applied as a supplement to the outcome indicators.

The fourth step is known as policy outcomes, indicating what the policy outputs led to. The outcomes of the policy emerge on the societal level. For instance, introduction of new buses can lead to a reduction of congestion level on the roads, reduction of the personal car use, etc. (Segnestam, 2002; Boker, 2005). In this example the reduction of road congestion and a modal shift are the outcomes of the policy, which can be measured by the outcome indicators. In transport policy case these indicators can be e.g. congestion level, travel speed, travel time, number of accidents, etc. Monitoring of these indicators together with the output indicators can give an insight in how a transport system performance has changed since the implementation of the new policy.

The fifth step of the cycle is policy effect/impact. These are effects/impacts that are created by policy implementation also on the societal level (Segnestam, 2002; Boker, 2005). In general, these are long terms policy results, such as air quality improvement, social acceptance, users satisfaction with a new system etc. Impact indicators are used to monitor these results. In some cases outcome and impact indicators are merged (Neij & Astrand, 2006).

Since the goal of this research is to evaluate the successfulness of a new policy implementation, from the description of the policy implementation steps it is apparent that the main focus has to be put on the evaluation of 'output', 'outcome' and 'impact' steps by applying suitable indicators. The selection of these indicators is discussed in the following section.

4.2.2 Factors for indicator selection

According to Castillo & Pietfield (2009), an indicator can be defined as a quantifiable measure used to monitor the objective and/or impacts of implemented policy. Indicators provide information that can summarise the characteristics of the system, and give an insight in system performance. Segnestam, (2002) reports that there is no universal set of indicators existing that would be equally applicable for any policy (transport policy in this case) evaluation. Therefore, for the evaluation of a particular policy it is important to make a selection of suitable indicators, depending on the goal of evaluation.

[12] Only the determination and analysis of the results of a particular policy implementation will not give an indication whether this policy was successful or not (Neij & Astrand, 2006). According to Neij & Astrand (2006), the results obtained have to be compared to so-called reference values, which can be established before implementation of the new policy. A comparison of system's functioning before and after policy implementation can reveal whether a new policy led to improvement of transport system performance (have been successful), whether it failed.

[13] These indicators are used to measure, for instance, number of new busses, km of improved sidewalks, etc.

[14] The effects of the policy functioning can be seen only on the societal level (see the description of the steps four and five).

In order to select the most appropriate and representative indicators for policy evaluation, it is suggested by Castillo & Pietfield, (2009) and Carriker, (1995) to consider several factors. The main factors to be considered, according to these authors, are the following:

- Measurability: it should be possible to perform quantitative and/or qualitative evaluation of a particular indicator.
- Accessibility: it should be relatively easy to collect reliable data on a particular indicator or calculate the value of the indicator using existing accepted methods.
- Understandability: an indicator should represent clear information that is easy to understand and use for the further policy evaluation. These indicators should be clear not only for policy makers and policy evaluators, but also for other audience, e.g. stakeholders.
- Comparability: it should be possible to compare the estimated values of indicators after policy implementation with the past conditions (reference values).
- Reliability: an estimated value of a particular indicator should be identical regardless who performs data collection and in case when the data collection is repeated.
- Relevance: when evaluating the impacts of policy implementation, indicators have to be selected in such a way, insuring that they are appropriate (relevant) to characterise selected policy evaluation criteria[15].
- Cost effectiveness: before indicator selection it has to be estimated whether information (data) on this indicator is available and can be obtained with reasonable costs and efforts.

Considering 'measurability' factor, selected indicators can be quantitative and/or qualitative. The *quantitative indicators*, such as e.g. noise level, number of accidents, are directly measurable, obtaining numerical value (e.g. percentage, ratio, number) based on the statistical or/and reported data in the literature.

Qualitative indicators, on the other hand, are introduced when it is not possible to perform a quantitative evaluation of policy (e.g., when a level of public satisfaction with the results of new implemented policy needs to be evaluated). These indicators cannot be directly measured, but have to be evaluated using a particular scale.[16]

Knowing which factors have to be taken into consideration as well as which types of indicators need to be selected for the evaluation of policy outcomes and impacts, the indicator' selection process can be initiated. However, prior to this, it is essential to define the main evaluation criteria[17], which are going to be used for the final evaluation of the transport policy. For the evaluation of one criterion, a set of indicators might need to be selected.

In the following section, first, the selection of the main evaluation criteria for BRT system evaluation on its successfulness is performed. After the selection of these criteria, a selection of suitable indicators is performed and discussed.

4.2.3 Selection of main criteria for BRT system evaluation

In order to keep a broad scope of evaluation, which is required under 'goal-free evaluation' approach (see Section 4.1.2), the evaluation of the selected BRT systems is going to be performed on three main sustainability dimensions (later in the text 'blocks'), which are environment, society and economics (see Table 4.1). The selection of these blocks was made based on literature

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[15] See discussion of evaluation criteria in the following section.

[16] Qualitative evaluation, according to Vickerman, (2009) can be performed using a quantitative base of evaluation, for instance, evaluating large negative and large positive effects of a policy/program/project implemented. This can be done for instance, by introducing 10 point scale, where 1 represents large negative effects and 10, respectively, large positive effects.

[17] As defined in Paragraph 4.1.2 a particular criterion represent the outcome of the policy and can be evaluated by the use of a set of indicators.

study[18]. As defined in the introduction of the research, the evaluation of the performance of BRT system within these blocks[19] will reveal, whether BRT system is successful or not. However, in order to be able to perform this BRT system evaluation on its successfulness, the main evaluation criteria within each block have to be selected.

These criteria were selected based on an extensive literature study[20], and the results of the selection are represented in Table 4.1.

Table 4.1 *Main criteria for the evaluation of BRT system performance/successfulness*

Main blocks	**Main evaluation criteria**
	Reduction of local pollution (NOx, PM, CO, SO_2)
	Reduction of noise level in urban areas
	Contribution to CO_2 reduction
	Increased road safety
	Equity
	Travel convenience
	Revenues/costs ratio
	Congestion reduction
	Creation of new job market

As shown in Table 4.1 each sustainability block contains three main evaluation criteria. BRT performance within the 'environmental block' is going to be evaluated by the use of '*reduction of local pollution (NOx, PM, CO, SO_2)*', '*reduction of noise level in urban areas*' and '*contribution to CO_2 reduction*' criteria. The evaluation of these criteria will give the main insight on the effects of BRT implementation on the environment.

There are several indicators on which the evaluation of each selected criteria is going to be based. These indicators were selected based on the 'goal-free evaluation' approach, taking into consideration the main factors for indicator selection (see Paragraph 4.2.2) and policy implementation cycle (Paragraph 4.2.1), which defined the type of indicators to be selected for the evaluation of policy results[21]. In a similar way, the selection of all indicators in this research was performed[22]. The set of indicators that is going to be applied for evaluation of the main criteria under environmental block is given in Annex D.

The contribution of the new BRT system to societal benefits is evaluated using the following main criteria: 'increased road safety', 'equity' and 'travel convenience'. These criteria are more abstract in comparison to criteria under 'environmental block' and therefore need to be explained.

[18] The evaluation of policy on these three dimensions is referred in Campos et al., (2009); Vickerman, (2000) and Neij & Astrand, (2006).
[19] Whether there are environmental, social and economical benefits from the implementation of the new BRT system in the city.
[20] Farrington, et al.,1993; Talvitis, 2000; The EC, 2007; The EC, 2009; DoT, 2005; Button, 1992; Bouwman & Moll, 2002; Boonekamp, 2005; The EEC, 2004; Bongardt, et al., 2009; Bakker & Huizenga, 2009; Boker, 2005; Vasconcellos, 2996; Farrington & Ryder, 1993; Linden et al., 2005; The ERF, 2004; Joumard & Nicolas, 2010; Moberoela, 2009; Neij & Astrand, 2006; VTPI, 2010; WBCSD, 2001; and other sources of information which were not included in the literature list (chapter 13) due to its extensity.
[21] The selection of suitable indicators is based on NZMT, (2009) and VTPI, (2010).
[22] Indicators for the evaluation of main criteria under each sustainability block.

- '*Road safety*' criterion will be evaluated as: "whether the transportation of city's inhabitants became safer in comparison to the situation before the BRT system integration[23]". There are two main indicators which are going to be used for the evaluation of this criterion:
  - 'reduction of the amount of road accidents' (quantitative indicator);
  - 'improvement of travelling conditions for NMT commuters[24]'. This indicator is qualitative and can be assessed based on the technical data on BRT system[25] (e.g. integration of segregated lane for NMT, construction of new overpasses for pedestrians, etc). This indicator is also applicable for the evaluation of 'equity' issue[26]. The full set of indicators used for the evaluation of this criterion, as well as for the evaluation of other criteria under this block is included in Annex D.
- '*Equity*' criterion is going to be evaluated as: "whether travelling possibilities for low-income people and disabled people were improved after the BRT system integration in a transportation system of the city", by using indicators such as 'travel costs' and 'improvement of travelling conditions for NMT commuters and physically disabled people' (see Annex D).
- '*Travel convenience*' criterion is going to be evaluated as: "whether travelling with the new BRT system became more convenient for commuters, in comparison to a bus service before BRT integration". The following main indicators will be used for this evaluation: 'accessibility and reliability of the public transport service', 'travel comfort[27]', 'reduction of travel time' and 'modal shift'. The full list of indicators applied for the evaluation of '*travel convenience*' criterion is shown in Annex D.

BRT performance within the 'economical block' is going to be evaluated by the use of three main evaluation criteria: 'revenue/cost ratio', 'congestion reduction' and 'creation of a new job market'.

- '*Revenue/cost ratio*' is a criterion which will be determined as: "undiscounted annual revenues from system performance divided by the total investment costs". Operational costs will not be taken into consideration in this calculation. As a final result, the pay-back time of the BRT system will be determined, which later will be compared to the pay-back times of the other public transport modes in the city (e.g. metro) and among all BRT systems evaluated in this research.
- '*Congestion reduction*' criterion evaluation will be based on the main quantitative indicator, respectively, 'traffic speed[28]'. However, indicators such as 'modal shift' and 'travel time saving for bus commuters', which are used for the evaluation of other criteria (see 'travel convenience'), are also going to be taken into consideration while the evaluation of 'congestion

[23] This definition for 'road safety' evaluation as well as for the evaluation of the following criteria was given by the author of this research. Here it has to be mentioned that safety improvement will be assessed only on the new BRT corridor and not in the entire city.

[24] According to the literature study performed, NMT commuters are the most vulnerable group, which in general accounts for the highest percentage of road accidents in comparison to commuters who use the other mode of transportation (Badami, 2007). Therefore, high attention has to be paid to NMT commuters (concluded by the author of the research).

[25] The scale for the assessment of most selected qualitative indicator is given in Annex D. In case the scale is not indicated, '*improved / no changes / deteriorated*' scale is applied.

[26] Even though '*road safety*' and '*equity*' are different evaluation criteria, improvement of road conditions for NMT transportation is contributing to both of these criteria. However, it is not the only indicator that is going to be taken into consideration while the evaluation. Therefore it is expected that the overlap between 'road safety' and 'equity' evaluation will be minimal. This also concerns other criteria, which evaluation involves the use of one particular indicator.

[27] 'Accessibility and reliability of the public transport service', and 'travel comfort' are one of the main indicators which also can be applied for the evaluation of '*public acceptance*' with the service. Therefore, by the use of these indicators, 'public acceptance' will be indirectly evaluated under the 'travel convenience' criterion. The indicators mentioned have a qualitative nature, however they can be assessed by the use of technical data on BRT system performance. The scale as shown in Annex D is applied for the evaluation of these indicators.

[28] This indicator consists mainly out of two parts, respectively 'speed of public bus transit' and 'speed for private motorized vehicles'. Considering the fact, that in developing Asian countries public transit is used by the majority of the population (see Chapter 5), more attention will be paid specifically to 'public transit speed' change after BRT integration, rather than to the speed change of private vehicles.

reduction'[29]. In order to determine factors that facilitated/impeded congestion reduction on BRT corridors, the analysis of technical data[30] on BRT system will be performed.
  Potentially, congestion reduction, which leads to travel time savings, can be expressed in a monetary unit. This was one of the main reasons to include this criterion under the 'economical block'. However, in this research this conversion to the monetary unit will not be performed, since it requires the application of different policy valuation approach, namely, 'cost-benefit analysis'. This approach, though, was not selected for the performance of this research.
- '*Creation of a new job market*'. Based on the literature study performed, it was decided to include this criterion into the general BRT system evaluation. Creation of new job market, as one of the outcomes of the BRT policy implementation, can potentially increases the level of employment in the country, in this way contributing to the countries' economical development. The number of new job places created will be used as an indicator for the evaluation of this criterion.

'*Policy transferability potential*' was selected as the last criterion for BRT evaluation. This criterion could not be included under the main sustainability blocks (see Table 4.1), as it provides different type of information. As reported in Macario and Marques (2008), "the successful implementation of a transportation measure or of a package of measures at a given city should provide grounds for potential transfer to other cities, if the right conditions are met". That is why this criterion is not used for the evaluation of how successful was a particular policy, but for the evaluation of how easy is it to transfer a particular policy from one country to another, ensuring similar results.

Within this research, the potential of BRT policy transfer will be determined. Base on the fact that an extensive study on transport policy transferability was performed by Macario and Marques (2008), the results of his study will be used and applied within the current research.

According to Macario and Marques (2008), BRT systems are placed under those measures that: "can typically be undertaken under current common circumstances, but still need careful attention in terms of adequate local conditions, and still require particular attention to supportive packaging". Based on this, '*policy transferability potential'* for BRT system is assessed as 'moderate'[31] and this result is applicable for all BRT systems evaluated in this research[32].

As mentioned before, in order to evaluate changes in the transportation system caused by the integration of the new BRT policy, it is important to define technical data/characteristics of general transport system performance before BRT policy implementation[33]. For this, several indicators, so-called 'contextual factors,' for data collection are going to be used. These data will be used as a reference point a comparison of system's functioning after BRT policy implementation. The set of these 'contextual factors', which is going to be used for the data collection, is given in Annex D.

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[29] The use of similar indicators for the evaluation of different criteria cannot be prevented, as the selected indicators sometimes are strongly interconnected.

[30] For instance, location and distance of the stations, width of the bus lane and 'mixed traffic lane', functioning of the traffic light system, etc.

[31] The explanation and discussion on the evaluation scale applied is presented in the following paragraph 4.2.4.

[32] BRT systems were introduced in all Asian cities evaluated in this research, which already indicates on the possibility of this policy transferability, however the success of the performance of BRT systems depended to a large extent on the local circumstances, planning and support from government and international organisations (discussed in Chapter 9).

[33] For instance, data on transport modal share, average speed on city's main roads, etc.

Technical data on BRT system itself is also useful information, which can be used for explanation of transport system's functioning after the BRT system integration in it[34]. The set of indicators, which will be used for a collection of technical data on BRT system, is shown in Annex D.

4.2.4 Evaluation performance of the selected criteria

The evaluation of policy effects on social, economical and environmental blocks has to be performed separately and independently from each other (Vickerman, 2000). The reason for this is to prevent the compensation of negative policy effects in one block with positive effects from the other block. In this way, a transparent policy evaluation can be ensured (Vickerman, 2010). Based on this, in this research the evaluation of BRT system performance within each sustainability blocks is going to be performed independently. In order to ensure even more transparent evaluation, the evaluation results of the main criteria under one particular block are going to be discussed separately[35]. Applying this approach, a general 'picture' of BRT performance within each sustainability block will be created.

Evaluation of all selected criteria is going to be performed, applying a qualitative evaluation scale: 'high-moderate-low'. In order to increase readability, 'high-moderate-low' scale will also be given three colours, respectively, green, yellow and red.

- In case the evaluation of a particular criterion (based on the selected indicator set) will indicate a significant improvement, as a result of a new BRT operation, this criterion will be evaluated as 'high'[36]. Whether this contribution is significant is assessed based on data from literature analysis. Next to it, the indication of the certainty of this evaluation result is going to be given.
- When the evaluation of a particular criterion reveals small positive changes in the system caused by the BRT system operation, this particular criterion will be evaluated as 'moderate'. This would mean that BRT system performance showed a 'moderate' contribution to benefits in this particular evaluation field. Whether the changes in the transport system functioning after BRT implementation are small will be assessed based on data from literature analysis. The certainty of this evaluation will also be indicated.
- If the evaluation of BRT system on a particular criterion shows that there were no changes made in the performance of the entire transportation system due to the implementation of the new BRT system, or this performance has worsened, the evaluation mark 'low' will be applied for this particular criterion.

In case no data on the selected indicators can be found in the literature while performing evaluation of a particular criterion and/or no judgment can be made[37], this criterion has to be left unevaluated (marked as 'n/a' and white colour). This limitation is applicable for all selected evaluation criteria.

The BRT system will be considered *successful*, when no 'low/red' evaluation mark is applied to any of the evaluation criteria *and* when more than 50% of the criteria are evaluated as 'high'[38].

In order to make the results of evaluation more robust, the certainty of evaluation will be indicated. The certainty of the evaluation will depend on two main factors: 1) data availability,

[34] For example, congestion level on the roads where BRT system was integrated could have increased in comparison to the congestion level before BRT integration. This phenomenon can be explained only if knowing that there was no road space widening when construction of a segregated bus lane on BRT corridor, meaning that currently there is less road space available for the mixed traffic than before.

[35] This way of result's representation will give an option to track back the evaluation of each particular criterion to its information sources, ensuring a high level of transparency.

[36] 'High' - meaning a high contribution of BRT system to this particular field of evaluation, e.g. reduction of the local air pollution.

[37] For instance, which evaluation mark is applicable for a particular criterion?

[38] At least five criteria out of nine have to receive 'high' evaluation mark.

which can be high or low, and 2) whether the agreement of these data[39] is high/low. This evaluation is going to be integrated in the overall BRT system performance evaluation table and the 'level of certainty' is going to be indicated next to the final evaluation result:

- If data primarily required for the evaluation of a particular criterion is available in three or more literature sources, it will be evaluated as 'high data availability' (HD), otherwise - 'low data availability' (LD).
- If the information is consistent in 70% of the sources where it is found (at least in two sources), this will be considered as 'high agreement' (HA), otherwise - 'low agreement' (LA).

The limitation of three information sources was selected considering general poor data availability[40] on BRT systems in Asia, as concluded from the literature study performed[41].

The evaluation of each BRT system on its successfulness is going to be carried out within the theoretical framework defined in Section 4.1 and applying a new evaluation methodology, as discussed in the Section 4.3. This following section of the report gives an overview of the main steps for the conduction of each BRT case studies.

[39] Whether the authors of several information sources agree upon each other's data.
[40] For instance, case studies, evaluation report, monitoring data, etc.
[41] As it will be discussed later, data availability is the main concern and obstacle of this research.

4.3 The basic steps in BRT case study conduction

In Chapter 2, the general methodology of the research was presented, which gave the main insight in how the entire research is going to be conducted. This section, on the other hand, gives more detailed explanation on how each of the selected BRT case studies is going to be performed and which steps are going to be undertaken during this process (see Figure 4.2).

As can be seen from Figure 4.2 each BRT case study will consist out of two main blocks, which are '*description*' and '*evaluation & analysis*'.

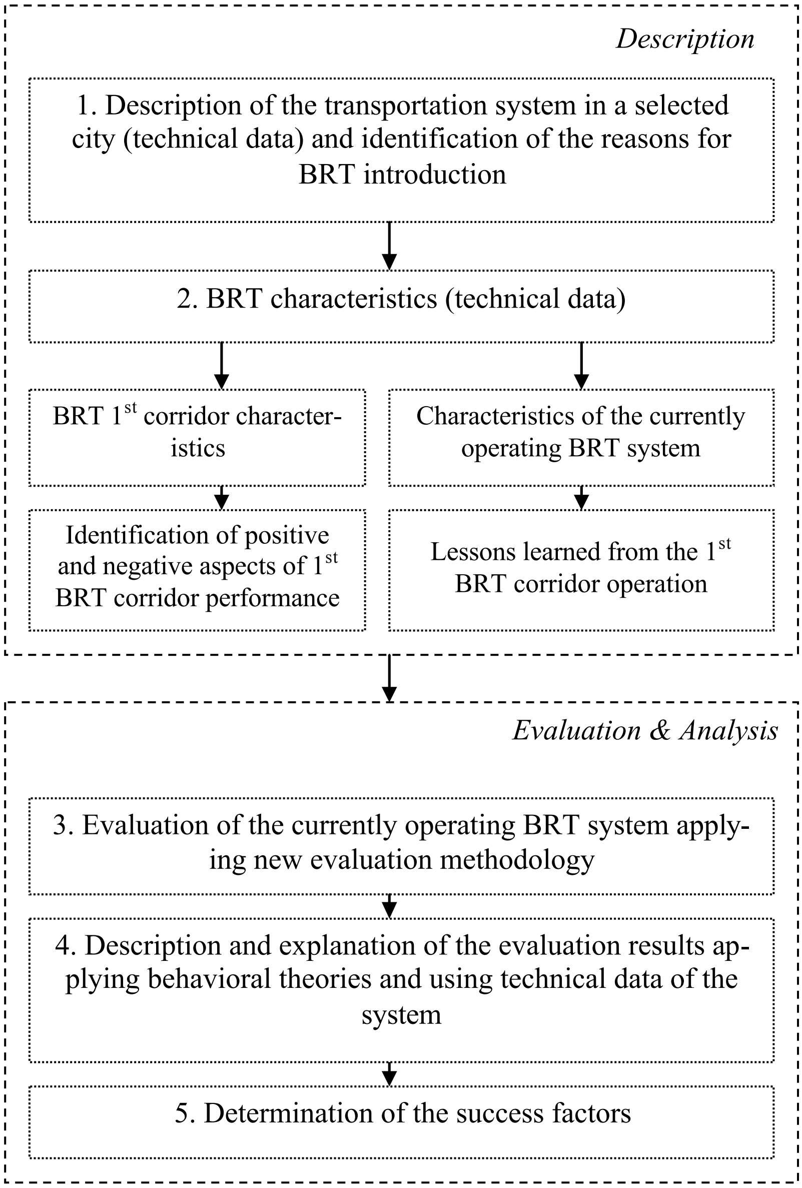


Figure 4.2 *The basic steps in BRT case study conduction*

As the first step, the transportation system of the selected city is described (applying the set of contextual factors as discussed in Paragraph 4.2.3) and the main reasons for the integration of BRT system are defined. Then, the main characteristics of the new BRT system are given, which will be used in the 'evaluation & analysis' part for explanation of the evaluation results. Within this step, special attention is paid to the characteristics of the 1st BRT corridor. The positive and negative aspects of 1st BRT corridor operation are identified. The identification of these aspects is an important step in this research for two reasons. First, knowledge of strengths and weaknesses of the 1st BRT corridor operation is useful when evaluating the performance of the entire BRT system, as it can be seen which lessons were learned from the 1st corridor operation (what was changed/improved or kept identical when constructing the next BRT corridors). Second, the initial implementation stage of i.e. Beijing's BRT system (operation of the 1st corridor) can be compared to the initial stage of implementation of the other BRT systems, revealing the best practices and main constraints of these systems, in this way drawing lessons for planning and implementation of BRT in the future. The comparison of three Asian BRT systems mentioned is going to be made and discussed in Chapter 9 of the research.

Evaluation of the currently operating BRT system is going to be performed applying the new developed evaluation methodology, as discussed in Paragraphs 4.2.3 and 4.2.4. Each of the evaluation results will be discussed directly after the evaluation. Therefore, these two steps are going to be merged. The behavioural theories (see Chapter 3) together with BRT system's technical data are going to be applied for the result analysis. As the last step in BRT case study performance, the 'success factors' which facilitated a successful operation of BRT system are going to be determined. In case the performance of the BRT system was not successful, the factors that impeded the 'success' are going to be defined. These factors will be summarised from the literatures study.

5. Selection of the case studies

This research is focused on the evaluation of transport policies, particularly BRT, in Asia. Most of Asian countries can be characterised as ‘developing’ and, therefore, they have some common characteristics (wiki, 2010). In this chapter, first, a general insight in transport sector in developing courtiers will be given. This information will be used as a base for the further analysis of transportation patterns in each of the selected countries, as well as for the conduction of the selected BRT case studies.
Next, the concept of BRT system will be introduced in this chapter and a selection of the BRT case studies will be described.

5.1 Main characteristics of transportation in developing countries

Reliable access to roads, lack of transport services in rural areas, road safety, urban road congestion, poor air quality and a high level of GHG emissions are major problems related to the transport sector in developing countries (The WBG, 2008). In general, developing countries do not possess enough resources (time and money) to cope with high motorisation rates, e.g. to improve/build new infrastructure in order to accommodate a fast growing amount of motorised vehicles. According to WBCSB (2001), “the developing cities house and transport too many people on insufficient numbers of poor maintained roads and rails, and generally lack the money and institutional vigour to fix the problems”. The private car ownership is constantly rising in the developing countries, highly contributing to such problems as congestion and air pollution, while public transportation services are deteriorating. This increase in private vehicle ownership, according to Wright & Fulton (2005), has also a strong correlation with per-capita income (the higher the income, the more affordable it becomes to have a car), however, social status is also an important issue to consider (see discussion in Chapter 3). It is predicted, that by the year 2050, the absolute number of private vehicles and the level of their use in the developing world will surpass these indicators in OECD region (Organisation for Economic Co-operation and Development), see Figure 5.1. On the other hand, the car ownership per capita as well as the amount of travel (in general) per capita in developing countries will still be much lower than in OECD countries (see Figure 5.2).

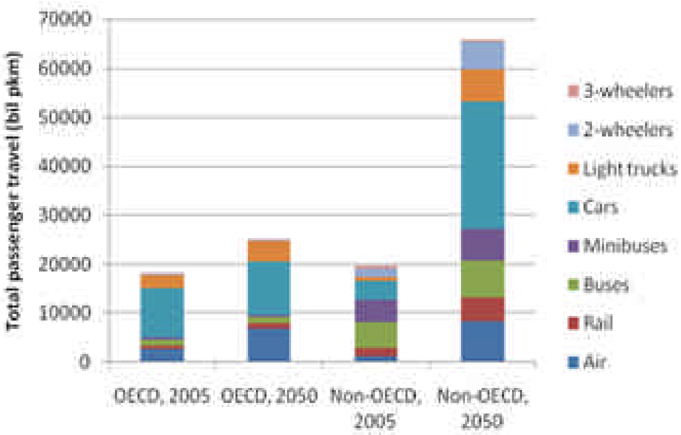
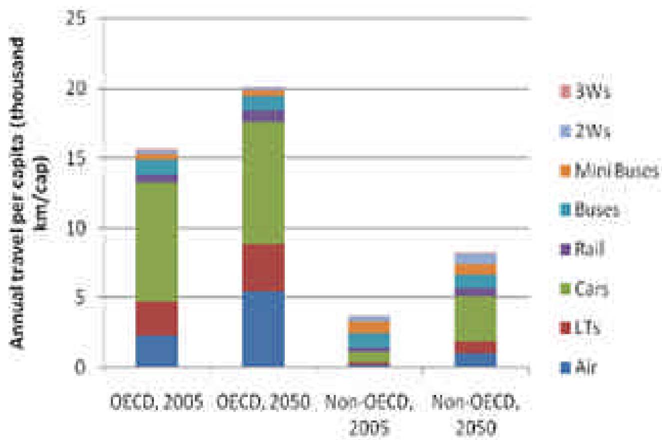


Figure 5.1 *Total passenger travel in OECD and Non-OECD countries with projection for 2050 (IEA, 2009).*



Figuur 5.1 *Annual travel par capita in OECD and Non-OECD countries with projection for 2050 (IEA, 2009).*

According to IEA, (2009), two-wheelers and three-wheelers are still the dominant modes of transportation in such developing countries as China, India and Indonesia[42].

An older vehicle fleet in the combination with a low vehicle's maintenance level and a limited vehicle technical control, which are common issues in the developing countries, indicate that the impacts of motorisation in developing world are worse in comparison to a developed world (Wright & Futon, 2005). Besides the increase in the local emission level, transport-related carbon dioxide emissions are also rapidly increasing in a developing world and it is predicted that in about a decade it will surpass transportation related CO_2 emissions in the developed countries, if the present motorisation trend continues. Considering motorisation and urbanisation of developing countries, road safety is also an important issue to mention. According to WBCSD (2001), "deaths and injuries from transport-related accident in developing countries occur at substantially higher rates than in the developed world".

While the use of private vehicles in the developing countries is growing, the use of public transit in the world, in general, is steadily decreasing (Wright & Fulton, 2005). General dissatisfaction with the quality of public transport services in the developing countries, which usually is slow, unsafe, uncomfortable, etc., have contributed to a steady decline and loss of public transit mode share (see Table 5.1).

Table 5.1 *Changes in modal share of public transport in selected cities*

City	Earlier year	Public transport as a percentage of motorized trips	Later year	Public transport as a percentage of motorized trips
Bangkok	1970	53	1990	39
Buenos Aires	1993	49	1999	33
Kuala Lumpur	1985	34	1997	19
Mexico City	1984	80	1994	72
Moscow	1990	87	1997	83
Sao Paulo	1977	46	1997	33
Seoul	1970	67	1992	61
Tokyo	1970	65	1990	48
Shanghai	1986	24	1995	15
Warsaw	1987	80	1998	53

Source: Wright & Fulton, 2005.

From this table can be seen that over about 20 years, since 1970, the public transport mode share in the selected cities has significantly declined. However, even if this decline is observed around the world, in developing countries the majority of people with low income cannot afford private cars, and therefore the use of public transportation remains their primary motorised mobility. From this perspective, even though the loss of public transport mode share is observed, in developing countries public transportation remains one of the most important transportation mode, which is struggling to keep up with a growing demand (WBCSD, 2001).

Besides the deterioration of public transport, the NMT (cycling and walking) infrastructure in the developing countries is generally of the poor quality. Walking and cycling is dominant in poor parts of the developing world. According to WBCSD (2001), walking is the major way transportation among the poorest city residents in Africa, Asia and Latin America. Even though the ownership of private cars in general is rising, a majority of poor citizens cannot afford motorised transport (even to public transport).

[42] The evaluation of BRT system was selected in these countries (see section 5.4) and, therefore, this fact an important factor to consider.

Notwithstanding the rapid growth of personal vehicle ownership, most developing countries still have the basis for a more sustainable future (Wright & Fulton, 2005). As it was discussed before, public transport and NMT remains a dominant share of travel, especially in the poor regions. However, the quality of these modes is often poor, regarding the aspects of security, comport, convenience and prestige. Difficult conditions for walking and cycling with the combination of unreliable and inadequate public transportation could be a strong motivation for developing-city citizens to move towards the use of private motorised vehicle, as soon as it is becomes economically viable. Therefore, the main focus for more efficient and sustainable transport future in developing countries has to be on a preservation and improvement of existing public transport and NMT services (Wright & Fulton, 2005). One of the options for this improvement can be an introduction of 'innovative high-quality bus systems', so-called Bus Rapid Transit (BRT), in combination with several support measures, including e.g. new (renovated) infrastructure for NMT transport and car-restriction measures (IEA, 2009; Wright & Fulton, 2005). The use of BRT in developing countries is discussed in the following section.

5.2 General description of BRT system

Promotion of the use of public transportation is one of the core measures for improvement and structuring the urban mobility, as well as for reduction of the local and global pollutants (Caldes et al., 2007). In the vast majority of developing counties, according to Wright (2005), public transit is "the only practical means to access employment, education and public services", especially when these services are located beyond walking distance.

Bus Rapid Transit system is a concept of public transportation, which offers the opportunity for developing cities to create a high-quality mass transit system at an affordable costs (Wright, 2005). Bus Rapid Transit (BRT), is "a bus-based mass transit system that delivers fast, comfortable, and cost-effective urban mobility" (Wright, 2005). In the core of its operation are the segregated bus lanes[43] that set a priority for a rapid movement of buses over other types of vehicles. BRT can be seen as a system that incorporates the infrastructure (bus lanes, station, terminals, and buses) with its organised operation, in order to provide a higher quality service than a traditional bus system and to attract travellers, who would otherwise drive personal cars on congested urban roads (Caldes, et al., 2007). At present, according to VTPI (2010), BRT systems are also considered as a more affordable alternative to a rail-based system, such as metro or light rail (discussed later in this section).

With regards to the core components of a BRT, Wright (2005) states that the most important ones are:

- Exclusive right-of-way lanes.
- Rapid boarding.
- Enclosed stations that are safe and comfortable.
- Clean vehicle technologies (rubber-tired vehicles that are easy to board and comfortable to ride).
- Excellence in marketing and customer service (high-frequency, all-day service, shorter waiting times).
- Pre-board fare collection and fare verification, ensuring faster service.
- Clear route maps, signage, and real-time information displays.
- Automatic vehicle location technology to manage vehicle movements.
- Free transfers between lines.

[43] Citation from Wright (2005): "Bus lanes are street surfaces reserved primarily for public transport vehicles on a permanent basis or specific hourly schedule. Bus lanes are not physically segregated from other lanes. While the lanes may be painted, demarcated, and sign-posted, changing lanes is still feasible. In some cases, bus lanes may be shared with high-occupancy vehicles, taxis, and/or mom-motorised vehicles. Bus lanes may also be open to private vehicle usage near turning points".

The extent to which the above mentioned characteristics are actually utilised within the system will determine the local circumstances, where BRT is integrated. In small and medium-sized cities, according to Wright (2005), it might be the case that not all of these features are feasible to achieve due to costs and capacity constraints.

Compared to other public transfer alternatives, such as light rail/metro, the most attractive features of BRT are:

- Low infrastructure costs, high operational capacity and compatible operational speed (see Table 5.2).
- Ability to be implemented within a short time period (1-3 years after conception).
- Flexible and scalable nature of BRT infrastructure, meaning that the system can be cost-effectively adapted to a range of city conditions (Caldes at al., 2007). BRT system can also be implemented as a supplement to a rail system (light rail/heavy rail) and function as a feeder service, or, it can also be a first stage for an eventual rail transit line (Wright, 2005; Zheng & Jiaqing, 2007).

Table 5.2 *Comparison of mass transit options*

	BRT	LRT [44]	Metro[45]
Initial costs (million$/km)	1-8	10-30	15-30 (at grade) 30-75 (elevated) 60-180 (underground)
Operational capacity (passengers/hour/direction)	15,000-35,000	10,000-20,000	up to 60,000
Speed (km/h)	15-25	15-25	30-40

Source: IEA, 2000.

Since the integration of BRT system in the city requires the restructuring of road's geometry, reserving a segregated lane specifically for bus transit, this simultaneously provides an opportunity to improve the infrastructure for NMT transportation. Segregated lanes for bicycles and pedestrian sidewalks on BRT corridors can significantly enlarge transportation opportunities for low-income population or people who travel for short distances, ensuring that all-income groups have rights and access for transportation[46] (DIMTS, 2008).

Beside these features, when properly designed and implemented, a successful BRT system contributes to the following objectives (Caldes at el., 2007):

- Decrease passenger's trip length.
- Decrease traffic congestion.
- Decrease local pollution.
- Optimise the existing transport modes in the area (e.g. metro).
- Improve life quality of the society.

However, the exact characteristics of each BRT strongly depend on the local conditions and limitations, availability of resources and environment where the system is been operated (Wright, 2005; Caldes et al., 2007). On one hand, it might seem that large buses with high occupancy can displace a high number of small vehicles (e.g. for every day commuting), potentially reducing both congestion and local emissions. However, on the other hand, if buses are strongly polluting and/or are under-occupied, then the impact on emissions or congestion or both could

[44] Citation: "Light rail or light rail transit (LRT) is a form of urban rail public transportation that generally has a lower capacity and lower speed than heavy rail and metro systems, but higher capacity and higher speed than traditional street-running tram systems" (wiki, 2010).

[45] Metros include subway and heavy rail transit (elevated and at grade). 'At grade' means 'at the ground level. (IEA, 2010).

[46] In this research, integration of a special NMT infrastructure (or its improvement) on BRT corridors will be considered as a contribution to social 'equity' (see sections 4.2, 6.3, 7.3 and 8.3).

even be negative. Therefore, the achievement of a clean, efficient, attractive and affordable public transportation system can only rely on the implementation of a proper integrated transportation policy (Caldes et al., 2007). This may require a change in transportation planning and roadway management practices, for example, giving busses a priority in the traffic, as well as a change in transit regulations and urban design, e.g. increase of city's development near BRT routes (VTPI, 2010).

5.3 History of BRT

The history of BRT comprises the variety of previous efforts to improve the transit conditions and experience for the customer. The first wide-scale development of the BRT concept occurred with the development of the 'surface subway' system in Curitiba (Brazil) in 1974 (Wright, 2005). The city initially planned to construct a rail-based metro system; however, a lack of sufficient funding finally resulted in the implementation of a more creative approach. That time Curitiba began a process of developing busway corridor originating from the city centre, instead of metro lines. Today the modernistic Curitiba's busway system with 'tubed' stations and 270-passenger bi-articulated buses[47] represent a world example of BRT (see Figure 5.3), (Wright, 2005).

Figure 5.2 *BRT system of Curitiba with modernistic 'tubed' stations and bi-articulated busses*
Source: Wright, 2005.

In the mid 1970's, other BRT applications were developed in cities of North and South America. However, the overall replication of the BRT concept that time was rather slow. Only in the late 1990s, the BRT concept became more widely known. It was launched in Bogotá (Colombia) and Los Angeles (United States), based on the Curitiba example. The potential of BRT as a high-quality and low-cost mass transit option was also recognised by OECD nations such as Australia, Canada, France, Germany, Japan, the United Kingdom, and the United States. The transfer of BRT technology from Latin America to OECD nations has made BRT one of the most famous examples of technology transfer from the developing to the developed world.

5.4 General insight in selected countries and cities

In this research, three developing countries in Asia were selected for the evaluation of their BRT systems, respectively, Indonesia, India and China. All these countries have two main common characteristics, such as being rapidly developing and located in Asia. Contextual factors (general characteristics) of these countries are summarised in Table 5.3 and later discussed in the text.

[47] A bi-articulated bus is an extension of an articulated bus (bus that can bend in the middle, also known as a 'tandem bus'), having three passenger compartment sections instead of two. For this reason, these buses have the addition of an extra axle. Due to the extended length, bi-articulated buses are mainly used on high frequency core routes or bus rapid transit schemes instead of conventional bus routes (Wiki, 2010).

There are currently 20 BRT systems operating in Asia and about 50 are planned to be constructed (Hidalgo, 2009). Since this research is focused on ex-post evaluation, only BRT systems which are in operation were considered. In Indonesia, these is only one system in operation, which is Jakarta BRT[48] (Hidalgo, 2009, TransJakarta, 2010). In India there are two BRT systems in operation (Hidalgo, 2009) and from those two systems Delhi BRT was selected. Delhi BRT, as well as TransJakarta, is located in the capital of the country and, as a preliminary literature study showed, it represents an interesting case for the research. In China there are currently 8 BRT systems in operation (Hidalgo, 2009), however, as in the other selected countries, BRT system in the capital of the country was chosen, respectively, Beijing BRT. From all BRT systems existing in Asia, the selected BRT systems are in operation for the longest time period[49]. In this way, TransJakarta, Delhi BRT and Beijing BRT represent the three case studies which are going to be conducted in this research (see Chapter 6, 7 and 8).

Tabel 5.3 *General characteristics of the selected countries*

Country name	Indonesia	India	China
Population, total (million)	240	1,185	1,338
Population density, persons/km^2	119.8	359.2	139.6
Evaluated region/country size, km^2	1,904,570	3,287,260	9,640,820
Urban/rural population, %	52	29	43
GDP/capita (level of economic development), $(PPP)/capita	4,000	3,100	6,567
GDP growth rate, % (annual)	4.5	6.5	8.7
Population below poverty line, %	17.8	25	2.8
Continent/region	South-eastern Asia	Southern Asia	Eastern Asia
Human development index	73.4	61.2	77.2
Gini index[50]	34.3	36.8	47

Source: wiki, 2010.

The selection of target countries, as indicated in Table 5.3, was made from the perspective, that, since being located in one region, these countries might have more similarities rather than developing countries located around the world. Therefore, BRT systems operating in Indonesia, India and China might have more in common. Each of the selected countries is going to be shortly described as follows.

The People's Republic of China, commonly known as China, is the most populous country in the world with over 1.33 billion people and the world's fastest growing major economy, see Table 5.3 (Darido, 2006, The WF, 2010). Since market-based economic reforms, which were introduced in 1978[51], China is characterised with a remarkable economical growth and high level of industrialisation. Main problems in China are: rapidly aging population due to the one-child policy[52], a rural-urban income gap and environmental degradation due to a high level of urbanisation and motorisation (Darido, 2006).

48 Official name of Jakarta BRT is 'TransJakarta' (Gobrt, 2007), see Section 6.2.

49 Data availability was the second concern for the selection of the case studies.

50 A low Gini coefficient indicates a more equal distribution, with 0 corresponding to complete equality, while higher Gini coefficients indicate more unequal distribution, with 1 corresponding to complete inequality (wiki, 2010).

51 During the past 30 years, China's economy has changed from a centrally planned system (largely closed to international trade) to a market-oriented economy with rapidly growing private sector (Darido, 2006). Reforms started in 1978 with the phasing out of collectivised agriculture. During the time these reforms have expanded to include: "the gradual liberalization of prices, fiscal decentralization, increased autonomy for state enterprises, the foundation of a diversified banking system, the development of stock markets, the rapid growth of the non-state sector, and the opening to foreign trade and investment" (ReportLinker, 2010).

52 One-child policy is a measure for population control in China. It is also known as a family planning policy. The policy was introduced in 1978 and it restricts a married urban couple to have more than one child. In several cases exemptions are allows, including rural couples, ethnic minorities and parents without any siblings (wiki, 2010).

India is developing, the second most populous country in the world, and has about 35 cities with a population of more than 1 million (FAI, 2010). Total population of India, which is also known as a largest democracy in the world, accounts for 1.18 billion people (wiki, 2010). Economic reforms since the beginning of 1990s have transformed this country into one of the fastest growing economies[53]; however, it is still characterised with high poverty, illiteracy, corruption and malnutrition.

Indonesia is a the world's fourth most populous country, with a population of around 240 million people (see Table 5.4). The country comprises 17,500 islands and it was under Dutch colonialism for three and a half centuries, which facilitated a continuous economical development (wiki, 2010; Cybriwsky & Ford, 2001). Indonesia still faces such problems as poverty, unequal resource distribution among regions, unemployment, inadequate infrastructure, corruption and high level of motorisation (wiki, 2010; MWH, 2005; RoI, 2008).

During the analysis of the selected countries, the following common characteristics were identified: large amount of population, large country size, high GDP growth rate, similar HDI index (see Table 5.3) and the fact that all these countries experienced economic crises and reforms. However, besides common characteristics, there are also major differences among those countries, respectively, different political regime and different religion. The latter two factors have a significant influence on people's life style, their social values and behaviour.

Besides the selected countries itself, it is important to take a look on the cities with BRT systems, which are going to be evaluated in this research. The main contextual data on these cities are summarised in Table 5.4.

Table 5.4 *Main characteristics of the cities with the selected BRT systems*

	Jakarta (Indonesia)	Delhi metropolitan area (India)	Beijing (China)
Population, total [million]	8.8	12.6	10.1
Population density [thousand persons/km^2]	12.9	11.5	7.4
Evaluated region size [km^2]	740.3	1,485	1,368

From Table 5.4 can be seen that the selected cities are similar contextual-wise. For this reason, the influence of city's contextual factors on the performance of the selected BRT systems will be eliminated[54].

However, the performance of the new BRT systems is dependent not only on the contextual factors of the city where it is implemented, but mainly on the general performance of transport system in this city (concludes based on the literature study). Common characteristics of transport systems in developing countries were discussed in Section 5.1. However, it has to be mentioned that the performance of transport system in a particular city mainly depends on the local conditions and therefore, in each case study it needs to be analysed separately. The organisation and functioning of transport systems in each selected city will help to understand the functioning of the new BRT systems, and explain the evaluation results.

53 Citation from The WF, (2010): "Economic liberalization, including reduced controls on foreign trade and investment, began in the early 1990s and has served to accelerate the country's growth, which has averaged more than 7% per year since 1997. India's diverse economy encompasses traditional village farming, modern agriculture, handicrafts, a wide range of modern industries, and a multitude of services. Slightly more than half of the work force is in agriculture, but services are the major source of economic growth".

54 Country contextual factors are important when evaluating transferability potential of a particular policy. In this research, BRT transferability in those countries was already defined, based on Macario & Marques (2008) study (see paragraph 4.2.3).

In the following chapters of the report, the selected BRT case studies will be conducted according to the scheme as discussed in Section 4.3.

6. TransJakarta BRT case study

6.1 General insight and characteristics of the urban transportation system in Jakarta

Jakarta is the largest and most populous city of Indonesia with a population about 8.5 million people. The general data on Jakarta are presented and discussed in Section 5.4. As all large cities in Asia, Jakarta is strained by transportation problems. The rapid population growth and increasing numbers of motor vehicles resulted in a high congestion level on Jakarta's roads, accompanied by air pollution and noise problems. It is estimated that in Indonesia the transportation sector contributes to about 80% of air pollution; remaining 20% are contributed by other sectors, such as industry, forestry and domestic activities (MWH, 2005).

According to Dalkmann (2010), over the last five years, the number of motorised vehicles in Jakarta was growing at a pace of about 9% per annum. Currently there are more than 9.6 million motorised vehicles registered in Jakarta (DPMJ, 2008); 91% of these vehicles are private (about 23% of these vehicles are private cars and the rest 77% are two-wheelers and scooters; DPMJ, 2008), serving in general about 44% of all trips. Only 3% of all motorised vehicles in the city are public transport vehicles, serving about 56% of all trips[55] and the rest 6% of motorised vehicles in Jakarta are trucks (Dalkmann, 2010; DPMJ, 2008). These numbers indicate that public transport (bus; there are no rail-based systems yet) remains the main motorised transportation mode for a majority of Jakarta's inhabitants (mainly these are people with low/medium income level), (Abubakar, 2008). Considering NMT transportation, on this transportation mode mainly rely low-income population of Jakarta. According to Ernst (2009), NMT trips account for 53% from all trips made by people of this income group. Due to a high and constantly increasing amount of motorised vehicles on the roads and low roads' capacity, a significant speed reduction, from 38km/h in 1995 to 17km/h in 2007, was registered on the roads of Jakarta (RoI, 2008). According to Cybriwsky & Ford (2001), several road-building projects for accommodation of a fast growing number of motorised vehicles, such as a construction of new freeways, ring roads and flyovers, failed to keep the pace with growing demand and were congested as soon as they were opened[56]. While giving a lot of attention to the private vehicles' sector and constructing the new road infrastructure, public transport sector in Jakarta was left without additional attention.

Before the integration of BRT, Jakarta's public transport system was characterised as inadequate in terms of fleet size and service quality (ADB, 2001; GENUS, 2009). Almost 90% of buses registered in Jakarta were operating with an average load factor of 130% (ADB, 2002) and only a limited number of buses were air-conditioned. Most of the buses in Jakarta were owned by private companies (private sector) and bus drivers could hire a vehicle from these companies on a daily basis. For this, drivers had to pay a fixed rate which didn't include fuel, vehicle operating and maintenance costs. Such a system has resulted in irresponsible drivers who were competing with each other to carry as many passengers as possible[57] without a concern for passengers' safety and comfort, creating overloading of the buses and dangerous driving pattern (e.g. loading and unloading passengers in the middle of the road), (ADB, 2002; Sutomo, 2006, RoI, 2008). Buses were not leaving stations until they were filled up with passengers, service schedules were not respected, causing long waiting time for passengers. In general, buses operating on Jakarta's roads were poor-maintained, since bus drivers themselves were not

[55] Data on NMT was not included in this modal split.

[56] Even though new roads were constructed, in general it was poorly developed in the city. Insufficient capacity on the secondary roads, which are serving the main arterial roads, was one of the main factors exacerbating the traffic congestion (The UNU, 1996).

[57] The amount of passengers was determining the income of bus drivers (ADB, 2002; Sutomo, 2006; RoI, 2008).

willing to invest into vehicle's maintenance[58] and there was not much incentive for the maintenance from the operator side (private companies). After the economical crisis in Indonesia (late 1990s), this situation became worse, since the revenues from bus operation could not cope with increasing service costs (Sutomo, 2006). Due to this, as Sutomo (2006) reports, the availability of buses reduced for 40%, making public transit more inconvenient and unattractive transportation mode.

In the city centre of Jakarta there is no such a transportation mode as metro existing, as it is in the other Asian cities analysed in this research (i.e. Beijing and Delhi), which makes bus transit the main means of public transport in Jakarta (Soehodo, 2010). However, poor service quality, unsafe and unreliable bus operation drove people towards private vehicle ownership[59], in such a way contributing to higher congestion level and air pollution problems in the city. In order to cope with the problems mentioned, a so-called 'Transportation Masterplan' was developed for Jakarta and its surrounding suburbs by several stakeholders in Jakarta, which consisted out of number of measures, including the three core aspects. As Dalkmann (2010) report, these three aspects were: "(1) public transport development, including MRT/subways, LRT/monorail, BRT/busways and waterways; (2) traffic restraint, including high occupancy vehicle zoning (3-in-1 policy[60]), road pricing and parking restraint; (3) network capacity improvement, including road parking optimisation, promotion of NMT and integration of signalling/intelligent transport system".

As one of the elements of the 'Transportation Masterplan', Jakarta began the improvement of its transportation system by designing the BRT system[61]. The decision to introduce BRT system in Jakarta was made in 2001 by Jakarta's Governor Sutiyoso (Matsumoto, 2007), who was re-elected partly because of the promise to implement BRT plan into a reality (see Section 6.4). Characteristics and technical details of this system are going to be discussed in the following section.

6.2 TransJakarta BRT 1st corridor characteristics

Figure 6.1. TransJakarta 1st corridor (SOP, 2010)

TransJakarta is the official name of Jakarta BRT system, which is the first BRT system in Indonesia. It was built with the objective of providing a fast, comfortable and affordable public transportation system for Jakarta's inhabitants (Gobrt, 2007).

The system currently has 8 corridors in operation and it is planned to have 10 corridors (out of 15 planned) at the end of 2010 (Jakartapost, 2010).
The 1st corridor of 12,9km, which is known as 'Block M-Kota' was implemented within 8 month from the design stage until the opening (Hook & Ernst, 2005). The corridor was opened for operation in January 2004 and it is mainly composed of

[58] There was no guarantee that one bus driver will operate always one particular vehicle. Besides this, bus drivers had to pay a fixed fare for bus renting and for the fuel. This was already quite high expenditure which they apparently didn't want to increase (concluded by author based on the literature study).

[59] Other main factor that facilitated high level of car ownership in the city was a social status. Possession of a car was prestige and it indicated on the higher social status of a person with a car, compared to a person who could not afford to have a car (discussed in Chapter 2).

[60] This policy restricted the access to a part of the central business district of Jakarta to vehicles (personal cars) containing less than 3 people (Dalkmann, 2010).

[61] According to Matsumoto (2007), Asian economy crisis in the late 1990s could have motivated policy makers to seek first for a lower costs solution for public transportation sector improvement and therefore could have effected to some extent the decision of BRT system integration in Jakarta instead of e.g. metro system.

business and shopping destinations (Wright, 2005). It has a physically segregated bus lane, located on the side of the road (see Figure 6.1). The corridor consists of 20 stations with a 250 - 860m interval and it is under operation from 5:00 till 22:00[62] (wiki, 2010b; Alvinsyah & Zulkati, 2005). The main elements of the corridor and corridor's technical data are summarised in Annex A_1.

According to the literature study performed on Jakarta BRT, the following operational aspects (positive and negative) of the 1st corridor were defined.

The main positive aspects identified are: initiated modal shift from personal cars to BRT (13-14%) (ITDP, 2004; Alvinsyah & Zulkati, 2005); CO_2 reduction and local air quality improvement (Matsumoto, 2007; Caldes, 2007); increased bus transit speed in comparison to the average traffic speed in the city[63] (Rini, 2003; Alvinsyah, & Zulkati, 2005); decrease in travel time for bus commuters (Susilo et al., 2007; Caldes, 2007)[64].

Main negative aspects identified are: the lack of feeder service (Matsumoto, 2007; Hook, 2005); low capacity and availability of BRT buses (Hook & Ernst, 2005; ITDP, 2003); and a fast deteriorating road infrastructure (Hook & Ernst, 2005; ITDP, 2003).

TransJakarta was built as an isolated system without functioning feeder services[65] (Hook, 2005). The mixed traffic lane was converted into BRT lane without the expansion of the road space for a mixed traffic. According to Hook (2005), no regulatory reforms were made in the corridor. As a result, the conventional buses[66] were continuing their operation in the mixed traffic lane after BRT integration, while the new BRT buses were operating on the new BRT bus lane. The fact that old buses were still operating in the mixed traffic contributed to congestion increase in the mixed traffic on the BRT corridor (Hook, 2005).

Low capacity buses operating on the corridor (capacity of 85 passengers; Matsumoto, 2007) had only a single door. Due to this, there was a slow boarding of passengers on BRT buses, causing bus queuing at the stations. Due to a limited number of buses available in the system, the maximums capacity of TransJakarta was about 3200 passengers/direction/peak hour (ITDP, 2003). However, the real demand for BRT was higher, respectively around 4000 passengers/direction/peak hour (ITDP, 2003). As the result, BRT buses were overcrowded and a constant overweight of the buses caused fast deterioration of the road infrastructure[67] (ITDP, 2003; Hook & Ernst, 2005).

However, these negative aspects of the 1st BRT corridor operation were realised during the first year of TransJakarta operation (Hook & Ernst, 2005). According to the literature study performed, during the construction and operation of the following seven BRT corridors similar mistakes were tried to be avoided. The performance evaluation of the currently operating TransJakarta BRT system is going to be presented in the following section.

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62 After 22:00 the corridor is closed for maintenance (wiki, 2010b; Alvinsyah & Zulkati, 2005).

63 According to Rini (2003), the average traffic speed on the roads of Jakarta is 11-18km/h.

64 Due to the lack of information, the positive aspects of the 1st TransJakarta BRT performance will not be discussed in details.

65 For instance, small buses could be used as a feeder service to carry passengers to the BRT corridor, where the passengers could switch to BRT buses for their further transportation. According to Hook (2005), there was an attempt to introduce a feeder service in TransJakarta, however, this attempt failed. The reason for this failure is the fact that buses in Jakarta are rented by the bus drivers (bus drivers are not employees of the private companies which own the buses) and therefore problems arose with fare price negotiation.

66 Buses which were operating in the corridor before the integration of BRT system.

67 BRT lane on the 1st corridor was made from the asphalt and only the later BRT lanes were made from the concrete, which is stronger material (ITDP, 2003; Hook & Ernst, 2005).

6.3 Evaluation of the currently operating TransJakarta BRT system

Technical data on TransJakarta BRT system are summarised in Annex A_2. These data are used later in this section as a base for the explanation of the evaluation results.

The evaluation of TransJakarta BRT performance was made applying the new developed methodology. The results of this evaluation are presented in Table 6.1 and later discussed in the text.

Table 6.1 *Evaluation of TransJakarta BRT system*

Main blocks	Criteria	Policy/country	Certainty of evaluation	Ref[68]
		TransJakarta (Indonesia)		
	Reduction of local pollution	high	HDA, HA	1-6
	Reduction of noise level in urban areas	n/a	LDA	
	Contribution to CO_2 reduction	high	HDA, HA	1-6
	Increased road safety	high	LDA, HA	7,16
	Equity	high	LDA, LA	8-11
	Travel convenience	moderate	HDA, HA	12-16
	Revenues/costs ratio	high	LDA, HA	17-19
	Reduced congestion	moderate	HDA, LA	3,7,11,16, 18-20
	Creation of new job market	n/a	LDA	

Reduction of local pollution (NOx, PM, CO & SO_2) and contribution to CO_2 reduction. According to Soehodo (2010) and Yunita (2008) the following annual reduction of local pollutants was reached in 2008 on TransJakarta BRT corridors: 23 tons of PM_{10}; 386 tons of NOx and 3362 tons of CO. Based on the data acquired, several calculations were performed in order to estimate the TransJakarta's contribution to local pollution and CO_2 emission reduction (see Annex A_3). The results showed that annually TransJakarta contributes to about 0.46% NOx reduction from Jakarta's transportation sector[69]. Based on this, it was concluded that TransJakarta BRT on yearly basis could contribute to 0.3-1% reduction of local emissions from Jakarta's transport sector. This reduction is made mainly due to the fact that there are newer buses in operation on the BRT bus lanes, which comply with higher emission standards (EURO II and III; Chinabrt, 2009) in comparison to conventional buses on Jakarta's roads (Tatamotors, 2010). As a result, TransJakarta's contribution to '*reduction of local pollution*' was evaluated as 'high'.

Considering '*CO_2 reduction*', calculations similar to '*reduction of local pollution*' were performed (see Annex A_3 data). The results of calculations showed that the annual reduction of about 1.33% CO_2 emissions in Jakarta's transport sector was reached due to TransJakarta's operation. This result can be considered rather robust, since it is calculated using information with high agreement (see Annex A_3). According to ITDP (2010), 37,000 tons of CO_2 were reduced in 2009 due to the operation of newer buses on TransJakarta. Based on this, TransJakarta's contribution to '*CO_2 reduction*' was also evaluated as 'high'.

Reduction of the noise level in urban areas. During the study performed, no data concerning TransJakarta's contribution to a reduction of noise level in Jakarta's urban area were found. Taking into consideration that transportation systems is a dynamic system that changes over

68 (1) Soehodo, 2010); (2) Yunita, 2008; (3) Chinabrt, 2009; (4) Tatamotors, 2010; (5) Susandi, (2004); (6) Syahril, et al., (2002); (7) Jakartapost, 2010; (8) Hook, 2006; (9) Hook, 2005a; (10) Primanita, 2010; (11) ITDP, 2010a; (12) Dirgahayani, et al., 2007; (13) Alvinsyah & Zulkati, 2005; (14) RoI, 2008; (15) Gobrt, 2007a; (16) Hook & Ernst, 2005; (17) Dalkmann, 2010; (18) Caldes, 2007 (19) Hidalgo et al., 2007; (20) Rini, 2003.

69 Calculations could only be made for NOx emissions due to the lack of data on the other components, such as PM, CO and SO_2.

time, it is rather hard to estimate whether the noise level was changed as a result of TransJakarta integration in Jakarta's transportation system. According to the methodology, this field cannot be evaluated (n/a).

Increased road safety. Literature study (ITDP, 2010a; Jakartapost, 2010; RoI, 2008) on TransJakarta BRT showed that the integration of TransJakarta BRT into Jakarta's transportation system in general has improved transportation safety issues for bus commuters and pedestrians. This is mainly due to the installation of a special BRT shelters and the improvement of pedestrian sidewalks (the latter is discussed under 'equity'). The access to the BRT buses currently can only be done from special shelters and, in order to reach these shelters, commuters have to use special overpasses. According to Jakartapost (2010), before TransJakarta was integrated in Jakarta's transportation system, people could 'hop' on and off the buses anywhere they wanted (mostly not at the bus stops), resulting in a high level of road accidents. However, these were no precise data found on the reduction of road accidents after TransJakarta's opening. TransJakarta's contribution to '*increased road safety*' was evaluated as 'high'.

Equity. TransJakarta made public transportation more affordable for Jakarta's inhabitants and it became rather available transportation mode for a 'low-income' population. According to Hook (2006), roughly 40% of TransJakarta's passengers are 'low-income' inhabitants[70]. 47% of all people participating in this survey indicated that transportation with TransJakarta has reduced their travel costs, 29% said that their transportation costs remained the same and 21% indicated a travel cost increase. Besides travel affordability, TransJakarta made travelling more accessible and safe for pedestrians by improvement of the sidewalks along the corridors (Hook, 2005a). Considering bicycles, currently there are no special bicycle roads existing in Jakarta (Primanita, 2010). According to ITDP (2010a), there is a lack of integration of such facilities in the entire Jakarta's transportation system including TransJakarta BRT corridors (even though there is a high demand for it; ITDP, 2010a). Currently, ITDP Indonesia is working on master plan for the bicycle lane facilities as means of BRT feeder system.
Considering the affordability of service for Jakarta's poor as well as the improvement of travelling conditions for Jakarta's pedestrians, TransJakarta's contribution to '*equity*' was evaluated as 'high'.

Travel convenience. Literature analysis showed, that in general, TransJakarta BRT made public transportation more convenient for Jakarta's inhabitants, however there are still some barriers and problems. Based on a passenger survey conducted by Jakarta's Communication Agency in 2006 (Dirgahayani, et al., 2007), the main reasons for using TransJakarta busway were identified: shorter travel time (indicated by 65% of respondents) and improved comfort (indicated by 20% of respondents). According to Susilo et al., (2007) and Hook (2006), since BRT buses are faster than other vehicles on BRT corridor (see '*congestion reduction*') it enables passengers to travel about 10-20 minutes faster than regular bus users. Already four months after 1st BRT corridor launching date, a modal shift of 14% was reached[71] (Alvinsyah & Zulkati, 2005; RoI, 2008). However, the main problem of TransJakarta, which makes travel less convenient, is the undersupply of buses in the system[72]. As the result, TransJakarta buses are overcrowded and often delayed (Gobrt, 2007a; Hook & Ernst, 2005), contributing to long waiting time for passengers. For this reason TransJakarta's contribution to '*travel convenience*' was evaluated as 'moderate'.

Revenues/costs ratio. Compared to other BRT systems analysed in this research, TransJakarta has the lowest investment costs per kilometre (see Annex A_2, B_2 and C_2). There is currently 124

70 There were in total 350 people participating in the TransJakarta commuter's survey (Hook, 2006).
71 Modal shift from personal cars to BRT.
72 Citation from Gobrt, (2007a): "The Jakarta Post reports that only 94 of 126 buses are deployed in the second and third corridors and only 32 of 113 planned buses operate on the four newest busway corridors". According to The SCC (2010), 20 buses that are running on Corridor 8 are reassigned from the seven existing corridors.

km of TransJakarta busway. Assuming that US $ 1.35 million[73] is the average investment cost per kilometre for the entire TransJakarta system, the total investment in the system would be about US $ 193 million. As indicated in Annex A_2, the commuter price for using BRT is US $ 0.39 and there are about 82 million people using TransJakarta BRT on a yearly basis (data on 2009; Dalkmann, 2010). Roughly calculating, revenue from system's operation would be ($ 0.39*82,377,655[74]) about US$ 32,1 millions/year. Using these data, it was calculated that system's payback time is about 6 year, which is rather low in comparison to other BRT systems, such as Beijing BRT (see Section 8.3), meaning that currently TransJakart should have reached it's 'break-even point[75]', since it is in operation from 2004. Based on this, '*revenues/costs ratio'* was evaluated as 'high'.

Reduced congestion. The average BRT bus speed on TransJakarta in 2007 reached in average 17km/h (Hidalgo et al., 2007), which was about the same as the average speed on Jakarta's roads with a mixed traffic (RoI, 2008). However, TransJakarta was constructed on the existing roads of Jakarta, without the extension of road's width, in this way leaving less space available for a mixed traffic (Chinabrt, 2009; Hook & Ernst, 2005). Due to the reduced space availability and constantly growing amount of vehicles on Jakarta's roads (see Section 6.1), the average speed in the mixed traffic lanes in TransJakarta's corridors was reduced, contributing to the higher level of congestion[76] in those lanes (ITDP, 2005a; Jakartapost, 2010). The precise number of speed reduction in the mixed traffic lane was not defined during this study. Nevertheless, taking into consideration time saving for bus commuters, transportation with TransJakarta became faster than with conventional buses that indirectly indicates on higher TransJakarta's operational speeds. These speeds, respectively, could be reached on corridors, which are less congested than mixed traffic lanes. Taking into consideration all the facts mentioned, TransJakarta's contribution to '*reduced congestion*' was evaluated as 'moderate'.

Creation of new job market. There were no precise data found on this indicator during the literature study performed, therefore, it is hard to carry out an objective evaluation of this criterion. According to the methodology, TransJakarta's contribution to a 'c*reation of new job market'* was not evaluated.

Based on discussion of the evaluation results presented in Table 6.1 it can be concluded that currently TransJakarta BRT is a successful system, showing mainly a high performance in all evaluation blocks[77]. However, this success was achieved gradually. The analysis of the 1st TransJakarta corridor showed (see Section 6.2) that the performance of that corridor was rather far from the desired performance and there were several lessons to be learnt for the future implementation/operation of TransJakarta BRT corridors. The main barriers of TransJakarta 1st corridor operation (e.g. such as the lack of feeder system) have been steadily overcame, resulting in a more successful functioning of the system. This proves the fact that the monitoring of the system (especially in the initial system's operation stage) is a very important step in BRT projects, which leads to essential lessons drawing for the future.

[73] No precise data on the investment costs per kilometre on the other TransJakarta BRT corridors except for the 1st corridor was found.

[74] Due to the lack of data, this number was used for each operation year of TransJakarta. However, it has to be strongly considered that the annual ridership during the initial operation stage of TransJakarta was lower, as the system was smaller in size, consisting out of less corridors compared to system's size in 2009 (in total 8 corridors in operation).

[75] Income is still been generated even after the investment costs are been repaid.

[76] The precise information on the speed reduction in the mixed traffic lanes was not found during the performed literature study.

[77] The definition of when BRT system can be considered as 'successful' is given in section 4.2.

6.4 Factors that impeded/facilitated the performance of TransJakarta

This section contains a short summary of the factors which facilitated a successful performance of TransJakarta:

1) *Strong political will*. The introduction of TransJakarta into Jakarta's transportation system was initiated and supported by Jakarta's Governor Sutiyoso. According to Matsumoto (2007), Sutiyoso made a promise to implement the BRT plan in Jakarta[78], which was/is one of his major political commitments. Partly because of this promise he was re-elected as a Governor of Jakarta (Matsumoto, 2007).
2) *Learning from Latin America good practices in BRT system operation*. As Matsumoto (2007) reports, in February 2003 a delegation of 15 Indonesian representatives from the government, local parliament, private sector, press and NGOs attended the International Seminar of Human Mobility (ISHM seminar) in Bogotá. In this seminar the practices of TransMilenio BRT in Bogotá were presented, which was the major focus of the Indonesian delegation. After this seminar, in May 2003, the Governor Sutiyoso himself visited Bogota's TransMilenio bus system. As a result, several elements of TransMilenio were integrated into TransJakarta, which are: "physically separated bus lanes in the median of the roadway, high floor bus stations and wheel chair-usable pedestrian ramps, high-floor buses, pre-board fare payment with turnstiles using electronic smart-cards" (Matsumoto, 2007). The task force was formed to implement TransJakarta BRT, consisting out of five Jakarta's agencies: Transportation, Public Works, Parks, Utilities, and Planning, together with three local municipalities within Jakarta (Dalkmann, 2010, Caldes, 2007).
3) *Support from international organisations and technical assistance of experts*. The Institute for Transportation and Development Policy (ITDP) provided technical assistance for the TransJakarta project based on a grant from the US Agency for International Development (USAID), (Matsumoto, 2007; Caldes, 2007). ITDP sponsored several lesson-drawing activities, such as the visit of stakeholders to the ISHM seminar in Bogotá, visits to Jakarta by key consultants who developed the TransMilenio system, including the visit of the former Mayor of Bogota to Jakarta (Matsumoto, 2007).
4) *Public support*. According to Matsumoto (2007) and Caldes, (2007), after the ISHM seminar in Bogotá, transportation experts asked for public involvement in the process of improving the transportation problems in Jakarta. Experts noted that public participation was one of major factors of a successful performance of TransMilenio BRT system. Since then, various public surveys were performed, web-discussion blogs were initiated where commuters could exchange their experience and share opinion on TransJakarta performance. Besides, a local newspaper 'JakartaPost' is actively following changes and progresses in the TransJakarta BRT system, giving recent information and updates to the public (Jakartapost, 2010; Matsumoto 2007).
5) *TransJakarta BRT implementation together with other policies*. TransJakarta was not implemented as a 'stand-alone' policy, but it was supplemented by so-called '3-in-1'policy (see footnote 60), which was in operation since 1992 (Rini & Sutomo, 2006). The 1st TransJakarta corridor was build in the area where '3-in-1' policy was functioning, reducing the number of vehicles entering this area (restricted zone) during the morning peak-hours. It has to be mentioned that the '3-in-1' policy was in force only from 6:00 till 10:00 in the morning, meaning that a congestion relief was reached only during those hours. After the integration of TransJakarta bus system into the same area where '3-in-1' policy was in force, '3-in-1' policy was extended for functioning during the evening hours, respectively, from 16:00-19:00. This interaction of BRT and '3-in'1'policy contributed to a general reduction of congestion level during peak hours on BRT corridors (Rini & Sutomo, 2006).

[78] Sutiyoso had a substantial control over the budget allocation, which was required for the BRT project implementation (Matsumoto, 2007).

7. Delhi BRT case study

7.1 General insight and characteristics of the urban transportation system in Delhi

Delhi (National Capital Territory of Delhi or NCT), is one of the largest metropolis in India (FAI, 2010). The name Delhi is often used referring to New Delhi, the capital of India, which lies within the metropolis. In this research, the term 'Delhi' will be used to refer to the entire Delhi NCT area, as the integration of BRT system was/is planned to be made in the Delhi NCT area, covering also New Delhi.

For decades, Delhi, similar to other mega-cities of developing world, faces transportation, economic, and environmental challenges[79] (Bose et al., 2001). A fast growing population, urban sprawl, and the third highest level of income per capita in India (Sahai & Bishop, 2009), resulted in a high demand for motor vehicles. The numbers of private vehicles on Delhi's road has grown about 12 times over the last 30 years (see Table 7.1, including the projection for 2020), (DIMTS, 2010a; Bose, et al., 2001).

Table 7.1 *Motor vehicles in Delhi (1000s)*

Year	Scooters and motorcycles	Cars/jeeps	Auto-rickshaws[80]	Taxis	Busses	Freight	All motor vehicles
1971	93	57	10	4	3	14	180
1980	334	117	20	6	8	36	521
1990	1077	327	45	5	11	82	1,547
2000	1568	852	45	8	18	94	2,584
2010	2958	1472	403	14	39	223	4,809
2020	6849	2760	209	28	73	420	10,339

Source: Bose et al., 2001.

Bose et al (2001) estimated that in 2010 Delhi motor fleet will stand at 4,8 million vehicles (table 7.1). Due to a poor data availability, no precise number of currently registered motorised vehicles in Delhi could be found. However, Narain, 2008 report that in general Delhi motor fleet is increasing by other 1000 vehicles each day. In order to accommodate the increasing number of motor vehicles and increase the throughput of roads, the roads of Delhi have been continuously widened, combined with the construction of various flyovers and underpasses, which was mainly accompanied by the reduction (up to removal) of pedestrian facilities (Gupta, 2008). Currently, already 21% of Delhi's geographical area is occupied by roads, which is the highest in Asian mega-cities (Bhatia & Jain 2009). However, due to the rapid rate of motorised vehicle increase, new widened roads, flyovers and underpasses became soon congested at a similar rate as other roads of the city.

79 Since 1990's transportation is by far the largest source of air pollution in the city, contributing to more than 72% of total pollution (data on 2001, GOI, 2003). According to Bose et al., (2001) and Kandlikar (2007), air pollution levels in Delhi greatly exceed health-based standards (see Annex B_1 data).

80 Auto-rickshaw and bicycle-rickshaws are vehicles with three wheels, like a covered motor scooter with a back seat for passengers. These vehicles are used as a taxi in Asian cities (Encarta, 2010).

From the literature study performed, several reasons of high level of congestion on Delhi roads were determined. Besides the high increase of motorised vehicles and inadequate infrastructure, congestion was also caused by a variety of vehicles moving at different speeds in a mixed traffic (see Figure 7.1). In general, there is a lack of modal separation[81] and tive traffic regulation on Delhi roads. ing to Bose et al., (2001), many problems with Delhi's transportation system are due to miscommunication and disjoined decisions of several organisations involved in the transportation sector. There is no single agency existing at central, local or state level, which would be entirely responsible to plan, finance, build and manage transportation projects and traffic in general in Delhi (Bose et al., 2001).

Figure 7.1 *Traffic in Delhi (Bose et al., 2001)*

The strategy of new widened roads and flyovers in Delhi was entirely oriented on private cars[82] (cars in particular), serving only 10-13% of commuters, neglecting NMT and the public transportation system (Bhatia & Jain 2009; DIMTS, 2008). Even though the amount of busses in the city is not large in comparison to private cars and motorcycles (table 7.1), according to DIMTS (2008), in 2007 around 42% of total personal trips in Delhi were made by the use of bus service. Motorcycles and two-wheelers (scooters), which are present in Delhi in the largest amount (table 7.1) contribute to about 22% of Delhi's transport modal share. Together with bus transit, it is the most common way of transportation among people with a low-income (Bose, et al., 2001; DIMTS, 2008). Delhi's poor, who cannot afford buying motorcycle, entirely rely on NMT that contributes to 10-15% of total transport modal share[83] in Delhi.

Another important public transportation mode in Delhi is metro, which was opened for operation in 2002 and currently it is carrying approximately 1 million passengers on daily basis (DMR, 2010; wiki, 2010). Delhi metro opening was a significant contribution to unloading of Delhi's roads (wiki, 2010) and due to a high demand, expansion of the network is an ongoing process[84]. However, in comparison to other modes, transportation by metro is more expensive[85] and therefore is mainly used by the middle/high income population.

Despite a large variety of transportation modes in Delhi, Badami & Haider, (2007) reports that all income groups of Delhi still heavily rely on bus transit. However, the quality of the service is poor. In general, the public bus service in Delhi can be characterised as unreliable, inconvenient (as many buses are non-operational), time consuming and overcrowded. Operational bus fleet is fast ageing, with poor conditions and shortened life time, due to a heavy use[86]. The functioning of bus transit in Delhi is rather similar to Jakarta as discussed in Section 6.1. This is, a majority

81 Dedicated facilities for buses, rickshaws, bicycles and pedestrians.

82 Most popular car in India is Tata Nano, which is available at a comparably low costs (US$2.500) among middle/high income population (Gupta, 2008).

83 Indian poor, which account for about a third of India's urban population (Gupta, 2008) and most of whom lives in slums (unauthorized settlements without formal arrangements for water and electricity supply), in general have a different transportation pattern compared to higher-income class residents, who lives in formal housing. As Gupta (2008) reports, generally for Indian poor population, cycling and walking accounts for 50 to 75% of the commuting trips, while people living in formal housing sector (middle/high income people) rely on buses, cars and two wheelers. Therefore, despite high accident rates and hostile infrastructure, low cost modes in India are widespread, as their users do not have other choices for transportation (Gupta, 2008).

84 Average costs for construction is $ 44.6 million/km (Badami, 2009).

85 Costs for one trip in metro is about Rs. 30, which is $ 0.64, per one trip (wiki, 2010).

86 At the end of the 2009, the Delhi Transport Corporation accounted for about 3800 buses. In 2008/09 as many as 498 buses were added to the fleet while 232 were discarded. The strength and age profile of the fleet that year showed, that about 2100 buses were more than 8 years old, meaning that about 56% of the Delhi's bus fleet is averaged. (Bhatia & Jain, 2009).

of Delhi's buses are run by private operators, whose profit mainly depends on the number of passengers carried. A survey conducted by Badami & Haider, (2007) revealed that "private bus operators, because of the profit motive, stop to pick up passengers at unscheduled stops, causing over-loading and inordinate journey times, and often bribe the police to avoid being fined for overcrowding".

Other problems with bus service in Delhi are the lack of coverage, especially in the periphery of the city (Badami & Haider, 2007).

Considering the fact that on bus transportation rely the biggest part of Delhi's inhabitants there is an essential need for an improved low-cost public transportation system[87].

Instead of focusing on private vehicle transfer, Delhi transportation system should switch towards the transfer of people, improving the bus service performance, giving priority and dedicated road space to busses and NMT. As the first step towards a better functioning of low-cost public transportation system in Delhi was taken by the introduction of BRT system.

7.2 Delhi BRT characteristics and technical details

The concept of introduction of BRT in Delhi was agreed in 1995, after the Central Pollution control board commissioned a study for reduction of vehicular pollution in Delhi. The final report with recommendations to introduce segregated bicycle lanes and bus lanes was released in 1997. In 2002, an international workshop on high capacity bus system was organised by Delhi Transport Corporation, which was the major step in introduction of the BRT system in Delhi (DIMTS, 2010). However, based on the literature study performed, no information on any additional evaluation studies (e.g. a detailed project report including current demand analysis[88]) before constructing the 1st BRT corridor in Delhi was found. This type of reports contain essential information for the planning of a BRT system. According to DCH (2009), the 1st corridor of Delhi (5.6 km of it) was built based on the results from transport demand survey, which was performed in 2003. These results were significantly outdated for the present traffic context, taking into consideration that vehicle population of Delhi annually increases at a rate of about 8% (see Table 7.1). Currently, the corridor manager DIMTS (Delhi Integrated Multi-Modal Transit System[89]) is given the responsibility for preparation of the detailed project reports and transport demand forecast models for the construction of the other planned BRT corridors in Delhi (DCH, 2009).

In 2004 the design of the first Delhi BRT corridor, connecting Dr. Ambedkar Nagar and Delhi Gate, was initiated and consequently in 2006 the construction works on this corridor started. It was opened for trial operation in April, 2008 (DIMTS, 2010). This corridor is 14.5 km long, crosses over 17 intersections, and consists of 29 stations. At present only 5.6 km part is under operation (Thole, 2008; EMBARQ,2009; Hidalgo, 2009). This corridor is the 1st Delhi BRT corridor and as of August 2010 the only one.

Separate bus lanes in the middle of the road (with the width of 3.3 meters) have been provided in order to allow for faster travel times and safer trips (DIMTS, 2010). The corridor is the first in Delhi to offer designated lanes for NMT (bicycles and pedestrians separately). The change

[87] Delhi metro cannot completely replace the bus-based system, since it is more used by people with higher income. As DIMTS (2010) reports, even in well developed metro networks, such as in London and Paris, busses still account for a larger number of passenger trips than a metro.

[88] According to Wright & Hook (2007), city's demand analysis for daily transportation is the basics for BRT system design. Citation from Wright & Hook (2007): "Understanding the size of customer demand along the corridors and the geographical location of origins and destinations permits planners to closely match system characteristics to customer needs".

[89] DIMTS is Delhi BRT Corridor Manager. It is responsible for the operation and maintenance of the BRT corridor (DIMTS, 2010)

after the integration of BRT system in this corridor is shown in Figure 7.2a and 7.2b. The general data of this corridor are summarised in Annex B_2.

Figure 7.2a *Road design from Dr. Amberkar Nagar to Delhi Gate before BRT. Cross section.*
Source: DIMTS, 2010.

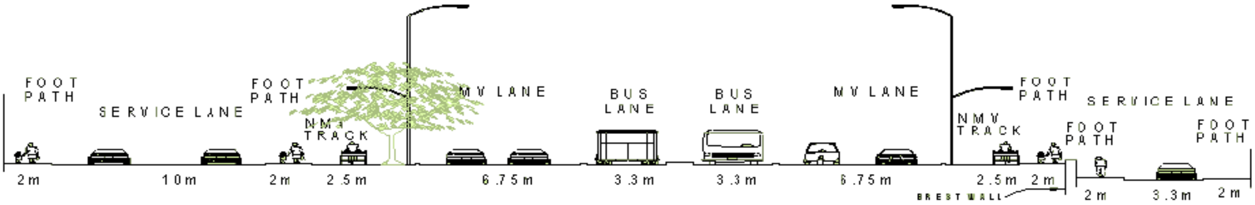

Figure 7.2b *Road design from Dr. Amberkar Nagar to Delhi Gate after BRT. Cross section.*
Source: (DIMTS, 2010)[90]

From Figure 7.2a and 7.2b it can be seen that after the integration of BRT system, the road design from Dr. Ambedkar Nagar to Delhi Gate has become more structured. In this design, no space from pedestrians was taken for roads extension, instead, unpaved 6 m of road (Figure 7.2a) was dedicated for a foot path and partly for a service lane. The carriage way, compared to the situation before modifications, became smaller, resulting in lesser space for motorised vehicles. However, as all buses were entirely moved from mixed traffic to a special lane, the traffic speeds on each lane were expected to be increased, compensating for a reduced space.

The traffic volume on the BRT corridor is high. More than 135000 vehicles are daily registered on this corridor (in 16 hours). 35-40% of these vehicles are cars, however, they carry only 15-20% of the total commuters. Busses, which accounts only for 2-2.5%, carry around 55-60%[91] of the total commuters. The rest of transportation is done by NMT, two-wheelers or rickshaws (DIMTS. 2010, Rawat, 2009, EMBARQ, 2009).

During the peak hours, about 12,000 passengers per hour are commuting both directions on this corridor, however, this number varies from 11,000 to 13,000 depending on the information source (DIMTS, 2008, 2010, EMBARQ, 2009, Thole, 2008). About 500 new low-floor Compressed Natural Gas (CNG) buses were purchased in Delhi in 2009, which is about 13% of the total bus fleet (Bhatia & Jain, 2009; Hidalgo, 2010). A part of these buses is used on the BRT corridor. However, the main disadvantages of the BRT corridor is that all types of buses, including new and old buses, are allowed to use to the BRT bus lane. During the peak hours, about 120-200 buses of different types per hour are operating on the BRT corridor, however, this number varies depending on the information source used (DIMTS, 2008, 2010, EMBARQ, 2009). Data presented indicate that the average bus capacity operating on the corridor during peak hours is about 75-110 people.

[90] MV line - motorised vehicle line (DIMTS, 2010).
[91] This was also one of the main reasons for BRT introduction (DIMTS, 2010).

7.3 Evaluation of the currently operating Delhi BRT system

In comparison to other BRT systems, which are evaluated in this research (i.e. TransJakarta and Beijing BRT), there is only one corridor in operation in Delhi BRT and it is in operation only for two years. However, the Delhi BRT system was still chosen for evaluation as it represents an interesting and a valuable case for lessons drawing and future BRT system development in India. The results from the evaluation are represented in Table 7.2 and explained below.

Table 7.2 *Evaluation results of Delhi BRT by applying new developed methodology*

Main blocks	Criteria	Policy/country	Certainty of evaluation	Ref[92]
		Delhi BRT (India)		
	Reduction of local pollution	moderate	LDA, LA	1-7
	Reduction of noise level in urban areas	n/a	LDA	
	Contribution to CO_2 reduction	moderate	LDA, LA	1-7
	Increased road safety	high	LDA, LA	9
	Equity	high	HDA, HA	1;2;5;10
	Travel convenience	moderate	HDA, HA	2;3;5;11-13
	Revenues/costs ratio	high	LDA, LA	3;5;10
	Reduced congestion	moderate	HDA, HA	2;3;9;11;14;15
	Creation of new job market	moderate	LDA, LA	9

Reduction of local pollution (NOx, PM, CO & SO_2) and contribution to CO_2 reduction
No primary data on local pollution and CO_2 reduction on BRT corridor were found. However, this criterion still can be evaluated by analysing other system performance indicators.

Since the introduction of Delhi BRT, about 500 new CNG buses (which is about 13% of the total Delhi's bus fleet, see Section 7.2) were purchased and started their operation on BRT corridor (partly). As a result of this fleet improvement, several old conventional buses were discharged from the operation[93]. The average bus speed in the 'Bus lane' significantly improved due to the separation of buses from the mixed traffic (discussed under '*travel convenience*'). This indicates a faster and more 'fuel-efficient' transportation of people. About 42% of personal trips in Delhi are made by the use of bus service (discussed in Section 7.1), leading to the conclusion that, in general, the transportation efficiency of the main part of Delhi's commuters improved. All buses in Delhi are operating on CNG, which is cleaner fuel in comparison to diesel[94] (Swartz, 2000), however, new BRT buses have more efficient fuel utilisation and higher passenger capacity, which eventually would result in lower generated emissions per passenger transferred. Considering all facts mentioned, Delhi BRT contribution to 'reduction of local pollution' was evaluated as 'moderate'.

Considering *'contribution to CO_2 emission reduction'*, a general bus fuel switch in Delhi from diesel to CNG (CAI, 2010) might have contributed to small increase in GHG emission from

[92] (1) Bhatia & Jain, 2009; (2) Hidalgo, 2010; (3) EMBARQ, 2009; (4) CAI, 2010; (5) DIMTS, 2008; (6) Swartz, 2000; (7) TataMotors, 2010; (8) LSI, 2010; (9) DIMTS, 2010; (10) DTC, 2010; (11) Rawat, 2009; (12) ENS, 2009; (13) Hidalgo, 2009; (14) DCS, 2005; (15) ITDP, 2008a; (16) Macario & Marques, 2008.

[93] However, the exact number of these buses was not determined from the literature study performed.

[94] According to Swartz (2000): "CNG mixes more uniformly in the ignition chamber, causing more complete combustion and fewer pollution (particularly NOx and PM_{10}) than diesel fuel". However, as Swartz (2000) also reports, the use of CNG results in higher greenhouse gas emissions (particularly CH_4) in comparison to diesel. The reason for that is diesel engines are more efficient than CNG engines. "Operating at high compression ratios, a large percentage of the fuel's available energy is converted into usable work" (Swartz, 2000). Due to a higher fuel efficiency of diesel engines, generally lower carbon dioxide emissions are produced.

transport sector in Delhi (see footnote 93). BRT buses are also operating on CNG and, from this point of view, BRT introduction didn't contribute to CO_2 emission reduction. However, new buses complies to new emission standards (TataMotors, 2010), meaning more efficient fuel utilisation, in comparison to conventional buses, and lower level of generated emission (including CO_2 emissions). During this research, no other information that could help the evaluation of this criterion, e.g. modal shift, was found. Based on the analysis made (more quantitative analysis was not possible), Delhi BRT contribution to '*CO_2 reduction*' was also evaluated as 'moderate'.

Reduction of the noise level in urban areas
During the literature study, there were no data found on the noise level change in Delhi BRT corridor area. According to LSI (2010), the main sources of urban traffic noise are motors and exhaust systems of cars, buses, motorcycles and other motorised vehicles. From available information it is only known that the new BRT buses were added to Delhi's bus fleet for operation on BRT corridor. These buses, though, partially substituted old conventional buses. Data on modal shift on the BRT corridor also are not known[95]. It has to be considered, that the transportation system is dynamic and vehicle population on Delhi's roads is constantly increasing. Therefore it is hard to estimate whether the overall number of vehicles on BRT corridor has changed and whether it causes changes in the noise level on BRT corridor. According to the evaluation methodology, this criterion could not be evaluated (n/a).

Increased road safety
Positive effect from BRT system is an increased safety for Delhi commuters. As DIMTS (2010) reports, there are 180 road marshals working on the corridor in order to guide bus passengers, help children and elderly people to cross the road, manage traffic and instruct people to follow traffic rules. However, in order to access BRT station, commuters have to cross mixed traffic lane (in special allocated places/crosswalks) which is not very safe. There are no special pedestrian overpasses existing for a safe access to BRT station (DIMTS, 2010). Commuters, though, have to cross only two lanes at the time to reach BRT station, as stations are located in the median lane (bus lane). Before the introduction of BRT system, commuters had to cross six lanes (as the bus stops for both directions were located on the curb-side of the road; the road consists of 6 lanes). From this perspective commuter safety has improved, but there are no precise data in the literature about the reduction of road accidents on the operational part of Delhi BRT corridor. Besides, the introduction of a special lane for NMT (described under 'equity') also considerably improved safety issues of people, who are using this transportation mode on daily basis. Taking into consideration all mentioned above, Delhi BRT contribution to '*increased road safety*' was evaluated as 'high'.

[95] These data could have indicated whether there could have been a reduction of car users on the BRT corridor.

Equity
Even though travelling in low floor AC (Air-conditioned) BRT busses is more expensive than in ordinary (old) buses[96], there is a good NMT integration in BRT corridor, which significantly improved travelling possibilities for low-income people. According to Bose et al (2001) and DIMTS (2008), NMT is the most common transportation mode among low-income population of Delhi. Before BRT corridor integration, cycling and walking on Delhi roads was unsafe and inconvenient, because there were no special lanes existing for NMT (Delhi roads did not have a clear lane separation, see Figure 7.1). Considering the new road geometry, there is a special lane for cycling (see 'NMV' lane in Figure 7.2b) and a special 'foot paths' separated from the motorised traffic on BRT corridor. DIMTS (2008) reports that a bicycle flow of 1200/hour was registered in peak hours on 'NMV' lane, which is the highest in the world after China. Improved pedestrian foot paths also improved pedestrian's transportation safety. Besides this, BRT bus shelters are now provided with the tactile tiles to guide blind people. Low-floor BRT buses provides the possibility to use public transportation for physically disabled people (in a wheelchair), (Bhatia & Jain, 2009; Hidalgo, 2010). The contribution of the BRT to 'equity' was evaluated as 'high'.

Travel convenience
The most significant improvement on BRT corridor was the increase of the average bus speed from 7-15 km/h (average traffic speed in the mixed traffic lane) to about 19 km/h (Hidalgo, 2010, Rawat, 2009, EMBARQ, 2009). Due to the increase of the bus speed, travel time for bus passengers reduced in average for 35% (ENS, 2009; EMBARQ, 2009; Rawat, 2009). However, this positive effect was offset with an increase of travel time for people, who are using other transportation modes. As EMBARQ (2009) reports: "the average time for motorised travel along the bus corridor decreased from 27 to 22 minutes. This is the combined effect of a reduction in travel time for bus users from 30 to 22 minutes, and increase in travel time for car users from 22 to 26 minutes. The average speed of buses along the pilot corridor has increased to 19 km/h. As a result, the average travel time for bus users has decreased by 35 %".

The increase of travel time for the other transportation modes was a result of malfunctioning of the traffic light system and other aspects (discussed under 'congestion reduction'). Nevertheless, from a perspective that the majority of Delhi's inhabitants are commuting by bus, the decrease in travel time for the bus commuters has in general a stronger impact on the transportation pattern, meaning that a major part of Delhi commuters spend less time on the transportation than they used to spent before the introduction of BRT. According to a survey results reported by Hidalgo (2009) and DIMTS (2008), 88% of 1500 respondents were positive about Delhi BRT system and think it should be extended. However, currently there are not enough buses on the corridor to satisfy the demand for bus service. In general, buses on the BRT corridor are overcrowded and there is a low frequency of buses during the evenings (DIMTS, 2010). Based on this, BRT contribution to '*travel convenience*' was evaluated as 'moderate'.

Revenues/costs ratio
The total investment costs for Delhi BRT 1st corridor were about US$ 3 million/kilometre[97] (DIMTS, 2008; EMBARQ, 2009). The costs for transportation in new air-conditioned BRT buses in the corridor vary from about $0.2 to $0.53, depending on the distance travelled (DTC, 2010). However, it has to be considered that old conventional buses are also operating in the same bus lane on BRT corridor. The fare for transportation in these (old) buses is two times lower than in air-conditioned BRT bus, respectively $0.11 - $0.32.

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96 Comparison of transportation prices: the costs for ordinary bus service, depending on the kilometres travelled, start from $ 0.11 to $ 0.32 (Rs. 5 to Rs. 15). Costs for low floor AC busses fares starts from $ 0.21 rising up to $ 0.53, depending on the distance travelled. For instance, adult's price for a trip up to 4 km on the ordinary bus is Rs.5 ($ 0.11). However, for the same distance using a new bus the price is doubled (Rs.10), (DTC, 2010).

97 For comparison, the average costs for the construction of Delhi's metro are about US$ 44.6 million/km (Badami, 2009).

It is known that about 12,000 passengers/hour (in peak hours) are using BRT. The total amount of passengers transferred daily on BRT corridor (bus lane) was not found during this study. Assuming that system is operating for 16 hours (from 6:00 till 22:00) and there are four traffic peak hours daily (two in the morning and two in the evening), a total number of 120,000 passengers/day[98] using bus service on Delhi BRT corridor was estimated.

The total length of Delhi BRT corridor is 14.5 km and the total investment cost of this BRT corridor are about US$ 43.5 million. Assuming that the system is operating 365 days/year, the revenue would be ($0.32[99]*120,000*365) about US$ 14 million/year, or 32% of the total investment. With this rough calculation it can be predicted that a pay-back time of Delhi 1st BRT corridor will be only about 3 years if no additional investment in this corridor will be made. Compared to other BRT systems evaluated in this study, Delhi BRT has the fastest pay-back time period. Based on this, '*revenues/costs ratio'* was evaluated as 'high'.

Congestion reduction

Congestion reduction in Delhi BRT case was evaluated as 'moderate', based on several aspects:

- Slow speeds on the bus lane. Currently all types of busses (new and old) are allowed to use the bus lane. This results in frequent breakdowns of old and deteriorated busses, causing the reduction of the average bus speed and contributing to increased congestion on the bus lane (Hidalgo, 2010, EMBARQ, 2009, DIMTS, 2010). Even though the average speed on the corridor has improved (see discussion under '*travel convenience*'), it is rather far from potential speeds on BRT corridors, which is 24-32 km/h (DCS, 2005).
- Problems with traffic signals. According to DIMTS (2010) report and Rawat (2009), the current traffic signals are not appropriate to discharge the traffic of the corridor at the peak hours. This control system has long cycle time[100], more than 240 seconds (efficient system should have less than 60 seconds, DIMTS, 2010) and unsaturated phases[101]. The signal phasing[102] used at BRT corridor gives only about 25 % of the green time to mixed traffic in the peak flow direction. Before the introduction of BRT, mixed traffic received about 45 - 50 % and the other part was devoted to pedestrians (Rawat, 2009). Due to this, traffic flow is not stable and creates long queues of cars in motorised vehicle lanes as well as in the bus lane. This is one of the major factors contributing to high congestion level on the BRT corridor (Hidalgo, 2010, EMBARQ, 2009, DIMTS, 2010).
- Bus stations location is another issue that contributes to a high congestion level on the BRT corridor. According to ITDP (2008a), bus stops are located in a close vicinity of intersections[103], causing the queuing of the buses already at the intersections itself. (ITDP, 2008a; DIMTS, 2010).
- Reduction of road space for car users. Delhi BRT corridor was integrated in Delhi transportation system without the expansion of road width. The geometry of the corridor's road was changed only, allocating special lanes for bus transit and for NMT (see Figure 7.2). This measure reduced the net space available for car users, resulting in more congested 'MV' lane and longer travel times for this commuters group. According to DCH (2009), the main criticism against Delhi BRT is coming exactly from this commuter group.

98 Assuming that off-peak hour bus ridership is 40% less than during peak hour (author).
99 In this calculation $0.32 is a transportation fare in the new BRT buses.
100 Cycle time can be defined as "time required for one complete sequence of signal displays (sum of phase green and inter-green times). For a given movement, cycle time is the sum of the durations of red, yellow and green signal displays" (GOR, 2010).
101 The degree of saturation can be defined as "the ratio of arrival (demand) flow rate to capacity of road/intersection during a given flow period. Also known as the volume to capacity ratio" (GOR, 2010).
102 Signal phasing in GOR (2010) is defined as: "sequential arrangement of separately controlled groups of vehicle and pedestrian movements within a signal cycle to allow all vehicle and pedestrian movements to proceed".
103 The exact distance from an intersection to a bus stop is not mentioned in the literature, however, according to ITDP (2008a), BRT bus stops should be located around 70 meters away from the intersection (indicating that currently bus stops are located closer than 70 meters).

Creation of new job market

Currently Delhi BRT is a small system, however, the construction, operation and maintenance of this BRT corridor created a new job market. First, BRT corridor was given a corridor manager (DIMTS). Second, about 180 road marshals were located on the corridor for guiding people and managing the traffic (see 'increased road safety'). Next to it, for bus operation on BRT corridor (new buses), bus drivers had to take an educational course[104], which required additional educating personnel. However, as the job market created is not large[105] yet and could be expanded in the future, '*creation of new job market*' was evaluated as 'moderate'.

Other aspects considering Delhi BRT system functioning, which were identified during this case study but not mentioned in the text, are summarised in Annex B_3.

Based on the results from the evaluation, Delhi BRT currently cannot be considered as a successful system[106]. However, despite all negative sides and problems discussed, it succeeded in meeting of some key objective of BRT system. The major part of the Delhi commuters are travelling at greater speeds with reduced average person travel time and therefore reduced person delays (Rawat, 2009). Besides, the main focus of the system is already put on the reduction of person's delay and not on vehicle delay, which is a big step towards sustainable urban transportation system.

7.4 Factors that impeded/facilitated the performance of Delhi BRT

Summarising the case study of Delhi BRT, it is rather important to indicate the main factors, which impeded a 'successful' performance of the system. These factors are:

- The lack of research in BRT project planning phase (discussed in Section 7.2) and current absence of BRT performance monitoring system (EMBARQ, 2010).
- The lack of technical support and participation of international organisations. According to Ghosh (2008), only state owned, mostly non-technical organisations, were involved in the project, including RITES[107], Delhi Integrated Multimodal Transport System (DIMTS), Indian Institute of Technology (IIT-Delhi) and the state transport department[108]. The only organisation which was equipped to provide technical knowledge to the project, so-called PWD (Public Works Department), was never really involved in the project (Ghosh, 2008). The reasons for this are not uncovered to public. No information upon the participation of external organisations in the Delhi BRT project was found during Delhi BRT case study.
- A strong criticism of the system by mass media (mainly from car-user's point of view).[109]
- The lack of technologies and BRT supportive infrastructure. Delhi BRT was implemented as a stand-alone policy, lacking such elements as e.g. feeder service to the system, parking facilities (see Annex B_3), and implementation of other policies, such as e.g. car restriction measures, etc.

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104 About 200 drivers were trained to insure better discipline in the bus lane (DIMTS, 2010).

105 Due to the lack of data it is hard to estimate whether with the same financial investments more jobs could have been created.

106 Results from the evaluation are not consistent with the definition of a 'successful' BRT system as defined in section 4.2.

107 Citation from DCH (2009): "RITES Ltd., a Government of India Enterprise, provides engineering, consultancy and project management services in the transport infrastructure sector. RITES Ltd. took professional advice to develop conceptual guidelines and design details for the BRT system."

108 Citation from DCH (2009): "The Transport Department of the Government of Delhi organised an International Workshop 'Bus Rapid Transit Delhi' in December 2005 to evaluate the deigns proposed. The designs were approved and recommendations presented to the Chief Minister of Delhi."

109 As DIMTS reports: "the negative media campaigns have converted even non-users of the existing BRT corridor into anti-BRT protestors. During presentation sessions at different places it was observed that people are against the BRT Corridor because they don't have any information about the system. They learnt everything from the media. Children are very sensible towards the surrounding environment and, therefore, receiving appropriate information and education, can be 'champions of environment friendly system' like BRT" (DIMTS, 2010).

As discussed in this entire chapter, Delhi BRT system needs significant improvements for its successful operation.

8. Beijing BRT case study

8.1 General insight and characteristics of the urban transportation system in Beijing

The development of China and its transport system have been strongly related to country's political system. A centrally planned economy for many years hindered the development and advancement of the transportation system across the country (Shaheen & Martin, 2006). Before the beginning of 1980s, walking, cycling, and public transit were the primary transportation modes. A gradual modernisation of China's transportation system began in 1980s since the economic reforms and market liberalisation (Shaheen & Martin, 2006; Boahua, 2008). At that time, the focus from public transit was shifted to private vehicles and the car manufacturing became a national priority. A goal of a central government of China, as a part of country's five-year development plan (from 1991 till 1995) was to make car manufacturing a leading domestic industry (Shaheen & Martin, 2006; Boahua, 2008).

As Darido (2006) reports, from 1986 to 2005 the number vehicles in Beijing increased from 0.6 million to 3.39 million[110], an average annual increase of 21%. Currently about 1000 new private vehicles are added to Beijing's traffic daily, which makes Beijing to be the most motorised city in China (Darido, 2006; Shaheen & Martin, 2006). The change in modal share of daily trips in Beijing from 1986 to 2005 is shown in Table 8.1.

Table 8.1 *Modal share of daily trips in Beijing (excluding walk)*

	1986	2000	2005
Car	5.0	23.2	29.8
Public transit	28.2	26.5	29.8
Bicycle	62.7	38.5	30.3
Taxi	0.3	8.8	7.6
Others	3.8	3.0	2.5
Total	100	100	100

Source: Boahua, 2008; Huapu, 2003.

From Table 8.1 can be seen that the use of personal cars for daily transportation increased from 5% (in 1986) till 29.8% (in 2005). In contrast, the share of public transit almost didn't change over this time. Until 2000, the share of public transit declined owing to a rapid increase of personal vehicles, which was/is more comfortable and prestige mode of transportation in Beijing (Darido, 2006; Boahua, 2008). Next to it, the use of bicycles in Beijing declined almost by 50% from 1986 till 2005. However, it is important to mention that despite rapid increase of private car ownership, bicycles in 2005 still had the largest modal share in the city.

Besides the transportation modes mentioned, Beijing also have a growing metro system (Boahua, 2008, ChinaDaily, 2006). The first metro line was opened in 1971 and currently the network has in operation 9 lines with the total length of 228 km, carrying about 4 million passengers on a daily basis (Boahua, 2008, wiki, 2010c). However, the existing network cannot meet the mass transit needs of the city and therefore it currently undergoes a rapid expansion (ChinaDaily, 2006). Nevertheless, the transportation in Beijing's metro is more expensive in com-

[110] Including about 2.2 million of private cars, which is roughly 150 vehicles per 1000 inhabitants (Darido, 2006).

parison to a conventional bus transit[111] and therefore this transport mode became less affordable transportation mode for people with low-income[112].

The rapid growth of motorised vehicles in Beijing (in the entire country in general) and much slower growth in urban road network, contributed to a high level of congestion. The average traffic speed in the centre of Beijing in the past 10 years decreased by 50% and currently it is in average 10-12km/h (Darido, 2006; Tyrer, 2007). Motor vehicles in Beijing and other largest cities of China became the main source of urban air pollution (Darido, 2006). According to Huapu (2003), setting cars as a major mean of daily transportation (while ignoring the public transportation sector) by China's government, was the main reason of public transit deterioration and rapid increase in private vehicle ownership, leading to a high level of congestion and other problems related to a rapid motorisation in the city. Instead of upgrading public transit sector, the primary focus of the government was the expansion of the roads[113] and parking facilities in order to satisfy increasing demand of cars (Huapu, 2003).

In the beginning of 21st century, China's government realised that the problems with traffic congestion and car ownership became too severe and therefore critical actions had to be taken for situation improvement. The accessibility of poor, elderly and disabled people to a public transport service was also a growing issue, that indicated the necessity for the improvement of the transportation system and its functioning.

Since then, China's government shifted the focus from a private car sector to a public transportation sector, which needed to be significantly improved. In 2004, urban public transport became a key strategic objective of Chinese government to tackle the congestion problems in the country (Darido, 2006).

Next to Chinese government, a consortium of international organisations, such as the David and Lucile Packard Foundation, the Energy Foundation and the William and Flora Hewlett Foundation initiated the China Sustainable Energy Program (CSEP), (Hossain, 2006). The mission of the program was: "to assist in China's transition to a sustainable energy future by promoting energy efficiency and renewable energy" (Hossain, 2006). As the transport sector is one of the largest consumers of country's oil, it was included in this program. As Hossain (2006) reports, the CSEP team has developed so-called 'China Transportation Program Strategy' and one of the main goals of this strategy was "the identification of BRT system as means towards a sustainable transportation system" (Hossain, 2006; Matsumoto, 2007). This incentive generated a high interest among local politicians and mayors. The Chinese government realised that BRT eventually would be the most cost-effective and fast strategy to tackle the congestion problem in the city, increase the bus speed in urban areas and by this stimulate a modal shift from personal cars to a public transit (Darido, 2006). Since then, BRT plans were made for 14 Chinese cities (Kangming, 2006). The 2008 summer Olympics together with the World EXPO 2010[114] were

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[111] Transportation fare in Beijing's subway is 3 CNY (yuan). Regular bus fare is 1 CNY and transportation fare on BRT lane is 2 CNY (Darido, 2006). For price comparison, 550 ml of water costs 2 yuan ($ 0.29), half of loaf of bread - about 4.8 yuan ($ 0.7), 12 eggs - 14.5 yuan ($ 2,13), potatoes (500g) - 3.5 yuan ($ 0.51), (SIB, 2010).
1 CNY (Chinese Yuan Renminbi) is equal to 0.1472 $ (United Stated Dollar). Conversion rate on June 25, 2010. http://www.xe.com/ucc

[112] Citation from Wang (2005): "In 2002 the ratio between rich and poor incomes was 4.53 to 1; in 2003 it reached 4.7 to 1, and in 2004 5 to 1. The income gap among different professions has also increased. For instance, the highest annual salary of insurance salespeople can reach 240,000 yuan (US$ 30,000) or US$ 2,500/month. However, the lowest annual salary of housekeepers is only 6,540 (US$ 818) or US$ 68/month. Even in the same profession, the salary of managers can be 13 times more than ordinary employees".

[113] The city layout, styles of old districts and land availability were the main constrains for the expansion of road network in Beijing (Huapu, 2003). Expanded roads soon became congested due to a large number of new private vehicles on the roads.

[114] "The World Expo is a large-scale, global, non-commercial Exposition. It aims to promote the exchange of ideas and development of the world economy, culture, science and technology, to allow exhibitors to publicise and display their achievements and improve international relationships. Having 150-year history, this event is often regarded as the Olympic Games of the economy, science and technology" (EXPO, 2010).

two major stimulating factors for BRT introduction in Beijing, which was considered as a supplement for Beijing's subway system (Matsumoto, 2007). Due to this, the construction of BRT system became one of the "most-committed projects by Beijing municipal government" (Matsumoto, 2007).

8.2 Beijing BRT 1st corridor characteristics

Beijing BRT is the first bus rapid transit system in China (ITDP, 2008b). The implementation of the 1st BRT corridor, also known as 'Southern Axis BRT Line One', took about 18 months from a concept to a functioning system (Darido, 2006). A 5,5 km segment of this line was opened for operation in December 2004, while the entire corridor, which is 16 km long, was launched one year later (ITDP, 2005; Deng & Nelson, 2010; Matsumoto, 2007).

The main elements of this corridor are represented Figure 8.1.

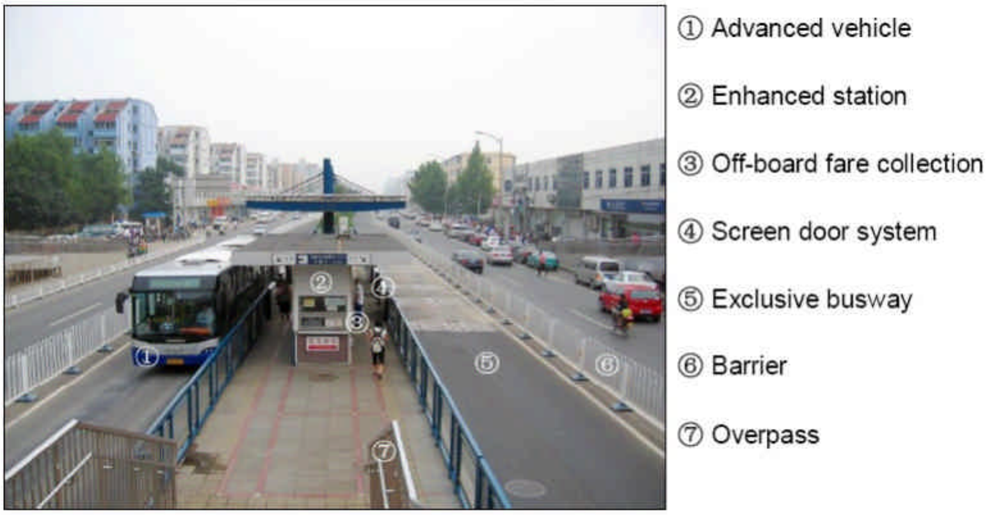

Figure 8.1 *Beijing BRT. Main elements of the 1st corridor*
Source: Deng & Nelson, 2010.

From Figure 8.1 it can be seen that the corridor has a segregated bus lane, which is located in the middle of the road, giving a priority to BRT over a mixed traffic (Deng & Nelson, 2010). It is characterised by advanced vehicles, enhanced stations, pedestrian overpasses and other elements, which are summarised in Annex C_1 together with technical data on this corridor's performance.

The operation and maintenance of the BRT system is made by the Beijing BRT Company Ltd., which was formed and owned by the Beijing General Bus Company (State -owned) and two private companies under the Beijing Transit Group (Darido, 2006). As Darido (2006) reports, the roadway infrastructure of BRT corridor was funded by the Beijing government, while the investment in the new bus fleet and station was done by BRT operator (Beijing BRT Company Ltd.).

Speed improvement. The speed of buses on BRT corridor in average reaches 25 km/h[115] (Zheng & Jiaqing, 2007; Darido, 2006) which is a significant improvement compared to the speed of regular public transit buses (16 km/h) before the opening of BRT. As Zheng & Jiaqing (2007) report, next to the speed improvement, the volume of motor vehicles in the corridor increased at all intersection of the corridor.

[115] Most of the BRT systems in the world are designed for 24-32 km/h operation (DCS, 2005).

Travel time savings and decrease in service delay. Since the opening of 1st BRT corridor with a separates bus lane, BRT commuter's travel time reduced from average 70 min to 40 min, which is about 40% reduction (Zheng & Jiaqing, 2007; Darido, 2006; Deng & Nelson, 2010). The main reasons for this reduction are: the priority of BRT buses over a mixed traffic in the corridor and corridor's intersections, and a pre-board fare collection system, together with pre-board ticket control.

Transit efficiency improvement. According to Zheng & Jiaqing (2007), the daily passenger volume of a single BRT bus on the 1st BRT corridor reaches 1037 passengers and the daily journey distance of 273 km. Compared to the regular buses operating in Beijing, these numbers are the following: daily passenger volume of a single regular bus is about 267 passengers and the daily distance driven by this bus is around 145 km (Zheng & Jiaqing, 2007). These numbers indicate that daily passengers volume of BRT bus is about 3.9 times higher than of a regular Beijing's bus, and the daily travelled distance of BRT bus is two times of a regular bus. This shows a significant increase in transit efficiency, simultaneously contributing to a reduction of environmental impacts of bus transit.

Increased passenger satisfaction with public transportation service. The Beijing 1st BRT line improved accessibility, comfort and convenience of commuters (Deng & Nelson, 2010; Zheng & Jiaqing, 2007). Besides, it has attracted modal shift from private cars to BRT (Deng & Nelson, 2010). However, many people[116] still found BRT vehicles overcrowded, as the number of vehicles operating in the 1st BRT corridor does not meet a growing demand for public transit in the corridor (Zheng & Jiaqing, 2007; Deng & Nelson, 2010).

Considering the negative aspects of Beijing BRT 1st corridor operation, during the literature study only two main aspect were identified, which overcrowded vehicles[117] and incomplete BRT integration in the transportation system.

In BRT 1st corridor there are no bicycle parking facilities (Chinabrt, 2009) which inhibits cycling from becoming one of the feeder service to the BRT system. According to Chinabrt, (2009), for physically disabled people, in a wheelchair, it is hard to reach the new BRT stations, since the access to the stations on the 1st corridor can be done by the use of pedestrian overpasses.

Currently there are 3 BRT corridors under operation in Beijing. Corridor 2 and 3 were opened in 2008 for the Olympic games (Hidalgo, 2009). During this research, an extensive data/information search on Beijing BRT corridor 2 and 3 was performed in various scientific publication, electronic journals, electronic newspapers, web-blogs, several web-pages of the organisations involved in Beijing BRT (e.g. ITDP web-side), etc. However, it was surprising to discover that few technical data on these corridors are available for public and this information was found only in couple of sources, i.e. Chinabrt, (2009) and Hidalgo, (2009). All data found are summarised in Annex C_2. There were no studies found on the performance evaluation of these corridors that could help to determine which practices from the 1st BRT corridor operation were used for the construction and operation of corridor 2 and 3. Due to the lack of information, these practices cannot be determined.

116 70% of respondents questioned by Zheng & Jiaqing, (2007). The exact number of respondents participating in the questionnaire is not identified in that article.

117 During the operation in the peak hours, the full loading rate of one BRT bus reached up to 130%, that is nearly two times more than the average full load of these buses (Zheng & Jiaqing, 2007).

8.3 Evaluation of the currently operating Beijing BRT system

The availability of technical data on the entire Beijing BRT system enables to perform the evaluation of this system by applying the new developed methodology. Evaluation results are shown in Table 8.2 and discussed afterwards in the text, similar to TransJakarta and Delhi BRT case studies.

Table 8.2 *Evaluation results of Beijing BRT by applying new developed methodology*

Main blocks	Criteria	Policy/country Beijing BRT (China)	Certainty of evaluation	Ref [118]
	Reduction of local pollution	high	LDA, LA	1-5
	Reduction of noise level in urban areas	n/a	LDA	
	Contribution to CO_2 reduction	high	LDA, LA	1-5
	Increased road safety	high	LDA, LA	4;7
	Equity	moderate	LDA, HA	2;4;5
	Travel convenience	high	HDA, HA	5-8
	Revenues/costs ratio	moderate	LDA, LA	3;4;5
	Reduced congestion	high	HDA, LA	1;2;4
	Creation of new job market	n/a	LDA	4;5

Reduction of local pollution (NOx, PM, CO & SO_2) and contribution to CO_2 reduction. During this research there were no data found on local air pollution reduction as a result of Beijing BRT implementation. However, the following facts on BRT operation were determined (see Annex C_1 and C_2). In the Beijing BRT system there are mainly low-emission vehicles in operation, which comply to EURO-III emission standard, which is an improvement compared to conventional buses. Together with the BRT system opening, several conventional bus routes were closed[119], reducing the amount of conventional buses on the roads. The average speed of bus transit on BRT corridors increased in comparison to a mixed traffic speed. Next to it, the efficiency of the bus transit improved, compared to conventional buses, since the high capacity BRT buses were integrated in the system (see Section 8.2). Since Beijing BRT opening, the modal shift to public transport was observed. According to Kangming (2006), it is predicted that by 2010 the share of public transport would increase to 40% (in 2005 it was 29.8%, see Section 8.1), that indicates a transition to a more sustainable transport system Based on the analysis of mentioned facts, the BRT contribution to 'reduction of local pollution' and 'CO_2 emission reduction' was evaluated as 'high'.

Reduction of the noise level in urban areas. There were no data available on this aspect as well. From the literature study performed it is only know that BRT corridor is constructed in the city centre with a segregated BRT lane in the middle of the road. None of the literature sources analysed in this research contained information about the installation of sound barriers along the corridor or other noise-preventive measures. Even though several conventional bus routes were closed due to the integration of BRT system, it is hard to estimate whether this contributed to a

118 (1) Hidalgo, 2009; (2) Chinabrt, 2009; (3) Tyrer, 2007; (4) Darido, 2006; (5) Zheng & Jiaqing, 2007; (6) Kangming, 2006; (7) Deng & Nelson, 2010; (8) Kangming, 2006; (9) Macario & Marques, 2008.

119 With the opening of the Beijing BRT 1st corridor (Line 1), three regular bus routed were discontinued and two routes were shorted to serve mainly as a feeder service to BRT corridor. Two other conventional bus routes were realigned to provide public transit service in Beijing's neighbourhood areas where this service was not available (Darido, 2006). As the result of this policy, about 300 standard buses were eliminated in the BRT corridor (in a mixed traffic lane), which resulted in high energy savings and environmental benefits. However, the elimination of the conventional buses caused serious overcrowding in the new BRT vehicles and at the BRT stations. Due to the high commuter ridership and the lack of BRT buses for operation in the corridor, a regular bus route (parallel to BRT lane) was restored and 25 conventional buses were added to this route in order to unload BRT service (Darido, 2006).

reduction of the noise level, since new BRT vehicles were added on the roads instead of conventional buses. Due to the lack of data, this field cannot be evaluated and, according to the evaluation methodology, it was marked as ‘n/a’.

Increased road safety. Commuters can access BRT station only by the use of overpasses, as BRT lane is physically segregated from the mixed traffic (Darido, 2006 and Deng & Nelson, 2010; this information was available only for corridor 1, see Annex C_1). Due to this, pedestrians do not have to cross the mixed traffic lane to reach BRT station, which makes their transportation safer. Based on this fact, Beijing BRT contribution to road safety increase was evaluated as ‘high’. However, there were no precise data in literature on road safety improvement since the introduction of BRT in Beijing.

Equity. Considering general affordability of public transit service, BRT system didn’t make it more affordable to low-income people. Transportation fare in new air-conditioned BRT buses is 2 yuan (US$ 0.29) per person per trip. Compared to the regular bus fare of 1 yuan, BRT transit became more expensive. On the other hand, BRT transit is still cheaper than metro service (metro fare is 3 yuan[120]). From this perspective, for faster and more comfortable transportation (compared to a conventional bus service) low-income people would rather choose for BRT than for metro service[121]. Besides the price for transportation, service accessibility for disabled people was also taken into consideration when evaluating BRT contribution to ‘equity’. As the results from literature study show, in Beijing BRT physically disabled people (in a wheelchair) do not have access to the stations, as pedestrian overpasses have to be used to reach the station (Chinabrt, 2009). However, this group of people was limited to public bus service even before introduction of BRT, as conventional buses were not ‘low floor’ buses, that would enable ‘easy’ transportation of people in a wheelchair. From this perspective, BRT didn’t contribute to equity in the use of public transportation service, but it improved the conventional bus service and made it more affordable than the metro.

No information on segregated bicycle lanes integration in Beijing BRT system was found. From this perspective, it is rather hard to evaluate, whether Beijing BRT improved travelling possibilities for people, who use bicycle as the main mode of transportation. Road conditions for pedestrians, though, have improved (Chinbrt, 2009). Taking into consideration all factors discussed, Beijing BRT contribution to ‘equity’ was evaluated as ‘’moderate’.

Travel convenience. According to the survey performed by Deng & Nelson (2010) Beijing BRT, especially BRT line 1, significantly improved accessibility and travel convenience of commuters. This information is consistent with other literature sources, such as Zheng & Jiaqing, (2007). Increased speed of bus transit, leading to a reduced commuters’ travel time attracted more people to use BRT service and resulted in a high daily service ridership (see Annex C_2). From commuters’ behavioural perspective, travel time and comfort are main factors (together with a price) which can affect commuter’s behaviour and particularly a choice for a transportation mode (chapter 2). Currently public transport modal share is growing and it is projected to reach 40% this year (see footnote 118). However, in peak hours BRT vehicles are overcrowded and BRT bus fleet capacity does not meet the demand for the service (Zheng & Jiaqing, 2007). Nevertheless, in this case study, Beijing BRT contribution to ‘*travel convenience’* was evaluated as ‘high’.

Revenues/costs ratio for Beijing BRT was calculated in a similar way as in TransJakarta and Delhi BRT (see Section 6.3 and 7.3). Investment in the Beijing BRT system per km was about US$ 5.8 million, however, this data was available only for the 1st BRT corridor (see Annex C_1). The costs for transportation in BRT system are $0.29 per trip. In general there are about 100,000

120 Price information on different public transit modes is taken from Darido, (2006).

121 Since BRT provides a cheaper transit option than metro, and it is more comfortable and faster than conventional bus, from financial perspective, people would choose to pay less and have a better service. Therefore, most likely, that they will choose BRT (see Chapter 2 for more discussion on people’s transportation behaviour).

commuters in corridor 1 per day (system operates 18 hours, from 5:00 to 23:00; Tyrer, 2007). It is known that in corridor 2 & 3 (together) there are in average 2000 passengers commuting per hour per direction in peak hours (Chinabrt, 2009), that is about 2 times less than in the 1st BRT corridor (see Annex C_1 and C_2). Based on this fact it was assumed that 50,000 commuters/day (in total) are using BRT 2&3 corridors. In this way, there would be about 150,000 commuters altogether transferred by the use of Beijing BRT.

The total length of Beijing BRT is about 34.5 km (Annex C_2). Therefore, total investment costs in the system would be about US$ 203 million. Assuming that the system is operating 365 days/year, the revenue from operation on yearly basis be ($ 0.29*150,000*365) US$ 15.88 million/year or 7.8% of the total investment, which results in a simple pay-back time of the BRT system of about 12.8 years[122]. Compared to Beijing's subway, particularly to Line 4, its payback time is about 22.5 years (Zheng & Jiaqing, 2007), which is 2 time higher than the current BRT system This line is 28.9 km long and therefore comparable to Beijing BRT. However, compared to other BRT systems evaluated in this research, Beijing BRT has the longest pay-pack time and the highest system investment costs per kilometre. Based on the analysis made, the '*revenues/costs ratio'* was evaluated as 'moderate'.

Congestion reduction. Based on literature (Zheng & Jiaqing, 2007; Darido, 2006) the average traffic speed on BRT corridors (corridor 1 in particular) increased in comparison to the average traffic speed in city centre of Beijing. The speed of BRT buses on the 1st corridor reaches more than 20 km/h (up to 26 km/h, Annex C_2). Corridor 2 & 3, however, operate under lower commercial speeds (about 17 km/h and 14 km/h in average, Annex C_2), which is still higher than the speed in a mixed traffic in the city centre (10-12 km/h; Darido, 2006; Tyrer, 2007). Increased transportation speeds consequently resulted in a decreasing level of congestion[123] and passenger travel time reduction of about 40% (see Section 8.2). Due to this Beijing BRT contribution to '*congestion reduction*' was evaluated as 'high'.

Creation of new job market. There were no precise data found on this indicator during the literature study performed, therefore, it is hard to carry out an objective evaluation of this criterion. According to the methodology, Beijing BRT contribution to a 'c*reation of new job market'* was not evaluated.

Results from the evaluation of Beijing BRT, as presented in Table 8.2, are consistent with the definition of a 'successful' BRT system (Section 4.2).

The general obstacle for Beijing BRT evaluation, as well as for the evaluation of other BRT systems in Asia, was the lack of data. According to Wright (2005), monitoring of the system performance is one of the crucial steps in BRT implementation[124]. Without a proper monitoring and data collection step it is rather hard to identify which parts of the system are of a good performance, which part are not functioning well and what has to be changed and/or improved. In Beijing BRT case, environmental and economical data are lacking the most. Data availability particularly concerns the operation of 2 and 3 BRT corridors. Based on this, it can be concluded that system monitoring and results' reporting with data accessibility for public need to be significantly improved

[122] No system's operational costs and discounting of future revenues was considered in this calculations (see evaluation methodology in section 4.2).
[123] Precise information on this particular indicator was not found.
[124] Citation from Wright, (2005): "To obtain an objective and quantifiable indication of a system's overall performance, a defined monitoring and evaluation plan is fundamental. The feedback from such a plan can help to identify system strengths as well as weaknesses requiring corrective action".

8.4 Factors that impeded/facilitated the performance of Beijing BRT

The most important factors contributing to a successful Beijing BRT system's implementation and performance were: strong political support; well-integrated institutional setup; knowledgeable planning teams and support from international institution and non-governmental organisations (Hossain, 2006; Chang, 2005; Matsumoto, 2007; Darido, 2006).

The initiation of the China Sustainable Energy Program (CSEP) by international organisations was the first fundamental step to BRT system integration in Beijing (Hossain, 2006). The Energy Foundation together with Hewlett-Packard Foundation provided grants to BRT study teams, technical support and a full-time consultants for BRT development (Hossain, 2006; Matsumoto, 2007). Institute for Transportation and Development Policy (ITDP) together with World Resources Institute (WRI)/Embarq were supporting and advising local governmental institution in transportation policy planning (Darido, 2006). However, one of the main factors for BRT introduction in Beijing was the support from the Mayor of Beijing (by accepting BRT plans for implementation). According to Matsumoto (2007), Mayors in China have high influence on transportation planning and budget allocation.

One of the reasons why the Mayor of Beijing strongly supported BRT implementation could be the fact that in the beginning of 21st century urban public transport became a key strategic objective of the Chinese government to tackle the congestion and air quality problems of the country (see discussion in Section 8.1). However, no other reasons that would explain a strong Mayor's support for BRT system integration in Beijing were found.

9. Result analysis

The analysis of the results obtained during the BRT case studies will begin with the discussion of the common aspects of the 1st BRT corridors.

In order to be able to make a meaningful comparison between BRT corridors together, these corridor have to have some common characteristics. In case of TransJakarta, Delhi BRT and Beijing BRT, 1st corridors represented the initial stage of BRT system operation and these corridors are of the similar length. Considering the fact that these corridors are also implemented in the cities with similar characteristics (i.e. population density) and similar patterns of transport system in these cities, the analysis and comparison of the performance[125] of those corridors could be made.

The analysis (see Section 6.1, 7.1 and 8.1) showed that the operation of TransJakarta, Beijing and Delhi 1st BRT corridors improved traffic speed for bus transit and consequently reduced travel time for bus commuters[126], in this way initiating a modal shift from private cars to public bus transit. However, all these corridors also had similar negative aspects. Lack of BRT vehicles on the corridor and low vehicle's capacity resulted in overcrowded buses, causing travel discomfort for passengers and fast deterioration of the new road infrastructure. All these corridors lacked a proper integration into city's transport system (e.g. feeder services, parking facilities for cars and bicycles next to BRT stations, etc) and system's control. Particularly in case of Delhi BRT, as well as in TransJakarta, no strict regulations and punishments for personal vehicles entering the BRT corridor were introduced.

Even though the initial stage of operation in all BRT systems was characterised by several negative aspects, which were similar in all cases, the evaluation showed that these systems can turn out successful (i.e. TransJakarta). Therefore, it is important to monitor the system performance and conduct evaluation studies, in order to identify problems and draw lessons for the future expansion and improvement of a particular BRT system.

The new methodology, which was developed in this research (see Section 4.2), was applicable for the selected BRT systems evaluation on their successfulness. The initial purpose of the evaluation was not to give a final score to a particular BRT system, but to create a general 'picture' of this BRT performance on the three sustainability dimensions. As shown in Table 9.1, the final results from all selected BRT system evaluation represents the general 'picture' of BRT performance, meaning that the goal of the evaluation was achieved.

According to this methodology a BRT system can be called 'successful' when no 'low/red' evaluation mark is applied to any of the evaluation criteria *and* when more than 50% of the criteria are evaluated as 'high'.

[125] Since the cities where the BRT systems are implemented are of the similar characteristics (see section 5.4) and the patterns of transport system are also similar in these cities (see section 6.1, 7.1 and 8.1), altogether it provides a common base for the BRT case studies comparison. Therefore, the influence of such factors as population density and modal split on the BRT systems performance will not be considered while analysis.

[126] In all case studies conducted in this research, public transportation is used by the largest part of commuters.

Table 9.1 *Summary of the results from BRT systems' evaluation*

Main blocks	Criteria	Policy/country					
		Trans-Jakarta	Cer-tainty	Delhi BRT	Cer-tainty	Beijing BRT	Cer-tainty
	Reduction of local pollution	high	HD, HA	moderate	LD, LA	high	LD, LA
	Reduction of noise level	n/a	LD	n/a	LD	n/a	LD
	Contribution to CO_2 reduction	high	HD, HA	moderate	LD, LA	high	LD, LA
	Increased road safety	high	LD, HA	high	LD, LA	high	LD, LA
	Equity	high	LD, LA	high	HD, HA	moderate	LD, HA
	Travel convenience	moderate	HD, HA	moderate	HD, HA	high	HD, HA
	Revenues/costs ratio	high	LD, HA	High	LD, LA	moderate	LD, LA
	Reduced congestion	moderate	HD, LA	moderate	HD, HA	high	HD, LA
	Creation of new job market	n/a	LD	moderate	LD, LA	n/a	LD

The evaluation results of the three currently operating BRT systems (Table 9.1) showed that only TransJakarta and Beijing BRT systems can be called 'successful'. It has to be considered that these BRTs, compared to Delhi BRT, are also more expanded systems, consisting of several BRT corridors, which have been in operation for a longer time period. Delhi BRT currently consists of one single corridor, meaning that this BRT is still in its initial stage of operation. This is the main reason why this system does not have proper functioning yet.

In 2009, D. Hidalgo performed the assessment of the Delhi BRT functioning and his main observation was that the Delhi BRT is still evolving system, but it has succeeded in meeting some of BRT key objectives: "it is moving a mass of people at a greater speed and has succeeded in reducing the average person delay" (reported in Rawat, 2009). Hidalgo in his research, though, does not perform an evaluation on how successful Delhi BRT is, but identifies only the main problems with system's functioning.

Considering the level of uncertainty of the evaluation results, success of TransJakarta BRT is more certain than in case of Beijing BRT, which is the result of higher data availability on TransJakarta BRT and higher agreement between those data. Data availability on each BRT system evaluated in this study was a major barrier that impeded a precise evaluation of the selected BRT systems. Even though an extensive data/information search was performed in various scientific publication, electronic journals, electronic newspapers, web-blogs, several web-pages of the organisations involved in the selected BRTs, not always the necessary information could be found. Due to the lack of data, several criteria such as 'reduction of noise level' and 'creation of new job market' were not evaluated in most of the BRT case studies (see Table 9.1).

The evaluation results indicate that in general BRT systems in Jakarta, Beijing and Delhi was a positive measure towards improvement of the transport system in those cities. It highly contributed to the reduction of local pollution and CO_2 emissions from transport sector, as well as the road safety and equity of city's inhabitants were increased. None of the evaluation criterion during the performance of the case studies was given 'low' mark, indicating that only positive changes towards more sustainable transport system were made.

10. Conclusions

The evaluation results of the selected BRT case studies revealed the current problems and positive aspects of these BRT systems' operation, creating knowledge, which can be applied for the improvement of these system's functioning as well as for the planning and implementing stages of the new BRT systems in Asia. In this way, the main goal of this research was achieved.

Based on the results obtained from the evaluation of TransJakarta, Beijing BRT and Delhi BRT, it can be concluded that these BRTs have contributed to improvement of the transport system in these cities, ensuring a faster transfer of a majority of cities' inhabitants. However, all these systems still have several problems in operation and the most common problem is the lack of the BRT system capacity.

The new methodology, which was developed in this research, was relevant and applicable for the evaluation of the selected BRT systems on their successfulness. The selected BRT systems were evaluated on sustainable development indicators, reflecting the performance of BRT on environmental, social and economical dimensions. Fulfilling the selected indicators, BRT systems were considered successful. Applying this methodology, two selected BRT systems, i.e. TransJakarta and Beijing BRT were evaluated as 'successful'.

Answering the main research question, during the performance of TransJakarta, Beijing BRT and Delhi BRT case studies it was found that in order to be successfully applicable in large developing Asian cities BRT systems have to fulfil several conditions. These conditions can be summarised as follows:

- Support from government and international organisations in BRT system planning and implementation.
- Careful planning of the new BRT system, using up to date information and research in the project planning stage.
- Integration of the new BRT system with the other transport modes in the cities (i.e. bus, metro and NMT).
- Complementation of BRT policy with the other policies (i.e. '3-in-1' policy in Jakarta, see Section 6.1).
- System monitoring and data reporting.

The results obtained from the evaluation are in line with the other researches.

This research was performed by applying three integrated ex-post policy evaluation approaches: case-study evaluation, goal-free evaluation together with elements of multi-criteria analysis. These approaches were the most suitable for the evaluation of the BRT systems, showing satisfactory results that can be used in the future for the improvement of these systems' operation.

Last but not least, during this study it was found that people's transportation behaviour can have a significant impact on the transport system performance. Therefore when implementing a new BRT system or another transport policy in a particular city, it is important to take transportation behaviour of people into consideration and perform in-depth research for understanding how several factors (e.g., travel time, costs and comfort) can influence the performance of the new system/policy.

11. Recommendations

In this chapter several recommendations for further research are given.

First, it is advised to perform a similar evaluation research on other BRT systems in other developing countries in the world, in order to broader the knowledge obtained. It is also recommended to perform a similar evaluation for other transport policies besides BRT. The new evaluation methodology, which was developed in this research, was designed to be applicable for the evaluation of variety of transport policies. However, this methodology in the current research was applied specifically for BRT evaluation. Therefore, it is advised to test this methodology for the evaluation of the other transport policies.

Data availability on BRT system performance was the main barrier of this research. Therefore it is advised to pay more attention on BRT system's monitoring phase in Asian countries and ensure transparent data reporting with public access to these data. This could significantly reduce the amount of time spent on data search, as well as to improve the level of certainty of the results obtained from the evaluation.

At last, it is recommended to extend the current research and make it more complete by performing a field-study research, involving interviews of BRT stakeholders, BRT commuters and make observations of the BRT functioning on its corridors.

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Appendix A Additional information on TransJakarta BRT case study

This annex consists out of several sub-annexes, respectively, Annexes A.1 - A.3, containing different technical data on TransJakarta 1st corridor performance, as well as on the entire TransJakarta system performance.

A.1 Main elements and technical data on TransJakarta 1st corridor

Table A.1 *Elements for TransJakarta 1st corridor*

System components	TransJakarta 1st corridor 'Block M-Kota'
Stations	The stations are located on the side of the road (median busway) and ensure at-level boarding (1).Stations are equipped with sliding doors (2) and are fully weather -protected (3). Pedestrians can access the bus stops by the use of overpasses (1;2).
Vehicles	Air-conditioned non-articulated (12 m long with 1 doors), low capacity (85pax), diesel buses (1-3). In total 56 buses are operating on the 1st corridor (1;4).
Service frequency	Buses are running on the corridor with 2-3 minutes interval in peak hours and 3 to 4 minute off-peak (1). Currently the 1st corridor is carrying about 60.000 passengers per day (4). BRT corridor is opened from 5:00 till 22:00 (1;2).
Route structure	The route structure is simple, consisting out or one segregated lane (1)
Fair collection	Electronic fare collection system (the use of 'smart cards') is integrated in the BRT station (1;2), however, the service is still slow (2). Ticket price is Rp. 3,500 ($ 0.39).
Investment costs	About US $ 1,35 million/km (5;6)
ITS[127]	Buses are equipped with electronic board and speaker enabling the announcement of the stations in two languages (Indonesian and English) (1;2). Each bus also has radio transceiver, that allows the driver to receive and give updated information about e.g. traffic jams (2)
System integration	BRT terminal is not integrated with other modes (i.e. NMT). It also does not have feeder service (1;7).

Note: (1) Matsumoto, 2007; (2) Wiki (2010b); (3) Chinabrt (2009); (4) Alvinsyah & Zulkati (2005); (5) Caldes, 2007; (6) Hidalgo et al., 2007. (7) Hook, 2005.

[127] ITS - Intelligent Transportation System, as defined in Answers.com (2010), is: "The application of advanced technologies to surface transportation problems, including traffic and transportation management, travel demand management, advanced public transportation management, electronic payment, commercial vehicle operations, emergency services management, and advanced vehicle control and safety systems". In general ITS adds information and communication technologies to vehicles and transport infrastructure.

Tabel A.2 *Technical data on TransJakarta 1st corridor*

Name	TransJakarta (1st corridor)	
Evaluated corridor (Nr)	1	Hidalgo, (2009)
Planned number of corridors	15	Chinabrt, (2009)
Existing bus ways, km	12.9	Hidalgo, (2009)
Planned total ways, km	172 (for 10 corridors)	Dalkmann, (2010)
Number of shelters (stations)	20	TransJakarta, (2010).
Average distance between stations, m	250-860	Rini, (2003); Caldes, (2007)
Short description of busses	One door, 12 m, 85 passengers, diesel, Euro 2	Chinabrt, (2009); Matsumoto, 2007
Number of buses in the system	56	Alvinsyah & Zulkati, (2005)
Frequency of busses/hour	25-30 buses (every 2-3 min)	Hidalgo, (2009)
Passenger/day	60,000	Wright, (2005); ITDP(2005a)
Passengers/hour/direction (peak)	2,500 (demand is about 4,000)	ITDP (2005a); Hook, (2005).
Electronic fare collection system	yes	
Costs, total capital costs (infrastructure & equipment), ($/km)	1.35	Caldes, (2007);
Fares ($/passenger)	0.39	Caldes, (2007);
Commercial speed (km/hour)	~20	Alvinsyah & Zulkati, (2005)
Reduction travel time, %	50	Caldes, 2007; Sutomo et al., (2008)

A.2 Technical on currently operating TransJakarta BRT system

Indicator	BRT evaluated	REF
Name	**Trans Jakarta**	
Year of commence	2004	Chinabrt, (2009)
Number of corridors	8	TransJakarta, (2010)
Planned number of corridors	15	Chinabrt, (2009)
Existing bus ways, km	124	Dalkmann, (2010); Chinabrt, (2009)
Planned total ways, km	172 (for 10 corridors)	Dalkmann, (2010)
Number of shelters (stations)	142	ITDP (2010)
Average distance between stations, m	250-860	Rini, (2003); Caldes, 2007
Number of buses in the system, total	426 (23 articulated, 403 regular)	ITDP (2010); Chinabrt, (2009)
Frequency of busses/hour	4-30 buses (interval between buses: 2-15 min depending on the corridor)	Matsumoto, (2007); Wiranti, (2009)
Passenger/day	230,000	Chinabrt, (2009)
Passengers per year	82,377,655 (total, year 2009)	Dalkmann, (2010)
Passengers/hour/direction (peak)	3200-4000	Hidalgo et al., (2007); Chinabrt, (2009)
Electronic fare collection system	yes	Caldes, 2007, Chinabrt, (2009)
Costs, total capital costs (infrastructure & equipment), (million $/km)	1.35	Hidalgo et al., (2007); Caldes, 2007
Fares ($/passenger)	0.39	Hidalgo et al., (2007), Chinabrt, (2009)
Commercial speed (km/hour)	17	Hidalgo et al., (2007)
Reduction travel time, %	10-20 min	ITDP (2008); Susilo et al., (2007)

A.3 Calculations on emission reduction

TransJakarta BRT			
Contribution to CO2 emissions			
CO_2 reduction from BRT (2010)	37,000	tons	ITDP, (2010); Yunita (2008)
CO_2 emission from transport sector in Indonesia (2010)	76	million tons	Parikesit, D. (2001
Population in Indonesia	240.27	million people	The WF, (2009)
Transport CO_2 emissions per capita in Indonesia (2010)	0.32	tons CO_2/capita	calculated
Population in Jakarta	8.8	million people	Wiki, (2010b)
Total CO_2 from transport in Jakarta (2010)	2.78	million tons CO_2	calculated
TransJakarta BRT contribution to transport CO_2 reduction in Jakarta	**1.33**	**%**	calculated
Contribution to NO_x and SO_2 emissions			
NOx in Indonesia (from all sectors) projections for 2015	3.2	million tons	Susandi, (2004).
Population in Indonesia	240.27	million people	The WF, (2009)
NOx per capita	13.32	kg NOx/cap/year	calculated
Population in Jakarta	8.8	million people	Wiki (2010b)
NOx (total) Jakarta	117,201.5	tons	calculated
Vehicle emissions contribution to total emission loads in Jakarta (projections for 2015):			
- NOx	71	%	Syahril, et al., (2002)
Transport NOx emissions in Jakarta	83,213.1	tons	calculated
NOx reduction by Transjakarta BRT	386	tons	Yunita, (2008)
Transjakarta contribution to NOx reduction from transport sector in Jakarta	**0.46**	**%**	calculated

Appendix B Additional information on Delhi BRT case study

This annex consists out of several sub-annexes, respectively, Annexes B_1 - B_3, containing additional information on Delhi BRT case study.

B.1 Air pollution levels and concentrations in Delhi

Air pollution sources in Delhi and their contribution (in %) to the air since 1970 till 2001, as reports GOI (2003) are summarised in Table B.1.

Table B.1 *Sources of Pollution: The contribution of industrial (including thermal power plants), vehicular and domestic sources of pollution to the air*

Source	1970-71	1980-81	1990-91	2000-01
Industrial	56%	40%	29%	20%
Vehicular	23%	42%	64%	**72**%
Domestic	21%	18%	7%	8%

Source: GOI, 2003.

Air-born concentration data for major air pollutants in Delhi, such as PM_{10}, NO_x, CO and SO_x, over the period 2000-2006, are summarised in Table B.2.

Tabel B.2 *Air-born concentration data for major air pollutants in Delhi over the period 2000-2006*

Pollutant	Daily concentration		Annual standard ($\mu g\,m^{-3}$)	Daily standard
	Mean	Std. Dev. ($\mu g\,m^{-3}$)		
PM10	$234\,\mu g\,m^{-3}$	125	60	$100\,\mu g\,m^{-3}$ 24 Hr
NO_x	$80\,\mu g\,m^{-3}$	23	60	$80\,\mu g\,m^{-3}$ 24 Hr
CO	$3.45\,mg\,m^{-3}$	2.62	—	$2\,mg\,m^{-3}$ 8 Hr
So_x	$10.9\,\mu g\,m^{-3}$	4.5	60	$80\,\mu g\,m^{-3}$ 24 Hr

Annual and 24-h standards are shown for areas classified by CPCB as residential zones. The 24-Hr standard (8 Hr for CO) is not to be exceeded 98% of the time. Exceedances are allowed 2% of the time but not on 2 consecutive days.

Source: Kandlikar, 2007

From Table B_2 can be seen that PM_{10} pollution levels over six year time period were extremely high and the annual mean PM_{10} concentration exceeded almost four times the allowed standard. It has to be mentioned, that the 24 hour (Hr) standard during 2000-2006 was exceeded 80% of days, when the allowed limit for the 24 Hr standard is only 2%. (Kandlikar, 2007). 80% of Delhi's PM10 emissions, though, result from industrial sources (including power plants) and only about 15% originate from transport sector (Kandlikar, 2007). Considering NOx emissions, Table B_2 data indicate that annual mean concentration of this component was also above the annual standard. As Kandlikar (2007) report, this standard was exceeded 50% of the time. Vehicular traffic is the major sources (>80% of NOx emissions in Delhi (Kandlikar, 2007).

The annual average SOx concentrations, as shown in Table B_2, were the only pollutant below the annual and daily standards. The main source of SOx emissions in Delhi is power production sector; 70% of these emissions are produced by three coal power plants. The reduction of diesel fuel utilisation in Delhi transportation fleet (replacing diesel fuel in public transport with CNG since 2002; Kumari et al., 2007) as well as utilisation of low diesel in Delhi (sulphur content of < 350ppm) resulted in low impact of transport sector on the concentration of this pollutant in the air. It has to be mentioned that in March 2010 Delhi became the first Indian city, which started utilising ultra-low sulphur diesel (sulphur content of 50 ppm). The quality of this diesel is close to European fuel quality (PTI, 2010).

For CO emissions, which are mainly produced from transportation sector (>86%; Kandlikar, 2007), the 8Hr standard during 2000-2006 was exceeded 80% of the time.

In summary, the daily data on Delhi emission concentration show that standards for PM10, NOx and CO, during 2000-2006 are considerably violated with the exception of SOx standards.

B.2 Technical data on Delhi BRT

Technical data on BRT system, Delhi 1st corridor

Indicator	BRT evaluated	REF
Name	Delhi BRT	
Evaluated corridor (Nr)	1	
Planned number of corridors	26	DIMTS, 2008
Existing bus ways, km	14.5km (only 5.6 in operation)	DIMTS, 2009; Thole, 2008
Planned total ways, km	(1) 294; (2) 310	(1) DIMTS, 2008; (2) DIMTS, 2010a
Number of shelters (stations)	29 (only 9 in operation)	DIMTS, 2008; Thole, 2008
Short description of busses	Tata Marcopolo buses, CNG, low floors, no info found on bus capacity	ITDP, 2008a
Number of buses in the system	about 500	Bhatia & Jain, 2009; Hidalgo, 2009
Passenger/day		
Passengers/hour/direction	12,000 (during peak time) (both directions)	DIMTS, 2010; DIMTS, 2008, Thole, 2008; EMBARQ, 2009
Electronic fare collection system	no	Concluded from literature study performed
Costs, total capital costs (infrastructure & equipment), ($/km)	(1) $ 2.5 million (estimated), real 1st corridor costs/km - $ 3.3million (2) $ 2.98 million/km	(1) DIMTS, 2008 (2) EMBARQ, 2009
Fares ($/passenger)	$0.21 - $0.53	DTC, 2010
Commercial speed, km/h	18	EMBARQ, 2009; Rawat, 2009
Reduction travel time, %	35%	ENS, 2009, Rawat, 2009, DIMTS, 2010
Frequency, busses/hour	(1) 120; (2) 200-250	(1)EMBARQ, 2009; (2) Narain, 2009; DIMTS, 2010

B.3 Additional aspects on Delhi BRT system operation.

There were several aspects identified, which were considered while Delhi BRT performance evaluation process but were not discussed under the main analysis of the evaluation results. These aspects concern (1) bus operation, (2) lane discipline and (3) infrastructure.

1) Considering bus operation, a problem with untrained drivers emerged on BRT corridor (DIMTS, 2010). The bus operation was reported to be inefficient due to a lack of training among the bus drivers. Drivers in Delhi transportation system are frequently changing in different routes; as a result many untrained drivers are operating on daily basis in the corridor.

2) Lane discipline is also an important issue to mention. Even though only bus operation is allowed in a special bus lane, numbers of vehicles (cars and scooters) are entering this lane on daily basis, which has to be prevented in order to increase the performance of the system. However, at the moment there are no regulations existing to insure strict lane discipline (DIMTS, 2008, 2010).
3) Besides all concerns mentioned, Delhi BRT system is also lacking a supportive infrastructure, such as parking facilities close to BRT corridor and flyovers (FOV)/subways that would make it easier for commuters to switch from car use to BRT.
    - The parking facilities at key intersection points would enable commuters to drive till the bus corridor and switch to BRT for the remaining part of their journey. In such a way, parking facilities could compensate for feeder services (DIMTS, 2010).
    - FOVs are needed as pedestrian crossing facilities in order to ensure safe crossing of the corridor and reduce traffic disturbance in the other lanes of the road by BRT users (as well as eliminating the number of jaywalking pedestrians).

Appendix C Additional information on Beijing BRT case study

This annex consists out of several sub-annexes, respectively, Annexes C.1 and C.2, containing additional information on Beijing BRT case study.

C.1 Main elements and technical data on Beijing's BRT 1st corridor

Main elements of Beijing BRT 1st corridor[128]

System components	Beijing's BRT 1st corridor (Southern Axis BRT Line One)
Stations	The stations are located in the middle of the roads, away from intersections (1;2). Stations ensure at-level boarding (3), newer stations have sliding doors (3). Pedestrians can access the bus stops by the use of overpasses (1;2).
Vehicles	Low floor, air-conditioned articulated (18.3 m long with 3 doors), high capacity (180 people[129]), CNG buses (3;4). Bus average cost: about US$250,000 (2). In total 87 buses with this characteristics operating on the 1st corridor (5).
Service frequency	About 55 buses/hour (both directions) with about 2-3 minutes interval (1;5). Currently the 1st corridor is carrying about 120,000 passengers per day (5)
Route structure	The route structure is simple, consisting of or one segregated lane (3.5 m in width).
Fare collection	Pre-board fare collection system, which is done at the ticket counter at the entrance to the station (1;3). There are one or more attendants controlling ticket sales (2). Ticket price is 2 yuan ($ 0.29).
Investment costs	About 38-40 million yuan/km[130] (5.58-5.88 million US$/km) (2-4)
ITS[131]	Buses are equipped with GPS and electronic stop announcement system (1;3). BRT has a signal priority at intersections (intelligent operation system of traffic lights)[132] (3). BRT stops are equipped with a real-time next bus information displays (3,4). There is a system control centre equipped with a video surveillance (3).
System integration	BRT terminal is located close to a subway station (1). However, there is no tariff integration between subway and BRT. The main negative aspects of the system integration are the following: • no bicycle parking at BRT stations; • disabled people (in wheelchair) are limited to access BRT station; • no full weather protection at all stations (3).

128 Sources of information: (1) Matsumoto, 2007; (2) Darido, 2006; (3) Chinabrt, 2009; (4) Zheng & Jiaqing, 2007; (5) Hidalgo, 2009.

129 Non-articulated bus capacity in average is about 60-85 passengers (Darido, 2006; The CTP, 2002).

130 Interesting to mention that according to Zheng & Jiaqing (2007): "the cost of Beijing BRT 1st corridor is only 1/15 of Line 4 of Beijing Subway and the investment pay-back period of BRT 1st corridor is 9.5 years while that of the Line 4 of Beijing Subway is 22.5 years".

131 ITS - Intelligent Transportation System, as defined in Answers.com (2010), is: "The application of advanced technologies to surface transportation problems, including traffic and transportation management, travel demand management, advanced public transportation management, electronic payment, commercial vehicle operations, emergency services management, and advanced vehicle control and safety systems". In general ITS adds information and communication technologies to vehicles and transport infrastructure.

132 Citation from Zheng & Jiaqing (2007): "if the BRT vehicle arrives at the intersection when the green light is on, the time of the green light will be extended to allow the BRT vehicles to pass though the intersection. However, if the BRT vehicle arrives at the intersection when the red light is on, the red signal will not be shortened owing to the security consideration for pedestrians to cross the street".

Technical data on Beijing's 1st corridor performance

Technical data on BRT system, Beijing 1st corridor		
Indicator	BRT evaluated	REF
Name	Beijing BRT	
Evaluated corridor (Nr)	1	
Existing bus ways, km	16	Hidalgo, 2009; Chinabrt, 2009; Zheng & Jiaqing, 2007
Planned total ways, km	323	Darido, 2006
Number of shelters (stations)	18	Hidalgo, 2009
Short description of busses	Iveco buses, low-floor, CNG, 18.3 m long; average capacity of 180 person	Chinabrt, 2009; Zheng & Jiaqing, 2007
Number of buses in the system	87	Hidalgo, 2009, Chinabrt, 2009, Zheng & Jiaqing, 2007
Passenger/day	100,000-120,000	Chinabrt, 2009, Hidalgo, 2009
Passengers/hour/direction	4,000-8,000	Hidalgo, 2009; Zheng & Jiaqing, 2007, Chinabrt., 2009
Electronic fare collection system	yes	Darido, 2006, Chinabrt, 2009
Costs, total capital costs (infrastructure & equipment), ($/km)	(1) 40 million yuan/km ($ 5.88 million) (2) 38 million yuan/km ($ 5,58 million)	(1) Chinabrt, 2009, Darido, 2006 (2) Zheng & Jiaqing, 2007
Fares ($/passenger)	$ 0.29 (2 yuan)	Darido, 2006
Commercial speed, km/h	(1) 25km/h (2) 22-26 km/h	(1) Zheng & Jiaqing, 2007;; (2) Darido, 2006
Travel time reduction , %	40	Zheng & Jiaqing, 2007; Darido, 2006
Frequency, busses/hour	55 (both directions)	Hidalgo, 2009; Chinabrt, 2009

C.2 Technical data on Beijing BRT

Indicator	BRT evaluated	REF
Name	Beijing BRT	
Number of corridors	3	Chinabrt, 2009
Existing bus ways, km	34.5 (segregated lane) (14/9.5/11 km for corridor 1/2/3)	Chinabrt, 2009
Planned total ways, km	323	Darido, 2006
Number of shelters (stations)	60 (18/20/22 for corridor 1/2/3)	Chinabrt, 2009
Average distance between stations, m	(940m/790m/1000m corridor 1/2/3)	Chinabrt, 2009
Number of buses in the system	87 (special BRT buses, corridor 1 only)	Chinabrt, 2009
Frequency of busses	55 (corridor 1) ~20 in corridor 2 and 3	Chinabrt, 2009
Passenger/day	120,000 (only corridor 1) corridor 2 & 3 much less (precise data not available)	Chinabrt, 2009, Hidalgo, 2009
Passengers/hour/direction	~ 2,000 (average in corridors 2&3)	Chinabrt, 2009, Hidalgo, 2009

Indicator	BRT evaluated	REF
Costs, total capital costs (infrastructure & equipment), ($/km)	(1) about 40 million yuan (US $ 5.88 million) data available only for corridor 1)	Chinabrt, 2009; Darido, 2006, Zheng & Jiaqing, 2007
BRT bus costs (public funds)	30.3 million USD	
Fares ($/passenger)	2 yuan ($ 0.29)	(Darido, 2006)
Commercial speed (average) (km/hour)	25 km/h in corridor 1 17 km/h in corridor 2 14 km/h in corridor 3	Chinabrt, 2009; Hidalgo, 2009

Appendix D Set of indicators for the evaluation of BRT performance

This annex gives an overview of the indicators, which were selected in this research for the evaluation of the BRT performance on three sustainability dimensions (environment, society and economics). These indicators were used for the evaluation of each selected BRT case study. Data availability on a particular BRT case determined whether a certain indicator could be applied for the evaluation or not. For instance, if during the BRT case study evaluation there was no information found on a particular indicator, this indicator could no longer be applied for this BRT case study evaluation. The application of indicators below is discussed in more details in Chapter 4.

Evaluation criteria	BRT evaluation indicators (evaluated after BRT implementation and compared to situation before)	Unit/Measure	Why is it relevant to transport policy evaluation?	Reference
	Economical block			
Revenue/cost ratio	Minimal costs for public transportation (costs for one single trip)	EUR/trip	Shows whether public transportation became more affordable for population (in general) after a particular policy implementation.	NZMT, 2009
	Capital investment in BRT construction	EUR/km	Indicator of policy financial input.	NZMT, 2009
	Operational/maintenance costs	EUR	-------- " -------	NZMT, 2009
Congestion reduction	Change in morning congestion	%(minutes delay per km)	This indicator can be applied to estimate how introduction of BRT influenced the level of congestion in the morning hours.	NZMT, 2009
	Change in evening congestion	% (minutes delay per km)	This indicator can be applied to estimate how introduction of BRT influenced the level of congestion in the evening hours.	NZMT, 2009; Goh, 2002
	General change in road passenger traffic	scale: no changes/became less congested/ became more congested	This indicator gives a general impression of congestion changes in the transportation system. Important when above indicators cannot be measured.	Goh, 2002
Creation of new jobs	Availability of new jobs due to policy implementation	scale: no changes/increased unemployment / increased availability of new jobs	Shows additional changes in societal/economical systems after a particular policy implementation.	Goh, 2002

Evaluation criteria	BRT evaluation indicators (evaluated after BRT implementation and compared to situation before)	Unit/Measure	Why is it relevant to transport policy evaluation?	Reference
Societal block			Important indicators, showing public acceptance of BRT outcomes	
Travel convenience	General public perception of BRT functioning	scale: excellent, very good; good; poor; very poor; dreadful	Gives overall picture whether similar systems are beneficial and should be introduced more in the future in the evaluated area.	NZMT, 2009; Moberoela, 2009
	'- Perception public transport **availability**	scale: excellent, very good; good; poor; very poor; dreadful	-------- " -------	NZMT, 2009; Moberoela, 2009
	'- Perception of bus service **reliability and frequency**	scale: excellent, very good; good; poor; very poor; dreadful	-------- " -------	NZMT, 2009; Moberoela, 2009
	'- Perception of bus service **accessibility**	scale: excellent, very good; good; poor; very poor; dreadful	-------- " -------	NZMT, 2009; Moberoela, 2009
	'- Perception of service **comfort**	scale: excellent, very good; good; poor; very poor; dreadful	-------- " -------	NZMT, 2009; Moberoela, 2009
	Reduction of travel time	% (minutes)	This indicator can be used to estimate how after BRT implementation the personal time for transportation changed	Goh, 2002
	Changes in passenger transport modal split	%	Changes in modal split can indicate a successful change towards modes that are assumed to be more sustainable (e.g. public transport)	NZMT, 2009; Enoch, 2003;
	passenger car ownership) per 1000 population	% (vehicle /1000 population)	Shows transportation mode switch tendency after BRT implementation	NZMT, 2009; Enoch, 2003; Walters, 2008
	change in car occupancy (passenger transported in one car)	%	Shows the change in the effectiveness of personal vehicle's use.	VTPI, 2010
	change in VKT (automobile) per capita	% (Vehicle km (all cars) /cap)	Showing the actual use of private cars in the selected country/area	NZMT, 2009; Enoch, 2003; VTPI, 2010
	change in VKT (bus) per capita	% (Vehicle km (all buses) /cap)	Showing the actual use of private cars in the selected country/area	author

Evaluation criteria	BRT evaluation indicators (evaluated after BRT implementation and compared to situation before)	Unit/Measure	Why is it relevant to transport policy evaluation?	Reference
	Changes in energy consumption in road transport sector	% (MJ/ annual; % of total MJ consumed within the country)	Shows the expansion and the demand growth (expressed as additional energy consumption) in the transportation sector	Castillo & Pietfield, 2009
Equity	General perception of transportation **costs**	scale: no changes/became less expensive/became more expensive	Important indicator, shows public whether transportation became more affordable	author
	Improvement of travel conditions for physically disabled people	Scale: improved/no changes/worsened	Important indicator, shows whether transportation conditions for physically disabled people improved	author
	Improvement of travel conditions for NMT	Scale: improved/no changes/worsened	Important indicator, shows whether transportation conditions for NMT improved	author
	increase in total footpath length	% (km)	Indicators under this group give a general impression of NMT improvement in the evaluated area.	NZMT, 2009
	increase in total cycle length	% (km)	-------- " -------	NZMT, 2009
	increase in personal cycled distance	% (km)	-------- " -------	NZMT, 2009; Castillo & Pietfield, 2009
	increase in total walked distance	% (km)	-------- " -------	NZMT, 2009; Castillo & Pietfield, 2009
Road safety	Changes in total annual road accidents	%	Show whether and to which extent the transportation safety issues are changed after BRT implementation	NZMT, 2009; Enoch, 2003; Castillo & Pietfield, 2009
	Changes in fatal accidents	% (number fatal accidents /10000 cars)	-------- " -------	Button, 1992; Vasconcellos, (1996)
	Change in annual deaths from road accidents per million people	% (number of deaths/million inhabitants'	-------- " -------	NZMT, 2009; Button, 1992
	Changes in annual number of injuries from road accidents	%	-------- " -------	NZMT, 2009; Castillo & Pietfield, 2009

Evaluation criteria	BRT evaluation indicators (evaluated after BRT implementation and compared to situation before)	Unit/Measure	Why is it relevant to transport policy evaluation?	Reference
Environmental block			Indicators, showing environmental benefits from a modified transportation system performance	
Noise level	Change in noise level close to arterial routes	% dBA	-------- " -------	NZMT, 2009; The ERF, 2004
Local pollution	Changes in local pollution level in urban areas	scale: worsened/no changes/improved	-------- " -------	NZMT, 2009
	'- Changes in emissions of PM10 and PM2.5	% (µg/m^3)	-------- " -------	NZMT, 2009
	'- Changes in emissions of NOx, NO and NO_2	% (µg/m^3)	-------- " -------	NZMT, 2009
	'- Changes in emissions of CO	% (µg/m^3)	-------- " -------	NZMT, 2009
	'- Changes in emissions of SO_2	% (µg/m^3)	-------- " -------	NZMT, 2009
	'- Changes in emissions of HC	% (µg/m^3)	-------- " -------	NZMT, 2009
Contribution to CO_2	Total country CO_2 emissions, (historical year)	Mtons	Gives a reference value. Against this value CO2 emission from transport sector can be weighted.	The EC, 2009
	Changes in transport CO_2 emissions	%	Shows the improvement of effectiveness in transportation system functioning.	The EC, 2009
	Changes in transport CO_2 emissions per km	% (gCO_2/km)	Gives a deeper insight into CO2 emission reduction from transport sector in the evaluated area.	The EC, 2009
	Changes in transport CO_2 emissions per capita	% (tCO_2/cap)	Gives a deeper insight into CO2 emission reduction from transport sector in the evaluated area.	The EC, 2009