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MASTER OF SCIENCE “ENVIRONMENTAL PLANNING AND ENGINEERING ECOLOGY“

MASTER THESIS

Defining and Evaluating Policy Projects to Support Sustainable Transport – Using BRT as an Example

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STATEMENT

I hereby certify that the content of this report is the result of work done by me, except where otherwise indicated. I have only used the resources given in the list of references or given in the annexes. This master thesis was not submitted for a higher degree to any other university or institution.

Munich, December 20, 2013

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This research was carried out at the offices of Siemens AG (Mobility Consulting, Munich) from July 1 to December 20, 2013.

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ABSTRACT

In this master thesis BRT systems were taken as an example to develop a methodology evaluating “policy projects”. “Policy projects” can be implemented in cities to overcome problems and achieve objectives, e.g. reducing emissions related to the transportation sector. The main objective was to find out, which instruments have to be implemented with BRT systems to maximize the modal shift from private car use to the public transport network.

The study provides an overview of possible “policy projects”. The “policy projects” were categorized using the avoid – shift – improve and the ‘push’ and ‘pull’ approaches. This first section ends with a discussion of important aspects, which should be considered when creating a successful transportation strategy to improve the sustainability of the transportation sector in a city.

Then, the study analyses BRT systems. The existing literature only focuses on descriptions of possible instruments to be implemented with BRT systems and how to implement them. It also describes the planning process. However, no study has been found comparing the instruments implemented in the various BRT case studies and the achieved results in modal shift. Accordingly, this master thesis investigated these questions. Furthermore, case studies were analyzed to learn, which instruments would have to be implemented to maximize the modal shift. Moreover, a literature research was conducted to find out, which quality attributes a BRT system should achieve (e.g. short travel times, reliability).

The study identified 41 possible instruments to be implemented with BRT systems. According to the passenger preferences, “running ways” and “intersection treatments” could be shown to be the most important instruments. In addition, the most important quality attributes are short travel times and high frequencies of the service.

The results lead to the conclusion that the implementation of BRT systems in smaller cities seems to be more successful in terms of modal shift from private car use. In addition, the master thesis shows that there is still the need and possibility to improve the already existing BRT systems. By getting closer to passenger expectations, the potential of BRT systems to attract private car users increases and therefore also the modal shift. Thus, BRT systems are a possibility to reduce the CO_2 emissions of cities.

Some of the results of this analysis were used to develop an user-oriented Excel tool. This tool enables a first assessment of the relevant instruments to be implemented with BRT systems to achieve a high modal shift from private motorized modes.

Keywords: Transport policy, Sustainable transport modes, Bus Rapid Transit Systems, Modal shift

1 INTRODUCTION

The objective of this master thesis was to develop a methodology to evaluate “policy projects” which support sustainable passenger transport. Thereby the focus is on improvements of the public transportation network. The term “policy project” is defined later in the study (see chapter 2.1.2). Some of the results of this evaluation were used to build an user-oriented Excel tool. The tool helps decision makers to choose the relevant set of instruments to be implemented with “policy projects”. This set of “policy projects” should lead to the best possible impact in terms of environmental benefits like CO_2 savings from the transportation sector.

1.1 Background

Large amounts of greenhouse gases (GHG) have been released into the atmosphere by human activities. GHG are trapping energy in the atmosphere and causing the atmosphere to warm up leading to a threat on the earth’s climate (EPA, 2013). Cities are responsible for around 70% of the global GHG emissions, whereby “cities refer to all urban areas, including towns and other small urban settlements” (UN-Habitat, 2011, p. 52).

A major part of the GHG emissions of a city stems from the transport sector, as it has an excessive energy and resource consumption (Redman, et al., 2013; Fujii & Gärling, 2005). The transportation emissions “are the result of three main factors; vehicle technology, fuel characteristics and vehicle miles traveled” (Dierkes, et al., 2002).

The rapid growth of private car use aggravates the environmental concerns (Redman, et al., 2013). These are, besides climate change, noise, the emission of various pollutants, and the impact on flora and fauna (Acutt & Dodgson, 1997; Fujii & Gärling, 2005). But additionally to these adverse environmental effects private transportation also contributes to social problems such as accidents, poor health caused by noise and air pollution, traffic congestion, visual intrusion, and community severance (Redman, et al., 2013; Acutt & Dodgson, 1997; Gärling, 2004).

However, on the other hand, “motorization is a reflection of economic growth” and, furthermore, “automobile ownership is strongly associated with the rising income and becomes the representation of one’s accomplishment in life” (Dirgahayani, 2013, p. 1). Moreover, it has the potency of a status symbol (Redman, et al., 2013; Gärling, 2004). Additionally, car travel is appealing to the individual: It is perceived as “more comfortable, flexible and faster for supporting private lifestyles” (Redman, et al., 2013, p. 119). Finally, it is always available and provides direct door to door travel (Gärling, 2004).

In this century climate protection is one of the main aspects of environmental politics. This comprises policies to decrease the number of cars on roads and thus contributing to reduce emissions. There are several ways to attract drivers out of their cars. For those driving out of necessity, “planners can explore ways of reducing the need for or the length of the trip or ways of enhancing alternatives to driving, and everyone benefits if the planners are successful” (Handy, et al., 2005, p. 184). But for those driving by choice, the policy implications are much more severe (Handy, et al., 2005). In this case, the car-use habits have to be broken (Fujii & Gärling, 2005). So there is the need of implementing policies or “policy projects” causing people to drive less (Handy, et al., 2005), considering both the trips driven by choice or necessity.

One way to avoid emissions is the reduction in private vehicle miles travelled and shifting them to more energy efficient transport modes such as public transport (ITDP, 2013b). In order to achieve a high modal share, the offered public transport network has to be attractive to the possible ridership. This includes, amongst others, short travel times, high frequency, and reliability (Redman, et al., 2013). These quality attributes are only achievable with a broad public transport network. A possibility to enhance the public transport system in a city is the implementation of a Bus Rapid Transit (BRT) system, as it is much cheaper than the construction of a light rail and it has a shorter construction time (Currie, 2005; McDonnell & Zellner, 2011; Wright, 2004).

Several guidelines and studies were published describing BRT systems and the elements or instruments that could be part of it. But no study could be found comparing in detail which elements or instruments were implemented most of all in case studies and what the achieved results in modal shift were. The present master thesis investigated exactly these questions. Furthermore it was analyzed which instruments are most important concerning the preferences of potential riders. It was also analyzed, which quality attributes a BRT system should have to attract as many riders as possible. The objective was to find out how to implement a successful and complete system with the highest possible impact on ridership and modal shift from private motorized modes. By increasing the modal shift to its maximum, the implementation of BRT systems would lead to the best possible impact on the reduction of the overall environmental footprint of transportation.

1.2 Initial Objective

The present master thesis is a work created in cooperation with the Department “Mobility Consulting” at Siemens AG (IC MOL ITSOL MC) in Munich and the Chair of Urban Structure and Transport Planning of the Technical University in Munich.

Siemens AG identified and evaluated possible technical solutions (“levers”) to reduce CO_2 emissions in the transport sector for cities like Helsinki and Singapore. The initial objective of the present master thesis was to select three of these levers. For each of these three levers about five non-technical policy measures should have been identified and evaluated, both economically and ecologically, which support and optimize the implementation of the levers. Furthermore, a methodological tool enabling a qualitative and quantitative assessment of the effects of these non-technical measures on the levers should have been developed.

Within the first two months of the work for this master thesis it was realized that this objective was too broad and not manageable within the scope of a master thesis because of the lack of data available in the literature. So the scope was specified and this thesis focuses now on the assessment of BRT systems as a possibility to reduce the CO_2 emissions of the cities. BRT systems comprise technical and non-technical instruments to support their success in terms of achieving a high modal shift from private motorized modes.

1.3 Structure of the Thesis

In the first months of the work it was noticed that the terms used in connection with "policy" are very different. So chapter 2 describes the policy environment and gives an overview of the terms used in the literature in connection with the term "policy". The main terms used in the present study (e.g. policy project, instruments) are also defined in this chapter. In a next step "policy projects" are categorized and a list of possible "policy projects" is provided (chapter 2.3). Chapter 2 ends with a short discussion of general findings relevant for the implementation of policies and "policy projects".

In order to develop a methodology to assess "policy projects" Bus Rapid Transit (BRT) systems were selected from the policy project list presented in Annex 7. Chapter 3 provides a short introduction to BRT systems and the description of the BRT instruments as well as an overview of the case studies used for the analysis. In chapter 4 the methodology used for the evaluation of BRT systems is presented and chapter 5 describes the results of this evaluation. Chapter 6 explains how some of the results of the analysis of BRT systems were used to develop an user-oriented Excel tool. This Excel tool enables city planners or decision makers to make a first assessment, as to which instruments should be implemented with BRT systems in order to create successful systems. The results of the analysis are then discussed in chapter 7. The master thesis closes with a conclusion and an outlook in chapter 8.

2 POLICY PROJECTS TO SUPPORT SUSTAINABLE TRANSPORT

This chapter provides a literature overview of the terms used in connection with the content of the term "policy" and defines the terms used in the present study. Furthermore, possible "policy projects", which could be implemented to decrease the emissions of the cities from the transport sector, are categorized and a list with possible "policy projects" is presented. The chapter concludes with a short discussion about the implementation of "policy projects".

2.1 Definitions

As mentioned, during the literature research in the first weeks of this master thesis it was noticed that the terms used in connection with "policy" are very different. So in a first step, this study provides an overview of the terms used in the literature. To avoid any confusion the terms used in the present work are subsequently defined.

2.1.1 Literature Overview

The definition of the term "policy" is not very explicit. Some of the definitions provided in the literature or in dictionaries are similar, some different. Thus the term "policy" and terms to be found in connection with "policy" can be used and are used in different ways in the literature or in different countries. "This is often due to differences in the institutional framework, in the economic and political context and in the procedures for forward planning in the countries concerned" (Wood & Dejeddour, 1992, p. 6).

The Oxford Dictionary defines policy as "a course or principle of action adopted or proposed by an organization or individual" (Oxford Dictionaries, 2013). In comparison, the Macmillan Dictionary defines policy as "a set of plans or actions agreed on by government, political party, business or other group" (Macmillan Dictionary, 2009). These definitions are broad and not very explicit. In the scientific world the situation is the same:

Wood & Dejeddour use the terms policies, plans and programmes and describe them as "tools for forward planning and for allocating and distributing resources even though there may be differences between them" (Wood & Dejeddour, 1992, p. 6). The study defines policies, plans, programmes and projects as follows:

- Policy: Inspiration and guidance for action (e.g. the national transport policy)
- Plan: A set of co-ordinated and timed objectives for implementing the policy (e.g. the longterm national road plans)
- Program: A set of projects in a particular area (e.g. 5 year road building programme)

- Projects: In contrast to policies, plans and programmes, projects are usually precisely geographically located and are usually carried out in a shorter time. (e.g. construction of a motorway section) (Wood & Dejeddour, 1992, p. 8f)

Tuominen & Himanen describe a policy as “a statement by a government of what it intends to do or not to do” (Tuominen & Himanen, 2007, p. 389). The paper also provides a definition of the main terms used in this context:

- Policy objective/goal: What the policy is trying to achieve, the overall goal; often quite abstract and qualitative.
- Policy target: More specific and quantitative than an objective or goal (e.g. 10% less emissions of air pollutants within 5 years). The target points out a clear sense of direction for policy measures.
- Causal model: What causes a policy problem and how would particular responses alleviate the problem? Do we know that model? If we do not know, how can we find it?
- Policy tools/measures/instruments: The means/methods that are chosen to meet the targets and objectives
- Policy implementation: The process by which the policies enacted by government are put into effect by relevant agencies (Tuominen & Himanen, 2007, p. 390)

In the “Decision Makers’ Guidebook” a policy (in the context of transportation) is defined as “a broad approach towards transport and land use planning, including the specification of objectives and the choice of a strategy and its component instruments” (May, 2003, p. 51). Additional “policies are influenced by neighboring towns and cities, as well as by regional, national and European policy” (May, 2003, p. 3).

The comparison of these different examples of the usage and of definitions of the terms used in connection with “policy” show that the term policy is not equally defined in the literature and can be used on different levels (e.g. regional policy, European policy). Furthermore some studies refer to policy as measures to meet the targets, like the ASSIST project (“Assessing the social and economic impacts of past and future sustainable transport policy in Europe”), which is coordinated by the “Fraunhofer ISI” Institute for Systems and Innovation Research (Karlsruhe, Germany) and co-funded by the European Commission (DG MOVE, 7^{th} Research Framework Programme): The Assist project “screened more than 300 policies or measures” (Krail, et al., 2011, p. 4). The measures referred to there would be comparable to the policy tools/measures/instruments defined by Tuominen & Himanen or to the programmes or projects defined by Wood & Dejeddour as already described above.

This shows that it is not sure that everyone uses or understands the same when using terms related to the content of “policy”. Therefore, the terms used in the present study are defined in the next chapter.

2.1.2 Term Definitions

In the present study the term policy and terms in this context are used as described in the following:

A policy (in the context of transportation) is defined as an “inspiration and guidance for action” (Wood & Dejeddour, 1992, p. 6) (e.g. the City Transport Policy). More specifically, it could be described as “a broad approach towards transport and land use planning, including […] the choice of a strategy and its component” projects and instruments (May, 2003, p. 51), in order to reach the objectives defined by a country or city (May, 2003; Wood & Dejeddour, 1992).

An objective is “a broad statement of the improvements which a city is seeking. Objectives specify the directions for improvement, but not the means of achieving it” (May, 2003, p. 50).

A strategy is a set of projects or instruments to solve problems concerning the transportation sector and to meet the targeted objectives (May, 2003; Wood & Dejeddour, 1992). This term is comparable to the “programmes” defined by Wood & Dejeddour.

Policy projects and instruments are “the specific components of a strategy” (May, 2003, p. 50; Wood & Dejeddour, 1992) “to overcome problems and achieve objectives” (May, 2003, p. 5). Thereby instruments are the specific elements (e.g. dedicated running ways) of the projects (e.g. Bus Rapid Transit systems). These terms are comparable to the terms “policy tools/measures/instruments” defined by Tuominen & Himanen (2007). The instruments can be either non-technical or technical. Technical instruments are ICT (“information and communication technology”), or simply technology based and need energy to be able to work. Non-technical instruments require a planning process at the outset, and could be implemented without using technologies.

The relationship between these terms is graphically illustrated in Annex 1.

2.2 Categorization

This section describes the categorization of different “policy projects”, which can be implemented in order to meet the targeted objectives concerning the emissions of the transport sector in cities.

2.2.1 Literature Overview

There are many approaches in the literature to categorize the different “policy projects”. “Policy projects” are the components of a transportation strategy (Meyer, 1999), which can be implemented in a city to reduce the emissions from the transport sector. A part of the “policy projects” is defined as “travel/transportation demand management” (TDM) in several studies (Gärling, 2004; Meyer, 1999; VTPI, 2013; MIP, 1999; Broaddus, et al., 2009). This term describes actions aiming at changing or reducing the demand for car use by trying to change the travel behavior (Meyer, 1997) especially focusing on private car use. TDM can be further defined as “a strategy which aims to maximize the efficiency of the urban transport system by discouraging unnecessary private vehicle use and promoting more effective, healthy and environmental-friendly modes of transport, in general being public transport and non-motorized transport” (Broaddus, et al., 2009, p. 8). The present study not only comprises “policy projects” which could be described as TDM measures. It also consideres “policy projects” to optimize the energy consumption and emissions by the different transportation modes.

In the following different approaches are presented categorizing TDM or “policy projects”:

For Meyer (1999) broad demand management strategies contain three categories:

- Offering travelers one or more alternative transportation modes or services that result in higher per vehicle occupancy
- Providing incentives/disincentives to reduce travel or to push trips to off-peak hours
- Accomplishing the trip purpose through non-transportation means (such as using telecommunications for work or shopping trips) (Meyer, 1999, p. 576)

The Victoria Transport Policy Institute divides TDM projects (referred to as strategies by the VTPI) in five major categories:

- Improved transport options
- Incentives to use alternative modes and reduce driving
- Parking and land use management
- Policy and institutional reforms
- TDM programs and program support (VTPI, 2013)

Within the AIUTO project TDM's are categorized in:

- Main measures
    - Innovative supply systems
    - Pricing measures
    - Regulation measures
- Complementary measures (MIP, 1999).

The "Deutsche Gesellschaft für Internationale Zusammenarbeit" (GIZ, formerly GTZ) classifies TDM as follows (instruments are comparable to "policy projects" in the present study):

- Planning instruments: Land use planning (master planning)
- Regulatory instruments: Standards (emission limits, safety), traffic organization (speed limits, parking, road space allocation), production processes
- Economic instruments: Fuel taxes, road pricing, subsidies, purchase taxes, fees and levies, emissions trading
- Information instruments: Public awareness campaigns, mobility management and marketing schemes, co-operative agreements, eco-driving schemes
- Technological instruments: Fuel improvements, cleaner technologies, end-of-pipe control devices, cleaner production (Broaddus, et al., 2009)

As it can be observed, the classification of TDM of the GIZ comprises a category of "technological instruments" which is also considered in the present study.

May (2003) categorizes policy instruments (comparable to "policy projects" in the present study) in different types:

- Land use measures
- Infrastructure provision
- Infrastructure management
- Information provision
- Attitudinal measures
- Pricing (May, 2003, p. 18)

Vieira et al. (2007) use a classification for "transport policy instruments" (comparable to the "policy projects" in the present study) based on three groups:

- Transport supply instruments: "'Supply side instruments' integrate all actions aiming to modify the behavior of the transport-system agents by changing the quality and/or quantity of the available transport infrastructure capacity, equipment and/or vehicles" (Vieira, et al., 2007, p. 422).
- Regulatory instruments: "Include actions aiming to modify agents' behavior by defining or changing sets of rules (e.g., restrictions, standards, and controls)" (Vieira, et al., 2007, p. 423).
- Economic instruments: "Include actions aiming to modifying agents' behavior through a market-based approach" (Vieira, et al., 2007, p. 423).

Bates et al. (2001) categorize "emission reduction options" in three main ways, how CO_2 emissions from transport can be reduced:

- Operational: Reducing energy use and emissions per vehicle km driven
- Strategic: Optimization of the vehicle use, reducing total vehicle km per passenger km or per ton km
- Demand: Reducing the overall demand for travel (Bates, et al., 2001, p. 7)

2.2.2 Categorization of Policy Projects

The presented approaches (see chapter 2.2.1) of classifications of “policy projects” or of TDM measures (as part of the possible “policy projects”) are similar, but yet there are differences. Furthermore, most of the classifications of TDM measures does not cover the kind of “policy projects” aiming to optimize the energy consumption and the emissions by the different transportation modes. These are reasons why neither of these classifications could simply be adopted for the present study. Instead, the classification of “policy projects” used in the present study is a synthesis of the presented approaches, especially considering the classifications of May (2003), Bates et al. (2001) and Broaddus et al. (2009).

The “policy projects” defined in this study will be categorized as follows (see Annex 1):

- **(Land use) Planning/Infrastructure** (e.g. transit oriented development): “Planning can reduce the need to travel through bringing people and the activities they need to access closer together. Planning can also enable the implementation of new transport infrastructure (road, rail, other public transport, cycling, walking)” (Broaddus, et al., 2009, p. 18)
- **Economic/Regulatory** (e.g. fuel taxes): Economic projects “can be used to discourage the use of motorized vehicle, which will encourage the use of alternative modes, or reduce the need to travel” (Broaddus, et al., 2009, p. 18).
- **Information/Education** (e.g. educational bicycle programs): “The provision of information, in easily accessible formats can increase the awareness of alternative modes, leading to a modal shift to walking or cycling” or public transport. “Information can also be provided related to improving driving behavior, resulting in reduced fuel consumption” (Education) (Broaddus, et al., 2009, p. 18).
- **Management/Organization** (e.g. environmental zone): “Better management of the road network and improved public transport services can reduce congestion, protect the environment, improve residential streets and reduce accidents” (May, 2003, p. 22) Furthermore it “can influence the types of vehicles use and standards that they should adhere to (both in terms of vehicle performance and road regulations)” (Broaddus, et al., 2009, p. 18).
- **System Optimization – ICT or technology based** (e.g. regenerative braking): “Where travel by motorized transport is necessary, technology can be used to reduce the impact of carbon emissions, through developing cleaner fuels and improving vehicle efficiency” (Broaddus, et al., 2009, p. 18). Furthermore emission can be decreased by ICT based systems like prioritization at intersections.

Furthermore "policy projects" are classified according to the avoid – shift – improve approach (Böhler-Baedecker & Hüging, 2012, p. 8) (see figure1).

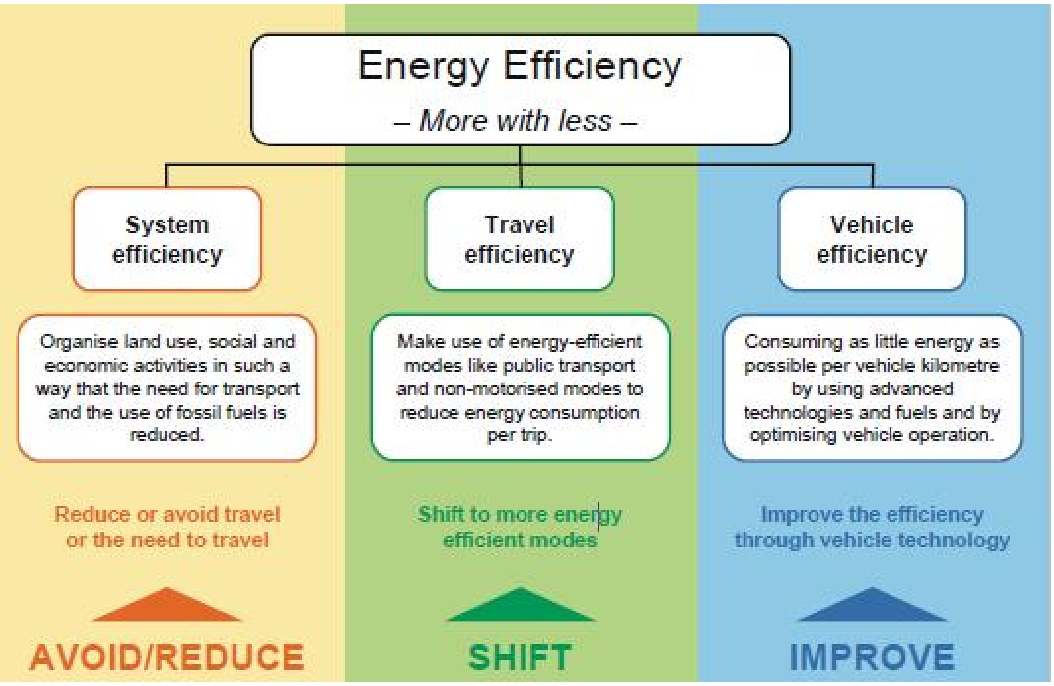


Figure 1: The Avoid – Shift – Improve Approach. Source (Böhler-Baedecker & Hüging, 2012, p. 8)

There is the potential to achieve greater energy efficiency on three different levels: For individual vehicles (vehicle efficiency), trips (travel efficiency) and for the whole transport system (system efficiency). According to these three different levels of energy efficiency, there are three basic strategies:

- "Avoiding increased transport activity and reducing the current demand for transport;
- Shifting demand to more efficient modes of transport;
- Improving the vehicles and fuels used" (Böhler-Baedecker & Hüging, 2012, p. 8).

Each "policy project" addresses one of these levels of energy efficiency (Böhler-Baedecker & Hüging, 2012). But some of the "policy projects" can both affect the system efficiency and the travel efficiency (see Annex 1 and 7, "avoid/shift").

Additionally, "policy projects" affecting the travel efficiency ("shift") were further classified in 'push' (disincentives) and 'pull' (positive incentives) measures (see figure 2).

Measures with push- and pull-effects
Redistribution of carriageway space to provide cycle lanes, broader sidewalks, planting strips, bus lanes…,
redistribution of time-cycles at traffic lights in favour of public transport and non-motorised modes,
public-awareness-concepts, citizens' participation and marketing, enforcement and penalizing…
Source: Müller *et al.*, (1992)

Figure 2: The 'push' and 'pull' approach. Secondary source (Böhler-Baedecker & Hüging, 2012, p. 61)

'Push' measures "discourage car use by making it less attractive" (Gärling, 2004, p. 3) through penalizing continued car use (Stradling, et al., 2000). "'Pull' measures encourage the use of alternative modes to the car by making such modes more attractive" (Gärling, 2004, p. 3).

2.3 Possible Policy Projects

A list of possible "policy projects" is presented in Annex 7. This list is a compendium of possible ways to reduce the CO_2 emissions of cities which were found in the literature.

These "policy projects" aim at bringing people to less driving or at improving the efficiency of the chosen transportation modes. The "policy projects" are categorized according to the two approaches (avoid – shift – improve and 'push' and 'pull') described in chapter 2.2.2. This list is only an excerpt of all possible ways to reduce the CO_2 emissions of cities and was prepared to give an idea of how many possibilities there are to support sustainable transport. To arrive at a clearer structure the "policy projects" are furthermore grouped by the subjects they address (see Annex 7).

2.4 Discussion

In order to improve the sustainability of the transport sector in cities (and thus to contribute to the reduction of CO_2 emissions, congestion and other concerns related to transportation) it will not be enough to implement single "policy projects". Instead it will be necessary to introduce packages of "policy projects" in order to implement an effective strategy (Zachariadis, 2005; MIP, 1999; Beirão & Cabral, 2007).

Therefore a strategy should comprise "policy projects" able to reduce the dependence on private transport and the need for driving by providing alternatives. A possibility would be to improve the public transport network and service, promoting it and also promoting non motorized transport, such as walking and cycling (Beirão & Cabral, 2007). These measures, encouraging people to use more sustainable transport modes, need to be combined with "policy projects" discouraging car use (e.g. congestion charging) (Mackett, 2001). When aiming to affect the modal shift from private motorized modes to sustainable transport modes, this means that 'push' and 'pull' measures have to be combined.

Demographic and socioeconomic factors, like gender and age, are also significant to be considered (Wang, et al., 2013; Redman, et al., 2013): The old and the poor are susceptible to 'push' measures, but "the young and those driving small cars to 'pull' measures" (Stradling, et al., 2000, p. 215). More difficult will it be to affect the driving habits of "those residing out-of-town, driving medium and large cars, doing high mileage and required to drive as part of their work" (Stradling, et al., 2000, p. 215) as they are not susceptible to either 'pull' or 'push' measures.

Additionally there exists the possibility to improve the effectiveness of the single "policy projects" within a strategy by combining complementary measures with the core ones identified for the specific strategy. As described in Vieira et al. (2007), there are four ways of achieving synergies between "policy projects":

First, project A "improves the *effectiveness*" of project B. This occurs "whenever the positive benefits of integrated implementation are greater than the aggregate positive results obtained by implementing" both projects separately. Second, project A "improves the *acceptability*" of project B. This "happens whenever the acceptability of" one policy project "can be improved by implementing another one". Third, project A "creates an *economic incentive* or *finances* the implementation" of project B. This takes place when one policy project (usually an economic project) "is used to finance another" project "or to create a market incentive to some transport product or service". Last, project A "improves the *enforcement*" of project B. This occurs when the implementation of a policy project "can be used to enforce the implementation" of another project (Vieira, et al., 2007, p. 425).

When creating a transportation strategy for a city, these possible interactions between "policy projects" should be considered in addition to the already above mentioned facts with respect to implementation of "policy projects". Thus not only the effectiveness of the impact of the implementation of “policy projects” could be increased. Also negative effects and barriers to implementation could be minimized (Vieira, et al., 2007).

However, there are possible negative feedback effects between “policy projects” or between the implemented instruments of a “policy project”. This is further described and explained in chapter 8.

The success of any transportation strategy or the success of the implementation of “policy projects” depends “to a large extent on the size of the political strength of the constituencies who support its implementation” (Meyer, 1999, p. 578). Especially when considering TDM, which focus on the change of travel behavior “of a large number of individuals, the strength of this constituency is critical to success” (Meyer, 1999, p. 578).

To conclude, the implementations of “policy projects” have “potentially important impacts on travel demand” (Meyer, 1999, p. 591) and travel behavior. Therefore they have the potential to save CO_2 emissions and contribute to reduce the overall environmental footprint of the cities (Redman, et al., 2013; Meyer, 1999).

But there still is the question how to implement the “policy projects” exactly to be able to ensure the highest possible contribution to the reduction of the negative impacts of the transportation sector in the cities. Which instruments can be implemented and which should be implemented in a particular city to answer the wishes, preferences and needs of the inhabitants?

To examine these questions, Bus Rapid Transit (BRT) systems were selected from the policy project list (see Annex 7) as an example to develop a methodology to evaluate “policy projects”. A further objective was to find out how to implement “policy projects”, with a special focus on improvements to the public transport system. BRT systems affect the travel efficiency and therefore contribute to a modal shift from private motorized modes to the public transport systems.

3 BUS RAPID TRANSIT (BRT)

This chapter provides general information about BRT systems, a description of the possible BRT instruments to be implemented as well as an overview of the case studies used for the analysis of BRT systems.

3.1 General Information

Bus Rapid Transit (BRT) systems are a good possibility to improve the public transport offer in a city. They can be as effective for passengers as heavy rail, light rail or metro while having lower capital costs (see figure 3) (Currie, 2005; McDonnell & Zellner, 2011; Levinson, et al., 2003b; Wright, 2004). Additionally, BRT systems usually have a shorter construction time than rail or other comparable public transport modes (McDonnell & Zellner, 2011). By affecting modal shift they are able to reduce congestion (McDonnell & Zellner, 2011) and can therefore contribute substantially to reduce emissions from the transport sector (ITDP, 2013b).

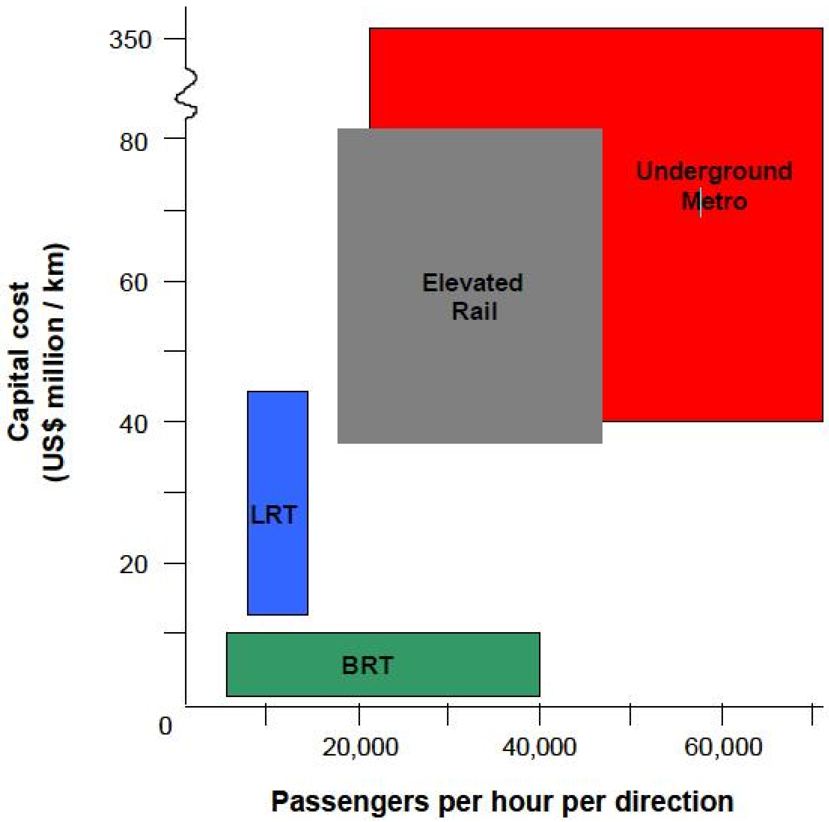


Figure 3: Capital cost and ridership of BRT systems. (Wright, 2004)

There are several definitions for the term “Bus Rapid Transit”. The ITDP (Institute for Transportation & Development Policy) describes it as a

> "high-quality bus-based transit system, that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service." (Wright & Hook, 2007, p. 11)

Levinson et al. provides a more complex definition. BRT is

> “a flexible, rubber-tired rapid-transit mode that combines stations, vehicles, services, running ways, and Intelligent Transportation Systems (ITS) elements into an integrated system with a strong positive identity that evokes a unique image. BRT applications are designed to be appropriate to the market they serve and their physical surroundings, and they can be incrementally implemented in a variety of environments. In brief, BRT is an integrated system of facilities, services, and amenities, that collectively improves the speed, reliability, and identity of bus transit. BRT, in many respects, is rubber-tired light-rail transit (LRT), but with greater operating flexibility and potentially lower capital and operating costs.” (Levinson, et al., 2003b, p. 1)

To summarize it, BRT is a

> "rapid mode of transportation that can combine the quality of rail transit and the flexibility of buses" (Thomas, 2001, p. 11)

BRT systems are very common in North America and in other developed or developing countries. But the application of this concept of a mass transit system to replace systems like metros, tramways und suburban trams is less necessary in Europe. These transit systems are already existing in many European cities to meet the needs of high capacity transit (Finn, et al., 2011). The cities in Europe are more dense with narrow streets where most activities and residence are mixed. They have therefore slightly different requirements to be met by the public transportation systems. The need for a transit system is not only for peak hour commuting travel, but also for the rest of the day as well as on evenings and weekends. In contrast, cities in North America are less dense and the public transportation system is needed more for commuters heading downtown, often from dispersed and far-off starting points. Therefore in Europe the concept of “BHLS” (Buses with High Level of Service) is more common (Finn, et al., 2011).

BHLS is a quality bus system giving priority for buses in traffic and providing higher quality vehicles, improved comfort at stops, improved information to passengers, integrated ticketing, intelligent transportation systems and a distinct identity (Finn, et al., 2011). Although the approach and the idea behind the system are similar to the BRT system, there are yet differences. Often the BRT systems in the developing countries are predominantly planned as mass transits and as an alternative to light rail or tramways or metros. Therefore they have much higher capacities than BHLS systems, which are built to complement the mass transit systems (Finn, et al., 2011).

But nevertheless, the BHLS systems can be understood as the European application of BRT systems, as the name attributed to one system can differ according to the source. For example, the BusWay in Nantes is described as a BHLS system by the city itself (Rabuel, 2011), but the ITDP refers to it as a BRT (ITDP, 2013a).

BRT and BHLS are not the only names used for this kind of public bus transportation systems. It is also referred to as: High-Capacity Bus Systems, High-Quality Bus Systems, Metro-Bus, Surface Metro, Express Bus Systems and Busway Systems (Wright & Hook, 2007). For the sake of clarity the term “BRT” will be used in the present study for all of these systems.

Although there are several guidelines and studies describing BRT systems and the elements or instruments that could be part of it (VTA, 2007; Wright, 2004; Levinson, et al., 2003a; Wright & Hook, 2007; Tann & Hinebaugh, 2009; Rickert, 2010), there is little agreement where the focus of policy makers should be when implementing BRT systems (McDonnell & Zellner, 2011) in order to attract as many passengers, especially car users, as possible. Furthermore critics argue “that the ‘brand’ of BRT is weaker” than that of “alternative transport modes such as light rail” (McDonnell & Zellner, 2011, p. 825).

To strengthen the ‘brand’ of BRT the ITDP, in cooperation with the GIZ (“Deutsche Gesellschaft für Internationale Zusammenarbeit”), ClimateWorks Foundation, ICCT (the international council on clean transportation) and the Rockefeller Foundation, has created a BRT standard catalogue: “The BRT Standard 2013” (ITDP, 2013b). This catalogue provides the criteria for BRT corridors to be certified as gold, silver, bronze or basic in order to set an internationally recognized standard and best practice.

The existing literature focuses on detailed descriptions of possible instruments and how to implement them, e.g. (Tann & Hinebaugh, 2009). It also provides an overview of case studies, e.g. (Wright & Hook, 2007) and describes the planning process.

However, it has not been possible to find a study that compares in detail which instruments were implemented for the most part by cities and what the achieved results in modal shift were. Furthermore the question remains, which instruments are most important concerning the preferences and wishes of potential riders.

The objective of the present study was to research into the implemented instruments in different BRT case studies and to analyze the success of the BRT systems in terms of the percentage of modal shift from private motorized modes as well as the percentage of BRT ridership that were former car users.

A further objective was to try to find out which quality attributes are important for the public transport riders and which instruments improve these quality attributes. Attributes are the quality features of a public transport system as perceived by the riders (Beirão & Cabral, 2007; Redman, et al., 2013). This was researched by analyzing studies investigating the reasons why people use or do not use public transport systems, especially buses or BRT.

The purpose of this analysis was to find out which instruments should be implemented with highest priority in order to achieve both a successful and complete system. The implemented BRT system should have the best possible impact on ridership and modal shift from private motorized modes, while considering the preferences and needs of the potential BRT riders. Some of the results of this research were then used to develop a tool for city planners. This tool provides a first assessment on which instruments should be implemented when introducing a BRT system in a specific city, particularly with a view of attracting car users. By increasing the modal shift to its maximum potential, the implementation of a BRT system should then result in a reduction of the overall environmental footprint of transportation.

3.2 BRT Instruments

As already mentioned, there are only a few studies providing examples with possible instruments of BRT systems. Instruments are defined as the specific elements that can be implemented with a BRT system (a “policy project”) (e.g. “running ways” or “off-board fare collection”).

As “The BRT Standard 2013” is the one study aiming to define the name and brand of BRT and to represent the best source in terms of comprehensiveness and structure of the instruments, it is used in this master thesis as the most important reference for BRT instruments. Further instruments where found in other sources, e.g. “The Bus Rapid Transit Planning Guide” and “Characteristics of BUS RAPID TRANSIT for Decision-Making” (Wright & Hook, 2007; Tann & Hinebaugh, 2009), or in specific case studies that are missing in “The BRT Standard 2013”. They were considered in the present study in order to implement a successful and complete system, resulting in a comprehensive list of 41 instruments. For a clearer structure, the instruments are categorized in seven groups, applying the structure of “The BRT Standard 2013” (see list of BRT instruments in table 1):

Table 1: List of BRT instruments

Groups	Instruments
BRT Basics	Running ways
	Off-board fare collection
	Intersection treatments
	Platform-level boarding
Service Planning	Multiple routes
	Peak frequency
	Off-peak frequency
	Express, limited and local services
	Control center
	Located in top-ten corridors
	Hours of operation
	Demand profile
	Multi-corridor network/network of routes and corridors
Infrastructure	Passing lanes at stations
	Minimizing bus emissions (Euro III or higher)
	Stations set back from intersections
	Center stations
	Pavement quality
Station Design and Station-Bus Interface	Distance between stations
	Enhanced station environment/safe and comfortable stations
	Number of doors on bus
	Docking bays and sub-stops
	Sliding doors in BRT stations
Quality of Service and Passenger-Information Systems	Branding
	Real time passenger information
Integration and Access	Universal access
	Integration with other public transport – physical transfer points
	Integration with other public transport –information
	Integration with other public transport – fare payment: Integrated tariff system
	Pedestrian access
	Secure bicycle parking
	Bicycle lanes
	Bicycle-sharing integration
	In BRT integrated bus feeder systems
	Park and ride
	Improvements to nearby public space
Supporting measures	Operational subsidies
	Restriction of on-street parking
	Supporting car restriction measures (e.g. road pricing)
	Marketing campaign
	Electronic card

Comments on the above classification are given below. A detailed description of all instruments and further explanatory notes are provided in Annex 2.

To ensure the quality of a BRT system and to strengthen the “brand”, five core instruments of BRT systems have been identified (“BRT basics”) by the ITDP (ITDP, 2013b). These instruments are essential for the operational performance of the service:

- “Busway alignment”,
- “Dedicated right-of way”,
- “Off-board fare collection”,
- “Intersection treatments” and
- “Platform-level boarding”.

The instrument “busway alignment” describes the location of the busway in the street. “The busway is best located where conflicts with other traffic can be minimized, especially from turning movements from mixed-traffic lanes. In most cases, the central verge of a roadway encounters fewer conflicts with turning vehicles than those closer to the curb due to alleys, parking lots, etc. Additionally, while delivery vehicles and taxis generally require access to the curb, the central verge of the road usually remains free of such obstructions” (ITDP, 2013b, p. 16). The instrument “dedicated right-of-way” concerns the segregation of the busways: “A dedicated right-of-way is vital to ensuring that buses can move quickly and unimpeded by congestion. Physical design is critical to the self-enforcement of the right-of-way. Dedicated lanes matter the most in heavily congested areas where it is harder to take a lane away from mixed traffic to dedicate it as a busway. Enforcement of the dedicated lanes can be handled in different ways and can have varying degrees of permeability (e.g. delineators, electronic bollards, car traps, colorized pavement, and camera enforcement)” (ITDP, 2013b, p. 18).

It was difficult to withdraw the specific information required from the case studies for these two instruments. Accordingly, they were treated together as “running ways” in this master thesis and were defined as follows (see also Annex 2): Running ways are the bus routes or lanes. They define where BRT vehicles travel. This includes all levels of implementation concerning the location (e.g. two-way median-aligned busway or curb-aligned busway, on-street or off-street) and the grade of physical segregation of bus lanes from pavements and or other traffic lanes (e.g. full physical segregation, segregation only with marking and signs) (ITDP, 2013b; Tann & Hinebaugh, 2009).

The instrument “operational subsidies” (see under “supporting measures” in the above list) has to be interpreted carefully. While operational subsidies can help to decrease fares, BRT systems, especially in the developing world, should be designed to function without operational subsidies (Wright & Hook, 2007).

All instruments are categorized in Annex 2 as either technical (T) or non-technical (NT). Technical instruments are ICT, or simply technology based, needing energy to be able to work, or which concern the technical parts of vehicles or stations. Non-technical instruments require a planning process at the outset, and could be implemented without using technologies. It is assumed that cities can implement most of the non-technical instruments on their own, whereas for the application of most of the technical instruments external support is needed. In total there are 12 technical and 29 non-technical instruments.

Further "policy projects" or single instruments of other projects (e.g. "supporting car restriction measures" like road pricing) were also included in the list of possible instruments of BRT systems above when they were considered important for the improvements of BRT systems. Between some of them could be a positive interaction, e.g. between BRT and road pricing (as described in chapter 2.4):

Example: Assuming the BRT system is built to serve the central business district in a city, it can be helpful to introduce a tolling scheme for cars entering this area. In this case, the ridership of the BRT can be increased and car usage for trips to the business district and congestion can be decreased.

"The BRT Standard 2013" works with an evaluation system giving more credits for a higher implementation level of the instruments. In the present study the possible instruments are only considered as implemented (marked as "1" in Annex 3 and 8), not implemented (marked as "-"), no information available (marked as empty in Annex 3 and in data base in Annex 8, and marked as "0" in calculation sheets of Annex 8) and not enough information available to draw a conclusion (marked as "?"). An assessment of the level of implementation of the instruments in case studies is principally not possible due to the lack of available data for the case studies.

3.3 Case Studies

To conduct the analysis information about BRT case studies was required. To obtain the necessary information about the implemented instruments and further data (e.g. percentage of modal shift from car to BRT, percentage of BRT ridership that were former car users, population of the metropolitan area, etc.), an internet based information research was performed. The literature taken into consideration was either scientific studies or case study reports of institutions and websites providing information about BRT systems. Information discussed for the case studies was collected from different sources.

33 case studies (BRT corridors or lines) for 29 metropolitan areas were found (see table 2):

Table 2: BRT case studies

Continent	Metropolitan area	Name of BRT system/ case study
Europe	Nantes	Busway
	Edinburgh	Fastlink/WEBS
	Kent Thameside	Fastrack - Route A
		Fastrack - Route B
	Leeds	Leeds superbus, A61 und elite
	Istanbul	Metrobus
	Stockholm	Trunk bus network
	Helsinki	Jokery line
North-America	Alameda County	San Pablo Ave Rapid
	Albuquerque	Rapid ride - red line
	Boston	Silver line - Washington street
		Silver line - Waterfront SLI-Airport
		Silver line - Waterfront SL2 -BMIP
	Miami-Dade	South Miami-Dade Busway
	Las Vegas	MAX
	Los Angeles	Orange Line
	Mexico City	Metrobus
South-America	Bogota	Transmilenio
	Curitiba	Rede Integrada de Transporte
	Pereira	
	Rio de Janeiro	TransOeste
Canada	Vancouver	Translink #99
Australia	Adelaide	ANEB
	Brisbane	BSEB
		BINB
	Sydney	SLPT
Asia	Ahmedabad	Janmarg
	Changzhou	
	Guangzhou	Zongshan Ave. BRT
	Jinan	Jinan BRT
	Jakarta	Trans Jakarta
	Kunming	
	Nagoya	Key Bus Route System - Tako line and Shin-dekimachi line

Data about BRT systems are rare. It was very difficult to obtain the required information and the information research was not always successful. This is the reason why also case studies were included for the calculation, which do not completely meet the BRT basic requirements ("BRT basics"), or where some information about them was missing (e.g. Nagoya, Istanbul, Vancouver).

As already mentioned, the instruments are based on the "BRT Standard 2013". But the literature seldom refers to this standard catalogue. This leads to a problem. The instruments could only be counted as implemented, when there is information given in the literature that allows to draw the conclusion that this instrument was also actually implemented in the case study. It is possible that there is no information provided, even if this instrument was actually implemented. For example, the instrument "marketing campaign" was only counted as implemented for eight out of 33 case studies. But it has to be assumed that in more than eight case studies broad marketing campaigns were carried out to support the BRT systems and that it is only not mentioned expressly in the literature. This applies also for the instruments "pavement quality", "supporting car restriction measures", "integration with other public transport modes – information", "operational subsidies", "located in top-ten corridors" and "center stations" (marked with "few information available" in Annex 2). Accordingly, whenever evidence supporting the implementation of an instrument could not be found, the instrument was considered as not implemented for the calculation.

A summary of the important data about the case studies is provided in Annex 3 and the full database will be found in Annex 8.

4 METHODOLOGY

This chapter describes the methodology used for the evaluation of the BRT case studies. Both a qualitative and a quantitative analysis were carried out. First, the qualitative analysis will be presented followed by the quantitative analysis.

4.1 Qualitative Analysis

The qualitative analysis was conducted in two parts: As a first step, the quality attributes, which a public transport system should have, were investigated. Second, the quality attributes are then allocated to the respective BRT instruments as defined in chapter 3.2.

4.1.1 Identification of Passenger Preferences

For the implementation of a successful and complete public transport system it is essential to determine the most important quality attributes according to the preferences of the current and potential riders that a public transportation system should have (Beirão & Cabral, 2007; Friman, et al., 2001). Attributes are the quality features of a public transport system as perceived by the riders (Beirão & Cabral, 2007; Redman, et al., 2013), e.g. “travel time” or “reliability”. Redman et al. state that there “may be significant discrepancies between the objective level of quality supplied and evaluated by PT [public transportation] operators and how it is perceived by PT users” (Redman, et al., 2013, p. 121). For this reason it is very important to identify the preferences and needs of the current and potential riders and how they evaluate the attributes provided by the public transport system. To improve the overall effectiveness of public transport quality enhancement the identification of the important attributes should be done before improvements to the public transport system are actually implemented, especially when a modal shift from private motorized modes is targeted (Redman, et al., 2013).

To evaluate which quality attributes are in principle the most important ones according to the passenger preferences, a literature research was conducted. Studies considered were both scientific papers addressing questions like “What is people holding back from using public transport?” and “Why are people using public transport?” and also surveys asking current BRT riders for their satisfaction with the system used.

Passenger surveys mostly provided a percentage for each particular attribute stating for how many passengers asked this attribute was the most important reason for using public transport.

In contrast, scientific papers, often literature reviews, listed the important attributes found in the original sources. Because of this difference and because not many scientific papers addressed the above mentioned questions (Friman, et al., 2001), it was not possible to perform a quantitative analysis calculating an average for each attribute out of the percentages provided. Instead a qualitative analysis was conducted, as follows:

With respect to the surveys providing a percentage, the two to four attributes with the highest percentages were further considered in this analysis. Concerning the scientific papers the attributes were considered, which were listed in the literature review.

In total the analysis comprised 11 studies (both scientific papers and surveys):

1. Mackett found out, which events have to happen to make car users switch from their cars to use public transport. These results are provided as percentages of car trips that could be shifted to alternative modes. Out of the list of 29 actions identified only those were taken into account that are relevant for BRT or bus usage (“bus routes improved”, “weather improved”, “bus frequency improved”) (Mackett, 2001).
2. Redman et al. revealed through a literature review that the attributes travel time, frequency, reliability and fares are key quality features of public transport services (Redman, et al., 2013).
3. Fellesson & Friman reported that key elements of public transport user satisfaction are reliability, frequency, comfort, information, driver behavior and cleanliness (Fellesson & Friman, 2008).
4. Thompson & Schofield found out that in the literature travel time and fare are evaluated as key attributes of performance. Furthermore reliability, information provision, cleanliness, comfort and security are important (Thompson & Schofield, 2007).
5. Among Chinese cities the level of impact of attributes is different. Nevertheless the study asserted that travel time savings are a key quality attribute to attract riders in all corridors and travel groups (Wang, et al., 2013).
6. A public transport survey conducted in the metropolitan region of Perth determined that the most cited reasons for using buses and trains are lower cost than driving, less stress by avoiding traffic and environmental benefits. (RAC, 2008)
7. A survey executed in 2007 found out that the top three reasons for choosing Fastrack (BHLS) in Kent Thameside are frequency, convenience and traffic free routes (George, 2010).
8. The most important reasons for riding the Rapid Bus in Alameda County (only considering the reasons that are quality attributes) are convenience and economic advantages (Tann, 2006).

9. A survey conducted in Brisbane concerning the user perceived advantages of the South East Busway determined that reduced travel time, reduced traffic congestion, convenient departure and boarding points and more frequent services are very important (Currie, 2006).
10. The important benefits according to the public perception for the Fastlink in Edinburgh are reliability, journey time, frequent services and affordability (BRT-UK, 2006).
11. The top three reasons for riding Metrobus in Istanbul (only considering quality attributes) are rapidity, comfort and the avoidance of traffic congestion (Yazıcı, et al., 2013).

After having analyzed the studies above the reported attributes were grouped and defined. The number of quotations of each attribute stated in the studies was determined. Then the attributes were ranked in the order of significance which was measured by the respective number of quotations.

It is to be noted that the analyzed papers and surveys addressed different questions. Some of them asked for the public perceptions of already implemented BRT systems or for the attributes that are important for public transport users. Other studies investigated what attracts drivers out of their cars or what public recommendations are to enhance the already existing system.

For the present analysis it was therefore assumed that the scientific papers produced more important results than the surveys as they were established on a broader basis. As a consequence it was determined, how often each attribute was stated in the scientific papers as compared to the surveys. Accordingly, when two attributes had the same total number of quotations, but one of them was stated more often in papers than the other, it was ranked higher (see chapter 5.1.1).

4.1.2 Allocation of Attributes to Instruments

To be able to enhance the quality attributes of a public transportation system, it is important to know which instruments address which attributes. Only with this background information it is possible to identify the instruments that have to be implemented in order to achieve the targets.

Information about this subject was only found in three studies: “Quality attributes of public transport that attract car users: A research review”, “The BRT Standard 2013” and “Characteristics of BUS RAPID TRANSIT for Decision-Making” (Redman, et al., 2013; ITDP, 2013b; Tann & Hinebaugh, 2009).

As the allocations stated in these studies did not cover all the attributes and instruments, the missing interdependencies were identified through discussions with several members of the Mobility Consulting Department at Siemens AG in Munich and with scientists from the Chair of Urban Structure and Transport Planning of the Technical University in Munich.

After the allocation of the attributes to the instruments (see table 21 in Annex 4) the instruments were ranked in the order of importance based on the passenger preferences. Therefore a points system was established (see table 22 in Annex 4). Points on a scale from one to seven were assigned to each instrument for each attribute it addresses. The higher an attribute ranked, the more points were assigned. In the end the points for each instrument were added up and the instruments were sorted according to their score. Instruments with the same score rank on the same position of importance of implementation in order to create a successful system that is attractive to the riders (see Annex 5).

4.2 Quantitative Analysis

Originally it was planned to measure the success of the BRT system in terms of the percentage of car users who shifted to BRT due to the implementation of the BRT system. As there was only little information available in the literature about this value, the percentage of BRT ridership who were formerly car users and who shifted due to the implementation of the BRT system was taken as an additional auxiliary value to measure the success of BRT systems.

The objective of the quantitative analysis was therefore to determine the success of the BRT systems in terms of the following two key values and to research into the relationship between each of them and the implemented instruments in the case studies:

- First, the percentage out of the **total population of BRT ridership** who were formerly car users and who shifted due to the implementation of the BRT system (referred to as **“percentage of BRT ridership”** in the following) was determined.

- Second, the percentage out of the **total population of the car users** who shifted to BRT due to the implementation of the BRT system (referred to as **“percentage of modal shift”** in the following) was determined.

Then, the implemented BRT instruments (e.g. “separated running ways”, “off-board fare collection”), were evaluated and counted for all of the 33 case studies.

4.2.1 Percentage of BRT Ridership that were former Car Users (Percentage of BRT Ridership)

The interesting value for this analysis was the percentage of BRT ridership. Case studies were investigated where information concerning this value was found in the literature. In total this value was found for 17 case studies:

Nantes, Pereira, Mexico City, Istanbul, Alameda County, Miami-Dade, Vancouver (Translink #99), Los Angeles, Bogota, Boston (Silver line – Washington street), Kent Thameside (Fastrack Route B), Guangzhou, Curitiba, Rio de Janeiro, Changzhou, Kunming and Jinan.

For all of these 17 case studies the following values were calculated:

- The number of instruments implemented and the percentage of technical and non-technical instruments thereof
- The share of implementation of the eight most important instruments according to the passenger preferences in the total number of implemented instruments. The eight most important instruments were defined as those having reached more than 60% of the achievable points (see chapter 4.1.2 above)

Furthermore it was determined, how often the individual instruments were implemented in the 17 case studies and the average percentage of BRT ridership was calculated.

<u>Grouping of case studies according to size of the system and size of the city</u>

The case studies differ in terms of the size of the system and the city. So, as a next step, they were split in order to create groups of comparable cities. Originally it was planned to categorize them according to the value of BRT place kilometer per inhabitants. This would have been an appropriate parameter to compare different public transport systems, since this parameter is also used by the uitp (International Association of Public Transport) (UITP, 2001). To determine this parameter, the annual distance travelled in kilometers ("annual distance travelled") by the fleet of the BRT system would have been multiplied by the number of places offered in the vehicles ("places"). Subsequently this product would have been divided by the number of the inhabitants of the metropolitan area. The resulting formula would have been as follows:

$$\text{BRT place km per inhabitants} = \frac{\text{annual distance travelled} * \text{places}}{\text{inhabitants of metropolitan area}}$$

But because many data needed to determine this value were not available, only the annual distance travelled of the BRT system could be calculated. This calculation was carried out by multiplying the number of services offered per day in each direction (how often the BRT route is operated by vehicles per day) by the length of the network (in kilometers). The result was then converted into an annual figure. Therefore, the following formula was used:

$$\text{Annual distance travelled} = \text{number of services per day} * \text{length of the network} * 7 * 52$$

Where no information was available about the number of services, it was estimated as follows: The number of buses operating per day in one direction was calculated and multiplied by two (to consider both directions). If the headways for peak and off-peak hours were available, the number of buses per hour was calculated by dividing the number of minutes per hour by the headway (in minutes). Then the number of office hours ("# hours") was taken. It was assumed in this respect that there are four hours of peak-hour travel per day. The number of services per day was then calculated as the sum of the products of the number of buses per peak hours ("# peak hour") multiplied by four and the number of buses per off-peak hours ("# off peak hour") multiplied by the remaining operating hours per day. Accordingly, the following formulas were used:

$$\text{Number of buses per hour} = \frac{60\,\text{min}}{\text{Headway (in minutes)}}$$

$$\text{Number of services per day} = (4 * \#\,\text{peak hour}) + ((\#\,\text{hours} - 4) * \#\,\text{off peak hour})$$

When there was no information available concerning the headways or the operation hours per day, the number of services per day for a weekday and for the weekend were counted with the help of the schedules offered on the websites of the BRT system operators.

When there was no information available concerning the number of services per day, the headways for peak and off-peak hours, the office hours or a schedule for the BRT system, the annual distance travelled had to be roughly estimated. In this case the number of average daily passengers was divided by the average vehicle capacity (standing and seating places). This number was then multiplied by the length of the network and converted into an annual figure. Therefore, the following formula was used:

$$\text{Annual distance travelled} = \frac{\text{average daily passengers}}{\text{average vehicle capacity}} * \text{length of the network} * 7 * 52$$

The calculated number of services per day was taken for the weekend as well, when there was no other information available.

Since so many assumptions had to be made in calculating the value of the annual distance travelled, this value is not very meaningful. Therefore the groupings were additionally based on the average number of daily passengers, the population of the metropolitan area and the length of the system, resulting in three different groups (groups A to C, see table 3). Two of these additional values are also not very meaningful, because they refer to different bases: The average daily passengers sometimes refer to the daily average (the average for all days of the week) and sometimes to the average for a workday. But due to the lack of more detailed data this could not be considered further. As the definitions for metropolitan areas in the sources were differing, it is uncertain whether these numbers are completely comparable. The only meaningful value is the length of the network.

Table 3: Grouping of the BRT systems according to size of the city and size of the system

	Group A	Group B	Group C
Metropolitan region			
Inhabitants	2 million to 20 million	5 million to 13 million	<1 million to around 5 million
BRT systems			
Average daily passengers	0.5 million to 1 million	60,000 to 800,000	6,000 to 115,000
Network length	34 to 85 km	22 to 25 km	4 to 27 km
Annual distance travelled	7 million to over 200 million km	around 4.5 million km	<1 million to around 3 million km

In group A there are very big cities (around two to 20 million inhabitants), with large BRT systems (average daily passengers around 500,000 to one million, network lengths around 34 to 85 km and an annual distance travelled from seven million km to over 200 million km). Group B comprises big cities (around five to 13 million inhabitants) with medium sized systems (average daily passengers around 60,000 to 800,000, network length around 22 to 25 km and an annual distance travelled of around 4.5 million km). Group C includes medium sized cities (from under one million to around 5 million inhabitants) with smaller BRT systems (average daily passengers from 6,000 to 115,000, network length from four to 27 km and an annual distance travelled from under one million to around three million km).

As three out of the four values above are not very meaningful, the allocation of the BRT systems to the groups was difficult and was done more from a qualitative rather than from a quantitative aspect. This is why there may be some overlappings in the values between the groups. For example, Curitiba has two million inhabitants of the metropolitan area (less than the cities in group A) and was nevertheless categorized in group A as the other values (length of the network and annual distance travelled) were very high.

For the three groups the average percentage of BRT ridership was calculated. Furthermore it was examined for the groups, which other public transport modes are offered in the metropolitan areas of the case studies. Of further interest was the question, whether a trend can be recognized that BRT systems are more successful in cities having only a low public transport offer (only conventional bus systems are additionally provided). To learn, whether there is such a trend, the success rates (percentage of BRT ridership) of the BRT systems providing only conventional bus systems in addition to BRT systems were compared to systems providing additional public transport modes like light rail or metro.

Additionally, it was examined whether the different success rates in the groups can be explained by the transportation modal shares in the cities, especially by the car usage or by the private motorized modes. Therefore the modal shares in the cities were researched and grouped according to the size of the cities applying the grouping described above. They were graphically represented and compared (see graphics chapter 5). Because data about the modal shares were not available for all the cities of the 17 case studies considered in this evaluation, the analysis was carried out with the respective data for all of the 29 cities. These data were only available for 12 cities out of the 29. This is further explained in chapter 4.3.

Grouping of cases studies according to running time

The case studies differ with respect to running time. Running time is the time span between the implementation or the start of the system and the reference year of the literature evaluating the case studies. So as a next step the cities were grouped according to their running time. Three groups were identified: One to three years, three to six years and eight to 18 years. For these groups the average percentage of BRT ridership was calculated.

Trend analysis between the success rates and the percentages of the implementation of the most important instruments according to the passenger preferences

The next step consisted in the analysis of a trend between the success rates of the BRT systems in terms of the percentage of BRT ridership and the percentage of the implementation of the most important instruments according to the passenger preferences. The assumption was to be verified that a system is very successful, if many of the most important instruments according to the passenger preferences were implemented. Therefore the case studies were simply sorted according to the percentage of the implementation of the important instruments in order to learn, if such a trend can be recognized.

Instruments implemented in the most successful systems

As a result it was determined which instruments were implemented most of all (in more than 60% of the case studies) in the most successful systems (concerning case studies where the success rate is above the overall average of 13.82%).

Additionally it was assessed which attributes are addressed by these instruments by applying the allocation of attributes to instruments (see chapter 4.1.2).

4.2.2 Percentage of Car Users Shifting to BRT (Percentage of Modal Shift)

The percentage of car users shifting to BRT due to its implementation, referred to in the following as percentage of modal shift ("% modal shift"), was found in the literature for only three case studies (Pereira, Nagoya, Leeds). As this is too little for any analysis it was calculated for additional three case studies (Nantes, Mexico City, Istanbul) out of the following values: the percentage of the BRT ridership ("% BRT ridership"), the number of average passengers per day ("average daily passengers") and the number of average daily car trips ("car trips") in the city. Accordingly, the following formula was used:

$$\%\ \text{modal shift} = \frac{\%\ \text{BRT ridership} * \text{average daily passengers}}{\text{car trips}}$$

A trip is defined as "a ride between two (physical) points with one given mode of transport" (Rietveld, et al., 2001, p. 541). For the case studies, where the information about the daily car trips in a city was missing, it was calculated by multiplying the total daily number of all transportation modes by the modal share for private car use or private motorized modes in the city.

The analysis of the six case studies was conducted where possible in the same way as for the percentage of BRT ridership.

First, the following values were calculated:

- The number of instruments implemented and the percentage of technical and non-technical instruments thereof
- The share of implementation of the eight most important instruments according to the passenger preferences in the total number of implemented instruments

Next, it was evaluated how often each individual instrument was implemented in the six case studies and the average percentage of modal shift was calculated.

Grouping of case studies according to size of the system and size of the city

The six case studies were split according to the size of the system and the size of the city in the same way as explained in chapter 4.2.1 above. For this calculation only case studies for groups A und C were available.

The average percentage of the modal shift was calculated for both groups. Additionally, an analysis concerning the other public transport modes offered and concerning the modal shares in the cities was performed in the same way, as also described in chapter 4.2.1.

Grouping of case studies according to running time

For this analysis the case studies could only be divided in two groups (two to six and 12 to 25 years) as there were not sufficient case studies available for a further grouping. The average percentage of modal shift was calculated for each group.

Trend analysis between the success rates and the percentages of the implementation of the most important instruments according to the passenger preferences

In this evaluation the success was measured by the percentage of modal shift. It was conducted in the same way as described in chapter 4.2.1.

4.2.3 Evaluation of the Implemented Instruments in BRT Case Studies

To gain more information about the instruments implemented in the case studies, another analysis was carried out covering all 33 case studies. The following values were calculated:

- The number of instruments implemented and the percentage of technical and non-technical instruments thereof
- The share of implementation of the eight most important instruments according to the passenger preferences in the total number of implemented instruments

Furthermore it was evaluated how often each individual instrument was implemented in the case studies. The ten most implemented instruments (implemented in more than 60% of the case studies) were identified. Additionally, it was assessed which attributes are addressed for the most part by the cities through these ten most implemented instruments by applying the allocation of attributes to instruments (see chapter 4.1.2).

4.3 Problems in the Evaluation

4.3.1 General Problems

While collecting the data for the case studies it was realized that for a case study sometimes the information offered in one literary source was not sufficient. Then another literary source was searched concerning this case study. It was tried to find literature referring to the same year or to a year close to the first reference year. But often these two sources referred to different years. This complicated the evaluation. But because of the lack of further data, the information had to be used, even if the reference years were different.

Another difficulty was that for some cities the information provided concerned the whole BRT system (possibly including several BRT corridors) and for some other cities extra information for each BRT corridor was provided. As most of the information provided related to the entire BRT systems, it would have been useful, if the information for the individual BRT corridors in a city could have been summarized. Unfortunately this was not possible, since in most cases the information for one single corridor was not complete. It was tried to overcome this problem by grouping the case studies depending on their size and the size of the cities. But still it is not the ideal way to compare different levels with each other. However, this aspect could not be further considered due to the lack of data.

4.3.2 Identification of Passenger Preferences

As already mentioned in chapter 4.1.1 there were only few studies available for the analysis of the passenger preferences. The reviewed studies addressed different questions like asking for the public perception of already implemented BRT systems or for the attributes that are important to public transport users. Other studies investigated into what attracts car users out of their cars or what the public recommendations are to enhance an already existing system. Furthermore, some literary sources were scientific papers and some only surveys carried out in cities. These aspects were the reasons, why it was difficult to evaluate the studies. In the present study the scientific papers were weighted more than the surveys, as it was assumed that these produced more important results, since they were established on a broader base.

In summary it should be mentioned that the methodology applied to evaluate the passenger preferences is not very substantiated, but it was not possible to do in another way, as there is only few literature available which is focusing on this subject.

4.3.3 Allocation of Attributes to Instruments

With respect to the allocation of the attributes to the instruments it was difficult to find detailed information in the literature. The information provided in “Characteristics of BUS RAPID TRANSIT for Decision-Making” (Tann & Hinebaugh, 2009) could not be used in the present study at all, except for one case of the allocation of an attribute to an instrument. This study could not be considered, as it used quality attributes and instruments different from those used in the present study.

Again, since only little information could be found in the literature on this topic, it was tried to allocate the attributes to the instruments by discussing this subject with a number of competent individuals. The allocation was also not always clear between the participants. As this part of the evaluation is a key component and changes affect all subsequent assessments, this allocation may be subject to reconsideration at a future point of time.

4.3.4 Success of the BRT systems

Percentage of BRT ridership

The percentages of BRT ridership were available on the basis of two different populations. Some studies referred to this number on the basis of the whole ridership and some only on the basis of new passengers. In the present study only values were considered referring to the whole ridership, thereby decreasing the number of case studies appropriate for the evaluation.

Percentage of modal shift

This value was only available for a few case studies. After a closer examination it was recognized that for some case studies the literature refers to the percentage of modal shift (percentage of car users who shifted to BRT), but actually discusses the percentage of BRT ridership that were former car users. When this was recognized, it was tried to find out for the rest of the values, if they are appropriate. Therefore the authors of the studies or the cities themselves were contacted via email or telephone to obtain the required information. In the end most case studies had to be excluded from the analysis. Three case studies were left, where it could not be proven whether the percentages are appropriate or whether they are inappropriate. These case studies were taken into account for the analysis but it still could be that for some of them the values are actually inappropriate. To be able to perform an evaluation it was tried to calculate the desired value for additional case studies. This was only successful for three further case studies, so in total six case studies were considered in the analysis.

Problems in the evaluation of the values measuring the success

As already mentioned in chapter 4.2.1 the case studies were grouped according to the size of the system and the size of the city for both analyses. It was not possible to do that on the basis of the BRT place km per inhabitant due to a lack of data. Instead the grouping was performed on the basis of the values of the annual distance travelled of the BRT system and other values. Even for the annual distance travelled some assumptions had to be made, as also already described. Furthermore, the annual distance travelled should only contain the life mileage. The life mileage excludes deadhead runs from and to depots (UITP, 2001). As for the calculation only the length of the network was taken into account it was assumed that this also only includes the life mileage. To summarize, many assumptions had to be made to be able to calculate this value. If the data base had been better, the grouping would have resulted in a more precise categorization.

For the analysis of the modal share it was again difficult to obtain the required information. It was only found for 12 cities. Most of the data considered the non motorized transport modes (walking and using the bicycle) in the modal share, but not all. In total the modal share could be found with respect to the case studies in group A for five cities, three thereof considering non motorized transportation modes (NMT) and two not. For group B only three modal shares were found for the cities covered by case studies: Los Angeles and two cities in China, Guangzhou and Changzhou. For group C modal shares were available for four cities, three considering the NMT and one modal share without considering the NMT. Because of this difference it was not possible to calculate an average modal share for the evaluation. The analysis had to be done graphically. Furthermore, it was tried to find the modal shares of the cities referring to a year prior to the implementation of the

BRT systems to compare the success rates of the systems with the original modal shares in the cities. This was not possible for two of the cities. Therefore, the modal shares for years after the implementation had to be considered, as otherwise there would not have been enough modal shares available for an evaluation.

As mentioned above, the literature for the case studies referred to different years so that the running time of several case studies could not be ascertained exactly. If these differences were overlapping two groups and it was not clear to which group the case study belonged to, the case study was not considered in the further analysis concerning this grouping.

5 RESULTS

This chapter presents the results of the analysis using the methodologies described in chapter 4. The analysis was conducted in two steps. First the results of the qualitative analysis are presented, followed by the results of the quantitative analysis.

5.1 Qualitative Analysis

The qualitative analysis was carried out in two steps. The quality attributes a public transport system should have, especially BRT systems, were researched. To improve these quality attributes it is important to know which BRT instruments, as defined in chapter 3.2, address which attributes. So as a next step, the attributes were allocated to the instruments. The results of these two steps are presented in the following.

5.1.1 Identification of Passenger Preferences

As discussed, to be able to implement a successful and complete public transport system, it is necessary to determine the quality attributes a public transport system (e.g. Bus Rapid Transit) should have. Therefore a literature research and a study analysis were conducted as described in chapter 4.1.1.

After analyzing the studies and surveys, the identified quality attributes were grouped and defined, resulting in a list of 13 quality attributes (see table 4). Subsequently, the attributes were ranked according to their number of quotations in the papers and surveys.

The results are also presented in table 4 below.

Table 4: Attributes ranked by their importance according to passenger preferences

Rank	Attributes	Definition	Number of quotations		
			Total	Papers	Surveys
1	Travel time	The time spent travelling between specified points[1] (including waiting times)	6	3	3
	Frequency	Number of service operatings during a given period[1]	6	3	3
2	Price	The monetary cost of travel[1]	5	2	3
	Reliability	Match between actual service delivery and route timetable[1]	4	3	1
3	Less congestion	Insuring less congestion on the bus routes than on the streets	4	0	4
	Comfort	Comfort of journey regarding access to seat, noise levels, driver handling, air conditioning[1]	3	2	1
4	Information provision	Extent of information provided about the system, routes, interchanges, waiting times and special offers[1]	2	2	0
5	Convenience	Simplicity of the use of the PT service and addition to one's ease of mobility[1]	2	0	2
6	Bus routes improvement	Improvement of the bus routes for a better public transport offer (planning of the routes)	1	1	0
	Weather improvement	Improvement of travel comfort by offering weather protection	1	1	0
	Safety/Security	Safety from traffic accidents passengers feel during the journey as well as personal security[1]	1	1	0
7	Environmental benefits	Improvement of direct environmental benefits by travelling with public transport	1	0	1
	Accessibility	Degree to which public transport is reasonably available to as many people as possible[1]	1	0	1

For the present study it was assumed that scientific papers produced more important results than surveys (see chapter 4.1.1). Therefore, when two attributes had the same total number of quotations, but one of them was stated more often in papers than the other, it was ranked higher: The attribute "less congestion" (rank three, see table 4) was stated in total four times, as well as the attribute "reliability". But as "reliability" was stated three out of the four times in papers, it was ranked higher as "less congestion", which was stated four times in surveys and not at all in papers. "Reliability" is therefore on the same rank as "price", even though "price" was stated

[1] See (Redman, et al., 2013)

in total one more time than “reliability”. However, “reliability” was mentioned one more time in papers. That is why they were considered as equally important.

5.1.2 Allocation of Attributes to Instruments

To improve the identified quality attributes, it is important to find out which instruments, described in chapter 3.2, affect which attributes. This was carried out as explained in chapter 4.1.2. Table 21 in Annex 4 presents the allocations of the attributes to the instruments (marked with an “x”):

All instruments address as a minimum one attribute (e.g. “center stations”). The instrument “running ways” affects the most attributes, six in total. The rest of the instruments are in between.

The attribute “weather improvement” is addressed by the least number of instruments (by only one). This is further explained in chapter 7. All the other attributes are affected by three to 18 instruments, with “accessibility” as the one affected by the highest number of instruments.

After the allocation of the attributes to the instruments, the instruments were sorted (see chapter 4.1.2) depending on their importance of implementation to attract as much riders as possible. The ranking of the quality attributes according to the passenger preferences (see chapter 5.1.1) was considered and a points system was established (see table 22 in Annex 4). The instruments were ranked according to their score. The eight most important instruments (i.e. the instruments which achieved 60% and more of the possible points) are:

- “Running ways” (rank one),
- “Intersection treatments” (rank two),
- “Control center” (rank three), and
- “Multiple routes”, “passing lanes at stations”, “docking bays and sub stops”, “platform-level boarding” and “number of doors on bus” (rank four).

Three of the eight most important instruments are core instruments of a BRT system (“running ways”, “intersection treatments”, “platform-level boarding”). The full list of the instruments is provided in Annex 5.

5.2 Quantitative Analysis

The results of the quantitative analysis are presented in the following chapter. First the results of the analysis of the BRT ridership are described. Then the results of the evaluation of the percentage of modal shift are shown. At last the results of the analysis considering the frequency of the implemented instruments are presented.

5.2.1 Percentage of BRT Ridership that were former Car Users

The analysis was conducted on the basis of 17 case studies. The BRT system which implemented the most instruments is the TransOeste BRT in Rio de Janeiro with 31 implemented instruments (thereof are 32% technical and 68% non-technical instruments) and a success rate of 9% of BRT ridership that were former car users ("percentage of BRT ridership"). The BRT system with the lowest number of implemented instruments is located in Kunming (seven instruments implemented, 29% technical and 71% non-technical) with a success rate of 5%. The other analyzed BRT systems are in between (see Annex 8). On an average the BRT systems implemented 17 instruments, thereof 39% technical (range between 25% and 64%) and 61% non-technical (range between 36% and 75%) .

The BRT systems implemented between 25% (Alameda County, Vancouver and Kunming) and 100% (Rio de Janeiro) of the eight most important instruments (see rank one to four in Annex 5) according to the passenger preferences. The average amounts to 51%.

The overall average success rate, measured by the percentage of BRT ridership, is 13.82% for all 17 case studies.

The instruments implemented in most cases in these 17 BRT systems were "branding" and "enhanced station environment/safe and comfortable stations" (16 times implemented). The least implemented instrument is "operational subsidies" (zero times implemented, see chapter 3.3).

Grouping of case studies according to size of the system and size of the city

As already described, there were three size groups identified and the averages of the measured values were calculated (see table 5).

Table 5: Results of grouping the case studies according to the size of the system and the size of the city (percentage BRT ridership)

Group	Case studies comprised	Average success rate
A	Mexico City, Istanbul, Bogota, Curitiba, Rio de Janeiro, Kunming, Jinan	10.89%
B	Los Angeles, Guangzhou, Changzhou	8.33%
C	Nantes, Pereira, Alameda County, Miami-Dade, Vancouver (Translink #99), Boston (Silver line-Washington Street), Kent Thameside (Fastrack-Route B)	19.11%

As can be seen, the cities in Group A show an average value of 10.89%, the case studies of Group B 8.33% and Group of C 19.11%.

It was not possible to find a trend within the groups between the success rates of the BRT systems and the number of alternative public transportation modes offered in a city:

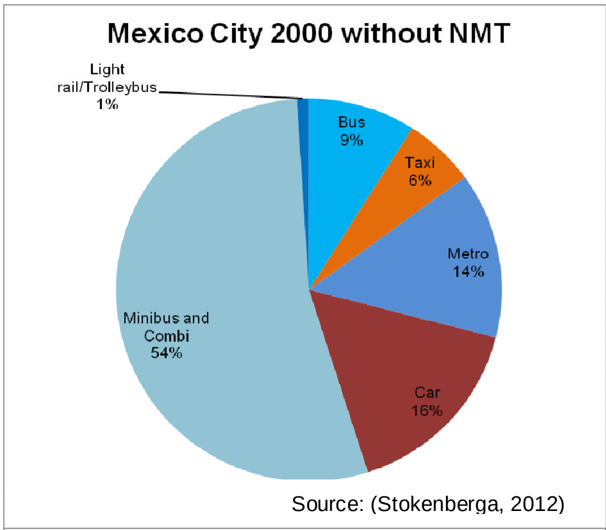
Table 6: Trend analysis between transport modes offered in city und success rates (percentage BRT ridership)

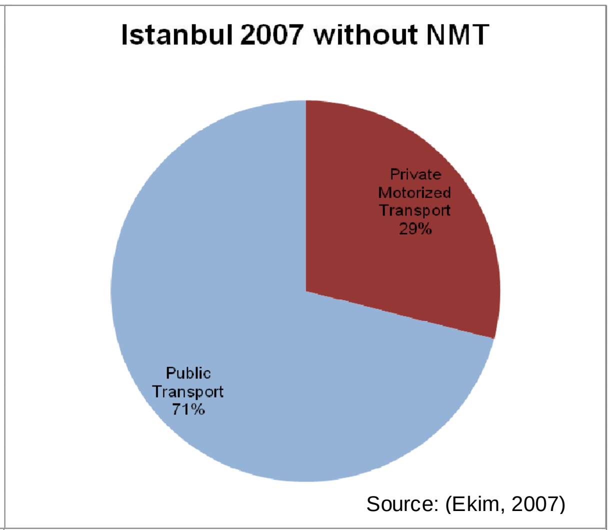
Case study	Transport modes offered in the city	Average success rate
Group A		
Bogota	Bus	9.00%
Curitiba	Bus	28.00%
Jinan	Bus	6.00%
Mexico City	Metro, Bus, Light Train	15.00%
Istanbul	Bus, Sea Bus, Ferry, Metro, Tram, Train	4.00%
Rio de Janeiro	Airport, Bus, Subway	9.20%
Kunming	Airport, Bus, Subway	5.00%
Group B		
Los Angeles	Airport, Bus, Train, Ferry	18.00%
Guangzhou	Subway, Bus	3.00%
Changzhou	Airport, Port, Bus	4.00%
Group C		
Nantes	Tram, Bus	25.00%
Pereira	Bus	10.00%
Alameda Conty	Bus, Light rail, Ferry, Train, Rail	18.20%
Miami-Dade	Metrorail, Metromover, Metrobus	41.80%
Vancouver	Bus, SkyTrain, SeaBus, Train, Airport	18.00%
Boston	Rail, Bus, Subway, Boat	1.80%
Kent Thameside	Bus, Rail	19.00%

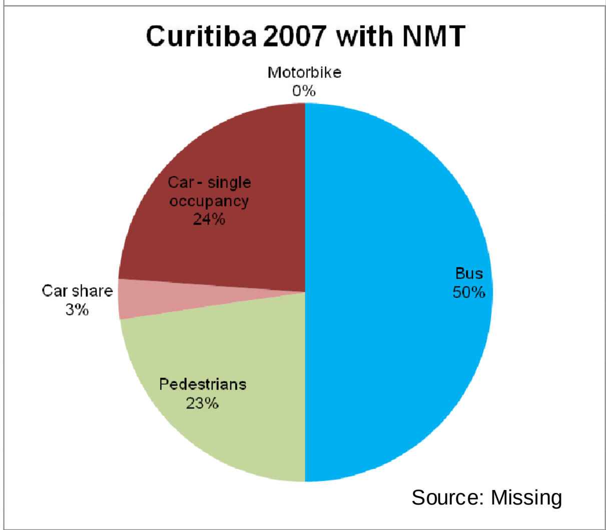
As presented in table 6, there are only three case studies in group A without other public transport modes offered in the city except for buses with success rates between 6% and 28%. As the success rates of the case studies in cities with only buses as public transport modes cover almost the whole range of all success rates of the case studies (from 1.80% to 41.80%) except for the lowest and highest percentages, there is no trend to be observed. Within group B there is no case study where the city only offers bus as an additional public transport mode. Group C shows only one case study with only bus as an additional public transport mode: Pereira, with a success rate of 10%. Again, there is no trend recognizable.

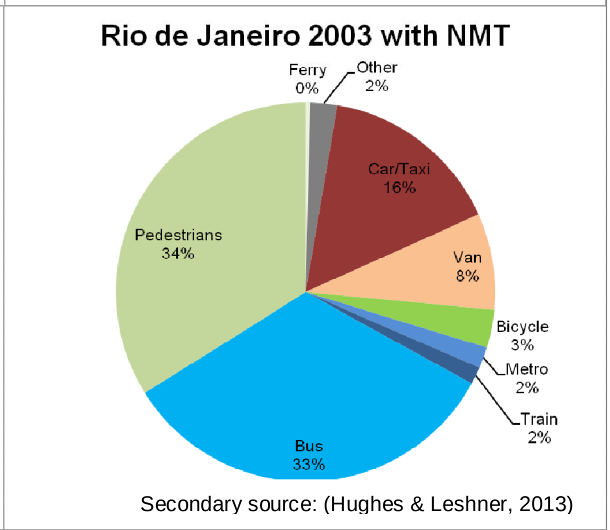
Furthermore, it was investigated whether the success rates of BRT systems could be explained by the modal shares in cities. In this respect the modal shares of the case studies were investigated. Because there were not so many modal shares available, all applicable modal shares of all 29 cities were used for this calculation. These were only 12 in total. The modal shares are presented in the following (NMT stands for non motorized transport):

Group A:









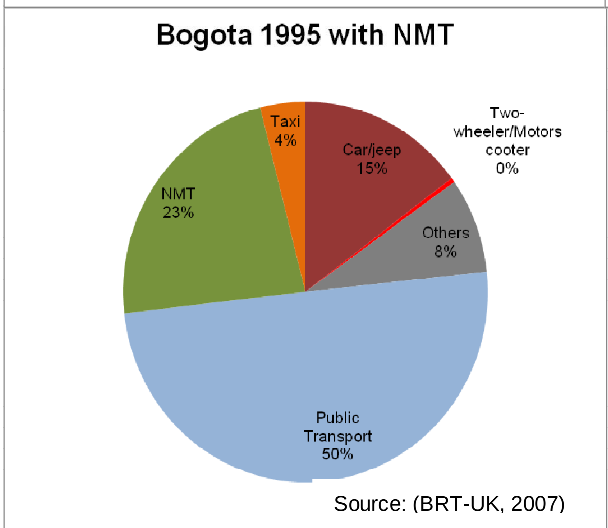


Figure 4: Modal shares for the cities of group A: Mexico, Istanbul, Bogota, Rio de Janeiro and Curitiba

As can be seen in figure 4, the modal share for car use or private motorized transport for the case studies in group A is below 25%, except for Istanbul, where private motorized transport has a proportion of more than 25%. But it is to be recognized that this modal share was found in the literature without considering the non motorized transport (NMT). So it is to be assumed, when the non motorized transport is considered in addition, that the share of the private motorized transport would also be below 25%.

Group B:

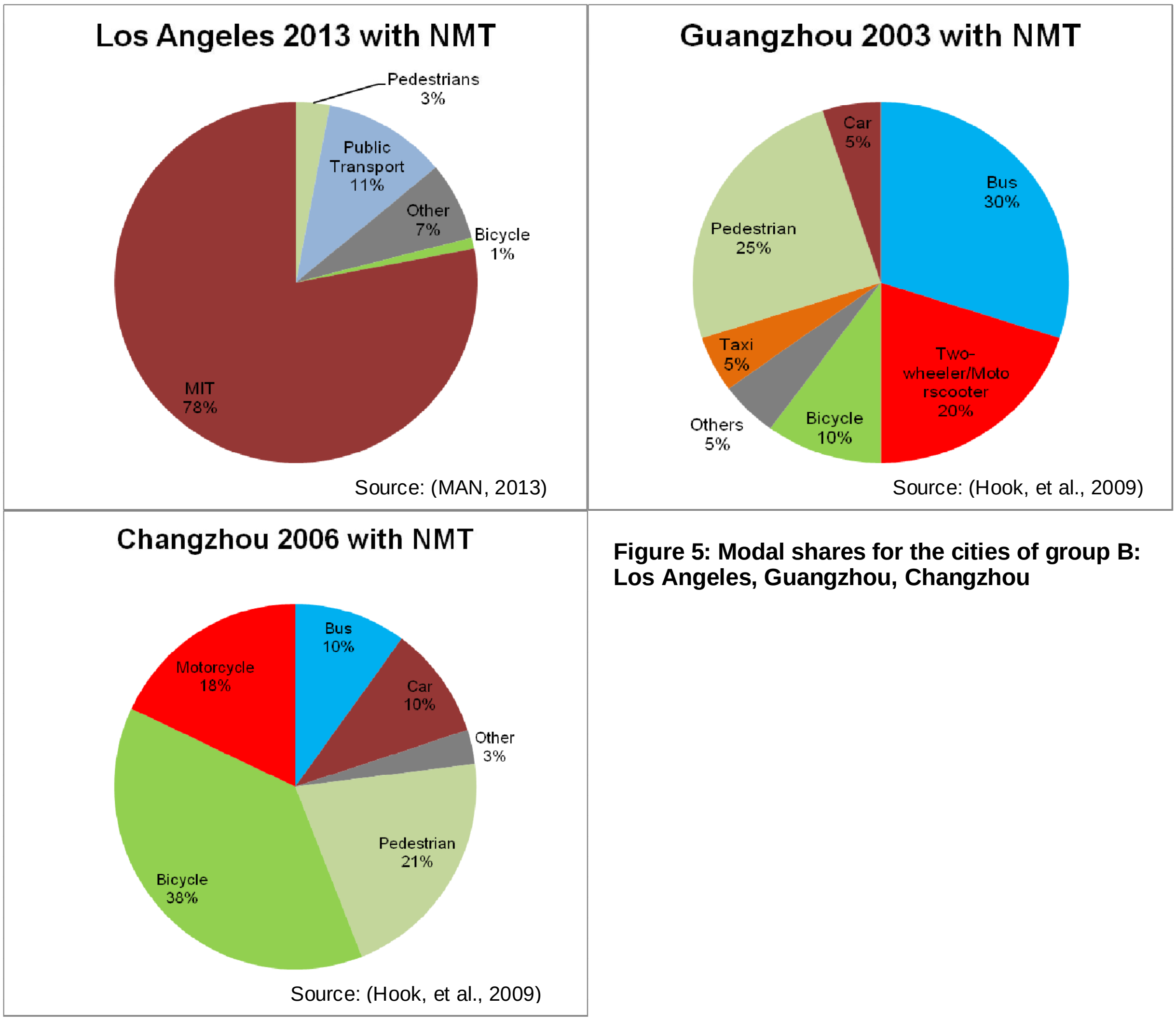


Figure 5: Modal shares for the cities of group B: Los Angeles, Guangzhou, Changzhou

Within the cities in group B there are big differences concerning the modal share (see figure 5). Los Angeles has a very high modal share for motorized individual transportation, whereas the modal share for car usage and motorcycles together is much lower in Guangzhou and Changzhou.

Group C:

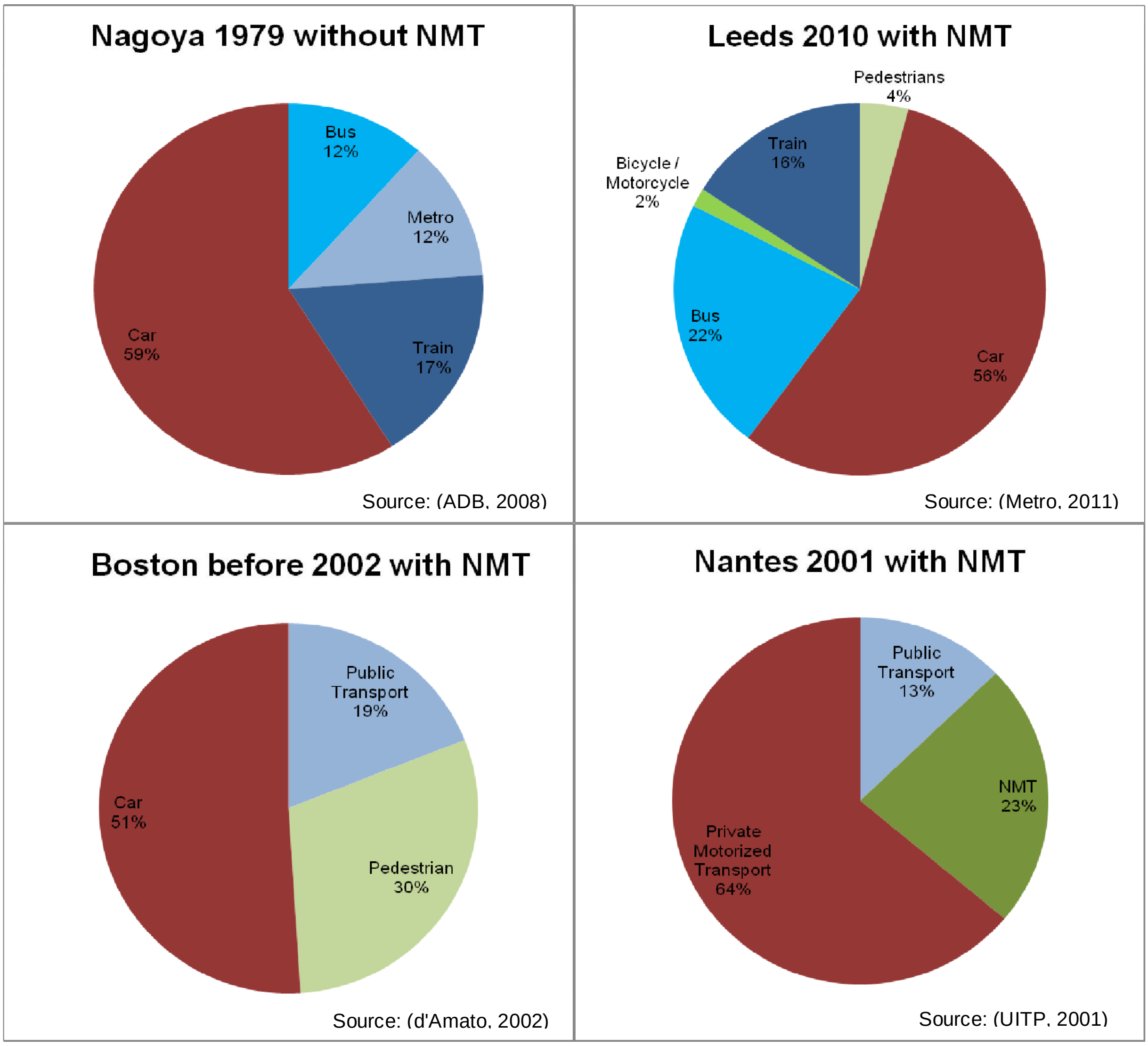


Figure 6: Modal shares for the cities of group C: Nagoya, Leeds, Boston, Nantes

In contrast to group A, the modal shares for car use or private motorized transport for the case studies of the cities in group C are clearly above 50% (see figure 6). Although the modal share for Nagoya does not consider the non motorized transport, it is to be assumed that the share would not decrease dramatically, when the non motorized transport would also have been considered.

Grouping of cases studies according to running time

There were three groups identified for the purpose of grouping the cities according to the running time (see table 7).

Table 7: Results of grouping the case studies according to their running time (percentage BRT ridership)

Running time	Case studies comprised	Average success rate
1 – 3 years	Nantes, Alameda County, Vancouver (Translink #99), Los Angeles, Guangzhou, Rio de Janeiro	15.23%
3 – 6 years	Miami-Dade, Pereira, Mexico City, Istanbul	17.70%
8 – 18 years	Bogota, Curitiba, Kunming	14.00%

The average success rate, measured by the percentage of BRT ridership, for case studies running between one and three years amounts to 15.23%, for case studies running between three and six years to 17.70% and for case studies running between eight and 18 years to 14.00%. There were also case studies, which could not be allocated to one group, which is explained in chapter 6.

Trend analysis between success rates and the percentages of the implementation of the most important instruments according to the passenger preferences

It was analyzed, whether a trend can be recognized between the percentages of implementation of the most important instruments according to the passenger preferences and the success rates (see table 8).

Table 8: Trend analysis between success rates and the percentages of the implementation of the most important instruments according to the passenger preferences (percentage BRT ridership)

Case study	% Implementation of most important instruments according to passenger preferences	% BRT ridership
Alameda County	25.00%	18.20%
Vancouver	25.00%	18.00%
Kunming	25.00%	5.00%
Pereira	37.50%	10.00%
Miami-Dade	37.50%	41.80%
Kent Thameside	37.50%	19.00%
Curitiba	37.50%	28.00%
Jinan	37.50%	6.00%
Mexico City	50.00%	15.00%
Boston	50.00%	1.80%
Changzhou	50.00%	4.00%
Nantes	62.50%	25.00%
Istanbul	62.50%	4.00%
Los Angeles	62.50%	18.00%
Guangzhou	75.00%	3.00%
Bogota	87.50%	9.00%
Rio de Janeiro	100.00%	9.20%

As can be seen in table 8, a trend cannot be observed.

<u>Instruments implemented in the most successful systems</u>

At last, it was analyzed which instruments were implemented for the most part in the most successful systems. The most successful systems are these, where the success rates are above the overall average of 13.82%. The range is between 15% (Mexico city) and 42% (Miami-Dade). The most implemented instruments are defined as the ones that were implemented in more than 60% of the most successful case studies in this analysis. These instruments are shown in table 9.

Table 9: Instruments implemented for the most part in the most successful systems (percentage BRT ridership)

Instruments	% of implementation in the most successful systems
Intersection treatments	100.00%
Enhanced station environment/safe and comfortable stations	100.00%
Branding	100.00%
Real time passenger information	87.50%
Running ways	75.00%
Off-board fare collection	62.50%
Platform-level boarding	62.50%
Peak frequency	62.50%
Multi-corridor network/network of routes and corridors	62.50%
Universal Access	62.50%
Integration with other public transport – physical transfer points	62.50%
Electronic card	62.50%

The attributes addressed by the cities through the implementation of the most successful instruments in the most successful cities (see table 10) were identified by applying the allocation of the attributes to the instruments described in chapter 4.1.2.

Table 10: Ranking of the attributes addressed by the most implemented instruments in the most successful cities (percentage BRT ridership)

Attributes addressed by the most implemented instruments in the most successful case studies (% BRT ridership)	
Rank	**Attribute**
1	Travel time
1	Convenience
2	Safety/Security
3	Reliability
3	Accessibility
4	Frequency
4	Information provision
5	Comfort
5	Bus routes improvement
5	Less congestion
5	Environmental benefits
6	Price
6	Weather improvement

5.2.2 Percentage of Car Users Shifting to BRT

In this evaluation the success was measured by the percentage of modal shift. The analysis was carried out on the basis of six case studies. The case study with the most instruments implemented is Nantes (25 instruments implemented in total, thereof 36% technical and 64% non-technical) with a success rate of 0.46%. Leeds implemented the least number of instruments; in total nine (thereof 33% technical and 67% non-technical), with a success rate of 7.00%. The other analyzed BRT systems are in between (see Annex 8). On an average the case studies implemented 16 instruments, thereof 36% technical (range between 17% and 53%) and 64% non-technical (range between 47% and 83%).

The six case studies implemented between 38% and 62% of the eight most important instruments (see ranks one to four in Annex 5) according to the passenger preferences. Istanbul and Nantes implemented the highest number of these instruments and Leeds, Nagoya and Leeds the lowest. On an average they implemented 48% of the most important instruments according to the passenger preferences.

The overall average of the success rates, considering all six case studies, amounts to 2.23%.

The instruments implemented for the most part in all six cases are “running ways” and “enhanced station environment/safe and comfortable stations” (implemented in all six case studies). There are several instruments that were not implemented in any of the six case studies: “multiple routes”, “express, limited and local services”, “located in top-ten corridors”, “demand profile”, “passing lanes at stations”, “center stations”, “pavement quality”, “sliding doors in BRT stations”, “integration with other public transport – information”, “ bicycle lanes”, “operational subsidies”, “supporting car restriction measures” and “marketing campaign” (for some of them see chapter 3.3).

Grouping of case studies according to size of the system and size of the city

For this calculation there have only been case studies available for groups A und C.

Table 11: Results of grouping the case studies according to the size of the city and the size of the system (percentage modal shift)

Group	Case studies comprised	Average success rate
A	Mexico City, Istanbul	0.47%
C	Nantes, Pereira, Nagoya, Leeds	3.12%

As presented in table 11, group A has an average success rate of 0.47% and group C of 3.12%.

It was not possible to find a trend within the groups between the success rates of the BRT systems and the number of alternative public transportation modes offered in a city (see table 12).

Table 12: Trend analysis between transport modes offered in cities und success rates (percentage modal shift)

Case study	Transport modes offered in the city	Average success rate
Group A		
Mexico City	Metro, Bus, Light Train	0.71%
Istanbul	Bus, Sea Bus, Ferry, Metro, Tram, Train	0.23%
Group C		
Nantes	Tram, Bus	0.46%
Pereira	Bus	2.00%
Nagoya	Suburban railway, Subway, Bus	3.00%
Leeds	Metro, Bus	7.00%

As shown above, there is no case study in the cities in group A where only a bus system is offered in addition. In group C there is one city (Pereira) offering only bus services additionally to the BRT system. Pereira has a success rate of 2.00%, that is close to the overall average of 2.23%. Accordingly, there is no trend recognizable.

Concerning the modal share in the cities covered by the case studies, the same results can be observed as described in chapter 5.2.1, as this analysis was done using all available data concerning the modal shares in the cities with case studies and not regarding only the case studies used for the specific part of the evaluation.

<u>Grouping of case studies according to running time</u>

The case studies were split in only two groups concerning the running time, as there were not more case studies available for a further split for the purpose of this evaluation (see table 13). There would have been only one case study in the group with a running time between one and three years. That is why this group and the group with running times between three and six years were taken together. The group with running times between 12 and 25 years in this analysis corresponds to the group of running time between eight and 18 years in the analysis in chapter 5.2.1. The difference is that in this analysis the next case study after the one with a running time of six years was running for 12 years.

Table 13: Results of grouping the case studies according their running time (percentage modal shift)

Running time	Case studies comprised	Average success rate
2 – 6 years	Nantes, Pereira, Mexico City, Istanbul	0.85%
12 – 25 years	Nagoya, Leeds	5.00%

The average success rate for case studies with running times between two and six years accounts for 0.85% and for case studies with running times between 12 and 25 years for 5.00%.

<u>Trend analysis between success rates and the percentages of the implementation of the most important instruments according to the passenger preferences</u>

A trend can be recognized between the percentages of implementation of the most important instruments according to the passenger preferences and the success rates (see table 14). The more instruments of the most important ones according to the passenger needs are implemented by the case studies, the lower is the success rate.

Table 14: Trend analysis between success rates and the percentages of the implementation of the most important instruments according to the passenger preferences (percentage modal shift)

Case study	% Implementation of most important instruments according to passenger needs	% of modal shift (from car to BRT)
Pereira	37.50%	2.00%
Nagoya	37.50%	3.00%
Leeds	37.50%	7.00%
Mexico City	50.00%	0.71%
Nantes	62.50%	0.46%
Istanbul	62.50%	0.23%

5.2.3 Evaluation of the Implemented Instruments in BRT Case Studies

There were 33 case studies concerning 29 analyzed metropolitan areas. The case studies implemented between six (Helsinki – Jokeri line, Stockhom – Trunk bus network) and 31 (Rio de Janeiro – TransOeste) instruments, on an average 15 instruments. The proportion of technical instruments implemented thereof varies between 17% (Nagoya) and 67% (Helsinki), the average is 38%. For non-technical instruments the proportion of all instruments implemented lies between 33% (Helsinki) and 83% (Nagoya). The average amounts to 62%.

The case studies implemented between 13% and 100% of the eight most important instruments (see ranks one to four in Annex 5) according to the passenger preferences. The BRT system in Rio de Janeiro implemented the highest number of these instruments and the one in Stockholm the lowest. The average proportion of implementation of the most important instruments according to passenger preferences is 47%.

The 10 most implemented instruments (implemented by more than 60% in the case studies) are “enhanced station environment” (30 times), “running ways”, “intersection treatments” and “branding” (28 times), “real time passenger information” (26 times), “peak frequency” and “multi-corridor network/network of routes and corridors” (24 times)”, “off-board fare collection” (22 times), “platform-level boarding” (21 times) and “off-peak frequency” (20 times). The least implemented instruments (zero times) are “operational subsidies” and “integration with other public transport – information” (see chapter 3.3).

The ranking of the attributes addressed in the case studies through the ten most implemented instruments (see table 15) is determined by applying the allocation of the attributes to the instruments described in chapter 4.1.2.

Table 15: Attributes addressed for the most part by cities through the ten most implemented instruments

Rank	Attributes addressed through the ten most implemented instruments
1	Travel time
2	Reliability, convenience, frequency, safety/security
3	Accessibility, information provision
4	Comfort, less congestion, environmental benefits
5	Bus routes improvement, weather improvement
6	Price

As shown in table 15, the case studies address for the most part the quality attribute “travel time” through the most implemented instruments, followed by “reliability”, “convenience”, “frequency” and “safety/security”. The next important attributes for the cities are “comfort”, “less congestion” and “environmental benefits”, followed by “bus routes improvement” and “weather improvement”. The least addressed attribute is “price”.

6 CREATING AN EXCEL TOOL

Some of the results described in chapter 5 were used to build an user-oriented Excel tool. This Excel tool was developed to enable city planners or decision makers to make a first assessment as to which instruments should be implemented while introducing or improving a BRT system in a city, particularly to attract car users. The tool can also be used when improving an existing conventional bus system.

As a result the tool calculates a list of possible instruments to be implemented. It starts with the instrument with the highest priority and ends with the instrument with the lowest, based in the input of the respective user.

The tool can be found in Annex 9.

6.1 Structure of the Tool

In a first table sheet the tool provides a comprehensive instruction for its use and describes the content of the tool. Furthermore it defines the quality attributes used for the calculation and presents the architecture of the tool as well as an example.

The second table sheet contains the input fields, where the required information for the ranking of the instruments will have to be inserted according to the preferences of the user.

The next table sheet comprises the result list with the instruments according to their ranking. The user will be automatically redirected to the result list after filling in the input data and pressing the “start” button.

Next, information is provided about how to conduct a survey in the city concerned to gain information about the specific passenger preferences. If there is no possibility to conduct a survey, the default settings of the tool can be used. This is further explained in chapter 6.2.

The following two table sheets include the calculation method required to obtain the result list as well as the formulas to sort the instruments according to the input data.

The last table sheet consists in a first assessment of the possible costs of the implementation of the instruments. This is only a first approach of how to collect the required information to group the instruments according to the funds needed to invest for their implementation.

6.2 Methodology Calculating the Result List

The tool ranks the instruments according to a points system. This is described in the following.

In step one the user has to decide whether the assessment should be done for the implementation or improvement of a BRT system, or for the enhancement of a conventional bus system. If the tool is used to improve or implement a BRT system, the four core instruments of BRT systems (see chapter 3.2) will be awarded additional 1000 points to make sure that these four instruments will appear on the first four ranks of the result list. If the conventional bus system is chosen, there will not be a specific weighting of these instruments.

As a second step, the user has the possibility within the input file to give a rank to the four categories:

- "Passenger preferences": Which attributes of a public transport system are favored by (potential) riders?
- "Political preferences": Which attributes should be considered for political reasons?
- "Economic resources": Which economic resources are available for implementing instruments?
- "Implementation": Which instruments should be favored: non-technical or technical ones?

It is possible to give ranks from one to four. Rank one stands for the most important category and rank four for the least important one. It is also possible to give the same rank to more than one category, if they are of equal importance or to leave an empty cell, if one of the categories does not play a role. In the end the categories will be weighted according to their rank. Therefore, fractions are calculated. The numerators are in each case the cipher "one". The denominators are the respective rank numbers. Rank one will therefore be weighted $\frac{1}{1}$ = 100%, rank two $\frac{1}{2}$ = 50%, rank three $\frac{1}{3}$ = 33.33% and rank four $\frac{1}{4}$ = 25%.

In step three the user has the possibility to give ranks to the attributes within the category "passenger preferences". The attributes within the category are the same as defined in chapter 5.1.1. Only the attribute "weather improvement" is missing as this was only considered in the evaluation in chapter 4 to prove the importance of weather protection (see chapter 7). Therefore it was not considered in this assessment tool. Ranks can be awarded from one (the most important one) to 12 (the least important one). Two or more attributes can be given the same rank. If one attribute does not play a role, the field can be left empty. Points will then be allocated to the attributes according to the ranks given. If the ranks from one to seven are allocated, the highest possible number of points given to an attribute is seven (for rank one). Accordingly rank seven achieves one point. If ranks are awarded from one to ten, ten is the highest number of points achievable for rank one.

Step four comprises the same procedure for the category “political preferences” as described for the category “passenger preferences”.

The difference between steps three and four consists in the input information. Whereas the input information for step four is only dependent on the preferences of the city itself, the input information for the “passenger preferences” is dependent on the specific preferences and needs of the public transport riders in the corresponding city. Therefore this input information should be determined by a survey in the relevant city asking the ridership for their preferences. Examples for conducting such a survey are provided within the tool in table sheet four (“Annex”). If it is not possible to conduct a survey, the default settings for this category can be used. These default settings present the findings of the BRT analysis concerning the passenger preferences described in chapter 5.1.1.

In step five the user has the possibility to decide on the economic resources available for the implementation of the instruments. If “low” is chosen, medium and high cost solutions will have a lower weight, so that the cheapest solution is weighted with a higher priority. If “medium” is chosen, low and medium will be weighted equal and high cost solutions will be considered after the other ones. If “high” is chosen, all these three categories will be weighted equal.

The last input step (step six) asks for the information whether to give an extra weighting to non-technical or technical instruments.

In step seven, the user should press the “start” button to be redirected to the corresponding result list.

To calculate the result list the tool uses the information on the allocation of the attributes to the instruments identified in the present study (see chapter 5.1.2). For the first two categories (“passenger preferences” and “political preferences”) the tool adds up for each instrument the points achieved by the attributes, which the corresponding instrument addresses considering the rank given to the categories. Then all the other input information is transferred into the points system. In the following the points system is described using an example:

The city of “Duckburg” wants to improve its BRT system. So the decision maker of the city, Mr. Duck, opts in step one for a Bus Rapid Transit System (see figure 7):

Bus enhancement	0
Bus Rapid Transit System	1

Figure 7: Input information – BRT or bus enhancement

In step two, Mr. Duck decides that he wants to improve the system according to the “passenger preferences” having the highest priority, as the BRT system has not yet been used to its full capacity. Second he wants to achieve the “political preferences“ of his city. The economic resources and the kind of implementation are of lower priority (see figure 8):

Passenger Preferences	1
Political Preferences	2
Economic Resources	3
Implementation	3

Figure 8: Input information on the importance of the categories

Mr. Duck had no possibility to conduct a survey in his city, so he uses the default settings for the attributes within the category “passenger preferences” (see figure 9):

Travel time	1
Reliability	2
Comfort	3
Convenience	5
Frequency	1
Accessibility	7
Price	2
Information provision	4
Safety/Security	6
Bus routes improvement	6
Less congestion	3
Environmental benefits	7

Figure 9: Input information on the ranks of the attributes within the category “passenger preferences“

The important political objectives to be achieved by the BRT system for “Duckburg” are “safety/security”, “accessibility” and “environmental benefits”. Furthermore the attributes “reliability”, “price” and “comfort” are important (see figure 10):

Travel time	
Reliability	2
Comfort	2
Convenience	
Frequency	
Accessibility	1
Price	2
Information provision	
Safety/Security	1
Bus routes improvement	
Less congestion	
Environmental benefits	1

Figure 10: Input information on the ranks of the attributes within the category "political preferences"

Mr. Duck wants to assess the instruments that should be implemented disregarding their costs. So he inputs "high" (see figure 11):

Low	
Medium	
High	1

Figure 11: Input information on the economic resources

Furthermore he wants to implement especially non-technical instruments (see figure 12):

Instruments, that the city can implement by itself (non-technical)	1
Instruments, that the city cannot implement only by itself (technical)	

Figure 12: Input information on the kind of implementation

On the basis of this input information the tool calculates the result list. The method is further expained using this example for "Duckburg":

First the tool calculates the score each instrument achieves by considering the rank given to the categories "passenger preferences" and "political preferences" and the rank given to the attributes within the categories (see figure 13). This is explained using the example of the attribute "travel time":

	A	B	C	D	E	F	G
1			Travel time				
2		A	Pass.	Score	Polit.	Score	SUM_A
3	Bicycle lanes		7	0.00	0	0.00	0.00
4	Bicycle-sharing integration		7	0.00	0	0.00	0.00
5	Branding		7	0.00	0	0.00	0.00
6	Center stations		7	0.00	0	0.00	0.00
7	Control center		7	0.00	0	0.00	0.00
8	Demand profile		7	0.00	0	0.00	0.00
9	Distance between stations	1	7	7.00	0	0.00	7.00
10	Docking bays and sub-stops	1	7	7.00	0	0.00	7.00
11	Electronic card		7	0.00	0	0.00	0.00
12	Enhanced station environment / Safe and comfortable stations		7	0.00	0	0.00	0.00
13	Express, limited and local services	1	7	7.00	0	0.00	7.00
14	Hours of operation		7	0.00	0	0.00	0.00
15	Improvements to nearby public space		7	0.00	0	0.00	0.00
16	In BRT integrated bus feeder systems	1	7	7.00	0	0.00	7.00
17	Integration with other public transport - information		7	0.00	0	0.00	0.00
18	Integration with other public transport - fare payment: integrated tariff system		7	0.00	0	0.00	0.00
19	Integration with other public transport - Physical transfer points	1	7	7.00	0	0.00	7.00
20	Intersection treatments	1	7	7.00	0	0.00	7.00
21	Located in top-ten corridors		7	0.00	0	0.00	0.00
22	Marketing campaign		7	0.00	0	0.00	0.00
23	Minimizing bus emissions (Euro III or higher)		7	0.00	0	0.00	0.00
24	Multi-corridor network/Network of routes and corridors	1	7	7.00	0	0.00	7.00
25	Multiple routes	1	7	7.00	0	0.00	7.00
26	Number of doors on bus	1	7	7.00	0	0.00	7.00
27	Off-peak frequency	1	7	7.00	0	0.00	7.00
28	Operational subsidies (1)		7	0.00	0	0.00	0.00
29	Park and ride		7	0.00	0	0.00	0.00
30	Pavement quality		7	0.00	0	0.00	0.00
31	Passing lanes at stations	1	7	7.00	0	0.00	7.00
32	Pedestrian access		7	0.00	0	0.00	0.00
33	Peak frequency	1	7	7.00	0	0.00	7.00
34	Platform-level boarding	1	7	7.00	0	0.00	7.00
35	Off-board fare collection	1	7	7.00	0	0.00	7.00
36	Running ways	1	7	7.00	0	0.00	7.00
37	Real time Passenger information		7	0.00	0	0.00	0.00
38	Restriction of on-street parking		7	0.00	0	0.00	0.00
39	Secure bicycle parking		7	0.00	0	0.00	0.00
40	Sliding doors in BRT stations	1	7	7.00	0	0.00	7.00
41	Stations set back from intersections		7	0.00	0	0.00	0.00
42	Supporting car restriction measures (e.g. road pricing)		7	0.00	0	0.00	0.00
43	Universal access		7	0.00	0	0.00	0.00

Figure 13: Calculation of the score for each attribute and instrument

The yellow columns (figure 13) show the information on the allocation of the attributes to the instruments. For the cases where an interdependency exists, the cell is filled with a “1” (column B). If a rank was given to the category “passenger preferences”, the tool multiplies the cells in column “B” (allocation of attributes to instruments) by the cells in column “C” (number of points achieved by the attribute according to the rank) and by a fraction. This fraction has the cipher “one” as its numerator and the rank number given to the category as its denominator (the information about the rank for the category “passenger preferences” is within table sheet “Input” in cell D18). In the case of the instrument “bicycle lanes” (row three, figure 13) this formula is as follows:

$$\text{IF}\left(\text{Input!\$D\$18} = 0; 0; \text{B3} * \text{C3} * \frac{1}{\text{Input!\$D\$18}}\right) = 0 * 7 * \frac{1}{1} = 0$$

As there is no interdependency between “bicycle lanes” and “travel time”, the score is “zero”.

The same method is applied for the category “political preferences” (example “bicycle lanes”, row 3). The information about the rank is within the table sheet “Input”, cell D20. The formula is as follows:

$$\text{IF}\left(\text{Input!}\$D\$20 = 0; 0; B4 * E4 * \frac{1}{\text{Input!}\$D\$20}\right) = 0 * 0 * \frac{1}{2} = 0$$

As there is neither an interdependency between “bicycle lanes” and “travel time” nor a rank given to the attribute “travel time” within the input file for the category “political preferences”, the score is “zero”.

In a next step the two scores for the attribute “travel time” in the column “bicycle lanes” are added up, resulting in a subtotal for the attribute “travel time” concerning the instrument “bicycle lanes”.

The same calculation method is presented in the following for the attribute “travel time” and the instrument “distance between stations” (row nine) as there exists an interdependency.

For the category “passenger preferences” the score is calculated as follows:

$$\text{IF}\left(\text{Input!}\$D\$18 = 0; 0; B9 * C9 * \frac{1}{\text{Input!}\$D\$18}\right) = 1 * 7 * \frac{1}{1} = 7$$

There exists an interdependency between the attribute “travel time” and the instrument “distance between stations”. Furthermore this attribute is ranked number one within the input sheet (seven points). The category is ranked number one as well (multiplied by the fraction having the cipher “one” as its numerator and the rank number as its denominator). This input information results in seven points.

For the category “political preferences” the score is calculated as follows:

$$\text{IF}\left(\text{Input!}\$D\$20 = 0; 0; B9 * E9 * \frac{1}{\text{Input!}\$D\$20}\right) = 1 * 0 * \frac{1}{2} = 0$$

In the end, the two results are added up resulting in a subtotal with a score of seven points.

This method, as explained above, is applied to each attribute and each instrument. Subsequently the subtotals for the twelve attributes for each instrument are added up resulting in “SUM_Part1”.

The next calculation step contains the information about the category “implementation”. Within the tool the information is saved, whether the instruments are non-technical (filled with a “1” in column BY) or technical (filled with a “1” in column CA) (see figure 14). In this example non-technical instruments should be weighted higher. Therefore the non-technical instruments achieve the score one (by multiplying the corresponding cell in column BY - the allocation of the feature non-technical to the instrument - by the corresponding cell in column BZ – the weight of the non-technical instrument). The technical instruments achieve the score zero. These two results are added up and then multiplied by a fraction. This fraction has the cipher “one” as its numerator and the rank number of the category “implementation” (Excel tool: table sheet “Input”, cell D24) as its denominator.

	A	BY	BZ	CA	CB	CC
1		Implementation				SUM_Part2
2		NT	Weight	T	Weight	Score
3	Bicycle lanes	1	1		0	0.33
4	Bicycle-sharing integration		1	1	0	0.00
5	Branding	1	1		0	0.33
6	Center stations	1	1		0	0.33
7	Control center		1	1	0	0.00
8	Demand profile	1	1		0	0.33
9	Distance between stations	1	1		0	0.33
10	Docking bays and sub-stops	1	1		0	0.33
11	Electronic card		1	1	0	0.00
12	Enhanced station environment / Safe and comfortable stations	1	1		0	0.33
13	Express, limited and local services	1	1		0	0.33
14	Hours of operation	1	1		0	0.33
15	Improvements to nearby public space	1	1		0	0.33
16	In BRT integrated bus feeder systems	1	1		0	0.33
17	Integration with other public transport - information	1	1		0	0.33
18	Integration with other public transport - fare payment: integrated tariff system	1	1		0	0.33
19	Integration with other public transport - Physical transfer points	1	1		0	0.33
20	Intersection treatments		1	1	0	0.00
21	Located in top-ten corridors	1	1		0	0.33
22	Marketing campaign	1	1		0	0.33
23	Minimizing bus emissions (Euro III or higher)		1	1	0	0.00
24	Multi-corridor network/Network of routes and corridors	1	1		0	0.33
25	Multiple routes	1	1		0	0.33
26	Number of doors on bus		1	1	0	0.00
27	Off-peak frequency	1	1		0	0.33
28	Operational subsidies (1)	1	1		0	0.33
29	Park and ride	1	1		0	0.33
30	Pavement quality		1	1	0	0.00
31	Passing lanes at stations	1	1		0	0.33
32	Pedestrian access	1	1		0	0.33
33	Peak frequency	1	1		0	0.33
34	Platform-level boarding		1	1	0	0.00
35	Off-board fare collection		1	1	0	0.00
36	Running ways	1	1		0	0.33
37	Real time Passenger information		1	1	0	0.00
38	Restriction of on-street parking	1	1		0	0.33
39	Secure bicycle parking	1	1		0	0.33
40	Sliding doors in BRT stations		1	1	0	0.00
41	Stations set back from intersections	1	1		0	0.33
42	Supporting car restriction measures (e.g. road pricing)	1	1		0	0.33
43	Universal access		1	1	0	0.00

Figure 14: Calculation of the score for the kind of implementation

The formula for the instrument “bicycle lanes” (non-technical, row 3 in figure 14) is as follows:

$$\text{IF}\left(\text{Input!\$D\$24} = 0; 0; (\text{BY3} * \text{BZ3} + \text{CA3} * \text{CB3}) * \frac{1}{\text{Input!\$D\$24}}\right) = (1 * 1) + (0 * 0) * \frac{1}{3} = 0.33$$

The formula for a technical instrument is presented using the example of the instrument “bicycle-sharing integration” (figure 14, row 4):

$$\text{IF}\left(\text{Input!\$D\$24} = 0; 0; (\text{BY4} * \text{BZ4} + \text{CA4} * \text{CB4}) * \frac{1}{\text{Input!\$D\$24}}\right) = (0 * 1) + (1 * 0) * \frac{1}{3} = 0$$

These results are shown in “SUM_Part2”.

The next step of the calculation concerns the information about the economic resources in the city. This step is so far only considered as a placeholder (the corresponding cells are marked in red, see figure 15) in the Excel tool and is not yet considered in the assessment. This is further explained later.

	A	CE	CF	CG	CH	CI	CJ	CK
1		Economic Resources						SUM_Part3
2		Low	Weight	Medium	Weight	High	Weight	Score
3	Bicycle lanes		1		1		1	0.00
4	Bicycle-sharing integration		1		1		1	0.00
5	Branding		1		1		1	0.00
6	Center stations		1		1		1	0.00
7	Control center		1		1		1	0.00
8	Demand profile		1		1		1	0.00
9	Distance between stations		1		1		1	0.00
10	Docking bays and sub-stops		1		1		1	0.00
11	Electronic card		1		1		1	0.00
12	Enhanced station environment / Safe and comfortable stations		1		1		1	0.00
13	Express, limited and local services		1		1		1	0.00
14	Hours of operation		1		1		1	0.00
15	Improvements to nearby public space		1		1		1	0.00
16	In BRT integrated bus feeder systems		1		1		1	0.00
17	Integration with other public transport - information		1		1		1	0.00
18	Integration with other public transport - fare payment: integrated tariff system		1		1		1	0.00
19	Integration with other public transport - Physical transfer points		1		1		1	0.00
20	Intersection treatments		1		1		1	0.00
21	Located in top-ten corridors		1		1		1	0.00
22	Marketing campaign		1		1		1	0.00
23	Minimizing bus emissions (Euro III or higher)		1		1		1	0.00
24	Multi-corridor network/Network of routes and corridors		1		1		1	0.00
25	Multiple routes		1		1		1	0.00
26	Number of doors on bus		1		1		1	0.00
27	Off-peak frequency		1		1		1	0.00
28	Operational subsidies (1)		1		1		1	0.00
29	Park and ride		1		1		1	0.00
30	Pavement quality		1		1		1	0.00
31	Passing lanes at stations		1		1		1	0.00
32	Pedestrian access		1		1		1	0.00
33	Peak frequency		1		1		1	0.00
34	Platform-level boarding		1		1		1	0.00
35	Off-board fare collection		1		1		1	0.00
36	Running ways		1		1		1	0.00
37	Real time Passenger information		1		1		1	0.00
38	Restriction of on-street parking		1		1		1	0.00
39	Secure bicycle parking		1		1		1	0.00
40	Sliding doors in BRT stations		1		1		1	0.00
41	Stations set back from intersections		1		1		1	0.00
42	Supporting car restriction measures (e.g. road pricing)		1		1		1	0.00
43	Universal access		1		1		1	0.00

Figure 15: Calculation of the score of the costs of the implementation for each instrument

Nevertheless the formulas needed for this step have already been inserted in the tool, so that as soon as the information about the cost of implementation is available and inserted, this part of the calculation will work. The calculation for this part works corresponding to the calculation of "SUM_Part2". The formula used for the calculation is as follows:

$$\text{IF}\left(\text{Input!}\,\$D\$22 = 0; 0; (CE3 * CF3 + CG3 * CH3 + CI3 * CJ3) * \frac{1}{\text{Input!}\,\$D\$22}\right)$$

As there is not yet information available about the cost of the implementation of the instruments, the results for "SUM_Part3" are zero for all instruments.

The last calculation step comprises the information about implementing or improving a BRT system or enhancing a conventional bus system. If the BRT system is chosen (like in this example), the tool calculates a score of 1000 extra points for the four core instruments of BRT systems (see figure 16).

	A	CM	CN	CO
1				SUM_Part4
2		BRT	Weight	Score
3	Bicycle lanes			
4	Bicycle-sharing integration			
5	Branding			
6	Center stations			
7	Control center			
8	Demand profile			
9	Distance between stations			
10	Docking bays and sub-stops			
11	Electronic card			
12	Enhanced station environment / Safe and comfortable stations			
13	Express, limited and local services			
14	Hours of operation			
15	Improvements to nearby public space			
16	In BRT integrated bus feeder systems			
17	Integration with other public transport - information			
18	Integration with other public transport - fare payment: integrated tariff system			
19	Integration with other public transport - Physical transfer points			
20	Intersection treatments	1000	1	1000
21	Located in top-ten corridors			
22	Marketing campaign			
23	Minimizing bus emissions (Euro III or higher)			
24	Multi-corridor network/Network of routes and corridors			
25	Multiple routes			
26	Number of doors on bus			
27	Off-peak frequency			
28	Operational subsidies (1)			
29	Park and ride			
30	Pavement quality			
31	Passing lanes at stations			
32	Pedestrian access			
33	Peak frequency			
34	Platform-level boarding	1000	1	1000
35	Off-board fare collection	1000	1	1000
36	Running ways	1000	1	1000
37	Real time Passenger information			
38	Restriction of on-street parking			
39	Secure bicycle parking			
40	Sliding doors in BRT stations			
41	Stations set back from intersections			
42	Supporting car restriction measures (e.g. road pricing)			
43	Universal access			

Figure 16: Calculation of the score of the four core instruments of BRT systems

This sum ("SUM_Part4", see figure 16) is calculated as follows (example instrument "running ways", row 36):

$$\mathrm{CM36} * \mathrm{CN36} = 1000 * 1 = 1000$$

If in this step the instrument "bus enhancement" would have been chosen, the four core instruments would achieve a score of zero and so the 1000 extra points will not be considered in the "SUM_Part4". This will be illustrated again on the basis of the instrument "running ways" (row 36, figure 16):

$$CM36 * CN36 = 1000 * 0 = 0$$

In the end, the four sums (SUM_Part1 to SUM_Part4) are added up in order to calculate the final score for each instrument. On this score the ranking of the instruments is based. Therefore information about the instruments is in table sheet five (“A1_Calculation”). This information contains descriptions about the instruments, the attributes addressed by the single instruments, placeholders for information about cost and implementation time, information about the categorization in non-technical and technical and a placeholder for information about best practice examples. The placeholders will be explained further later.

To sort the instruments according to their score, the tool contains a pivot table in table sheet six (“A_2 Sorting”). This pivot table comprises the names of the instruments and the score for the instruments. The rest of the information about the instruments (see above) is linked to the “A1_Calculation” sheet. Therefore the following formula is used (example for the instrument “minimizing bus emission” and the description of this instrument):

```
INDEX(A1_Calculation!$CT$3:$CT$43;MATCH(A2_Sorting!A4;A1_Calculation!$CR$3:$CR$43;0))
```

This equation means that the source for the desired information about the description of the instrument is in table sheet “A1_Calculation” in column “CT” within rows three to 43. The description in these cells shall be taken for the desired instrument (in this case for “minimizing bus emissions” which is in table sheet “A2_Sorting” in cell A4). In table sheet “A1_Calculation” the tool checks, in which row this instrument is, copies the description in appropriate row and pastes it to the cell, which includes the formula.

This is then also done for the rest of the instruments and the rest of the information, so that all available information is within table sheet “A2_Sorting” in the appropriate rows. The rest of the sorting works using a programmed macro. Therefore the following formula was inserted (see figure 17):

```
Sub Result_3()
'
' Result_3 Macro
'

'
    Sheets("A2_Sorting").Select
    Range("B3").Select
    ActiveSheet.PivotTables("PivotTable1").PivotCache.Refresh
    Range("A4:A44").Select
    Selection.Copy
    Sheets("Result").Select
    Range("B9").Select
    ActiveSheet.Paste
    Sheets("A2_Sorting").Select
    Range("C4:H44").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Result").Select
    Range("C9").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Range("A3:G15").Select
    Sheets("A2_Sorting").Select
    Range("B4:B44").Select
    Application.CutCopyMode = False
    Selection.Copy
    Sheets("Result").Select
    Range("I9").Select
    ActiveSheet.Paste
    Range("A9:H49").Select
    Application.CutCopyMode = False
    ActiveWorkbook.Worksheets("Result").Sort.SortFields.Clear
    ActiveWorkbook.Worksheets("Result").Sort.SortFields.Add Key:=Range("I9:I49") _
        , SortOn:=xlSortOnValues, Order:=xlDescending, DataOption:=xlSortNormal
    With ActiveWorkbook.Worksheets("Result").Sort
        .SetRange Range("B8:I49")
        .Header = xlYes
        .MatchCase = False
        .Orientation = xlTopToBottom
        .SortMethod = xlPinYin
        .Apply
    End With

End Sub
```

Figure 17: Macro for the calculation of the result list

This macro refreshes the information in the pivot table so that the information is the same as the input information. Thereafter the information within the table is copied and pasted to the table sheet “result”. In the end the instruments are sorted in the order of their scores beginning with the instrument with the highest score and ending with the instruments with the lowest score.

As a last step the tool allocates the appropriate rank to the instruments according to their score. Therefore rank one is allocated to the instrument with the highest score (Excel tool: table sheet three “result”, cell A9). If the next instrument has the same score, it is allocated to the same rank. But if the score is less, one further rank is added to rank one resulting in rank two. This is calculated by using the following formula:

$$IF(I10 = I9; A9; A9 + 1)$$

The above formula refers to the instrument “intersection treatments”, which is ranked two on the basis of the corresponding input information. The information about the score is in column “I”. The first instrument is located in row nine. So if the next instrument (in this case “intersection treatments”, see Annex 6) has the same score, it also has the same rank. Otherwise it is ranked correspondingly lower. This calculation is done for all instruments.

The macro starts by pressing the “start” button in the input sheet and the user is automatically redirected to the updated result list.

The result list for this example can be found in Annex 6. With the given input information, “Duckburg” should implement at first “running ways”, followed by “intersection treatments” and “platform-level boarding”. The next instrument to be implemented is “off-board fare collection”. As can be seen, the first four instruments to be implemented are the four core instruments of BRT systems. The instrument on rank five is “control center”, followed by “number of doors on bus”.

Another example is presented in the following to see how the order of the instruments changes when using different input information. Therefore it is assumed that “City A” makes the following input information (compared to the input information of “Duckburg”):

Duckburg

Step one: BRT or bus enhancement

Bus enhancement	0
Bus Rapid Transit System	1

Step two: ranking of the categories

Passenger Preferences	1
Political Preferences	2
Economic Resources	3
Implementation	3

Step three: ranking of the attributes within the category “passenger preferences”

Travel time	1
Reliability	2
Comfort	3
Convenience	5
Frequency	1
Accessibility	7
Price	2
Information provision	4
Safety/Security	6
Bus routes improvement	6
Less congestion	3
Environmental benefits	7

Step four: ranking of the attributes within the category “political preferences”

Travel time	
Reliability	2
Comfort	2
Convenience	
Frequency	
Accessibility	1
Price	2
Information provision	
Safety/Security	1
Bus routes improvement	
Less congestion	
Environmental benefits	1

City A

Step one: BRT or bus enhancement

Bus enhancement	1
Bus Rapid Transit System	0

Step two: ranking of the categories

Passenger Preferences	2
Political Preferences	3
Economic Resources	
Implementation	1

Step three: ranking of the attributes within the category “passenger preferences”

Travel time	4
Reliability	3
Comfort	1
Convenience	1
Frequency	4
Accessibility	6
Price	1
Information provision	7
Safety/Security	8
Bus routes improvement	9
Less congestion	10
Environmental benefits	2

Step four: ranking of the attributes within the category “political preferences”

Travel time	7
Reliability	6
Comfort	8
Convenience	
Frequency	
Accessibility	5
Price	4
Information provision	
Safety/Security	3
Bus routes improvement	2
Less congestion	
Environmental benefits	1

Duckburg

Step five: selecting the amount of economic resources

Low	
Medium	
High	1

Step six: selecting the kind of implementation

Instruments, that the city can implement by itself (non-technical)	1
Instruments, that the city cannot implement only by itself (technical)	

Result

Rank	Instrument
1	Running ways
2	Intersection treatments
3	Platform-level boarding
4	Off-board fare collection
5	Control center
6	Number of doors on bus
7	Multiple routes
8	Passing lanes at stations
8	Docking bays and sub-stops
9	Sliding doors in BRT stations
10	Off-peak frequency
10	Peak frequency
10	Express, limited and local services

Legend: Grey: non-technical instruments
Violet: technical instruments

City A

Step five: selecting the amount of economic resources

Low	1
Medium	
High	

Step six: selecting the kind of implementation

Instruments, that the city can implement by itself (non-technical)	1
Instruments, that the city cannot implement only by itself (technical)	

Result

Rank	Instrument
1	Running ways
2	Multiple routes
3	Park and ride
4	Intersection treatments
5	Number of doors on bus
5	Platform-level boarding
6	Control center
6	Multi-corridor network/Network of routes and corridors
6	Integration with other public transport - Physical transfer points
6	In BRT integrated bus feeder systems
7	Demand profile
8	Improvements to nearby public space
9	Off-board fare collection

Legend: Grey: non-technical instruments
Violet: technical instruments

Comparing the results it can be observed, that for both cities “running ways“ is the most important instrument to be implemented. The next instrument to be implemented for “Duckburg” is “intersection treatments”, whereas for “City A” it is “multiple routes”, followed by “park and ride”. Next instrument to be implemented would be “intersection treatments”.

These two examples show, how the result list changes when different input assumptions are made.

6.3 Built-in Placeholders

As already described, there is some information which has only been inserted as placeholders in the tool: The categorization of the instruments according to the costs (low, medium, high), the possibility to insert further detailed information about the costs for each instrument, the possibility to insert information about the implementation time for each instrument and the possibility to insert best practice examples for each instrument.

This information has just to be inserted in the appropriate cells (marked in red within the table sheet “A1_Calculation” in the Excel tool). Correspondingly, for the categorization according to the amount of the costs, a “1” has to be inserted in the appropriate cell for each instrument.

If the information is inserted, it will be automatically considered in the macro, as all formulas have already been programmed.

The tool itself can be found in Annex 9.

7 DISCUSSION OF THE RESULTS OF THE BRT ANALYSIS

This chapter provides a discussion of the results presented in chapter 5.

7.1 Qualitative Analysis

In the following the results of the qualitative analysis, presented in chapter 5, are discussed.

7.1.1 Passenger Preferences

As already described in chapter 5, the quality attributes which are important for a public transportation system, especially bus or BRT, are “travel time”, “frequency”, “reliability”, “price”, “less congestion”, “comfort”, “information provision”, “convenience”, “bus routes improvement”, “weather improvement”, “safety/security”, “environmental benefits” and “accessibility”. In the following the individual attributes are discussed:

Travel time is found to be a key quality attribute to attract riders to use public transport, as well as a high frequency of the service. Reliability is also found to be a key attribute in determining public transport service quality. These findings are confirmed in a study by Redman, et al., 2003.

Price: Redman et al. state that passengers “compare an existing fare to their expectations of a reasonable price, which is the perceived monetary value of the service they believe is actually provided” (Redman, et al., 2013, p. 120). This leads to the conclusion that car users may only be attracted by the public transport system, in this case BRT system, if they evaluate the price for using it as justified. Otherwise it is to be assumed that they will still use their cars, as car travel may be more appealing to many individuals. If compared to other transport alternatives, car travel is “generally perceived as more comfortable, flexible and faster” (Redman, et al., 2013, p. 119). Redman et al. also mention a study which found out that public transport price can encourage car users to switch to public transport systems. But other quality attributes are needed to assure the duration of this effect (Thøgersen & Møller, 2008).

Less congestion: It seems to be important for public transport users that there is less congestion on the BRT routes than on mixed traffic lanes. This can be achieved by e.g. implementing separate running ways for BRT vehicles.

Comfort: The attribute comfort is one of the key quality attributes to attract “choice” riders from other modes (Hughes & Leshner, 2013). “Choice” riders are understood to mean people choosing the car while also having the possibility to do the same trip with public transport, especially BRT systems. But there is no clear evidence, which improvements to the attribute “comfort” particularly attract new passengers.

Redman et al. state that there is the possibility to only "improve the passenger service ratings rather than encouraging an increase in passenger numbers" (Redman, et al., 2013, p. 124). So it is necessary to combine improvements to comfort with improvements of other quality attributes in order to be sure to attract new riders to the BRT system.

Information provision: For a trip with a public transportation mode sufficient information about the journey must not only be available during the trip, but also in advance, like information about routes, times, luggage-capacity, refreshments, carriage of small children and of animals, fares and even maybe smoking restrictions. Whereas errors made while driving a car (e.g. a wrong turn) could be corrected more easily, such errors are not so easily to be corrected on public transport once the trip has begun. This could lead users not to use the public transport system again (Transport 2000 Trust, 1997; In (Stradling, et al., 2000)).

Convenience: This quality attribute is similar to some attributes already discussed. It can be differentiated from others by especially addressing the ease and simplicity of paying and planning for a trip (Redman, et al., 2013) as well as the ease of using the public transport system by e.g. switching from one transportation mode to another.

Bus routes improvement: This quality attribute especially aims at attracting car users to the BRT system, i.e. which actions have to happen to make car users switch to the alternative (Mackett, 2001).

Weather improvement: This attribute is not really to be counted as a quality feature of public transportation modes, as it is not improvable. Weather improvement was only taken into account to illustrate the need for weather protection during the use of the public transport system, as this is a key reason for not using public transport systems (Mackett, 2001).

Safety/Security: This quality attribute not only addresses the actual safety (e.g. from road accidents) and personal security (e.g. from robbing), but also how safe the riders feel. This is important because people will not use the public transport system offered if they do not feel safe when using it, irrespective of the fact how safe they actually are.

Environmental benefits: This attribute implies especially the increased CO_2 savings and the decrease in other emissions related to transport. This could be achieved by either improving the public transport system or by shifting the kilometers travelled from private motorized modes to the public transportation network.

Accessibility: This attribute has an impact on ridership and also on equity concerns. It can be improved e.g. by extending the public transport network to the outer, often lower-income areas. Sometimes low-income households have to use cars as they do not have sufficient access to the public transport network. If the mobility needs are fulfilled by improving the accessibility, some households may not need the car anymore (Redman, et al., 2013). So the money saved by not spending it on car related costs is on disposal for other expenses.

7.1.1.1 Allocation of Attributes to Instruments

It is important to know which instruments affect which attributes in order to improve the quality offered by a public transport system. As there was not much literature available concerning this subject, the allocation was carried out on the basis of discussions with several members of the Mobility Consulting Department at Siemens AG in Munich and with scientists from the Chair of Urban Structure and Transport Planning of the Technical University in Munich. It was tried to consider only direct effects of the instruments on the attributes.

The allocation of the attributes to the instruments was not clear for all interdependencies. In the following the allocations are discussed, where there were different opinions:

In the present study there is no interdependency considered between the instrument “control center” and the attribute “travel time”. An argument supporting an interdependency between these two would be that by implementing a control center the travel time will be reduced due to optimized activities. However, this is considered as an indirect impact in the present study and not as an direct impact like improving the reliability.

There were also discussions, if there exists an interdependency between the instrument “intersection treatments” and the attribute “frequency”. If buses are prioritized at intersections, the buses do not have to wait for a green signal and do not need to queue up. If not implemented that would lead to delays due to waiting times at intersections and therefore the impact of reduced headways would be negated. This interdependency is evaluated as having a major impact on frequency and is therefore considered in the present study.

The instrument “located in top-ten corridors” is considered as having an effect on the attribute “comfort”. Assuming that the BRT corridor was built on a former conventional bus line, the comfort of the system will be improved by implementing a BRT system. As this instrument requires to build the BRT corridor in one of the top-ten corridors in terms of aggregate bus ridership, this impact is considered in the present study.

To have more than three doors or two wide doors on the side of the bus increases not only the comfort of boarding and alighting but also the safety and security: If there is more space the doors will be less crowded and therefore the possibility of accidents will be reduced.

“Running ways” support the reduction of CO_2 emissions and the emission of other pollutants by BRT vehicles as they help to avoid buses being caught up in traffic jams.

“Sliding doors in BRT stations” improve the reliability and the travel time of BRT systems. Thus the headways of the BRT vehicles could be improved. But this interdependency is assessed as indirect and therefore not further considered in the present study.

7.2 Quantitative Analysis

In the following the results of the quantitative analysis, presented in chapter 5, are discussed.

7.2.1 Percentage of BRT Ridership that were former Car Users

The success rates of the BRT systems in relation to the size of the system and the size of the city were presented in chapter 5.2.1. It seems that the implementation of smaller systems in smaller cities (group C) is more successful (success rate: 19.11%) than the implementation of bigger systems in bigger cities (group A, success rate: 10.89%) or than in cities and systems lying in between (group B, success rate: 8.33%). Whether the difference in the success rates between groups A and B is statistically significant or only at random, should be further analyzed by a statistical analysis.

The investigation into a trend between the success rates of BRT systems and the number of alternative public transportation modes offered in a city was also conducted without performing a statistical analysis. A trend could not be recognized, nevertheless this result should be further confirmed by a statistical analysis.

With respect to the analysis whether the different success rates in the groups can be explained by the modal share of car usage or private motorized modes in cities, data were only available for 12 out of all 29 cities. Therefore it was not possible to conduct the analysis only for the case studies considered in this analysis. This might distort the results. Nevertheless, there is a system recognizable. The modal share for cities within group A is much less for car usage or private motorized modes than for cities in group C. Thereby the higher success rates of case studies in group C than in group A could be explained. The more people proportionally still use the car, the more car users can be attracted by the new public transport system. If the proportion of modal share for car usage is already low, it is more difficult to attract new BRT riders away from the car. Within group B there are, as already described, big differences between the case studies. The modal shares for the Chinese cities (Guangzhou and Changzhou) for private motorized modes are around 25%. But the modal share for motorized individual transport (considered identical to private motorized transport) is around 75% in Los Angeles. However, due to these differences, the impact of the modal share on the success rates for the case studies within group B could not be further analyzed.

Actually only the percentage of car usage should be considered in the evaluation of the modal share. But some literature only refers to private motorized modes (considering not only car usage, but also e.g. motorcycles). This could not be further considered as there were not enough modal shares for cities with case studies available.

Only small differences resulted between the groups formed by grouping the BRT systems according to running times. The results differ between 14.00% and 17.70%. Without carrying out a statistical analysis it is not possible to draw the conclusion, whether these small differences are statistically significant or only at random. This should be further analyzed. It has to be mentioned that this analysis could not be executed with all 17 case studies. As already described, there were case studies, which could not be exactly allocated to the different groups, as literature was considered for the data gathering which refers to different years.

A trend could not be observed between the success rates of the BRT systems and the percentages of implementation of the most important instruments according to the passenger preferences. Again this analysis was conducted without supporting the results by a statistical analysis. So this should be performed in the future.

Concluding the discussion of the results of the analysis of this value it has to be mentioned, that all the values used in the evaluation were found in the literature. As the literature did not provide the information, how a value was calculated, it was assumed that all values were calculated in the same way. Otherwise an analysis would not have been possible. Nevertheless it is possible, that some of the values were calculated in a different way than others. In this case, the results would be distorted.

7.2.2 Percentage of Car Users Shifting to BRT

The overall average of the success rate measured by the percentage of modal shift amounts to 2.23%. The success rates of the groups (groupings according to the size of the city and the size of the system) amount to 0.47% (group A) and to 3.12% (group C). This indicates again that the implementation of smaller systems in smaller cities (like case studies in group C) is more successful than the implementation in bigger cities (like case studies in group A and B). But this analysis was only conducted with six case studies. Therefore the results have to be evaluated as not very representative.

Furthermore the percentage of modal shift was only available in the literature for three case studies, for the other three case studies the percentage was calculated. As already mentioned, sometimes the literature refers to this value but actually means the percentage of BRT ridership. For example, Yorgos Voukas (Transport Director of CTS-Mexico) reports a modal shift of 15%, which is explained as people "quit using cars in order to travel by Metrobus" (Voukas, 2011, p. 21) in Mexico City. This would refer to the value relevant for this evaluation: The percentage of modal shift. But the same number (15%) was found in another source for the same case study: There it was explained as the percentage of Metrobus users who formerly travelled by car (Aguilera, 2012). This would indicate that the quoted percentage is actually the percentage of BRT ridership used in the present study. When this discrepancy was recognized, an email was sent to Mr. Voukas asking for the actual basis of the value of 15%. The email address was found on the slide set mentioning the 15% modal shift. But unfortunately, Mr. Voukas did not respond to the email, so the value had to be considered as the percentage of BRT ridership in the present study.

Another example for the poor data background was found in the study of Wang et al.. In the discussion part the study shows "probabilities for auto users shifting to BRT" (Wang, et al., 2013, p. 522). E.g. 3% are quoted for Nogoya and 20% for Jakarta. While researching the corresponding literature to which these percentages refer to, the 3% of auto users shifting to BRT for Nagoya could be confirmed (Takeshita, et al., 2007). Nevertheless, an email was written to the author to confirm that this is actually the right value. Again, an answer was not received. However, the value of 20% of auto users shifting to BRT for Jakarta could not be confirmed by the source literature (Ernst, 2005). Ernst states that "20% of BRT riders have switched from private motorized modes" (Ernst, 2005, p. 20), which indicates that this is actually the percentage of BRT ridership used in the present study.

These two examples indicate that there is a need for improving the data bases offered for public transport systems, especially concerning the success of BRT systems in terms of determining the percentage of modal shift.

When this inaccuracy of using these two values in the literature was recognized, it was tried to determine, which value is the right one, by contacting the authors of the studies or the cities themselves. Unfortunately, not many of the contacts replied to the information requests.

Furthermore, the percentage of modal shift was calculated for three more case studies to be able to conduct an analysis. Therefore the formula described in chapter 4.2.2 was used. For the present study the definition for trips was defined as described there. But as the data needed for the calculation were found in the literature (e.g. the number of car trips in a city per day) it is possible that the respective literature defines a trip differently. This could be a reason for another inaccuracy in the calculation.

When having a closer look at the values (see table 16), it can be recognized that the calculated values are much lower than the values found in the literature. It is possible that these differences are only at random. However, it is assumed that there are differences in the way of calculating this value, as there was no information provided in the literature explaining how the values were calculated. Additionally, as already described in chapter 4.1.3, the values found in the literature could be actually the percentages of BRT ridership, as it was not possible to confirm that these were actually the percentages of modal shift. For these reasons the results of this part of the present study are considered as not representative and should be interpreted carefully, as it is possible that the results are distorted.

Table 16: Percentages of modal shift

Case study	Percentage of modal shift	Calculated (calc.) or out of literature (lit.)
Mexico City	0.71%	Calc.
Istanbul	0.23%	Calc.
Nantes	0.46%	Calc.
Pereira	2.00%	Lit.
Nagoya	3.00%	Lit.
Leeds	7.00%	Lit.

Despite of the difficulties described above, the analysis was carried out:

A trend could not be found within the groups A and C between the success rates of the BRT systems and the number of alternative transportation modes offered in a city. This result was not confirmed by a statistical analysis.

The result of the analysis of the modal share for car usage or private motorized modes is the same as already described for the percentage of BRT ridership, as the same case studies were used for the evaluation. If the result that smaller systems in smaller cities are more successful in attracting car users, is also true for the percentage of modal shift, this could be due to the same reasons as already described in chapter 6.1.2.1.

Grouping the case studies according to running time the result suggests that BRT systems are more successful, the longer they are operating. But it has to be considered that with respect to the group of running times between 12 and 25 years, the two values were found in the literature and are much higher than the calculated ones (see above). Therefore, again, the result is to be interpreted carefully.

Comparing the success rates of the BRT systems with the percentages of implementation of the most important instruments according to the passenger preferences, there is a slight trend recognizable. The trend indicates that the more instruments of the most important ones are implemented, the less successful the systems are. This result is not proven by a statistical analysis. Nevertheless, the result seems to be absurd as it should be exactly the other way round. It is assumed that this distorted result is due to the fact that the origins of the percentages were different. The higher percentages were found in the literature while the lower percentages were calculated.

With respect to the percentage of the BRT ridership an analysis was conducted concerning the instruments implemented for the most part in the most successful systems. This was not carried out for the percentage of modal shift as the most successful systems are exactly the case studies, where the values were found in the literature. Because of this fact, this assessment is not reasonable for this value.

8 CONCLUSION AND OUTLOOK

BRT systems were taken as an example to develop a methodology to evaluate "policy projects". The main objective was to identify, which instruments have to be implemented in order to maximize the impact on modal shift and thus to contribute to the reduction of CO_2 emissions. Some of the results of this analysis were taken to develop an user-oriented Excel tool. This tool can be used for a first assessment on which instruments should be implemented when introducing or improving a BRT system.

A first finding is that smaller BRT systems in smaller cities seem to be more successful in terms of attracting car users than bigger systems in bigger cities. This could be explained by the modal shares for private car use or private motorized modes in the cities investigated. As there is a relatively higher modal share for car use in the cities of group C (see chapter 5), systems in these cities can be more successful as relatively more car trips can be shifted to the public transport network. It was not possible to explain this level of success of smaller BRT systems in smaller cities in dependency on the absence of other public transportation modes offered in the cities. The question was examined, whether BRT systems are more successful in cities with no other public transport modes offered than conventional bus systems. Such a trend could not be verified.

A second finding is that the focus of the cities and of the passenger preferences concerning the quality attributes do no completely match (see table 17). The most important attributes according to the passenger preferences (first column in table 17, "travel time", "frequency" and "reliability", marked in "red") were also prioritized in the case studies (second column). But "price", which is also important according to the passenger preferences, is considered as least important by the case studies (marked in "blue"). This leads to the conclusion that there are still possibilities to improve the systems according to the passenger preferences (e.g. to decrease the price for using the BRT systems). Another difference is to be noted: The cities evaluate the attributes "convenience", "safety/security" and "accessibility" as more important as compared to the passenger preferences (marked in "green"). This indicates that there could be other reasons behind the focus of the cities than answering only to the passenger expectations, such as e.g. political objectives (especially "accessibility" and "safety/security").

Table 17: Attributes focused on by passenger preferences and by the most implemented instruments in all case studies

Passenger preferences		Most implemented instruments in all case studies	
Rank	**Attribute**	**Rank**	**Attribute**
1	Travel time	1	Travel time
1	Frequency	2	Reliability
2	Reliability	2	Convenience
2	Price	2	Frequency
3	Less congestion	2	Safety/Security
3	Comfort	3	Accessibility
4	Information provision	3	Information provision
5	Convenience	4	Comfort
6	Bus routes improvement	4	Less congestion
6	Weather improvement	4	Environmental benefits
7	Safety/Security	5	Bus routes improvement
8	Accessibility	5	Weather improvement
8	Environmental benefits	6	Price

Table 18 compares the instruments that should be implemented with highest priority according to the passenger preferences with the instruments implemented for the most part by all case studies as well as with the instruments implemented in the most successful case studies in terms of the percentage of BRT ridership: The instruments “running ways”, “intersection treatments”, and “platform-level boarding” (marked in “red”) were considered as important by the passengers and were also implemented in more than 60% of the case studies. These instruments are three of the four core instruments for BRT systems (“BRT basics”). This supports the selection as “BRT basics” by the ITDP (ITDP, 2013b). But the rest of the important instruments for passengers was not implemented in more than 60% of the case studies (second column in table 18, instruments implemented for the most part by all case studies). As can be seen, the BRT systems did not completely implement the instruments which would primarily answer the preferences and wishes of the ridership. That leads also to the conclusion that there are still possibilities to improve the systems according to the passenger preferences. By doing so the success of the systems in terms of a modal shift from private car use towards BRT could be improved.

Table 18: Instruments that should be implemented according to passenger preferences and instruments implemented for the most part in all case studies and in the most successful case studies (percentage BRT ridership) (sorted in the order of importance or in the order of percentage of implementation)

Passenger preferences	Most implemented instruments in all case studies	Most implemented instruments in the most successful case studies (% BRT ridership)
Running ways	Enhanced station environment	Intersection treatments
Intersection treatments	Running ways	Enhanced station environment / safe and comfortable stations
Control center	Intersection treatments	Branding
Multiple routes	Branding	Real time passenger information
Passing lanes at stations	Real-time passenger information	Running ways
Docking bays and sub stops	Multi corridor network/network of routes and corridors	Off-board fare collection
Platform-level boarding	Peak frequency	Platform-level boarding
Number of doors on bus	Off-board fare collection	Peak frequency
	Platform-level boarding	Multi-corridor network/network of routes and corridors
	Off-peak frequency	Universal access
		Integration with other public transport - physical transfer points
		Electronic card

By comparing the instruments which should be implemented to answer the preferences, needs and wishes of the riders with the most implemented instruments in the most successful cities (see table 18), it can be recognized that there are differences. Again, the instruments "running ways", "intersection treatments" as well as "platform-level boarding" (marked in "red") overlap. But all the other instruments implemented for the most part in the most successful systems are not reflected in the passenger preferences. So, as a third finding, this indicates that there have to be additional reasons for success which are not considered in this analysis. Furthermore, the fourth core instruments of BRT systems "off-board fare collection" is represented in the instruments implemented for the most part in all case studies as well as in the most successful case studies, but not in the passenger preferences. This also indicates, that there are other reasons for a successful system besides the passenger preferences. These reasons should be further investigated in a future study concerning BRT systems.

What was also not considered in the present study is that there might be secondary feedback effects by implementing BRT systems. If BRT systems are implemented, car users will be attracted resulting in a modal shift. "Where bus lanes are using previously open lanes, the remaining car users are presented with less space on the route". But where "lanes are new or used space previously restricted to moving cars (e.g. parking lanes or shoulders), remaining car users may be presented with less congested road space as buses are removed from traffic and the bus modal share potentially improves (that ignores the impact that removing parking will have on the car users looking to store their cars at the end of their journey)" (McDonnell & Zellner, 2011, p. 826). This might result in shorter travel times for the remaining car users and therefore could be a renewed incentive for car use (McDonnell & Zellner, 2011).

Furthermore it has to be mentioned that the present study does not consider the cultural differences in the different parts of the world. In some countries driving a car might be very important as a status symbol. Additionally, demographic and socioeconomic factors, like gender and age, are also significant factors to be considered when trying to shift car trips to public transport modes (Wang, et al., 2013; Redman, et al., 2013). Besides, each city is one-of-a-kind and therefore it is difficult to compare them and especially to generalize results. These factors should be kept in mind when interpreting the findings of the present study.

One further point is to be considered when implementing BRT systems. As the example of implementing a BRT system in Bogotá showed, there could be negative reactions to implementation plans as the existing bus operators feared a loss of business. The existing bus operators strongly opposed the implementation of TransMilenio. Furthermore they proved to be a critical obstacle to the success of the BRT system. This could be solved by making them pertinent stakeholders in the planning and implementation process of TransMilenio (Turner, et al., 2012).

In conclusion it can be asserted that there is still the need and possibility to improve the already existing BRT systems in order to implement successful systems. By improving the quality of service, BRT systems have the potential to attract more private car users (Redman, et al., 2013). Thus, BRT systems are a possibility to save CO_2 emissions and contribute to reduce the overall environmental footprint of the cities.

In a future analysis the share of the BRT networks in the size of the complete bus networks could be analyzed. It might be interesting to investigate into the question whether BRT systems are more successful the higher their proportion in the complete bus systems is.

To confirm the findings it is recommended to conduct a statistical analysis to prove the individual results found in the present study. In this master thesis the influence of both the size of the system (in relation to the size of the city where the BRT system was implemented) and the running time on the success rates (in terms of the percentage of modal shift and of the percentage of BRT ridership) were evaluated independently. In further investigations a broader statistical analysis (e.g. a meta analysis) should be performed to assess, which impact of the named factors (size or running time) is stronger and if there exists a correlation or interdependency between them and the success rates of the systems. Therefore it is necessary to support the findings by improving the quality of the data needed for an investigation and evaluation of BRT systems. The need to improve the provided data is discussed in detail in the present study and can also be found in a study published by Hensher & Golob (2008).

By improving the data base and especially the data concerning the percentage of car users shifting to BRT systems due to its implementation, it will be possible to calculate the CO_2 savings achieved by shifting car trips to the public transportation system.

In future it should be tested, if the methodology developed in the present study is also applicable for the evaluation of other “policy projects”, especially for those aiming to improve the public transport network (like the implementation of a light rail). For “policy projects”, which cannot be assessed using the presented methodology, a new methodology to evaluate them and to assess which instruments should be implemented with the respective “policy projects” should be developed. Furthermore the results of these analyses of a large number of “policy projects” could be used to develop assessment tools like the one developed for BRT systems in the present study. It then might be possible to link all these assessment tools to one comprehensive tool.

This tool would then make it possible to calculate not only the instruments a specific city should implement for the respective “policy projects”, but also to assess a whole, detailed transportation strategy. This transportation strategy will be created depending on the information the city inputs (such as the specific passenger preferences, political objectives, economic resources as well as further aspects e.g. the size of the city, the number of inhabitants, and the share of the transport modes).

To go one additional aspect further, this broad transportation strategy assessment tool could also calculate the possible CO_2 savings and the benefits for the other transport related environmental and social concerns, to which the respective transportation strategy, assessed by the tool, will contribute.

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GLOSSARY

Instruments	Specific elements of policy projects
ICT	Information and communication technology
Objective	A broad statement of the improvements which a city is seeking. Objectives specify the directions for improvement, but not the means of achieving it
Policy	Inspiration and guidance for action, a broad approach towards transport and land use planning including the choice of a strategy and its component projects and instruments
Policy Project	Specific components of a strategy to overcome problems and achieve objectives
Strategy	A set of policy projects or instruments to solve problems concerning the transportation sector and to meet the targeted objectives

ABBREVIATIONS

BRT	Bus Rapid Transit
CO_2	Carbon Dioxide
GHG	Greenhouse gases
GIZ	Deutsche Gesellschaft für internationale Zusammenarbeit
GTZ	Deutsche Gesellschaft für technische Zusammenarbeit
ITDP	Institute for Development & Transportation Policy
ITS	Intelligent Transportation Systems
KM	Kilometer
PT	Public Transportation
TDM	Transport/Transportation Demand Management

Annex 1

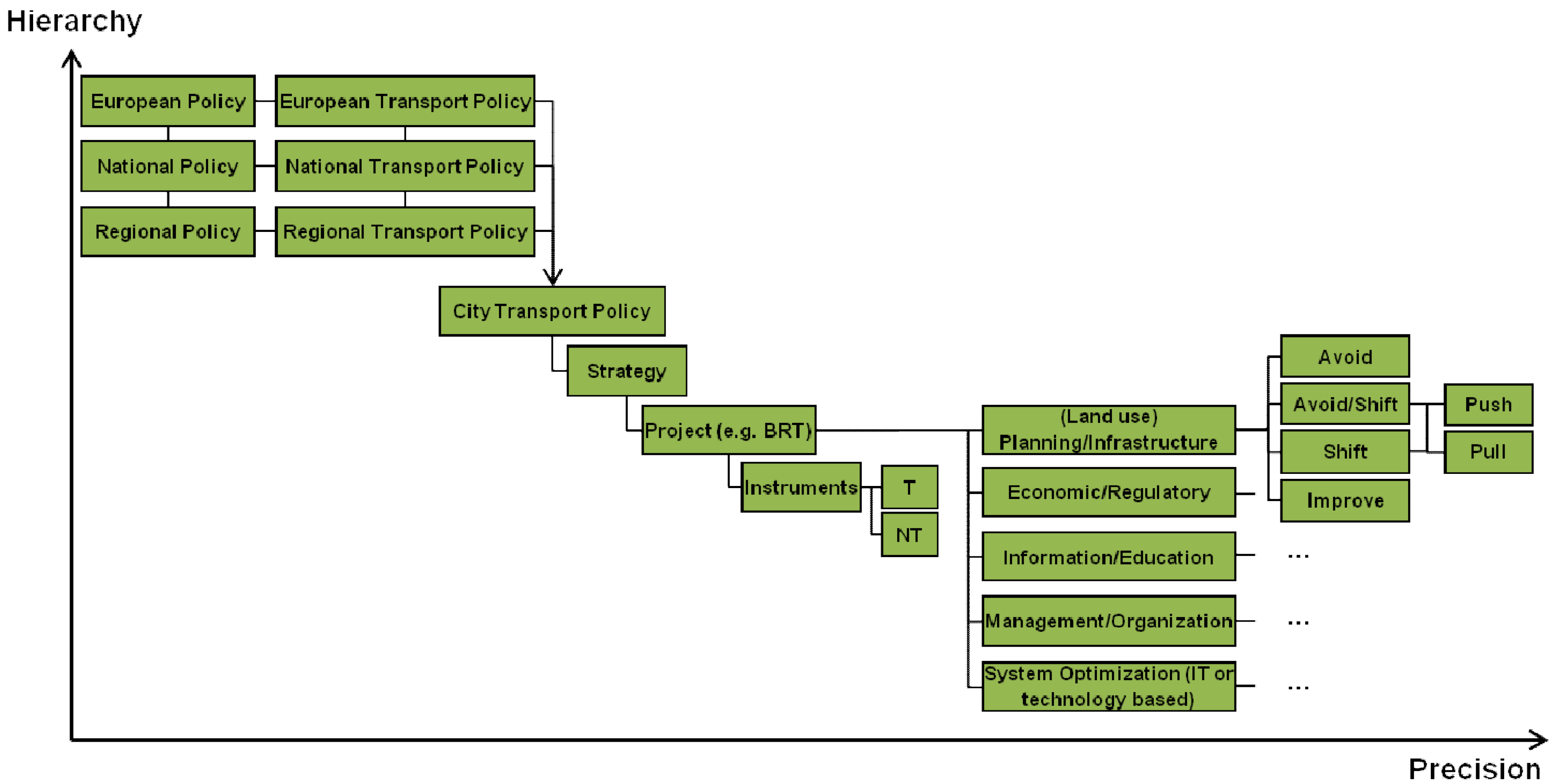

Figure 18: Policy levels and terms

SIEMENS

Annex 2

Table 19: BRT instruments with descriptions and further information

Instrument	Description	Non-technical/ technical	Source	Notes
BRT Basics				
Running ways	Running ways are the bus routes or lanes. They define where BRT vehicles travel. This includes all levels of implementation concerning the location (e.g. two-way median-aligned busway or curb-aligned busway, on-street or off-street) and the grade of physical segregation of bus lanes from pavements and or other traffic lanes (e.g. full physical segregation, segregation only with marking and signs). (ITDP, 2013b; Tann & Hinebaugh, 2009)	NT	(ITDP, 2013b) (Tann & Hinebaugh, 2009)	This instrument covers the "busway alignment" and the "dedicated right-of-way" of the "BRT Standard 2013". Both instruments were taken together, as it was difficult to withdraw the specific information required from the case studies. Case studies are considered as having implemented this instrument when having separated running ways, disregarding the level of segregation. Only mixed-traffic lanes with queue-jumper lanes have not been counted as running ways in the present study.
Off-board fare collection	Implementation of off-board fare collection can be managed in two ways: • Barrier-controlled: Fare payment at a turnstile or faregate, • Proof-of-payment: Fare payment at a kiosk with collecting a ticket, which is checked when boarding. (ITDP, 2013b; Tann & Hinebaugh, 2009)	T	(ITDP, 2013b) (Tann & Hinebaugh, 2009)	
Intersection treatments	Includes traffic-signal priority and the prohibition of turns across bus lanes. (ITDP, 2013b)	T	(ITDP, 2013b) (Tann & Hinebaugh, 2009)	Some studies refer to signal priority as part of ITS (Intelligent Transportation Systems). Case studies are considered as having implemented this instrument, when one of these two elements has been established. This instrument has a technical (signal priority) and a non-technical element (prohibition of turns across bus lanes). As the technical part is more significant, this instrument is categorized as technical.

Instrument	Description	Non-technical/ technical	Source	Notes
Platform-level boarding	Bus-station platform and bus floor are on the same level. (ITDP, 2013b)	T	(ITDP, 2013b) (Tann & Hinebaugh, 2009)	
Service Planning				
Multiple routes	Multiple routes operating on a single corridor. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Peak frequency	At least 8 buses per peak hour. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Off-peak frequency	At least 4 buses per off-peak hour. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Express, limited and local services	In contrast to local services, limited services skip lower-demand stations. Express services are often operating directly from one end to the other without stopping in between. (ITDP, 2013b)	NT	(ITDP, 2013b)	Case studies are considered as having implemented this instrument, when there is at least one local and one limited or express service.
Control center	Monitors the locations of all buses (e.g. with GPS) to: • Respond to incidents in real-time • Control the spacing of buses • Determine and respond to the maintenance status of all buses in the fleet • Record passenger boardings and alightings for future service adjustment • Use computer-aided dispatch (CAD) / automatic vehicle location (AVL) for bus tracking and performance monitoring. (ITDP, 2013b)	T	(ITDP, 2013b)	Case studies are considered as having implemented this instrument, when it is mentioned in the case studies, that there is a control center. It was not possible to research into the characteristics of the control centers in detail.
Located in top-ten corridors	BRT corridors should be located along one of the top-ten corridors (in terms of aggregate bus ridership). (ITDP, 2013b)	NT	(ITDP, 2013b)	(few information available)*
Hours of operation	BRT service should operate until midnight and on weekends. (ITDP, 2013b)	NT	(ITDP, 2013b)	Case studies are considered as having implemented this instrument, when the BRT operates until midnight and/or on weekends.
Demand profile	The BRT corridor should be built in the road segment with the highest demand within a two km distance from either end of the corridor. (ITDP, 2013b)	NT	(ITDP, 2013b)	

Instrument	Description	Non-technical/ technical	Source	Notes
Multi-corridor network/network of routes and corridors	BRT systems should include a network of BRT corridors. (ITDP, 2013b)	NT	(ITDP, 2013b)	Case studies are considered as having implemented this instrument, when there is more than one BRT corridor.
Infrastructure				
Passing lanes at stations	To allow both express and local services and to avoid congestion, it is necessary to have passing capabilities at stations. (ITDP, 2013b)	NT	(ITDP, 2013b) (Tann & Hinebaugh, 2009)	Case studies are considered as having implemented this instrument, when there is any passing capability available.
Minimizing bus emissions (Euro III or higher)	Buses with emissions that meet the Euro III or higher standards. (ITDP, 2013b)	T	(ITDP, 2013b)	In "The BRT Standard 2013" the requirement for this instrument is at least Euro IV. As there was only information available whether the BRT vehicles meet the EU III Standard, this lower requirement was adopted for this study.
Stations set back from intersections	Stations should be located away from intersections to avoid delays. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Center stations	Single stations in the middle of the busways that serve both directions. (ITDP, 2013b)	NT	(ITDP, 2013b)	(few information available)*
Pavement quality	Good pavement quality minimizes the need for maintenance of the busway and busways need to be closed less frequently (designed for fifteen year-life or higher). (ITDP, 2013b)	T	(ITDP, 2013b)	(few information available)*
Station Design and Station-Bus Interface				
Distance between stations	To optimize the travel speed of buses and to ensure the accessibility, average distances between stations should be between 0.3 km and 0.8 km. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Enhanced station environment/safe and comfortable stations	BRT stations should be safe and weather protected. (ITDP, 2013b)	NT	(ITDP, 2013b) (Tann & Hinebaugh, 2009)	In "The BRT Standard 2013" the requirement for this instrument is a safe and comfortable station environment. Since in most studies the instrument of a safe and comfortable station environment is not mentioned, but it is only referred to an enhanced station environment (which is not only just a bus shelter) this lower requirement of an enhanced station environment was adopted for this study.

Instrument	Description	Non-technical/ technical	Source	Notes
Number of doors on bus	More than three doors or two wide doors on the side of the bus. (ITDP, 2013b)	T	(ITDP, 2013b)	
Docking bays and sub-stops	Multiple docking bays and sub-stops at most of the stations. A station should be composed of sub-stops that connect to one another. They can have multiple docking bays. These are locations "within one sub-stop where buses can pull up to let passengers on and off. They are usually adjacent to each other and allow a second bus to pull up behind another bus already at the station." (ITDP, 2012, p. 32; ITDP, 2013b)	NT	(ITDP, 2013b)	
Sliding doors in BRT stations	Sliding doors in BRT stations, where passengers get on and off the buses. (ITDP, 2013b)	T	(ITDP, 2013b)	
Quality of Service and Passenger-Information Systems				
Branding	Gives an identity to the BRT system which promises a high level of service. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Real time passenger information	There should be real-time passenger information available at stations and on buses. (ITDP, 2013b)	T	(ITDP, 2013b) (Tann & Hinebaugh, 2009)	In "The BRT Standard 2013" the requirement for this instrument is real-time and static passenger information corridor-wide (at stations and on vehicles). As there was only information available about the real-time information, it was assumed, that every BRT system has adequate static information in principle. Case studies are considered as having implemented this instrument, if there is real-time information at stations or on vehicles.
Integration and Access				
Universal access	The stations and vehicles should be accessible to all special-need customers (including e.g. elevators). (ITDP, 2013b)	T	(ITDP, 2013b)	

Instrument	Description	Non-technical/ technical	Source	Notes
Integration with other public transport – physical transfer points	The BRT system should be integrated in the already existing public transport network. This includes physical transfer points, which means minimizing walking time between modes, and not requiring to exit one system to enter another. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Integration with other public transport – information	The BRT system should be integrated in the already existing public transport network. This includes information encompassing all public transportation modes, so the BRT information is included in existing public transportation maps and schedules. (ITDP, 2013b)	NT	(ITDP, 2013b)	(few information available)*
Integration with other public transport – fare payment: Integrated tariff system	The BRT system should be integrated in the already existing public transport network. That includes an integrated fare payment, so that one fare card may be used for all modes. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Pedestrian access	Safe passenger access to stations (e.g. at-grade pedestrian crossings, signalized crosswalks, pedestrian bridges or underpasses). (ITDP, 2013b)	NT	(ITDP, 2013b)	In "The BRT Standard 2013" the requirements for this instrument are a bit higher. In the absence of more detailed information, case studies are considered as having implemented this instrument, if the information in the case study suggests that the stations can be entered safely.
Secure bicycle parking	Provision of (safe) bicycle parking at stations. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Bicycle lanes	Building bicycle lanes on or parallel to the BRT corridor. (ITDP, 2013b)	NT	(ITDP, 2013b)	
Bicycle-sharing integration	Providing bicycle-sharing at stations. (ITDP, 2013b)	NT	(ITDP, 2013b)	
In BRT integrated bus feeder systems	Integration of a bus feeder system for the BRT network.	NT	(Tann & Hinebaugh, 2009)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system.

Instrument	Description	Non-technical/ technical	Source	Notes
Park and ride	Availability of park and ride lots at stations. (Tann & Hinebaugh, 2009)	NT	(Tann & Hinebaugh, 2009)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system.
Improvements to nearby public space	Pedestrian and public space upgrades in the surroundings of the BRT. (Wright & Hook, 2007)	NT	(Wright & Hook, 2007)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system.
Supporting measures				
Operational subsidies	Subsidizing the BRT system by public entities. (Wright & Hook, 2007)	NT	(Wright & Hook, 2007)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system. This instrument is to be interpreted carefully. While operational subsidies can help to decrease fares, BRT systems, especially in the developing world, should be designed to function without operational subsidies. (Wright & Hook, 2007) (few information available)*
Restriction of on-street parking	Restriction of on-street parking (especially in the city center) is supporting BRT systems. (Wright & Hook, 2007)	NT	(Wright & Hook, 2007)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system.
Supporting car restriction measures (e.g. road pricing)	The application of car restriction measures is supporting BRT systems. (Wright & Hook, 2007)	NT	(Wright & Hook, 2007)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system. (few information available)*
Marketing campaign	Supporting BRT systems not only by branding but also by a broad marketing campaign. (Wright & Hook, 2007)	NT	(Wright & Hook, 2007)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system. (few information available)*
Electronic card	Providing fare payment with electronic cards or smart cards. (Tann & Hinebaugh, 2009)	T	(Tann & Hinebaugh, 2009)	This instrument was added to the instruments of "The BRT Standard 2013", as it was considered important for a complete BRT system.

* Few information available: see chapter 3.3

Annex 3

Table 20: Summary of data of the case studies

A lot of information about the case studies (especially about the implemented instruments) is out of the following resources:

- Bus Rapid Transit Information (ITDP, 2013a)
- Bus Rapid Transit Planning Guide (Wright & Hook, 2007) (Information about "partly implemented" is considered as implemented in the present study)
- Characteristics of BUS RAPID TRANSIT for Decision-Making (Tann & Hinebaugh, 2009)
- WG 3 – Operation management and supporting ITS (Ambrosino & Mension, n.d.)
- Buses with High Level of Service (Finn, et al., 2011)

The remaining sources for the data can be found in Annex 8 within the comments of the respective cells.

Table 20: Summary of data of the case studies

City	**Nantes**	**Edinburgh**	**Kent Thameside**	**Kent Thameside**	**Leeds**	**Istanbul**	**Stockholm**	**Helsinki**	**Alameda County / Oakland**
Name of system	Busway	Fastlink/WEBS	Fastrack - Route A	Fastrack - Route B	Leeds superbus, A61 und elite	Metrobus	trunk bus network - 4 lines	Jokery line	San Pablo Ave Rapid
ITDP score	BRT Standart Bronze								
Name in literature	BHLS	BRT	BHLS/BRT	BHLS/BRT	BRT	BRT	BHLS	BHLS	BRT
Year of implementation	2005	2004	2007	2006	1995	2007	1992	1993	2003
Implemented Instruments									
BRT Basics									
Running ways	1	1	1	1	1	1			-
Off-board fare collection	1	-	1	1	-	1			-
Intersection treatments	1	1	1	1	1	1	1	1	1
Platform-level boarding	1	1	1	1	1			1	
Service Planning									
Multiple routes									-
Peak frequency	1	1	?	-		1	?		-
Off-peak frequency	1	1	?	?		1	?		1
Express, limited and local services		-							1
Control center	1	1			-	1			
Located in top-ten corridors									
Hours of operation	1		-			1	1		-
Demand profile									
Multi-corridor network	1	?			1	-	1		1
Infrastructure									
Passing lanes at stations	-	-			-	-			
Minimizing bus emissions (Euro III or higher)	1	1			1	1		1	
Stations set back from intersections	1					1			
Center stations									
Pavement quality									
Station Design and Station-Bus Interface									
Distance between stations	1		1	1		-			-
Enhanced station environment	1	1	1	1	1	1			1
Number of doors on bus	1	-			-	1			1
Docking bays and sub-stops						1			
Sliding doors in BRT stations	-					-			
Quality of Service and Passenger-Information Systems									
Branding	1	?	1	1	-	1		1	1
Real time Passenger information	1	1	1	1	?	-	1	1	1
Integration and Access									
Universal access	1		1	1		1	1		1
Integration - physical transfer points	1	?		1	?				
Integration - information									
Integration - fare payment: Integrated tariff system	1								
Pedestrian access	1	1	1	1	1		1		
Secure bicycle parking	1	?			?	-			
Bicycle lanes	-								
Bicycle-sharing integration	1					-			
In BRT integrated bus feeder systems	1	1			1				
Park and ride	1				1				1
Improvements to nearby public space	1	?			-	-			
Supporting measures									
Operational subsidies	-								
Restriction of on-street parking									1
Supporting car restriction measures	-	-			-				
Marketing campaign			1	1				1	1
Electronic card		1			-	1			1
Data									
% modal shift from car to bus	0.46% (calc.)				7%	0.23% (calc.)			
% BRT ridership that were former car users	25%			19.00%	10-20% (new passengers)	4%	5% (new passengers)	12% (new passengers)	18%
Average daily passengers/weekday	21,000			35,500		600,000	163,000.00		6,050
Population metropolitan area	1,246,789	831,586		1,389,600	1,130,014	13,710,512	1.9 million	969,000	1,443,741
Annual distance travelled BRT system (calc.)	2,016,560			909,480		50,450,400	4,149,600.00	0.00	1,065,930
Length of network (km)	7	8	10	15	7	42	40	28	23
Other PT modes in city	Tram, Bus	Bus, Train, Tram	Bus, Rail	Bus, Rail	Metro, Bus	Bus, Sea Buses. Ferry, Metro, Tram, Train	Metro, Commuter rail, Light railway, Bus, Ferry	Bus, Tram, Metro, Commuter trains, Ferry	Bus, Light rail, Ferry, Train, Rail

City	Albuquerque	Boston	Boston	Boston	Miami-Dade	Las Vegas	Los Angeles	Mexico City	Bogota
Name of system	Rapid ride - red line	Silver line - Washington street	Silver line - Waterfront SLI-Airport	Silver line - Waterfront SL2 -BMIP	South Miami-Dade Busway	MAX	Orange Line	Metrobus	Transmilenio
ITDP score		BRT standard below basic	BRT standard below basic	BRT standard below basic		BRT standard below basic	BRT Standart bronze	BRT Standart Silver	BRT Standart bronze
Name in literature	BRT	BRT	BRT	BRT	BRT	BRT	BRT	BRT	BRT
Year of implementation		2002	2005	2005	1997	2004	2005	2005	2000
Implemented Instruments									
BRT Basics									
Running ways		1	1	1	1	1	1	1	1
Off-board fare collection	-	-	1	1	-	1	1	1	1
Intersection treatments	1	1	1	1	1	1	1	1	1
Platform-level boarding		1	1	1	-	1	-	1	1
Service Planning									
Multiple routes	-	-	1	1	-	1	-		1
Peak frequency	-	1	1	1	-	-	1	1	1
Off-peak frequency	1	1	1	1	-	1	-		
Express, limited and local services	1								1
Control center					-		1	1	1
Located in top-ten corridors									
Hours of operation						-			
Demand profile									
Multi-corridor network	-	1	1	1	-	1	1	1	1
Infrastructure									
Passing lanes at stations	-	-	-	-	1		1	-	1
Minimizing bus emissions (Euro III or higher)		1	1	1	-		1	1	1
Stations set back from intersections					1			1	1
Center stations									
Pavement quality									
Station Design and Station-Bus Interface									
Distance between stations	-	1	1	1	-		-	1	1
Enhanced station environment	1	1	1	1	1	1	1	1	1
Number of doors on bus	1	1	1	1		1			1
Docking bays and sub-stops							1	-	
Sliding doors in BRT stations							-	-	1
Quality of Service and Passenger-Information Systems									
Branding	1	1	1	1	1	1	1	1	1
Real time Passenger information		1	1	1	1		1	1	1
Integration and Access									
Universal access		1	1	1	1	1		1	
Integration - physical transfer points			1	1	1		1	-	1
Integration - information									
Integration - fare payment: Integrated tariff system								1	1
Pedestrian access		1	1	1					
Secure bicycle parking					?		1	-	1
Bicycle lanes					1			-	
Bicycle-sharing integration							-	1	
In BRT integrated bus feeder systems	1				1			-	1
Park and ride	1	-	1	1	1	-	1		-
Improvements to nearby public space					-		1	-	1
Supporting measures									
Operational subsidies								-	
Restriction of on-street parking									
Supporting car restriction measures					-		-	-	1
Marketing campaign					1	1			
Electronic card		1	1	1	1		1	1	1
Data									
% modal shift from car to bus								0.71% (calc.)	
% BRT ridership that were former car users	33.00%	1.80%	22%	8%	42%	7% (new passengers)	18.00%	15%	9%
Average daily passengers/weekday	12,430	14,102	9,338	7,434	10,429	4,281 (cal.)	62,597	650,000	1,260,000
Population metropolitan area	887,077	4,032,129	4,032,129	4,032,129	4,919,036	2,000,759	12,828,837	20,116,842	8,350,000
Annual distance travelled BRT system (calc.)		643,107			963,147	311,309.44	4,429,939	96,851,740	7,032,480
Length of network (km)	22	4	7	4	13	12	23	67	84
Other PT modes in city	Bus, Rail, Airport	Rail, Bus, Subway, Boat	Rail, Bus, Subway, Boat	Rail, Bus, Subway, Boat	Metrorail, Metromover, Metrobus	Monorail, Bus	Airport, Bus, Train, Ferry	Metro, Bus, Light Train	Bus

City	Curitiba	Pereira	Rio de Janeiro	Vancouver	Adelaide	Brisbane	Brisbane	Sydney	Ahmedabad	Changzhou	Guangzhou
Name of system	Rede Integrada de Transporte		TransOeste	Translink #99	ANEB	BSEB	BINB	SLPT	Janmarg		Zongshan Ave. BRT
ITDP score	BRT Standart silver		BRT Standart Gold						BRT Standard silver	BRT Standart Bronze	BRT Standart bronze
Name in literature	BRT	BRT		BRT	BRT	BRT	BRT	BRT		BRT	BRT
Year of implementation	1973	2006	2012	1996	1986	2001	2004	2003		2008	2010
Implemented Instruments											
BRT Basics											
Running ways	1	1	1		1	1	1	1	1	1	1
Off-board fare collection	1	1	1		1	1	1	1	1	1	1
Intersection treatments	1	-	1	1	1	1	-	1	1	-	1
Platform-level boarding	1	1	1	1	-	-	-	-	1	1	1
Service Planning											
Multiple routes			1								
Peak frequency	1	1	1	1	1	1	1	1	1	1	1
Off-peak frequency	1	1	1	1	1	1	1	1	1		
Express, limited and local services	1		1		1	1	1	-			
Control center	-	1	1		1	1		1	1	1	1
Located in top-ten corridors			1						1		
Hours of operation			1	1	1	1	1	1	-		
Demand profile			1	1							
Multi-corridor network	1	1	1		1	1	1	-	1	1	1
Infrastructure											
Passing lanes at stations	-	-	1		1	1	1	1	-	-	1
Minimizing bus emissions (Euro III or higher)	-	-	1		1	1	1	?	1	1	1
Stations set back from intersections	1		1						1	-	1
Center stations			1								
Pavement quality			1								
Station Design and Station-Bus Interface											
Distance between stations	1	1	1	-	-	-	1	1	1	-	-
Enhanced station environment	1	1	1	1	1	1	1	1	1	1	1
Number of doors on bus			1			-	-	-	-	1	?
Docking bays and sub-stops			1						-		1
Sliding doors in BRT stations	-		1						-	1	1
Quality of Service and Passenger-Information Systems											
Branding	1	1	1	1	1	1		1	1	1	1
Real time Passenger information	1	1	1		1	1	1	1	1	1	1
Integration and Access											
Universal access	-		1							1	1
Integration - physical transfer points	1	1	1		1	1		1			1
Integration - information			?								
Integration - fare payment: Integrated tariff system	1	1	?								
Pedestrian access			1						1		1
Secure bicycle parking	1	-	1		1	1		1	-	-	1
Bicycle lanes			1						-	?	1
Bicycle-sharing integration	-	-	-						-	-	1
In BRT integrated bus feeder systems	1	1	1		1	1		1			
Park and ride					1	1	-	1			
Improvements to nearby public space	1	1			1	1		1	-	-	1
Supporting measures											
Operational subsidies											
Restriction of on-street parking	1										
Supporting car restriction measures	-	-			-	-		-			
Marketing campaign											1
Electronic card	1	1				1				1	1

Data											
% modal shift from car to bus		2%									
% BRT ridership that were former car users	28%	10%	9.20%	18%	40% (new passengers)	26% (new passengers)		9% (new passengers)		4%	3%
Average daily passengers/weekday	562,000	115,000	100,000	26,000	25,000	93,000		6,800	115,000	350,000	805,000
Population metropolitan area	2,051,000	700,000	15,993,583	1,957,766		1,857,830			5,340,000	4,600,000	12,700,800
Annual distance travelled BRT system (calc.)	43,944,237	3,167,112	19,670,560	1,944,540	1,612,416.00			880,152.00			
Length of network (km)	58	27	39	27	12	17	5	31	38	25	23
Other PT modes in city	Bus	Bus	Airport, Bus, Subway	Bus, SkyTrain, SeaBus, Train, Airport	Bus, Train, Tram	Train, Bus, Ferry	Train, Bus, Ferry	Train, Bus, Ferry, Light rail	Bus, Shared rickshaw	Airport, Port, Bus	Subway, Bus

City	Jinan	Jakarta	Kunming	Nagoya city
Name of system	Jinan BRT	Trans Jakarta		Key Bus Route System
ITDP score	BRT Standart bronze	BRT Standart Bronze		
Name in literature	BRT	BRT	BRT	BRT
Year of implementation	2008	2004	1999	1982 / 1985

Implemented Instruments				
BRT Basics				
Running ways	1	1	1	1
Off-board fare collection	1	1	-	
Intersection treatments	-	1	?	1
Platform-level boarding	1	1	?	
Service Planning				
Multiple routes				
Peak frequency	1	1	1	1
Off-peak frequency		1	1	
Express, limited and local services				
Control center		-	1	1
Located in top-ten corridors				
Hours of operation		-		
Demand profile				
Multi-corridor network	1	1	1	1
Infrastructure				
Passing lanes at stations	-	-	-	
Minimizing bus emissions (Euro III or higher)	1	-	-	
Stations set back from intersections	-	1		
Center stations				
Pavement quality				
Station Design and Station-Bus Interface				
Distance between stations	1	-	1	1
Enhanced station environment	1	1	?	1
Number of doors on bus	1		-	
Docking bays and sub-stops	-	-		
Sliding doors in BRT stations	1	1		
Quality of Service and Passenger-Information Systems				
Branding	1	1	-	1
Real time Passenger information	1	1	-	
Integration and Access				
Universal access		-		
Integration - physical transfer points		-		
Integration - information				
Integration - fare payment: Integrated tariff system		-		1
Pedestrian access				
Secure bicycle parking	-	-	?	1
Bicycle lanes	1	-		
Bicycle-sharing integration	-	-		
In BRT integrated bus feeder systems		1		
Park and ride				1
Improvements to nearby public space	-	-	-	
Supporting measures				
Operational subsidies		-		
Restriction of on-street parking				1
Supporting car restriction measures		?	?	
Marketing campaign				
Electronic card	1	1	1	

Data				
% modal shift from car to bus				3%
% BRT ridership that were former car users	6%		5%	
Average daily passengers/weekday		260,000	1,200,000	26,815
Population metropolitan area	6,041,000	13,670,000	6,439,000	9,250,000
Annual distance travelled BRT system (calc.)			254,982,000	3,715,712
Length of network (km)	34	47	47	16
Other PT modes in city	Bus	Bus, Public vans, Minibus	Airport, Bus, Subway	Suburban railway, Subway, Bus

Annex 4

Table 21: Allocation of attributes to instruments. Interdependencies are marked with an "x".

	Attributes													
Instruments	**Travel time**	**Reliability**	**Comfort**	**Convenience**	**Frequency**	**Accessibility**	**Price**	**Information provision**	**Safety / Security**	**Bus routes improvement**	**Weather improvement**	**Less congestion**	**Environmental benefits**	**Sum**
Bicycle lanes						x						x	x	**3**
Bicycle-sharing integration						x							x	**2**
Branding				x				x	x					**3**
Center stations				x										**1**
Control center		x			x			x	x	x				**5**
Demand profile						x				x		x	x	**4**
Distance between stations	x					x								**2**
Docking bays and sub-stops	x	x			x									**3**
Electronic card				x			x							**2**
Enhanced station environment /safe and comfortable stations			x					x	x		x			**4**
Express, limited and local services	x				x					x				**3**
Hours of operation						x				x				**2**
Improvements to nearby public space						x			x				x	**3**
In BRT integrated bus feeder systems	x			x		x				x				**4**
Integration with other public transport - information				x				x						**2**
Integration with other public transport - fare payment: Integrated tariff system				x			x							**2**
Integration with other public transport - physical transfer points	x			x		x				x				**4**
Intersection treatments	x	x			x							x	x	**5**
Located in top-ten corridors			x			x				x				**3**
Marketing campaign								x						**1**
Minimizing bus emissions (Euro III or higher)													x	**1**
Multi-corridor network/network of routes and corridors	x			x		x				x				**4**
Multiple routes	x			x	x	x				x				**5**
Number of doors on bus	x	x	x						x					**4**
Off-board fare collection	x	x		x										**3**
Off-peak frequency	x				x	x								**3**
Operational subsidies							x							**1**
Park and ride				x		x			x				x	**5**
Pavement quality		x	x						x					**2**
Passing lanes at stations	x	x			x									**3**
Pedestrian access				x		x			x					**3**
Peak frequency	x				x	x								**3**
Platform-level boarding	x	x	x						x					**4**
Running ways	x	x			x				x			x	x	**6**
Real time passenger information				x				x						**2**
Restriction of on-street parking						x			x	x				**3**
Secure bicycle parking						x			x					**2**
Sliding doors in BRT stations	x	x							x					**3**
Stations set back from intersections		x							x			x		**3**
Supporting car restriction measures (e.g. road pricing)												x	x	**2**
Universal access				x		x			x					**3**
Sum	**16**	**11**	**5**	**14**	**9**	**18**	**3**	**6**	**15**	**10**	**1**	**6**	**9**	
Non- technical instruments	11	4	2	10	7	16	2	4	9	9	1	5	6	
Technical instruments	5	7	3	4	2	2	1	2	6	1	0	1	3	

Legend: (Tann & Hinebaugh, 2009) (Redman, et al., 2013) (ITDP, 2013b)

SIEMENS

Table 22: Points system according to the ranks of the attributes

	Attributes (Points)													
Instruments	**Travel time (7)**	**Reliability (6)**	**Comfort (5)**	**Convenience (3)**	**Frequency (7)**	**Accessibility (1)**	**Price (6)**	**Information provision (4)**	**Safety / Security (2)**	**Bus routes improvement (2)**	**Weather improvement (2)**	**Less congestion (5)**	**Environmental benefits (1)**	**Score**
Bicycle lanes						1						5	1	**7**
Bicycle-sharing integration						1							1	**2**
Branding				3				4	2					**9**
Center stations				3										**3**
Control center		6			7			4	2	2				**21**
Demand profile						1				2		5	1	**9**
Distance between stations	7					1								**8**
Docking bays and sub-stops	7	6			7									**20**
Electronic card				3			6							**9**
Enhanced station environment /safe and comfortable stations			5					4	2		2			**13**
Express, limited and local services	7				7					2				**16**
Hours of operation						1				2				**3**
Improvements to nearby public space						1			2				1	**4**
In BRT integrated bus feeder systems	7			3		1				2				**13**
Integration with other public transport - information				3				4						**7**
Integration with other public transport - fare payment: Integrated tariff system				3			6							**9**
Integration with other public transport - physical transfer points	7			3		1				2				**13**
Intersection treatments	7	6			7							5	1	**26**
Located in top-ten corridors			5			1				2				**8**
Marketing campaign								4						**4**
Minimizing bus emissions (Euro III or higher)													1	**1**
Multi-corridor network/network of routes and corridors	7			3		1				2				**13**
Multiple routes	7			3	7	1				2				**20**
Number of doors on bus	7	6	5						2					**20**
Off-board fare collection	7	6		3										**16**
Off-peak frequency	7				7	1								**15**
Operational subsidies							6							**6**
Park and ride				3		1			2				1	**7**
Pavement quality		6	5						2					**13**
Passing lanes at stations	7	6			7									**20**
Pedestrian access				3		1			2					**6**
Peak frequency	7				7	1								**15**
Platform-level boarding	7	6	5						2					**20**
Running ways	7	6			7				2			5	1	**28**
Real time passenger information				3				4						**7**
Restriction of on-street parking						1			2	2				**5**
Secure bicycle parking						1			2					**3**
Sliding doors in BRT stations	7	6							2					**15**
Stations set back from intersections		6							2			5		**13**
Supporting car restriction measures (e.g. road pricing)												5	1	**6**
Universal access				3		1			2					**6**

Annex 5

Table 23: List of instruments sorted according to their importance of implementation in order to attract as many riders as possible

Ranking	Instrument	Attributes	Score
	Most important instruments to be implemented according to passenger needs		
1	Running ways	Travel time, Reliability, Frequency, Less congestion, Safety/Security, Environmental benefits	28
2	Intersection treatments	Travel time, Reliability, Frequency, Less congestion, Environmental benefits	26
3	Control center	Reliability, Frequency, Information provision, Safety/Security, Bus routes improvement	21
4	Passing lanes at stations	Travel time, Reliability, Frequency	20
4	Docking bays and sub-stops	Reliability, Frequency, Speed/Travel time	20
4	Multiple routes	Travel time, Convenience, Frequency, Accessibility, Bus routes improvement	20
4	Platform-level boarding	Travel time, Reliability, Comfort, Safety/Security	20
4	Number of doors on bus	Travel time, Comfort, Safety/Security, Reliability	20
	Second important instruments to be implemented according to passenger needs		
5	Express, limited and local services	Travel time, Frequency, Bus routes improvement	16
5	Off-board fare collection	Travel time, Reliability, Convenience	16
6	Off-peak frequency	Travel time, Frequency, Accessibility	15
6	Peak frequency	Travel time, Frequency, Accessibility	15
6	Sliding doors in BRT stations	Travel time, Reliability, Safety/Security	15
7	Stations set back from intersections	Reliability, Safety/Security, Less congestion	13
7	Pavement quality	Reliability, Comfort, Safety/Security	13
7	In BRT integrated bus feeder systems	Travel time, Convenience, Accessibility, Bus routes improvement	13
7	Integration with other public transport - physical transfer points	Travel time, Convenience, Accessibility, Bus routes improvement	13
7	Multi-corridor network/network of routes and corridors	Bus routes improvement, Travel time, Convenience, Accessibility	13
7	Enhanced station environment/safe and comfortable stations	Comfort, Information provision, Weather improved, Safety/Security	13
8	Integration with other public transport - fare payment: Integrated tariff system	Convenience, Price	9
8	Electronic card	Convenience, Price	9
8	Demand profile	Accessibility, Bus routes improvement, Less congestion, Environmental benefits	9
8	Branding	Convenience, Information provision, Safety/Security	9
9	Distance between stations	Travel time, Accessibility	8
9	Located in top-ten corridors	Comfort, Accessibility, Bus routes improvement	8
10	Park and ride	Convenience, Accessibility, Safety/Security, Environmental benefits	7
10	Bicycle lanes	Accessibility, Less congestion, Environmental benefits	7
10	Integration with other public transport - information	Convenience, Information provision	7
10	Real time passenger information	Convenience, Information provision	7
11	Operational subsidies	Price	6
11	Supporting car restriction measures (e.g. road pricing)	Less congestion, Environmental benefits	6
11	Pedestrian access	Convenience, Accessibility, Safety/Security	6
11	Universal access	Convenience, Accessibility, Safety/Security	6
12	Restriction of on-street parking	Accessibility, Safety/Security, Bus routes improvement	5
13	Improvements to nearby public space	Accessibility, Safety/Security, Environmental benefits	4
13	Marketing campaign	Information provision	4
14	Hours of operation	Accessibility, Bus routes improvement	3
14	Secure bicycle parking	Accessibility, Safety/Security	3
14	Center stations	Convenience	3
15	Bicycle-sharing integration	Accessibility, Environmental benefits	2
16	Minimizing bus emissions (Euro III or higher)	Environmental benefits	1

Annex 6

BRT / Bus improvement assessment tool
Results

SIEMENS

The result sheet offers you information about the possible instruments to be implemented to improve or built a BRT or to enhance the conventional bus system in your city. The list of instruments is calculated according to a score, which is evaluated depending on:
- the rank given to the four categories,
- the rank given to the attributes within the categories "passenger preferences" and "political preferences" and
- the rank given to the criterias within the categories "economic resources" and "implementation" in the input sheet.

The list starts with the instrument having the highest rank and ending with the instrument having the lowest one. It is possible, that some instruments are having the same rank. Instruments having the same rank are of equal importance. Furthermore the result sheet offers you a short description of the instruments and which attributes they are addressing. You can also find information on the average cost and time of implementation as well as a best practice example for this instrument. Non-technical instruments are marked in gray, technical instruments in violet.

Rank	Instrument	Description	Attributes adressed	Cost	Implementation time	Additional Information	Best Practice Example
1	Running ways	Running ways are the bus routes or lanes. This includes all levels of implementation concerning the location (e.g. two-way median-aligned busway or curb-aligned busway, on-street or off-street) and the grade of physical segregation (e.g. full physical segregation, segregation only with marking and signs).	Travel time, Reliability, Frequency, Less congestion, Safety/Security	0	0	Non-technical	0
2	Intersection treatments	Includes the prohibition of turns across bus lanes and traffic-signal priority.	Travel time, Reliability, Frequency, Less congestion, Environmental t	0	0	Technical	0
3	Platform-level boarding	Bus-station platform and bus floor are on the same level.	Travel time, Reliability, Comfort, Safety/Security	0	0	Technical	0
4	Off-board fare collection	Implementation of off-board fare collection can be managed in two ways: • Barrier-controlled: fare payment at a turnstile or faregate, • Proof-of-payment: fare payment at a kiosk with collecting a ticket, which is checked by boarding	Travel time, Reliability, Convenience	0	0	Technical	0
5	Control center	Monitors the localisation of all buses (e.g. with GPS) to: • Respond to incidents in real-time • Control the spacing of buses • Determine and respond to the maintenance status of all buses in the fleet • Record passenger boardings and alightings for future service adjustment • Use Computer-Aided Dispatch (CAD) / Automatic Vehicle Location (AVL) for bus tracking and performance monitoring.	Reliability, Frequency, Information provision, Safety/Security, Bus ro	0	0	Technical	0
6	Number of doors on bus	More than 3 doors or two wide doors on the side of the bus.	Travel time, Comfort, Safety/Security, Reliability	0	0	Technical	0
7	Multiple routes	Multiple routes operating on a single corridor	Travel time, Convenience, Frequency, Accessibility, Bus routes imp	0	0	Non-technical	0
8	Passing lanes at stations	To allow both express and local services and to avoid congestion, it is necessary to have passing capabilities at stations.	Travel time, Reliability, Frequency	0	0	Non-technical	0
8	Docking bays and sub-stops	Multiple docking bays and sub-stops at most of the stations. A station is composed of sub-stops that connect to one another. Sub-stops can have multiple docking bays - locations within one sub-stop where buses can pull up to let passengers on and off. They are usually adjacent to each other and allow a second bus to pull up behind another bus already at the station.	Reliability, Frequency, Travel time	0	0	Non-technical	0
9	Sliding doors in BRT stations	Sliding doors in BRT or bus stations, where passengers get on and off the buses.	Travel time, Reliability, Safety/Security	0	0	Technical	0
10	Off-peak frequency	At least 4 buses per off-peak hour.	Travel time, Frequency, Accessibility	0	0	Non-technical	0
10	Peak frequency	At least 8 buses per peak hour.	Travel time, Frequency, Accessibility	0	0	Non-technical	0
10	Express, limited and local services	On the contrary to local services, limited services skip lower-demand stations. Express services are often operating directly from one end to the other end without stopping in between.	Travel time, Frequency, Bus routes improvement	0	0	Non-technical	0
		Good pavement quality minimizes the need for maintenance on the					

Description / Input / Result / Annex / A1_Calculation / A2_Sorting / A3_Cost

Figure 19: Result list calculated by the excel tool for the example of the city "Duckburg" in chapter 7

Annex 7

- CD
    - List of possible policy projects
      ("Master thesis Silvia Burgmeier_Annex 7_ Policy project list.xlsx")

Annex 8

- CD
    - BRT Analysis
      ("Master thesis Silvia Burgmeier_Annex 8_BRT analysis.xlsx")

Annex 9

- CD
    - BRT assessment tool
      ("Master thesis Silvia Burgmeier_Annex 9_BRT Assessment Tool.xlsm")

Annex 10

- CD
    - Master thesis
      ("Master thesis Silvia Burgmeier.pdf")