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German Technical Cooperation

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CO2 Reduction Potential of Sustainable Urban Transport Measures in Surabaya

July 2001, Surabaya

GTZ's Sustainable Urban Transport Project (SUTP) in Surabaya aims to work with related agencies and the people of Surabaya to devise and implement policies toward environmentally, economically, and socially sustainable transport in the city.

This will result in a range of "local" economic (enhanced investment climate), social (poverty reduction) and environmental (cleaner air) benefits, and will also contribute to a stabilisation of "global" carbon dioxide emissions from Surabaya's transport sector. The project is hoped to provide a model of how to reduce such emissions from the transport sector in large cities in developing countries.

GTZ SUTP has embarked on an integrated program, including – working closely with the City Government – development of sustainable transport policies, design and implementation of a public awareness campaign, technical measures to reduce vehicle emissions, enhanced air quality management capability, adoption of appropriate fiscal instruments and transport demand management measures, improvement of conditions for non-motorized transport and pedestrians, elaboration of an effective inspection & maintenance and roadworthiness program, promotion of the use of CNG, a public transport demonstration route including regulatory and institutional reforms to be applied nationally if successful, and dissemination of international experiences.

GTZ SUTP commenced in Surabaya in 1998 and is due to finish in 2001.

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Dino Teddyputra, July 2001

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Editor's comments

Mr. Reinhard Kolke provided an expert peer review of this report. Mr. Lee Schipper provided some helpful comments and suggestions.

1 EXECUTIVE SUMMARY

(a) The purpose of this report

The purpose of this report is to calculate the potential of CO2 reduction from the road transportation sector achievable through measures proposed by the Sustainable Urban Transportation Project (SUTP) in Surabaya. The SUTP, established in partnership between the Municipality of Surabaya and the German Agency for Development Cooperation (GTZ), is developing options to reduce carbon dioxide (CO_2) emissions from the transportation sector in Surabaya.

The calculations in this report are basically divided in two parts. In the first part, the importance of reducing CO2 emissions is discussed, and the possible CO2 emissions in 2010 are estimated for the case if no counter measures are taken (Business As Usual scenario). In the next part of the report, the potential of each measure in reducing CO_2 emissions is calculated.

(b) Methodology

To ensure the plausibility of the input data, calculations of the CO2 emissions were conducted based on the fuel sales figures and on the traffic data, and crosschecks (between the results of the two approaches) were performed. The fuel sales figures were provided by Pertamina (the state-owned fuel supplier), and the traffic data was extracted from the reports of the extensive studies conducted previously in the frame of the Surabaya Integrated Transportation Network Project (SITNP). Furthermore, in order to ensure comparability and usability of the estimation results (e.g. to be used later when calculating provincial or national CO_2 emissions), the *Guidelines for National Greenhouse Gas Inventories* were used wherever applicable. The guidelines, which were issued by the *Intergovernmental Panel on Climate Change* (IPCC) contain estimation methodologies that are internationally recognized to be used as a reference when constructing and reporting national inventories of CO_2 emissions and other greenhouse gas emissions.

(c) CO_2 emissions from fuels sold in 2000

In Surabaya the following amounts of fuels were sold in year 2000:

Type of Fuel	2000 (L per month)	2000 (L per year)
Gasoline	30,000,000	360,000,000
Diesel	14,000,000	168,000,000
CNG*	840,500	10,086,000

*CNG is sold in "Liters gasoline-equivalent" by Pertamina

Source: Rifky Hardijanto, UPPDN V Pertamina, Fjellstrom by phone 05-Jan-01

This is equal to CO_2 emissions of approximately:

Type of Fuel	2000 (kg per year)
Gasoline	838,800,000
Diesel	440,160,000
CNG	4,841,280
Total	**1,283,801,280**

The CO_2 emissions in the year 2000 were calculated directly by multiplying the fuel consumption figures with the corresponding CO_2 emission factors.

Using the traffic data it was possible to break down the CO_2 emissions to different categories of vehicle types. The following table shows the fuel consumption and the corresponding CO_2 emissions in 2000, distinguished by vehicle category based on their fuel type. The vehicle categories include private car, motorcycle and public transport vehicles. The latter category consists of minibus/angkots, taxis and city buses.

2000	Fuel Consumption	CO2 Emissions
	[Liters]	**[kg]**
Private cars (gasoline)	192,387,405	448,262,654
Motorcycles (gasoline)	99,692,595	232,283,746
Public transport		
Angkots (gsln)	46,080,000	107,366,400
Angkots (CNG)	0	0
Taxis (gsln)	21,840,000	50,887,200
Taxis (CNG)	6,960,000	13,084,800
Buses (Diesel)	6,500,000	17,030,000
Other Diesel Vehicles	161,500,000	423,130,000
Other CNG Vehicles	3,126,000	5,876,880
Total		**1,297,921,680**

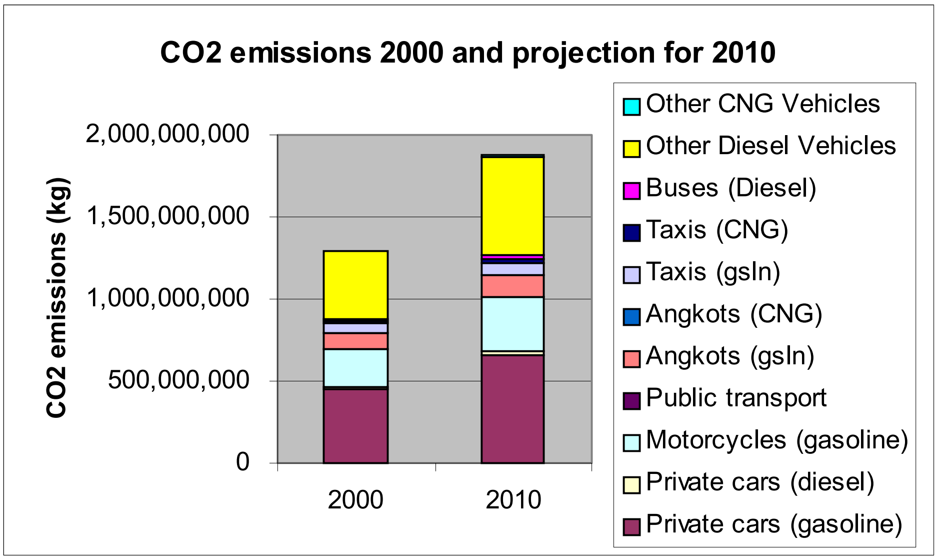
In total, there were approximately 1,297 kilotons of CO_2 emitted from the road transport sector in Surabaya in 2000. Private cars emitted the biggest share, which accounted more than 448 kilotons of CO_2. The second biggest share was from the vehicle category "Other Diesel Vehicles", followed by motorcycles with more than 232 kilotons of CO_2 emissions.

(d) Fuel consumption and CO_2 emissions projection for 2010 (Business As Usual Scenario)

According to the SITNP forecast, trips by car, motorcycle and public transport will grow by 29.5%, 27.3% and 26.6% respectively over 15 years from 1995 to 2010. The increase of number of trips will not only result in higher traveled kilometers, and thus in higher total fuel consumption, but also in more congestions due to the fact that currently some city's road links are already heavily loaded or even overloaded. According to the calculations based on the speed pattern 2010 that was forecast by SITNP, these congestion effects would increase the fuel consumption further by approximately 15%.

According to the calculations, the total CO_2 emissions will increase by approximately 46% from 2000 to 2010, from approx. 1,300 kilotons to approx. 1,900 kilotons. The break down of the CO_2 emissions by vehicle type can be seen in the following table and diagram:

CO2 Emissions (kg)	2000	2010
Private cars (gasoline)	448,262,654	664,522,596
Private cars (diesel)	9,493,508	14,073,558
Motorcycles (gasoline)	232,283,746	338,496,865
Public transport		
Angkots (gsln)	107,366,400	132,714,734
Angkots (CNG)	0	0
Taxis (gsln)	50,887,200	73,747,905
Taxis (CNG)	13,084,800	18,963,051
Buses (Diesel)	17,030,000	23,124,907
Other Diesel Vehicles	413,636,492	599,459,681
Other CNG Vehicles	5,876,880	8,517,026
Total	**1,297,921,680**	**1,873,620,323**



While interpreting these figures, a total error margin of 10% or more have to be considered, bearing in mind the uncertainties of the input data of the calculations (especially related to the traffic data). However, these figures do show clear negative signs of rapidly increasing CO_2 emissions, if no counter-measures are taken. The relatively modest increase of the total CO_2 emissions (of 46% over 10 years from 2000 to 2010) is due to the slowing or reversing growth of the current economy.[1] The total CO_2 emissions are expected to jump as soon as the economy recovers back to the "normal" growth level as it was in the early until midst 90's. Therefore, counter measures are considered necessary, and the current economic slow down should be seen as a chance to develop them before the total CO_2 emission level is too high and too difficult to reduce.

(e) Retrofitting microbuses (angkots) with CNG systems

One of the CO_2 reduction measures proposed by the SUTP is to retrofit angkots with CNG conversion systems, enabling older gasoline-vehicles to use CNG. According to a study conducted by GTZ in cooperation with ITS Surabaya in 2000, there are currently 4,800 angkots operating on 57 different routes in Surabaya, all of which still using gasoline fuel.

According to the calculations based on the operational data, angkots consumed approx. 46,080 kiloliters gasoline in 2010. This is equal to 107 kilotons CO_2

1 In the SITNP traffic forecast used for the calculations here, the economy is expected to recover to 1995 levels not earlier than 2010.

emissions. If 30% of these angkots used CNG instead of gasoline, the total CO_2 emissions would decrease from 107 kilotons by 6,220 tons, to 101kilotons, which represents a reduction of around 6%. This reduction of CO_2 emissions is caused by the fact that the same energy amount of CNG would only emit 20% less CO_2 of the same energy amount of gasoline if burned through combustion process. If 50% of angkots would use CNG, their total CO_2 emissions can be reduced by around 10% from 107 kilotons to 97 kilotons.

(f) Retrofitting from 25% to 50% of taxis with cng systems

Another technical measure to reduce CO_2 proposed by SUTP is to increase the share of CNG taxis to 50%. According to the Statistical Year Book Surabaya 2000, there were in 1999 2,750 taxis operating in the city. According to Taxi Zebra, there are currently 800 operating taxis in Surabaya that are equipped with CNG converters. The Taxi Company Taxi Zebra owns all these taxis. The rest of the taxis (1,950 taxis) are currently using gasoline.

According to the calculation result, the total amount of CO_2 emissions would decrease by around 4% (or by 2,898 tons) from 68 kilotons to 65 kilotons, if the number of taxis using CNG is increased from around 25% to 50%, assuming the same operating conditions (the same average daily fuel consumption and the same number of operating days).

(g) Improvement of public transport system

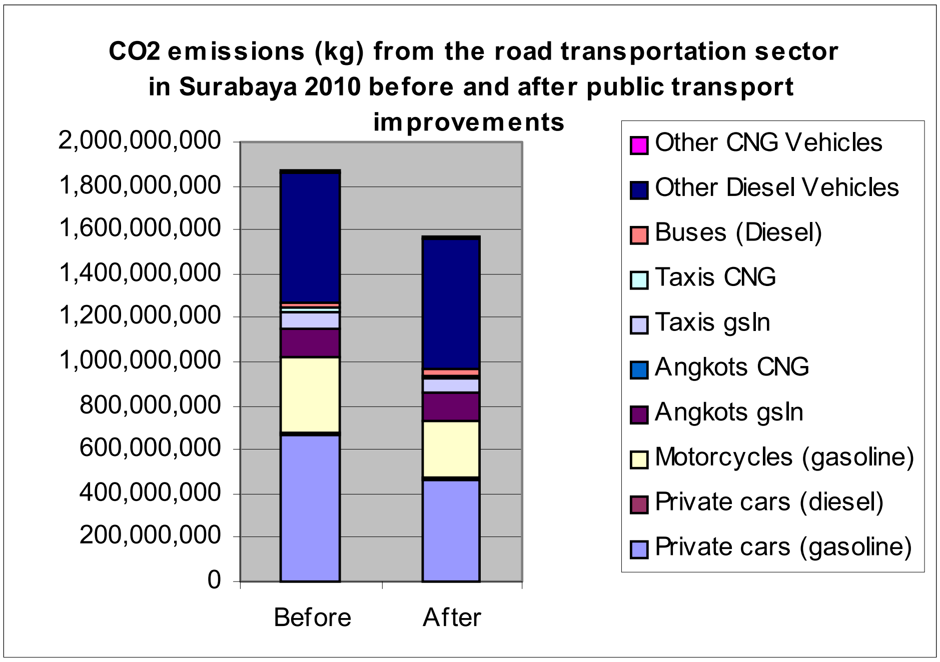
Besides the technical measures discussed above, SUTP also proposes measures that are based on modal shifts towards more efficient transportation mode (such as public transport) or pollution free transportation mode (such as non-motorized modes). These measures are harder to implement successfully, however they promise greater CO_2 reduction impacts.

One of these measures is the improvement of the public transportation system which includes city buses and angkots. An improved public transportation system will have a better image, and be faster, more reliable, comfortable, and secure, thus becoming more attractive, so that more trips will be conducted by bus and a smaller proportion of trips will be made with individual motorized vehicles.

According to the GTZ staff, bus improvement measures could increase the share of public transport to 40% in 2010, instead of 34.3% as forecast by SITNP. This modal shift would lead to more trips on city buses and angkots, and thus basically will lead to increased emissions of those vehicles. This effect however will be more than compensated by fewer trips that otherwise would be conducted by car or motorcycle. Furthermore, there is even less CO_2 emissions are expected from the public transport vehicles due to the bus prioritization program which is an integral part of the public transport improvement measures.

The following table and diagram summarize the calculation results: the reduction of CO_2 emissions by vehicle type before and after public transport improvements. The CO_2 emissions were calculated directly from the fuel consumption using the fuel-specific conversion factors.

CO2 emissions 2010 [kg]		Before and after public transport improvements	
		Before	**After**
Private cars (gasoline)		664,522,596	459,883,668
Private cars (diesel)		14,073,558	10,553,519
Motorcycles (gasoline)		338,496,865	257,456,478
Public transport	**Angkots gsln**	132,714,734	131,305,193
	Angkots CNG	0	0
	Taxis gsln	73,747,905	64,423,195
	Taxis CNG	18,963,051	16,565,357
	Buses (Diesel)	23,124,907	23,842,000
Other Diesel Vehicles		599,459,681	599,459,681
Other CNG Vehicles		8,517,026	8,517,026
Total		**1,873,620,323**	**1,572,006,117**



The table shows that the increase of CO_2 emissions due to more public transport trips are more than offset by the decrease in the CO_2 emissions due to relatively fewer trips on cars and motorcycles. The calculated reduction of CO_2 emissions amounts to 272 kilotons, around 14% less than the total CO_2 emissions before the public transport improvements, which is considered as a significant reduction potential.

(h) Transport Demand Management

Another modal split shifting measure that is proposed by the project is transport demand management (TDM). TDM measures are needed in Surabaya to avert intolerable future congestion conditions. These measures aim to reduce congestion in congested areas at congested times, primarily by encouraging shifts from private cars to more efficient modes such as walking, cycling, and public transport. Demand management measures for short-term application in Surabaya currently being developed include an “odd/even” scheme based on number plates, which is to be applied in Jl. Achmad Yani. Mid term solutions under serious consideration include using parking policy to restrict demand for private vehicle use, and applying an area-licensing scheme. An area-licensing scheme is the only measure which can have a large impact on the modal split; but since the development of such a scheme is still at a very early stage, the following calculations are based on the projected implementation of more modest TDM measures, including the odd/even scheme and tighter parking policy.

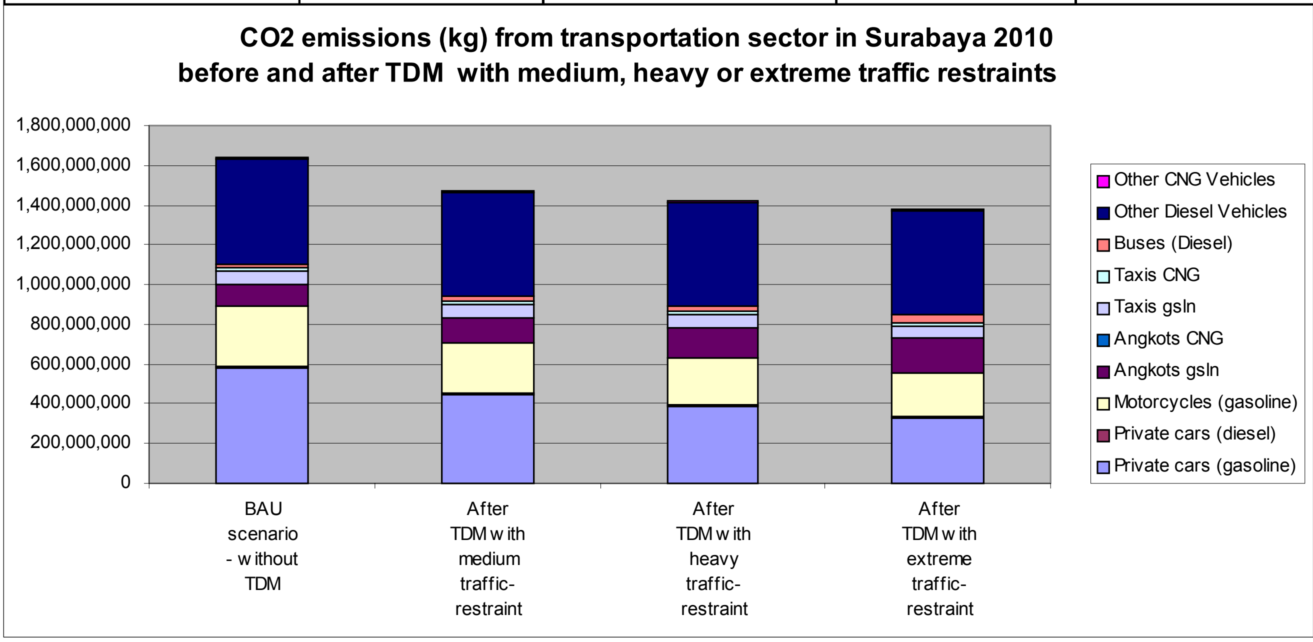
It is expected that the share of public transport in the modal split would increase after successful implementation of transport demand management measures. The increase of public transport share in the modal split varies depending on the intensity of the traffic restraint effects of the measures. In the following calculations, the CO_2 emissions are calculated using the share of public transport in the modal split of 40%, 45% or even 50% depending on whether medium, heavy or extreme traffic restraint is applied, as shown in the following tables. The calculation results are later compared to the BAU scenario, which has the share of public transport in the modal split of 35%.

Public Transport (Bus)	Private cars/motorbikes	Traffic restraint
40%	60%	Medium
45%	55%	Heavy
50%	50%	Extreme

The TDM measures will result in lower trips by car and motorcycle compared to the "average scenario" without TDM. Less cars and motorcycles also mean less load for the city's road network which in turn will reduce the **congestion effects**. Considering the currently already high volume/capacity ratio in some road links, it is not expected that these congestion effects can be totally eliminated by solely increasing the share of public transport to 40% - 50%. Thus the congestion effects will still persist in these scenarios, but they would lead to higher fuel consumption by a factor of lower than 15% (as calculated in the scenario without bus improvement in the chapter 4.1). Accurate calculation to determine the congestion factor can only be calculated by testing the network load using a computerized traffic model such as that was built by SITNP. For the purpose of the CO_2 calculations here, it is assumed that the congestion factor is 4.0%. Public transport vehicles, such as city buses, angkots and taxis, however will not be affected by congestion due to prioritization measures in the frame of public transport improvements.

The following table and diagram summarize the calculated reductions of CO_2 emissions by vehicle type before and after the TDM measures for the three scenarios with medium, heavy and extreme traffic-restraints. The CO_2 emissions were calculated directly from the fuel consumption using the fuel-specific conversion factors.

CO2 emissions 2010 (in kg)		BAU scenario - without TDM	After TDM with medium traffic-restraint	After TDM with heavy traffic-restraint	After TDM with extreme traffic-restraint
Private cars (gasoline)		580,500,137	445,324,967	387,577,865	329,830,763
Private cars (diesel)		12,294,092	10,219,422	8,894,228	7,569,034
Motorcycles (gasoline)		295,697,208	249,306,086	233,645,498	217,984,910
Public transport	Angkots gsln	115,934,239	131,305,193	152,555,143	173,805,092
	Angkots CNG	0	0	0	0
	Taxis gsln	64,423,195	64,423,195	64,423,195	64,423,195
	Taxis CNG	16,565,357	16,565,357	16,565,357	16,565,357
	Buses (Diesel)	20,200,986	23,842,000	29,904,680	35,899,240
Other Diesel Vehicles		523,663,799	523,663,799	523,663,799	523,663,799
Other CNG Vehicles		7,440,130	7,440,130	7,440,130	7,440,130
	Total	1,636,719,144	1,472,090,150	1,424,669,895	1,377,181,520



The calculated CO_2 emissions reduction through TDM measures would decrease from approximately 1,637 kilotons by 10%, 13% or 16%, respectively, depending on the intensity of the traffic restraints measures (medium, heavy or extreme traffic restraint).

(i) Improvements for non-motorized transport

The improvements of NMT would encourage emissions-free transport modes for trips conducted on foot, by bike or by becak (rickshaw). The emission reduction effects can be achieved through substitution of motorized trips by non-motorized trips. Since NMT trips are, by nature, mostly conducted for short distances, it is highly expected that non-motorized ones will substitute only short-distance motorized trips. Therefore it is assumed that this substitution effect only applies to short-distance motorized trips, which here are defined as trips with an average length of 3 km. In reality, NMT improvements that mainly aim at short distance trips, do encourage longer non-motorized trips, too. But the effects on the longer trips are very limited, because most of the times they are significantly lower than the impacts affecting the short trips.

Given the poor conditions of NMT facilities, which are to be seen as the major constraint for NMT in Surabaya, and the fact that the urban mixed land-use pattern that is ideal for non-motorized trips, it is believed that the level of substitutable motorized trips is very high. In the center areas of city (e.g. Kedungdoro and Rungkut), is believed that more than 50% of the motorized trips are substitutable. For the purpose of that calculations here, the substitution rate is set lower to 30% citywide, which means that the improvement of NMT facilities would lead that 30% of short-motorized trips to be substituted by non-motorized trips.

The following table shows the modal split of short distance trips (average 3 km) based on the NMT surveys survey conducted by GTZ in cooperation with ITDP/LPIST in 2000.

Mode	**Modalsplit share**	**Fuel consumption** (liter per person.trip)
walk	40%	-
becak	7%	-
bike	3%	-
angkot	17%	0.04
motorcycle	33%	0.11
Car	1%	0.58

Source of modal split: Improving NMT facilities in Surabaya, GTZ/ITDP 2000

If the NMT improvements citywide would lead to a reduction of short distance motorized trips by 30% as mentioned above, then it would lead to a following modal split:

Mode	**Modalsplit share**
walk	50%
becak	14%
bike	11%
angkot	12%
motorcycle	23%
Car	1%

This would reduce the fuel consumption of short trips by motorcycle, angkot and car proportionally by 8,800 kiloliters gasoline and 34 kiloliters diesel, which is in total equal to CO_2 emissions of approximately 20 kilotons.

(j) Summary table of impact of measures in travelled kilometres

The table on the following page shows the reductions of travelled motorised kilometres achievable by different measures.

(k) Cost effectiveness of the measures

Preliminary assessment of the cost-effectiveness of the measures show that although relatively harder to implement successfully, measures that are mainly based on modal split changes – in particular promoting more efficient, less polluting modes such as public transport and non-motorised transport – have a significantly higher cost effectiveness compared to technical measures or measures that rely very much on expensive infrastructure improvements. Obviously, this is due to both the higher CO_2 reduction potentials and lower costs. Clearly, emissions reductions gained by expensive technology retrofits can be offset by even small shifts in the modal share, and conversely even small shifts in the modal split can achieve significant CO2 reductions.

Vehicle Type \ Scenarios	Traveled kilometers						
	2000 Status quo (BAU) estimates	2010 Status quo projection	2010 Improvement of public transport	2010 Transport Demand Management			2010 Improvement of Non Motorized Transport
				Medium traffic-restraint	Heavy traffic-restraint	Extreme traffic-restraint	
Private cars (gasoline)	1,420,402,680	2,491,416,899	1,837,755,725	1,837,755,725	1,599,446,456	1,361,137,186	2,474,646,972
Private cars (diesel)	28,987,810	46,924,017	37,505,219	37,505,219	32,641,764	27,778,310	46,581,774
Motorcycles (gasoline)	2,347,046,485	3,172,716,826	2,572,075,009	2,572,075,009	2,410,505,719	2,248,936,430	3,009,279,498
Public transport: Angkots gsln	460,800,000	497,571,840	563,541,602	563,541,602	654,743,101	745,944,600	491,875,929
Public transport: Angkots CNG	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Public transport: Taxis gsln	218,400,000	276,494,400	276,494,400	276,494,400	276,494,400	276,494,400	276,494,400
Public transport: Taxis CNG	69,600,000	88,113,600	88,113,600	88,113,600	88,113,600	88,113,600	88,113,600
Public transport: Buses (Diesel)	16,250,000	19,275,750	22,750,000	22,750,000	28,535,000	34,255,000	19,275,750
Other Diesel Vehicles	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Other CNG Vehicles	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Total	**4,561,486,975**	**6,592,513,332**	**5,398,235,555**	**5,398,235,555**	**5,090,480,040**	**4,782,659,525**	**6,406,267,923**

n.c. = not calculated
n.a. = not applicable

2 INTRODUCTION

The Sustainable Urban Transportation Project (SUTP), established in partnership between the Municipality of Surabaya and the German Agency for Development Cooperation (GTZ), is developing options to reduce carbon dioxide (CO_2) emissions from the transportation sector in Surabaya. The measures developed were based on a comprehensive strategy assessment. They are ranging from measures focusing on minimizing trip generations without restricting access (e.g. integration of land-use planning and transportation planning), measures enhancing efficiency of transport operations (e.g. transport demand management, improvements of bus system and fostering non-motorized transport), technical measures (such as promoting the use of CNG) and other supporting measures (such as a public awareness campaign and institutional reform). The measures developed are in varying stages of implementation.

Estimating the impacts of these measures, assuming the measures are implemented, in reducing CO_2 emissions is the objective of this report. Some measures have a direct impact on CO_2 emissions, while others are of a supplementary and enabling nature, making it possible for the emission reductions to occur, but not directly attributable to any emissions. A public awareness campaign, for example, is essential for the successful implementation of transport demand management measures, and moderate institutional reforms are essential for successful implementation of public transport improvements. Therefore while such activities – public awareness raising and so on – are an important and essential part of the GTZ SUTP project activities, they do not have any CO_2 reduction impact attributable to them per se. Their impact is only an enabling one, making the other measures possible. These “enabling” characteristic means that no CO_2 reduction is attributed to these measures in this report.

CO_2 cannot be filtered and reduced by exhaust gas after treatment. Every process of burning fossil fuels causes CO_2 emissions. Other than exhaust gas emissions the reduction of CO_2 depends highly on (1) the carbon content of the fuel used (2) the specific fuel consumption of vehicles, (3) the modal split and (4) the specific vehicle mileage traveled. While the first and second strategy is a technology approach, the third and fourth approach focuses on traffic management. As it is simpler to quantify the technology approach and their effects on CO_2-reduction (in terms of numbers, technical requirements or approaches and their reduction potentials), it is not the case in quantifying the CO_2 reduction impacts from traffic management measures. In general, traffic management measures have higher potential of an immediate CO_2-reduction than those based on the technological approach, but their successful implementation depends highly on a number of conditions, e.g. necessary to make the modal shift and a reduction of vehicle mileage traveled attractive.

3 METHODOLOGY

In order to ensure comparability and usability of the estimation results (e.g. to be used when calculating provincial or national CO_2 emissions), the *Guidelines for National Greenhouse Gas Inventories*[2] were used wherever applicable. The guidelines, which were issued by the *Intergovernmental Panel on Climate Change* (IPCC) contain estimation methodologies to be used as a reference when constructing and reporting national inventories of CO_2 emissions and other greenhouse gas emissions such as CH_4, N_2O, NOx and CO. The IPCC Guidelines also include a number of “default” assumptions and data for use in the estimation of greenhouse gas emissions. This default information however is included primarily to provide users with a starting point when developing their national calculations. Thus its usability for such detailed calculations as conducted in this report is limited, and more accurate local information or data is used instead, if they are available and applicable. Otherwise assumptions are used as described.

In the calculations, the CO_2 emissions reduction impacts are derived directly from the fuel usage by using the conversion factors (see the following flowchart diagram). This is in line with the basis of methodology of the IPCC Guidelines in estimating CO_2 emissions using an internationally accepted approach by accounting for the carbon in fuels supplied to an economic sector, such as transportation. This approach is simple, yet accurate, since CO_2 emissions are primarily dependent on the carbon content of the fuel consumed. It can only be used to estimate the total CO_2 emissions based on the fuel supply at a given time period, thus on a highly aggregated level in contrast to detailed calculations (e.g. by breaking down to different kinds of consumers in transport such as motorbikes, passenger cars, buses, taxis, trucks). This approach is applied in calculating the total CO_2 emissions based on the fuel sold in Surabaya for the year 2000. On the one hand the average specific fuel consumption of the different vehicle types in different transport modes have to be

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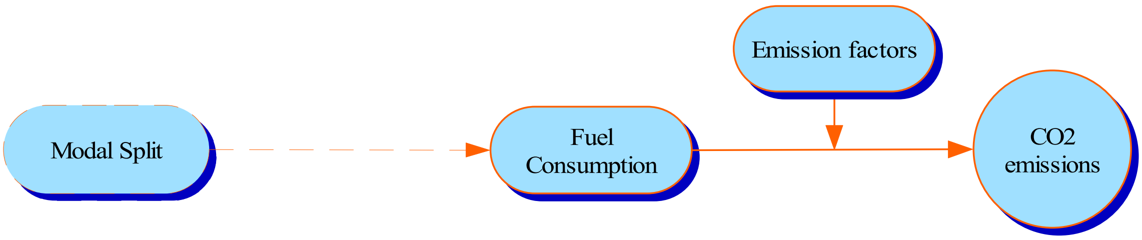
2 The Reference Manual in the IPCC Guidelines provides a compendium of information on methods for estimation of emissions for a broader range of greenhouse gases and a complete list of source types for each. It summarizes a range of possible methods for many source types. It also provides summaries of the scientific basis for the inventory methods recommended and gives extensive references to the technical literature.

estimated, because the required disaggregated fuel sales data (e.g. fuel sales by vehicle type) is not available for Surabaya; on the other hand the estimations and overall results can be cross checked with the fuel supply data at a given time period. For measures which have an effect on the use of specific vehicle types, such as angkots, taxis and buses, it is necessary as a check on the fuel consumption data to break the total fuel consumption down by vehicle type separately by deriving it from the traffic data. This is conducted by using simplified traffic forecasting methods (e.g. by using average values and generalizations.).

Flowchart: Basic methodology of check based on modal split and trip-making characteristics

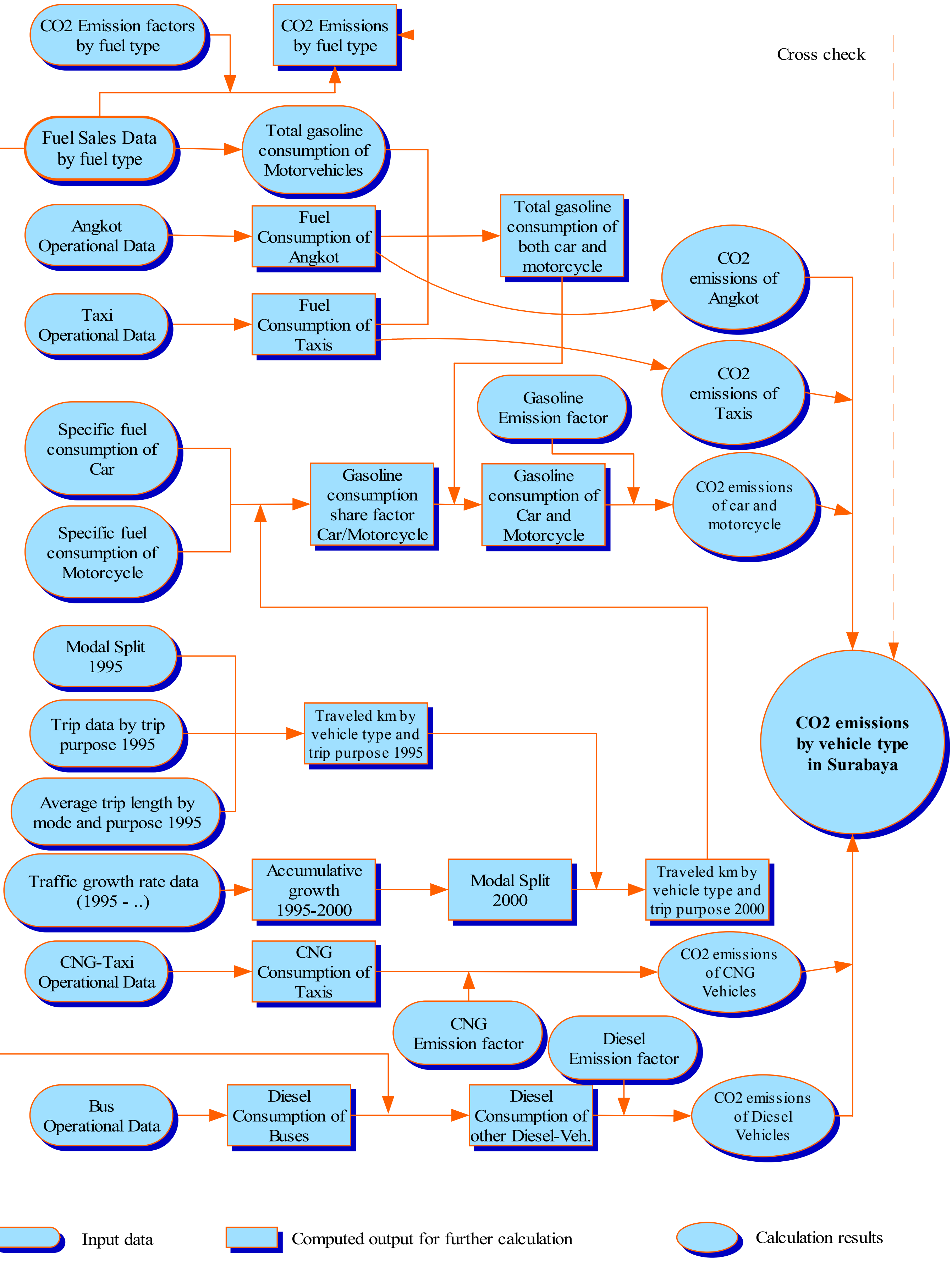


The CO_2 emission reduction potential caused by each measure of the SUTP project cannot be estimated directly using the methodology as described in the IPCC Guidelines. The impacts of the measures on the reduction of fuel usage have to be calculated by using the traffic forecasting methods. Each measure proposed by the SUTP project involves different mechanisms in reducing the fuel usage. This is for example the case for estimating the impacts of modal-split changes (such as are caused by certain traffic management measures) or the impacts of non-motorized transport improvements on CO_2 emissions. Appropriate traffic forecasting methodology is developed for each measure separately. Each chapter in this report contains detailed descriptions of the traffic forecasting methodologies used to estimate the CO_2 emissions reduction impacts of the selected measures. The overview to the calculation methodologies used in this report is shown in the following flowchart diagram. Comparing the results of the calculations that are based on these two methodologies (CO_2 from economic sectors and CO_2 from traffic forecasting methodologies) would provide some possibility to cross check, since they would ideally produce the same results.

Surabaya has been exhaustively studied. International consultant reports on transport, beginning with a public transport study in 1978 and culminating with a major World Bank transport sector project from 1993 – 1998 (SITNP) and the GTZ SUTP project (ongoing), have resulted in a large store of available data and reports. Therefore while there remains inherent uncertainty making emission reduction calculations, the calculations in this report are able to be based on more complete and accurate data than would usually be the case with a city in a developing country.

The limitations of the available data added to the complexity and decreased the precision of the calculation. Some data needed for the calculations in this report was not available (e.g. average trip length data), and thus has to be replaced by a set of assumptions. The main assumptions and estimations were agreed upon with the GTZ team. These assumptions were often necessary, but whenever possible data was taken from existing reports. The sources of available data and the assumptions and other estimations used for the calculations are specifically noted in each chapter, where the step-by-step calculations for each measure are described. Traffic data (that is used as input for the calculation here) was mainly obtained from the Surabaya Integrated Transportation Network Project Reports published (full reference is given at each relevant part of the calculations), which were based on two separate household surveys. Actual fuel sales figures were used to calculate the total CO_2 emissions. To test the plausibility of the data, cross checks were conducted whenever possible by comparing the calculation results derived from the traffic figures with those from the fuel sales figures. Since these calculations are rough estimations based on data collected with different methods and in different years, an error margin of more than 10% is possible. In an effort to minimize the error margin, conservative assumptions were in general made.

Methodology for CO2 Emissions Caculation



For further general studies on CO_2 emissions from the transportation sectors and methods for calculating CO_2 emissions, the following literature is recommended:

- Schipper L. et al: *Driving a Bargain? Using Indicators to Keep Score on the Transport - Environment-Greenhouse Gas Linkages*, 2000
- MEET: *Calculating transport emissions and energy consumption* - Part A. Road Transport, 2000
- ADB: Strategy for the use of Market-Based Instruments, 1997
- Report of an international roundtable organized by PTRC Education and Research Service Ltd.: *Evaluation of Environmental Effects of Transport*, The Hague, The Netherlands, 19-20 June 1995
- ECMT (European Conference of Ministers of Transport): *CO_2 Emissions from Transport*, 1997
- Organisation for Economic Co-Operation and Development (OECD): Motor Vehicle Pollution Reduction strategies beyond 2010, 1995
- International Institute For Energy Conservation: *Assessment of Transportation Growth in Asia and Its Effects on Energy Usage, Environment and traffic Congestion*, August 1991
- Michelis L. (OECD): Sustainable Transport Policies : *CO_2 Emissions From Road Vehicles Policies and Measures for Common Action*, Working Paper 1 July 1996
- Second Report Submitted by the Enquete Commission “Protecting the Earth’s Atmosphere” of the 12th German Bundestag: *MOBILITY AND CLIMATE, Developing Environmentally Sound Transport Policy Concepts*, 1994
- European Academy of the Urban Environment Berlin: *Environmentally Compatible Urban Transport and Traffic*, 1996

All of the above literature is available at the GTZ-SUTP project office in Surabaya.

4 DETAIL CALCULATIONS

4.1 CO_2 EMISSIONS 2000 AND ITS PROJECTION FOR 2010

4.1.1 CALCULATION OVERVIEW

The objective of the calculations in this chapter is to estimate the CO_2 emissions from the road transportation sector in Surabaya for the year 2000, and it's projection for the year 2010, each differentiated by vehicle type. The calculations of CO_2 emissions for the year 2000 comprises of the following steps:

Step 1: Calculating the total CO_2 emissions based on the fuel sales 2000
Step 2: Calculating fuel consumption by vehicle type for 2000

- Calculating total fuel consumption and CO_2 emissions based on fuel sales (by vehicle type)
- Calculating gasoline consumption by taxis and minibuses/angkots
- Calculating gasoline consumption by cars and motorcycles
- Calculating CNG consumption by Taxis and other vehicles
- Calculating diesel consumption by city buses and other vehicles

Step 3: Calculating CO_2 emissions by vehicle type for 2000

The projection of CO_2 emissions for 2010 can be calculated in two ways. One possibility is to directly project the historical fuel sales figures to the year 2010 and convert them into CO_2 emissions. Alternatively, one could project the fuel consumption indirectly for the year 2010 by projecting the traffic growth of each transport mode (private car, motorcycle, microbus, city bus and taxis), and then convert the fuel consumption figures into CO_2 emissions. Even though simpler and more straightforward, the first method would result in less accurate estimations due to the fact that many determining factors for fuel consumption would be left unconsidered. This includes, for example, the change of the traffic pattern resulting from the different growth rates of different vehicle types that have different specific fuel consumption. In contrast, the second calculation method can take account of significant traffic factors. Furthermore, by using the second method one also takes advantage of the fact that detailed traffic forecasts already exist for Surabaya as a result from a computer based traffic modeling conducted in the frame of the World Bank funded SITNP project in 1998. Because of these advantages, it is decided to use the second method to estimate the CO_2 emissions for 2010.

The calculation starts with the calculation of the total CO_2 emissions based on the fuel sale figures, which also will be used to cross check, the calculated CO_2 emissions by vehicle type.

4.1.2 CALCULATING TOTAL FUEL CONSUMPTION AND CO_2 EMISSIONS BASED ON FUEL SALES 2000

In Surabaya the following amounts of fuels were sold in year 2000:

Type of Fuel	2000 (L per month)	2000 (L per year)
Gasoline	30,000,000	360,000,000
Diesel	14,000,000	168,000,000
CNG*	840,500	10,086,000

*CNG is sold in "Liters gasoline-equivalent" by Pertamina

Source: Rifky Hardijanto, UPPDN V Pertamina, Fjellstrom by phone 05-Jan-01

For the purposes of this inventory, it was assumed that all fuels sold are used in road transportation vehicles only. This assumption introduces only a small degree of error and allows a separate, simplified analysis of alternatively fuelled vehicles in the other measure-related calculations in this report.

The methodology used to calculate CO_2 emissions is outlined in the *IPCC Guidelines for National Greenhouse Gas Inventories*. Fuel combustion CO_2 emissions depend upon the amount of fuel consumed, the carbon content of the fuel and the fraction of the fuel oxidized. The estimation process can be divided into six steps that lead to figures for CO_2 emissions from fuel combustion:

1. Estimate consumption of fuels by fuel/product type.
2. Convert the fuel data to a common energy unit (TJ), if necessary.
3. Calculate the total carbon content of the fuels by using carbon emission factors for each fuel type.
4. Calculate the amount of carbon stored in products for long periods of time.
5. Account for carbon not oxidized during combustion (the combustion process considers a 100% oxidation into CO_2).
6. Convert emissions of carbon to full molecular weight of CO_2.

For the energy content factors and carbon emission coefficients as needed for the calculation in the steps 1 and 2 average fuel data are used to estimate the total carbon content of the fuels. The resulting conversion factors [kg CO_2 per Liter fuel] consider stoichiometric calculations. Another calculation from fuel sold (data given in Liter) to convert the fuel data to an energy unit in Terra Joule, and calculating the total carbon content of the fuels using carbon emission factors for each fuel type in specific are not necessary. Step 1 and 2 are substituted by converting directly fuel sale figures to estimated CO_2 emissions. The formula for calculating the total CO_2 emissions can be expressed as:

*CO_2 Emissions [kg] = Total amount of fuel sold [L] * Conversion factor [kg/Liter]*

This simplification contained in the formula, which implies that fuel sale figures represent the apparent fuel consumption in Surabaya in the calculation time period, assumes that:

1) The effect of fuel exports and fuel imports are neutral to the total amount of fuel consumption in Surabaya.
2) There is zero effect of the fuel supply and fuel consumption on the fuel stock changes. This means that the amount of the fuel stored is constant, or the entire amount of fuel sold is consumed within the same calculation period.
3) The entire amount of fuel sold is consumed in the road transportation (no fugitive loss), and the entire carbon contents in the fuel are oxidized fully through the combustion process (oxidation rate = 100%).

The following table shows the conversion factors used in the calculations in this report.

Specific CO_2 emissions by fuel type

Fuel Type	Specific CO2 emissions	Unit
Gasoline	2,33	Kg per L
Diesel	2,62	Kg per L
CNG	1,88	Kg per Liter gasoline-equivalent (200 bar)

Performing the calculation by applying the formula to the input data (fuel sales figures) using these conversion factors for each fuel type results in the following total CO2 emissions for 2000:

Type of Fuel	2000 (kg per year)
Gasoline	838,800,000
Diesel	440,160,000
CNG	18,961,680
Total	**1,297,921,680**

In the calculation performed above, uncertainty is caused not only by the simplification of the methodology, but also by the assumptions used, and - in the first place - by the input data. Because of these many factors, the confidence level cannot be determined accurately. The generalization contained in the conversion factors alone ignores the fact that there is considerable variation in the carbon and energy content by weight of fuels depending on the type and origin of the fuels. According to IPCC, this can vary within a 10% range depending on the country where fuel is consumed (see IPCC 1997). Therefore the accumulative error margin in the calculations in this report can amount to more than 10%, which is normal for such calculations and still within the acceptable range for the purpose of this report.

4.1.3 CALCULATING FUEL CONSUMPTION BY VEHICLE TYPE FOR 2000 BASED ON TRAFFIC DATA

In order to improve accuracy and to allow the calculation of CO_2 emission reduction potential caused by different measures, it is necessary to sub-divide road transportation into numerous sub-sectors, as emissions and traffic conditions are related to vehicle type and modal splits. For the purpose of this report, it is useful to distinguish different vehicle types in Surabaya depending on the fuel type they use and how the are affected by the proposed emission reduction measures:

1) Private cars (gasoline)
2) Motorcycles (gasoline)
3) Public transport
    - Minibus/Angkots (gasoline)
    - Minibus/Angkots (CNG) – approximately 12 seated capacity
    - Taxis (gasoline)
    - Taxis (CNG)
    - Buses (Diesel) – approx. 50 seated capacity
4) Other Diesel Vehicles
5) Other CNG Vehicles

(l) Calculating gasoline consumption by taxis and minibuses/angkots

Since no disaggregated fuel sales data is available, the fuel consumption of each vehicle type has to be calculated indirectly from the traffic data. For minibuses/angkots and taxis, yearly gasoline consumption can be calculated by multiplying the total number in Surabaya with the average daily fuel consumption and the number of operational days in a year. Data for the total number of angkots in 1999 was available in the Surabaya Statistical Handbook 2000. The daily fuel consumption and the number of their operational days are assumed to be 30 liter per day per angkot and 320 operational days per year, respectively. These assumptions are based on the information obtained by the consultant through interviews with numerous angkot drivers and the two angkot associations in 1999, and were confirmed in GTZ SUTP project staff interviews by phone in May 2001 (data from Nurhadi, Kopatas). The data for the total number of taxis were obtained from the *Surabaya Statistical Handbook 2000*. The daily average fuel consumption data was obtained from the taxi companies Taxi Zebra and verified by interviewing numerous taxi drivers. The number of operational days per year is set to be 320 days according to information from Taxi Zebra. The following tables show the fuel consumption by angkot and by taxi in 2000:

A. Gasoline consumption by Angkots (for the year 2000)

Total number of angkots	4,800	units
Average daily fuel consumption	30	Liter/day
Number of operational days per year	320	days/year
Yearly total fuel consumption of angkots	**46,080,000**	**Liter**

B. Gasoline consumption by Taxis (2000)

Total number of Taxis	1,950	units
Average daily fuel consumption	35	Liter/day
Number of operational days per year	320	days/year
Yearly total fuel consumption of Taxis	**21,840,000**	**Liter**

In sum, angkots and taxis consumed 67,920,000 Liters of the total of 360,000,000 Liters gasoline sold in 2000 in Surabaya. Therefore the angkots and taxis consume approximately 20 % of the total gasoline consumption, which is a considerable share to the CO_2-emissions from gasoline vehicles and motorbikes/-cycles.

(m) Calculating gasoline and diesel consumption by cars and motorcycles

According to the calculations above, the remaining of 292,080,000 Liters (approximately 80%) gasoline was available for other gasoline vehicles, which practically are comprised only of cars and motorcycles. Assuming that there were no other gasoline vehicles, the amount of the gasoline consumed by cars and motorcycles depends on their consumption share, which again depends on their traveled kilometers [km] and their specific fuel consumption [km/l]. While specific consumption can be assumed to 8 km/l (12.5 l/100km) and 25 km/l (4 l/100km) for car and motorcycle respectively, based on consultant's interviews with numerous car and motorcycle users in Surabaya, it is not easy to find out their traveled kilometers [km]. Fortunately, some traffic data was available from the SITNP reports, from which these traveled kilometers can be derived through some calculation steps. These data are vehicular trips 1995 (source: SITNP Study Report C2, 1998), trip shares by purpose 1995 (Source: SITNP Study Report 9 1996, same data can be found also in the SITNP Study Report C2, 1998) and average length [km] of home-based trips by mode and purpose 1995. The following tables show an overview of all of these data:

C2-1. Input data: Daily vehicular trips by mode 1995
(source: SITNP Study Report C2, 1998)

Mode & purpose	Vehicular Trips
Home based - car	428,523
Non-home based - car	254,168
Cordon - car	72,642
Home based motorcycle	1,048,257
Non-home based motorcycle	70,074
Cordon - motorcycle	77,799

C2-2. Input data: Home based trips by purpose 1995
(Source: SITNP Study Report 9, 1996)

home-Work	38%
home-Education	25%
home-Others	16%

C2-3. Input data: Average length (km) of homebased trips by mode and purpose 1995
(Source: SITNP Report 9, 1996 based on SITNP and SSKLL home interviews)

	Car	Motorcycle
Work	9.2	7.07
Education	6.23	6.67
Other	7.25	5.51

Since the average trip length data is broken down by trip purpose, it is necessary to consider the share of the trip purposes. The traveled kilometers [km] can be calculated using the following formula:

*Traveled kilometers ab [km] = Average Trip length ab [km/trip] * trip share a [%] * modal split b [trips]*

Where: a = trip purpose (work, education, others, non-home-based)
b = transport mode (car, motorcycle, public transport)

Executing this calculation would result in traveled kilometers [km] by transport mode (car and motorcycle) and by trip purpose, as shown in the following table:

C2-4. Output: calculated traveled km by vehicle type and trip purpose (for the year 1995)
The traveled km is proportional to modal-split share,
share in trip-purpose and average length of traveled km per trip:

1995	Car	Motorcycle
Work	546,812,489	1,027,930,249
Education	243,609,969	638,008,520
Other	181,436,638	337,312,330
non-homebased	357,856,950	161,920,935
Total	**1,329,716,046**	**2,165,172,034**

Consultant's assumption: length of non-homebased trips (km) 3

Note: As there is no information provided in the SITNP reports on the average length of non-home-based trips (such as lunch trips etc.), we assume that it is 3 km per trip.

Since these figures still refer to 1995 (as they were collected by SITNP), they have to be projected to 2000 first before they can be used further to calculate the amount of gasoline consumed by car and motorcycle in 2000. For this purpose, the results of the trip generation forecasts of the SITNP traffic model can be used. The traffic model also considers the traffic impacts of economic downturns that have started in 1997. According to "average scenario" in the SITNP Study II Report C2 1998 (this average scenario is called "business as usual scenario" or BAU scenario or BAU scenario in this report), the car traffic and motorcycle traffic will grow yearly by 1.7% and 1.6% respectively from 1995 to 2010.[3] The accumulative growths of car and motorcycle traffic in 2000 are estimated to amount 9.0% and 8.4%, respectively.

Assuming that there is no change in the average length of both home-based and non-home-based trips, the total traveled kilometers by car and by motorcycle would amount to approximately 1,449,390,490 km and 2,347,046,485 km respectively, as shown in the following table. However, not all of these car trips were conducted by gasoline cars. In Surabaya it is known that there is a small amount of diesel cars

3 SITNP II Report C2 1998: "The basic assumption for this scenario was that for the “average scenario - 2010”, the household size and trip rate characteristics will be very similar to the “reference 1995” situation because the per capita income recovers its value to that of year 1995 only by year 2010. Thus household size and trip rates for use in 2010 are assumed to be exactly the same as those in the reference scenario for year 1995. However, some limited growth is forecast to occur after 2010 and therefore the household size is likely to reduce a little. Change factors for the trip rates are assumed to be limited." According to this scenario, the car and motorcycle traffic will grow by 29.5% and 27.3% respectively over 15 years from 1995 to 2010. The yearly traffig growth rates are results from a linear interpolation conducted by the consultant.

operating in the city (their share is assumed to be around 2%, according to an interview on July 4, 2001 by a GTZ staff Karl Fjellstrom with a staff from city's Department of Transportation).

C2-4. Output: calculated traveled km by vehicle types and trip purpose (for the year 2000)
The traveled km is proportional to modal-split share,
trip-purpose share and average length of traveled km per trip:

2000 (projected from 1998 data)	Car	Motorcycle
Work	596,025,613	1,114,276,389
Education	265,534,866	691,601,236
Other	197,765,936	365,646,566
non-homebased	390,064,076	175,522,294
Total	**1,449,390,490**	**2,347,046,485**

Now we have the total traveled kilometers [km] and the specific gasoline consumption [km/l] of both car and motorcycle for 2000. The total gasoline consumption can be calculated by subtracting the total traveled kilometers by 2%, and dividing the result by the specific gasoline consumption [km/l]. This calculation leads to a total gasoline consumption of 271,432,194 Liters in 2000 for both car and motorcycle as shown the following table:

D1. Output: Calculated gasoline consumption [Liters]
of cars and motorcycles (for the year 2000) - based on traffic data

2000 (projected from 1998 data)	**Gasoline Consumption** [L]	**Diesel Consumption** [L]
Cars	**177,550,335**	**3,623,476**
Motorcycles	**93,881,859**	**n/a**
Total	**271,432,194**	**3,623,476**

To test how reliable the traffic data is to be used to calculate the gasoline consumption, a crosscheck is conducted. The previous calculations based on the fuel sales figures leads to the total gasoline consumption (by car and motorcycle) of 292,080,000 Liters in 2000, while the above calculation (based on the projected traffic data) leads to a total gasoline consumption of 271,432,194 Liters. This is only a small discrepancy of around 7%, which indicates that the two independent input data sources (fuel sales figures from Pertamina, the state-owned fuel supplier, and the projected traffic data from SITNP) are of high consistency considering the error margins of the calculations here.

In order to calculate the impacts of modal split changes on CO_2 emissions it is important to have a reliable traffic data (traveled km, number of trips, length of each trip, specific fuel consumption) that is consistent in terms of both absolute values of each vehicle mode and relative values among vehicle modes.[4] To ensure this consistency another crosscheck is conducted here by comparing the gasoline consumptions of car and motorcycle as calculated in the table above (solely based on projected traffic data by using the absolute values of traveled km) with the gasoline consumptions that are calculated from the fuel sales figures by using the relative ratio between the traveled kilometers by car and the traveled kilometers by motorcycle.

In conjunction with the specific fuel consumption of car and motorcycle, this relative ratio has to be melted into a "consumption share factor", which represents the consumption shares of car or motorcycle. The consumption share factor itself is proportional to the traveled kilometers and is inversely proportional to the specific fuel consumption, a relationship which arithmetically can be expressed in the following formula:

$$\text{Consumption share factor} \approx \text{traveled kilometers [km]} / \text{specific fuel consumption [km/l]}$$

Executing this calculation will result in a consumption share factor for cars and motorcycles. This means that the remaining 292,080 kilo-liters (unused by taxis and angkots) were consumed for car and motorcycle trips. This is summarized in the following table:

D2. Output: Calculated gasoline consumption [Liters]
of cars and motorcycles (for the year 2000) - based on fuel sales figures
The consumption share factors represent the amount of gasoline consumed by each vehicle type.
The consumption share factor of a vehicle type is proportional to the traveled km and is inversely proportional to the specific fuel consumption. The actual fuel consumption is proportional to the share factors.

	Consumption-share factors		**Fuel Consumption**
	in figures	in %	[L]
Cars	181,173,811	65.9%	**192,387,405**
Motorcycles	93,881,859	34.1%	**99,692,595**
Total		100.0%	**292,080,000**

Comparing the results of the two calculations verifies their consistency as shown in the following table (with discrepancy of only approximately 7%), and therefore, both the gasoline sales figures and the traffic data can be used for further calculations in the next chapters of this report.

4 The reason for this is that there is a possibility that the traffic data can be accurate in term of relative values

D3. Output: Calculated gasoline consumption [Liters] for the year 2000

Projection from 1998 data	Fuel Consumption based on SITNP traffic data [L]	Fuel Consumption based on Pertamina sales figures [L]
Cars	**192,387,405**	**177,550,335**
Motorcycles	**99,692,595**	**93,881,859**
Total	**292,080,000**	**271,432,194**

Calculating CNG consumption by Taxis and other vehicles

Similar to the calculation of gasoline consumption by angkot or taxi as conducted above, the CNG consumption of taxis is calculated directly from their operational data. The assumptions on the number of operational days in a year and the daily fuel consumption of CNG are also based on the information obtained from the Taxi Zebra. Taxi Zebra is still now the only Taxi Company in Surabaya that operates taxis equipped with CNG converters. Their CNG-fleet consists of 800 units. Based on these assumptions, the total CNG consumption by taxis in Surabaya was 6,960 kilo-liters gasoline-equivalent in 2000. The following table summarizes this calculation:

Total number of Taxis	800	units
Average daily CNG consumption	29	Liter/day
Number of operational days per year	300	days/year
Yearly total fuel consumption of Taxis	**6,960,000**	**Liter gasoline-equivalent**

The CNG consumption by other CNG vehicles can be calculated as the difference between the CNG consumed by the Taxis and the total of 10,086,000 Liters gasoline-equivalent CNG sold in Surabaya in 2000. This amounts to 3,126,000 Liters gasoline-equivalent CNG. However, this number should be interpreted cautiously. According to CNG supplier Pertamina, there are only less than 150 CNG vehicles officially registered in Surabaya in 2000, that belong to the category "other CNG vehicles". These are mainly private cars. Because of their small number (compared to 800 CNG taxis) and their low traveled km, it is believed that their actual CNG consumption is much less than the calculation result. In addition a lot of the CNG was used for the industrial processes and/or was exported out of Surabaya, apart from losses during loading/unloading for storage and other distribution activities.

(among modes), but inaccurate in term of their absolute values (or vice versa), even though they lead to the same/similar results (here, the total gasoline consumption).

Calculating diesel consumption by city buses and other vehicles

The total diesel consumption by city buses is also obtained from the operational data. With their total number of 250 units (both the state operator *Damri* and private bus companies), they consumed 6,500 kiloliters diesel in total in 2000, assuming that they travel 65,000 km that year with a specific fuel consumption of 2,5 km/Liter. This calculation is summarized in the following table:

Total number of buses (Damri and private)	250	units
Average Yearly km traveled by each bus	65,000	km/year
Specific fuel consumption	2.5	km/Liter
Yearly total Diesel consumption	**6,500,000**	**Liter**

According to Pertamina, there were in sum 168,000 kiloliters diesel sold in Surabaya in 2000. If the city buses consumed 6,500 kiloliters of diesel that year, then other diesel vehicles consumed 161,500 kiloliters. To this category belong trucks, tractors and other diesel utility vehicles etc. However, this high number is hard to verify since many other diesel vehicles (especially trucks) are going across the city borders. Similar to the other calculations, while interpreting the amount of diesel consumed by other vehicle, it is likely that this number also includes amounts of diesel that went lost through leakages, or that are not used by road vehicles in Surabaya (e.g. production process by the small scale industries in Surabaya).

4.1.4 CALCULATING CO_2 EMISSIONS BY VEHICLE TYPE FOR 2000

The CO_2 emissions in the year 2000 were calculated directly by multiplying the fuel consumption figures with the corresponding CO_2 emission factors. The following table shows the fuel consumption and the corresponding CO_2 emissions, distinguished by vehicle category based on their fuel type. The vehicle categories include private car, motorcycle and public transport vehicles. The latter category consists of minibus/angkots, taxis and city buses.

2000	Fuel Consumption	CO2 Emissions
	[Liters]	[kg]
Private cars (gasoline)	192,387,405	448,262,654
Private cars (diesel)	3,623,476	9,493,508
Motorcycles (gasoline)	99,692,595	232,283,746
Public transport		
Angkots (gsln)	46,080,000	107,366,400
Angkots (CNG)	0	0
Taxis (gsln)	21,840,000	50,887,200
Taxis (CNG)	6,960,000	13,084,800
Buses (Diesel)	6,500,000	17,030,000
Other Diesel Vehicles	157,876,524	413,636,492
Other CNG Vehicles	3,126,000	5,876,880
Total		1,297,921,680

In total, there were approximately 1,298 kilotons of CO_2 emitted from the road transport vehicle use in Surabaya in 2000. Private cars emitted the biggest share, which accounted more than approx. 450 kilotons of CO_2 (from gasoline and diesel private cars). The second biggest share was from the vehicle category "Other Diesel Vehicles" (this however, to be interpreted with special caution - s. note above), followed by motorcycles with more than approx. 230 kilotons of CO_2 emissions.

At a first sight, these numbers suggest that CO_2 emission reduction measures should be aiming at private cars, motorcycles and trucks, rather than minibus/angkots, taxis and buses, which are public transport vehicles (that because of many other reasons should be encouraged anyway). Although technical CO_2 reduction measures aiming at angkots, taxis and buses are relatively easier and faster to implement successfully, their reduction effects however can be easily wiped out by unfavorable modal split changes towards more use of private motorized vehicles (cars and motorcycles). Therefore, although measures aiming at modal shifts toward more public transport use are harder to implement, they should remain one of the main objectives to be considered in the city's long-term transport development programs.

4.1.5 FUEL CONSUMPTION AND CO_2 EMISSIONS PROJECTION FOR 2010

The projection of CO_2 emissions for 2010 will be calculated from the projected fuel consumption, which is again, calculated from the projected traffic volume for 2010. In the calculation, it is assumed that the energy content and the composition of the fuels in 2010 will be the same as those in 1995, so that the same conversion factors can be used. Further, it is also assumed, that the average trip length of each vehicle type will stay the same as they were in 1995, so that the traffic increase projected for 2010 will solely be caused by the increase of vehicle trips, and not by the length of each trip. Furthermore it is assumed, that the specific fuel consumption of the vehicles will also be constant, because the impact of the technological improvement in regard of fuel efficiency is weighed as insignificant. This is seen as realistic if one considers the extremely high share of older fleet vehicles, as it is common in developing countries. Under these assumptions, it then can be concluded that the fuel consumption will rise proportionally with the increase of traffic volume, until the city's road network capacity is reached. According to the SITNP traffic forecasts however, the maximum capacity of many parts in the city's road network will be reached and overloaded, so that congestions will occur which would lead to higher fuel consumptions. (Several major road links in Surabaya are already overloaded.) This effect will also be considered in the calculations.

Since the available citywide trips data was only the trips data from the surveys conducted by SITNP in 1995, this will be used as the basis for the following calculations.

(n) The traffic growth for 2010

Forecasts for the traffic growth 2010 have been made by SITNP in 1998 with revisions considering the impacts of the ongoing economic crisis. As mentioned previously, according to the "average scenario", trips by car, motorcycle and public transport will grow by 29.5%, 27.3% and 26.6% respectively over 15 years from 1995 to 2010 (see SITNP Study II Report C2, 1998).

(o) Calculating the fuel consumption and the associated CO_2 emissions

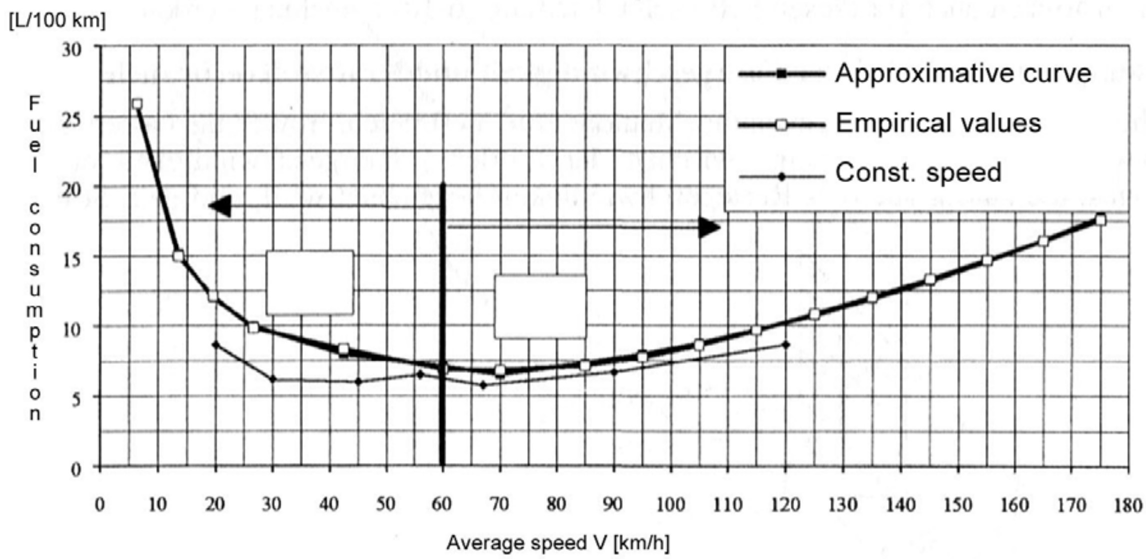
The increase of number of trips results, under the assumptions mentioned above, to a proportional increase of traveled kilometers, which translates to a proportional increase in fuel consumption in 2010. Additional fuel consumption due to congestion effects has to be considered. According to the SITNP forecasts, the extent of heavily loaded and overloaded road links can be seen to rise by 2010. The distribution of these congestion effects are summarized in the following table:

Speed Range (kph)	1995 SITNP I		2010 Average	
	PCU Hours	(%)	PCU Hours	(%)
0 - 10	375	2	4,117	8
10 - 15	216	1	2,717	5
15 - 20	1,066	6	5,457	10
20 - 25	3,168	17	9,100	17
25 - 30	3,529	19	10,335	20
30 - 35	3,223	17	6,138	12
35 - 40	3,303	18	5,150	10
40 - 50	1,930	10	2,885	5
50 - 60	503	3	2,522	5
> 60	1,368	7	4,544	8
Totals	**18,681**	**100**	**52,964**	**100**

Source: SITNP Study Report C2, 1998

The distribution of PCU hours (Private Car Units hours) by speed range has to be translated to changes in the specific fuel consumption. In reality, fuel consumption doesn't only depend on the average speed, but also on other factors such as driving cycles and vehicle type. For the purpose of the calculations in this report however, this is conducted by using simplified relationship between average speed and specific fuel consumption. The following diagram shows this empirical relationship.

Diagram: Empirical relationship between average speed and fuel consumption



Source: Merkblatt ueber Luftverunreinigungen an Strassen, Forschungsgesellschaft fuer Strasenverkehr, Bonn 1992

Because the effects of congestion on fuel consumption increases are different for every speed category (depending on changes in their share of PCU hours [%]), the calculation has to be done for each category separately, whereas the specific fuel consumption is weighed with their percentage share for each speed category for 1995 and 2010 (see columns 3 and 4 in the following table). Their changes in 2010 are calculated in the last column. The congestion factor (which represents the fuel consumption increase due to congestion effects) is then calculated by adding up all of these 1995-2010 changes, and comparing the total sum to the 1995 value. This leads to a congestion factor of approximately 15% (rounded up from 14,47), as shown in the following table:

Average speed [km/h]	Specific fuel Consumption [L/100km]	Weighed specific fuel consumptions [%.L/100km] 1995	2010	Weighed Changes 1995-2010
5	27.50	55.00	220.00	165.00
12.5	14.00	14.00	70.00	56.00
17.5	12.50	75.00	125.00	50.00
22.5	11.25	191.25	191.25	0.00
27.5	9.70	184.30	194.00	9.70
32.5	9.40	159.80	112.80	-47.00
37.5	9.00	162.00	90.00	-72.00
42.5	8.00	80.00	40.00	-40.00
55.0	7.50	22.50	37.50	15.00
65.0	6.50	45.50	52.00	6.50
Total		**989.35**	**1132.55**	**143.20**
		Congestion factor		**14.47%**

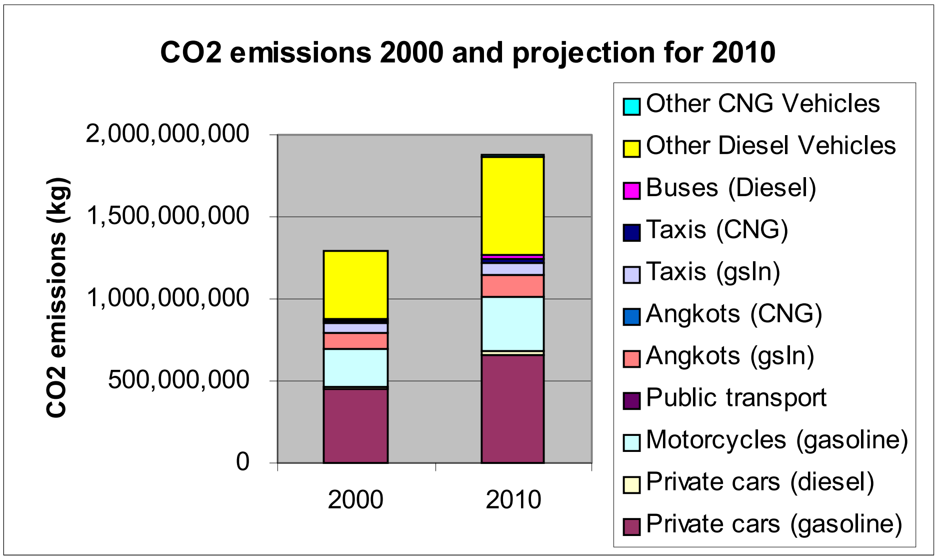
The following table shows the projected fuel consumption and the associated CO_2 emissions by vehicle type (congestion effect is considered):

2010	**Fuel Consumption**	**CO2 Emissions**
	[Liters]	**[kg]**
Private cars (gasoline)	285,202,831	664,522,596
Private cars (diesel)	5,371,587	14,073,558
Motorcycles (gasoline)	145,277,624	338,496,865
Public transport		
Angkots (gsln)	56,959,113	132,714,734
Angkots (CNG)	0	0
Taxis (gsln)	31,651,461	73,747,905
Taxis (CNG)	10,086,729	18,963,051
Buses (Diesel)	8,826,300	23,124,907
Other Diesel Vehicles	228,801,405	599,459,681
Other CNG Vehicles	4,530,333	8,517,026
Total		**1,873,620,323**

According to the calculations performed above, private cars will lead in term of fuel consumption and the associated CO_2 emissions compared to the other vehicle categories, followed by "Other Diesel Vehicles" and motorcycles. The total calculated CO_2 emissions in 2010 would be approx. 1,874 kilotons.

As these calculations involved more assumptions and other traffic data that are based on limited sample, the uncertainty of this projection is greater than the emission calculations for 2000 conducted in the previous part of this chapter. Therefore it is important to keep in mind that the results of these calculations can contain more than 10% error margins. In spite of this, the results do show clear negative signs of rapidly increasing CO_2 emissions, if no counter-measures are taken. The following table and diagram below summarize the calculated increase of CO_2 emissions from 2000 to 2010:

CO2 Emissions (kg)	2000	2010
Private cars (gasoline)	448,262,654	664,522,596
Private cars (diesel)	9,493,508	14,073,558
Motorcycles (gasoline)	232,283,746	338,496,865
Public transport		
Angkots (gsln)	107,366,400	132,714,734
Angkots (CNG)	0	0
Taxis (gsln)	50,887,200	73,747,905
Taxis (CNG)	13,084,800	18,963,051
Buses (Diesel)	17,030,000	23,124,907
Other Diesel Vehicles	413,636,492	599,459,681
Other CNG Vehicles	5,876,880	8,517,026
Total	**1,297,921,680**	**1,873,620,323**



4.2 RETROFITTING MICROBUSES (ANGKOTS) WITH CNG SYSTEMS

4.2.1 SCENARIO 1: 30% OF ANGKOTS USE CNG

The objective of the following calculation is to estimate the CO_2 emissions reduction potential achievable through retrofitting of 30% of the existing microbuses (angkots). Currently there are 4,800 angkots operating on 57 different routes in Surabaya (GTZ

- ITS/Atok 2000), all of which still using gasoline fuel. The total gasoline consumed in 2000 by these angkots is estimated from the operational data. Since there was no data on the number of angkots by route, the length of routes and the average daily trip lengths available to do accurate calculations, estimations have to be used for the operational data. These estimations were based on reliable sources including interviews with angkot owners, angkot drivers and the associations of angkot owners in 1999 and 2001.

It is estimated that the average daily fuel consumption of angkot is 30 liters of gasoline in average, and that the angkots were operating for 320 days out of 365 days in the year 2000. The following table shows the total gasoline consumption and the associated CO_2 emissions of angkots in 2000, based on the estimations used.

Total number of angkots	4,800	Units
Average daily gasoline consumption	30	Liters/day
Number of operational days per year	320	days/year
Total gasoline consumption of Angkots in 2000	46,080,000	Liters
CO2 emissions from Angkots in 2000	107,366,400	kg

If 30% of these angkots used CNG instead of gasoline, the total CO_2 emissions would decrease from 107,366 tons by 6,220 tons, to 101,145 tons, which represents a reduction of around 6%. These results were reached by assuming that the angkots have the same number of operating days and the same amount of specific fuel consumption (in terms of liter gasoline-equivalent) before and after the retrofit. This reduction of CO_2 emissions is caused by the fact that the same energy amount of CNG would only emit 20% less CO_2 of the same energy amount of gasoline if burned through combustion process, as shown by the conversion factors. The following tables show the calculation of fuel consumption and the associated CO_2 emissions for the scenario that 70% using gasoline and 30% using CNG:

Gasoline consumption by 70% of Angkots

Total number of angkots	3,360	Units
Average daily gasoline consumption	30	Liters/day
Number of operational days per year	320	days/year
Total gasoline consumption of Angkots	32,256,000	Liters
CO2 emissions from Angkots	75,156,480	kg

CNG consumption by 30% of Angkots with CNG systems

Total number of angkots	1,440	Units
Average daily gasoline consumption	30	Liters/day
Number of operational days per year	320	days/year
Total CNG consumption of Angkots	13,824,000	Liters gasoline-eq. at 200 bar
CO2 emissions from CNG Angkots	25,989,120	kg

4.2.2 Scenario 2: 50% of Angkots use CNG

The calculation for the scenario 2, assuming that 50% of the angkots are using CNG, is based on the same methodology and the same assumptions as the scenario 1 performed above. The results of the calculations show that the total CO_2 emissions could be reduced by around 10% from 107,366 tons to 96,998 tons, as summarized in the following tables:

Gasoline consumption by 50% of Angkots

Total number of angkots	2,400	Units
Average daily gasoline consumption	30	Liters/day
Number of operational days per year	320	days/year
Total gasoline consumption of Angkots	23,040,000	Liters
CO2 emissions from Angkots	53,683,200	kg

CNG consumption by 50% of Angkots with CNG systems

Total number of angkots	2,400	Units
Average daily gasoline consumption	30	Liters/day
Number of operational days per year	320	days/year
Total CNG consumption of Angkots	23,040,000	Liters gasoline-eq. at 200 bar
CO2 emissions from CNG Angkots	43,315,200	kg

4.3 Retrofit from 25% to 50% of Taxis with CNG-systems

The objective of the following calculation is to estimate the CO_2 emissions reduction potential achievable by increasing the share of CNG taxis to 50%. According to the Statistical Year Book Surabaya 2000, there were in 1999 2,750 taxis operating in the city. According to Taxi Zebra, there are currently 800 operating taxis in Surabaya that are equipped with CNG converters. The Taxi Company Taxi Zebra owns all these taxis. The rest of the taxis (1,950 taxis) are currently using gasoline.

The total gasoline and CNG consumed in 2000 by these taxis is estimated from the operational data. Since there was no detail record of daily fuel consumption and the daily traveled km available, estimations based on interviews with reliable sources are used to calculate on average daily fuel consumption and the number of operating days are used for the calculations of the taxis' fuel consumption in 2000. The estimations on the average daily fuel consumption and number of operating days by gasoline and CNG taxis are obtained from the taxi company Taxi Zebra, verified with direct interviews with the taxi drivers of various operators. The following table shows the calculated total fuel consumption and the associated CO_2 emissions of taxis in 2000, based on the estimations used:

Gasoline consumption by taxis 2000

Number of gasoline taxis	1,950	Units
Assumption: Average daily fuel consumption	35	Liters/day
Assumption: Number of operational days per year	320	days/year
Yearly total fuel consumption of Taxis	**21,840,000**	**Liters**
CO2 emissions from gasoline Taxis	**50,887,200**	**kg**

CNG consumption by taxis (Taxi Zebra fleet)

Number of CNG Taxis	800	Units
Average daily CNG consumption	35	Liters/day
Assumption: Number of operational days per year	320	days/year
Yearly total fuel consumption of Taxis	**8,960,000**	**Liters gasoline-equivalent at 200 bar**
CO2 emissions from CNG Taxis	**16,844,800**	**kg**

Assuming the same operating conditions (the same average daily fuel consumption and the same number of operating days), the amount of CO_2 emissions would decrease by around 4% (or by 2,898 tons) from 67,732 tons to 64,834 tons, if the number of taxis using CNG is increased from around 25% to 50%. The following tables show the calculations of the total fuel consumed and the associated CO_2 emissions for both gasoline and CNG taxis, after the number of CNG taxis is increased to 50% through retrofit measure.

Gasoline consumption by Taxis

Assumption: Number of gasoline taxis	1,375	Units
Assumption: Average daily fuel consumption	35	Liters/day
Assumption: Number of operational days per year	320	days/year
Yearly total fuel consumption of Taxis	**15,400,000**	**Liters**
CO2 emissions from gasoline Taxis	**35,882,000**	**kg**

CNG consumption by taxis (Taxi Zebra fleet and additional CNG taxis)

Assumption: Number of CNG Taxis	1,375	Units
Assumption: Average daily CNG consumption	35	Liters/day
Assumption: Number of operational days per year	320	days/year
Yearly total fuel consumption of Taxis	**15,400,000**	**Liters gasoline-equivalent at 200 bar**
CO2 emissions from CNG Taxis	**28,952,000**	**kg**

4.4 IMPROVEMENT OF PUBLIC TRANSPORT SYSTEM

An improved public transportation system will have a better image, and be faster, more reliable, comfortable, and secure, thus becoming more attractive, so that more trips will be conducted by bus and a smaller proportion of trips will be made with individual motorized vehicles. The CO_2 emissions reduction potential achievable through successful improvements of the city bus system in Surabaya will be reached through a change in modal split, which will be reflected by a modal shift from motorized trips on individual vehicles in favor of public transport.

(a) Modal split

The change in modal split will also have a positive effect on the fuel consumption pattern of the entire motorized fleet in the city, and thus also positive impacts in terms of CO_2 emissions. Therefore, the amount of CO_2 emissions estimated here is derived from the modal-split changes considering both increased fuel consumption by bus (caused by more bus trips), and decreased fuel consumption by motorized individual traffic (car and motorcycle).

As forecast by SITNP, the modal split for 2010 in the average scenario is as follows:

	Car	Motorcycle	Public Transport	Total
SHARE IN %	19.6%	46.1%	34.3%	100%

Source: SITNP Study Report C2, 1998

According to the GTZ staff, bus improvement measures could increase the share of public transport to 40% in 2010, instead of 34.3% as forecast by SITNP. Furthermore, it is assumed that the modal shift wouldn't cause a change in the total number of trips of 2010, and that the modal shift in favor of public transport is caused by the same number of people who otherwise would go by car or motorcycle. This means that the modal shares of car and motorcycle decrease by the same factor, namely by 2.85% each, leading to a modal distribution of trips as shown in the following table:

	Car	Motorcycle	Public Transport	Total
SHARE IN %	16.8%	43.3%	40.0%	100%

This modal split change leads to a relative reduction of car trips and motorcycle trips by 12.9% and 6.7%, respectively, as shown in the following table. These reduction factors will be needed later for the calculation of the total gasoline consumption of car and motorcycle.

	Before (2010)	After (2010)	Reduction (trips/day)	Relative reduction (in %)
Trips by cars	392,278	335,238	- 57,040	12.9%
Trips by Motorcycles	922,654	865,614	- 57,040	6.7%

(b) Calculating gasoline consumption by angkot

It is expected that a part of the additional public transport passengers would use angkots, which is for the calculation here assumed to be 30% of the total additional ridership, as estimated by GTZ staff. The other 70% additional passengers would take bus.

According to the SITNP projections (Study Report C2 1998), the total number of public transport passengers would increase to 688,098 passengers per day if the share of public transport in the modal split were maintained at 34.3%. This means that the total number of public transport passenger would increase to approximately 800,600 passengers if the share of public transport in the modal split increases to 40.0%. In other words, there are 112,700 additional passengers are expected if the modal share of public transport is increased from 34.3% to 40.0%. And if 30% of this additional ridership goes by angkots, the total angkot capacity should be increased to accommodate additional 33,800 passengers. According to the same SITNP report, in 1995, there were around 4,500 angkots serving 151,684 passengers per day. This means, the total number of angkots has to be increased to around 5,870 to maintain the same capacity-related level of service. Higher number of angkots increases their total gasoline consumption. Assuming the same operational characteristics (average daily fuel consumption and number of operational day per year), the total gasoline consumption of angkots in 2010 would increase to 56,400 kiloliters, as shown in the following table:

Total number of angkots 2010	5,870	units
Average daily fuel consumption	30	Liter/day
Number of operational days per year	320	days/year
Yearly total fuel consumption of angkots	**56,354,160**	**Liter**

(c) Calculating the total traveled kilometers

The next step is to calculate the traveled vehicle kilometers. It is assumed that the length of the trips previously conducted by motorized vehicles, and are now by bus, stays the same. Obviously, this is in reality not the case, since bus systems are always associated with fixed routes that don't always represent direct origin-destination links for the passengers, and thus are more likely to cause longer trips than would be conducted by individual vehicle.[5] However, taking these effects into account in the calculation would necessitate at least a sophisticated multi-modal traffic model that includes the modeling of the public transport supply side and based on a highly disaggregated origin-destination matrix. Such a traffic model is not available in Surabaya.

The calculation of the total traveled kilometers and the total fuel consumption, which is derived on the traffic data, is based on the same methodology as previously performed for the BAU scenario in the calculation of traveled kilometers for 2000 in subchapter 4.1.3 of this report. Using the new modal split reached by bus improvements, and the same input data provided in the SITNP reports for the share of trips (by purpose) and the average trip length (by transport mode and trip purpose), the **total traveled kilometers** by car and motorcycle in 2010 after the bus improvement would grow as shown in the following table:

2010	Car	Motorcycle
Traveled km	1,500,208,755	2,572,075,009

(d) Calculating fuel consumption by car and motorcycle

The next step is to calculate the total gasoline and diesel consumption by car as well as gasoline consumption by motorcycle from the total traveled km calculated above. Again here it is assumed, that the specific fuel consumption of the vehicles will also be constant, because the impact of the technological improvement in regard of fuel efficiency is weighed as insignificant (which is seen to be realistic considering the high share of older fleet vehicles, as it is common in developing countries). According to this calculation, the gasoline consumption of car, the diesel consumption of car and the gasoline consumption of motorcycle amount to approximately 184,775 kiloliters, 3,750 kiloliters and 103,000 kiloliters, respectively (see the following table).

2010	Car (gasoline)	Car (diesel)	Motorcycle (gsln)
Fuel consumption [L]	183,775,573	3,750,522	102,883,000

It is not expected that the fuel consumption of taxis and other diesel vehicles would be affected by the modal shifts caused by the public transport improvement measures. They would, however, benefit from less congestion effects which will be

[5] On the other hand, greater reliance on public transport is also associated with greater use of non-motorized modes such as walking and cycling.

taken account into the calculation below. Therefore their fuel consumption stays the same as calculated previously in the chapter 4.1.3. This means: taxis consumed 21,800 kiloliters gasoline and 6,500 kiloliters gasoline-equivalent CNG, and other diesel vehicles consumed 4,500 kiloliters diesel.

(e) Calculating diesel consumption by bus

The decrease of gasoline consumption will be accompanied by the increase of diesel consumption by city buses due to the higher number of bus trips necessary to accommodate the additional passengers. The GTZ team estimated that 100 additional buses would be needed to accommodate the additional passengers. Current low operating efficiency, in particular caused by long delays at terminals, mean that a substantial additional number of passengers can be transported with only a small additional number of public transport vehicles. With the same assumptions on the average yearly km traveled and the specific fuel consumption, the total diesel consumption by bus would increase from liters before the bus improvements to liters after, as shown in the following tables:

4G-1. Diesel consumption by city buses 2010 (BEFORE bus improvement)

Total number of buses (Damri and private)	250	units
Average yearly km traveled by each bus	65,000	km/year
Specific fuel consumption	2.5	km/Liter
Yearly total Diesel consumption	**6,500,000**	**Liter**

4G-2. Diesel consumption by city buses 2010 (AFTER bus improvement)

Total number of buses (Damri and private)	350	units
Average yearly km traveled by each bus	65,000	km/year
Specific fuel consumption	2.5	km/Liter
Yearly total Diesel consumption	**9,100,000**	**Liter**

(f) Taking congestion effects into account

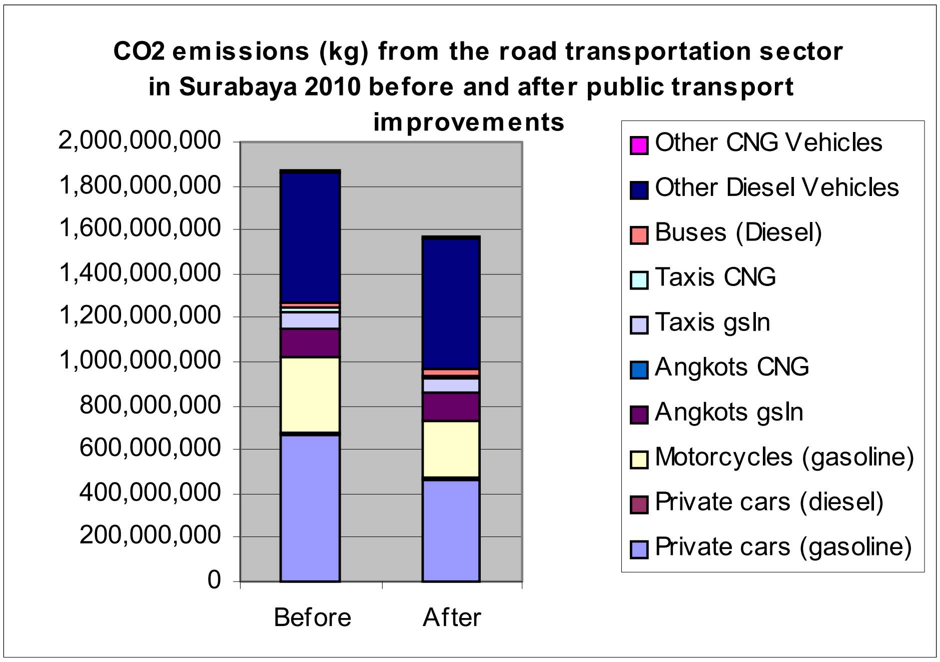
The public transport improvement will result in lower trips by car and motorcycle compared to the "average scenario" without public transport improvement. Less cars and motorcycles also mean less load for the city's road network which in turn will reduce the congestion effects. Considering the currently already high volume/capacity ratio in some road links, it is not expected that these congestion effects can be totally eliminated by solely increasing the share of public transport to 40%. Thus the congestion effects will still persist in this scenario, but they would lead to a higher fuel consumption by a factor of lower than 15% (as calculated in the previous scenario without bus improvement in the chapter 4.1). Accurate calculation to determine the congestion factor can only be conducted by testing the network load using a computerized traffic model such as that was built by SITNP. For the purpose of the CO_2 calculations here, it is assumed that the congestion factor is approximately 7%.

Public transport vehicles, such as city buses, angkots and taxis, however will not be affected by congestion due to prioritization measures in the frame of public transport improvements.

(g) Calculation results: CO_2 emissions by vehicle type 2010

The following table and diagram summarize the reduction of CO_2 emissions by vehicle type before and after public transport improvements. The CO_2 emissions were calculated directly from the fuel consumption using the fuel-specific conversion factors.

CO2 emissions 2010 [kg]		**Before and after public transport improvements**	
		Before	**After**
Private cars (gasoline)		664,522,596	459,883,668
Private cars (diesel)		14,073,558	10,553,519
Motorcycles (gasoline)		338,496,865	257,456,478
Public transport	**Angkots gsln**	132,714,734	131,305,193
	Angkots CNG	0	0
	Taxis gsln	73,747,905	64,423,195
	Taxis CNG	18,963,051	16,565,357
	Buses (Diesel)	23,124,907	23,842,000
Other Diesel Vehicles		599,459,681	599,459,681
Other CNG Vehicles		8,517,026	8,517,026
Total		**1,873,620,323**	**1,572,006,117**



The table shows that the increase of CO_2 emissions due to more public transport trips are more than offset by the decrease in the CO_2 emissions due to relatively fewer trips on cars and motorcycles. The calculated reduction of CO_2 emissions amounts to 272 kilotons, around 14% less than before the public transport improvements, which is considered as a significant reduction potential.

4.5 TRANSPORT DEMAND MANAGEMENT (TDM)

Transport demand management (TDM) measures are needed in Surabaya to avert intolerable future congestion conditions. These measures aim to reduce congestion in congested areas at congested times, primarily by encouraging shifts from private cars to more efficient modes such as walking, cycling, and public transport. Demand management measures for short-term application in Surabaya currently being developed include an “odd/even” scheme based on number plates, which is to be applied in Jl. Achmad Yani. Mid term solutions under serious consideration include using parking policy to restrict demand for private vehicle use, and applying an area-licensing scheme. An area-licensing scheme is the only measure which can have a large impact on the modal split; but since the development of such a scheme is still at a very early stage, the following calculations are based on the projected implementation of more modest TDM measures, including the odd/even scheme and tighter parking policy.

In general, the reduction impacts of TDM on the CO_2 emissions are estimated with the same methodology as the impacts of the other measures that have effects on modal split changes. This is preformed by deriving the reduction of fuel consumption from the modal split and other traffic data, and converting it to CO_2 emissions.

As forecast by SITNP, the modal split for 2010 in the average scenario is as follows:

	Car	Motorcycle	Public Transport	Total
SHARE IN %	19.6%	46.1%	34.3%	100%

Source: SITNP Study Report C2, 1998

It is expected that the share of public transport in the modal split would increase after successful implementation of transport demand management measures. The increase of public transport share in the modal split varies depending on the intensity of the traffic restraint effects of the measures. In the following calculations, the CO_2 emissions are calculated using the share of public transport in the modal split of 40%, 45% or even 50% depending on whether **medium**, **heavy** or **extreme** traffic restraint is applied, as shown in the following tables. The calculation results are later compared to the BAU scenario, which has the share of public transport in the modal split of 35%.

Public Transport (Bus)	Private cars/motorbikes	Traffic restraint
40%	60%	Medium
45%	55%	Heavy
50%	50%	Extreme

In the following calculations, the impacts of the TDM measure on CO_2 emissions are estimated for the three scenarios.

(a) Modal splits

As previously mentioned, In the medium, heavy and extreme traffic-restraint scenarios, the share of public transport would increase to 40%, 45% and 50% in 2010. Furthermore, it is assumed that the modal shift wouldn't cause a change in the total number of trips of 2010, and that the modal shift in favor of public transport is caused by the same number of people who otherwise would go by car or motorcycle. This means that the modal shares of car and motorcycle decrease by the same factor, namely by approximately 3%, 5% and 8% each, respectively, leading to a modal distribution of trips as shown in the following table:

TDM Scenarios	Car	Motorcycle	Public Transport	Total
Medium trffic restraint	16.8%	43.3%	40.0%	100%
Heavy traffic restraint	14.3%	40.8%	45.0%	100%
Heavy traffic restraint	11.8%	38.3%	50.0%	100%

This modal split change leads to a relative reduction of car trips and motorcycle trips by approx. 12% and 7%, respectively, for the medium traffic-restraint scenario as shown in the following table. The corresponding relative reductions of car trips and motorcycle trips for the heavy and extreme traffic-restraint scenarios are set out in the last column in the following tables. These reduction factors will be needed later for the calculation of the total gasoline consumption of car and motorcycle.

TDM with medium traffic restraint	Before (2010)	After (2010)	Reduction (trips/day)	Relative reduction (in %)
Trips by cars	392,278	335,238	- 57,040	12.9%
Trips by Motorcycles	922,654	865,614	- 57,040	6.7%

TDM with heavy traffic restraint	Before (2010)	After (2010)	Reduction (trips/day)	Relative reduction (in %)
Trips by cars	392,278	285,202	- 107,076	24.2%
Trips by Motorcycles	922,654	815,578	- 107,076	12.5%

TDM with extreme traffic restraint	Before (2010)	After (2010)	Reduction (trips/day)	Relative reduction (in %)
Trips by cars	392,278	235,167	- 157,111	35.5%
Trips by Motorcycles	922,654	765,543	- 157,111	18.4%

(b) Calculating the total traveled kilometers by car and motorcycle

The next step is to calculate the total traveled kilometers. The calculation of the total traveled kilometers and the total fuel consumption, which is derived on the traffic data, is based on the same methodology as previously performed for the BAU scenario in the calculation of traveled kilometers for 2000 and 2010 in subchapter 4.1.3 of this report. Using the new modal splits reached by public transport improvements, and the same input data provided in the SITPN reports for the share of trips (by purpose) and the average trip length (by transport mode and trip purpose), the **total traveled kilometers** by car and motorcycle in 2010 after the bus improvement would grow as shown in the following table:

Traveled km 2010	Car	Motorcycle
Medium traffic restraint	**1,500,208,755**	**2,572,075,009**
Heavy traffic restraint	**1,305,670,576**	**2,410,505,719**
Extreme traffic restraint	**1,111,132,397**	**2,248,936,430**

Assuming that 2% of cars use diesel (as previously discussed in the BAU scenario), the total traveled km can be split as follows:

Traveled km 2010	Car (Gasoline)	Car (Diesel)	Motorcycle
Medium traffic restraint	1,470,204,580	30,004,175	2,572,075,009
Heavy traffic restraint	1,279,557,164	26,113,412	2,410,505,719
Extreme traffic restraint	1,088,909,749	22,222,648	2,248,936,430

(c) Calculating gasoline consumption by car and motorcycle

The next step is to calculate the total gasoline and diesel consumption by car and the total gasoline consumption by motorcycle from the total traveled km calculated above. Again here it is assumed, that the specific fuel consumption of the vehicles will also be constant, because the impact of the technological improvement in regard of fuel efficiency is weighed as insignificant. According to this calculation, the gasoline consumption of car, the diesel consumption of car and the gasoline consumption of motorcycle in the medium traffic-restraint scenario amounts to 183,776 kiloliters gasoline, 3,750 kiloliters and 103 kiloliters, respectively (see the following table). The fuel consumption of car and motorcycle for the other scenarios is also shown in the following table:

Fuel consumption 2010 (in Liters)	Car (Gasoline)	Car (Diesel)	Motorcycle (Gasoline)
Medium traffic restraint	183,775,573	3,750,522	102,883,000
Heavy traffic restraint	159,944,646	3,264,176	96,420,229
Extreme traffic restraint	136,113,719	2,777,831	89,957,457

It is not expected that the fuel consumption of taxis and other diesel vehicles would be affected by the modal shifts caused by the public transport improvement measures, though they would benefit from less congestion effects which will be taken account into the calculation below. Their fuel consumption stays the same as calculated previously in the chapter 4.1.3. This means: taxis consumed 21,840 kiloliters gasoline and 6,960 kiloliters gasoline-equivalent CNG, and other diesel vehicles consumed 3,126 kiloliters diesel.

(d) Calculating diesel consumption by bus

As a part of the "push-pull" concept, it is necessary to complement TDM measures with other measures improving the public transport system. The decrease of gasoline consumption will therefore be accompanied by the increase of diesel consumption by city buses due to the higher number of bus trips necessary to accommodate the additional passengers. In the public transport improvement measures, the GTZ team estimated that 100 new buses would be needed to accommodate the additional passengers as a result of the modal share increase from 34.3% by 5.7% to 40.0%. This means, 17.5 new buses will be needed to increase the public transport share by 1%. In the heavy traffic-restraint scenario, the public transport share would increase from 34.3% by 10.7% to 45%, which means that 189 additional buses would be needed. The total number of buses for the heavy traffic-restraint scenario would be 439 units. Similar calculations for the extreme traffic-restraint scenario would result in a total number of 527 buses.

With the same assumptions on the average yearly km traveled and the specific fuel consumption, the total diesel consumption by bus would increase from 6,500 kiloliters before the TDM to 9,100 kiloliters, 11,414 kiloliters or 13,702 kiloliters after TDM with medium, heavy or extreme traffic-restraint measures, as shown in the following tables:

4F. CNG consumption by Taxis 2000 (Taxi Zebra, Before & after: no change)

Total number of CNG Taxis	700	units
Average daily CNG consumption	29	Liter/day
Number of operational days per year	320	days/year
Yearly total fuel consumption of Taxis	**6,496,000**	**Liter-equivalent**

4G-1. Diesel consumption by city buses 2000 (BEFORE TDM)

Total number of buses (Damri and private)	250	units
Average yearly km traveled by each bus	65,000	km/year
Specific fuel consumption	2.5	km/Liter
Yearly total Diesel consumption	**6,500,000**	**Liter**

4G-2. Diesel consumption by city buses 2010 (AFTER TDM with **medium** traffic restraint)

Total number of buses (Damri and private)	350	units
Average yearly km traveled by each bus	65,000	km/year
Specific fuel consumption	2.5	km/Liter
Yearly total Diesel consumption	**9,100,000**	**Liter**

4G-3. Diesel consumption by city buses 2010 (AFTER TDM with **heavy** traffic restraint)

Total number of buses (Damri and private)	439	units
Average yearly km traveled by each bus	65,000	km/year

(e) Calculating gasoline consumption by angkot

As previously explained, it is expected that a part of the additional public transport passengers would use angkots, which is for the calculation here assumed to be 30% of the total additional ridership, as estimated by GTZ staff. The other 70% additional passengers would take bus.

According to the SITNP projections (Study Report C2 1998), the total number of public transport passengers would increase to 688,098 passengers per day if the share of public transport in the modal split were maintained at 34.3%. For the **medium traffic-restraint scenario**, this means that the total number of public transport passenger would increase to approximately 800,600 passengers if the share of public transport in the modal split increases to 40.0%. In other words, there are 112,700 additional passengers are expected if the modal share of public transport is increased from 34.3% to 40.0%. And if 30% of this additional ridership goes by angkots, the total angkot capacity should be increased to accommodate additional 33,800 passengers. According to the same SITNP report, in 1995, there were around 4,500 angkots serving 151,684 passengers per day. This means, the total number of angkots has to be increased to around 5,870 to maintain the same capacity-related level of service. Higher number of angkots increases their total gasoline consumption. Assuming the same operational characteristics (average daily fuel consumption and number of operational day per year), the total gasoline consumption of angkots in 2010 would increase to 56,400 kiloliters, as shown in the following table:

Total number of angkots 2010	5,870	units
Average daily fuel consumption	30	Liter/day
Number of operational days per year	320	days/year
Yearly total fuel consumption of angkots	**56,354,160**	**Liter**

For the heavy and extreme traffic-restraint scenarios, similar calculations with the same assumptions lead to a total angkots' gasoline consumption of 65,474 kiloliters and 74,594 kiloliters, respectively. These calculations are summarized in the following tables:

4A1. Gasoline consumption by Angkots (After TDM - heavy traffic-restraint scenario)

Total number of angkots 2010	6,820	units
Average daily fuel consumption	30	Liter/day
Number of operational days per year	320	days/year
Yearly total fuel consumption of angkots	**65,474,310**	**Liter**

4A2. Gasoline consumption by Angkots (After TDM - Extreme traffic-restraint scenario)

Total number of angkots 2010	7,770	units
Average daily fuel consumption	30	Liter/day
Number of operational days per year	320	days/year
Yearly total fuel consumption of angkots	**74,594,460**	**Liter**

(f) Taking congestion effects into account

The TDM measures will result in lower trips by car and motorcycle compared to the "average scenario" without TDM. Less cars and motorcycles also mean less load for the city's road network which in turn will reduce the congestion effects. Considering the currently already high volume/capacity ratio in some road links, it is not expected that these congestion effects can be totally eliminated by solely increasing the share of public transport to 40% - 50%. Thus the congestion effects will still persist in these scenarios, but they would lead to a higher fuel consumption by a factor of lower than 15% (as calculated in the previous scenario without bus improvement in the chapter 4.1). Accurate calculation to determine the congestion factor can only be calculated by testing the network load using a computerized traffic model such as that was built by SITNP. For the purpose of the CO_2 calculations here, it is assumed that the congestion factor is 4.0%.

Public transport vehicles, such as city buses, angkots and taxis, however will not be affected by congestion due to prioritization measures in the frame of public transport improvements.

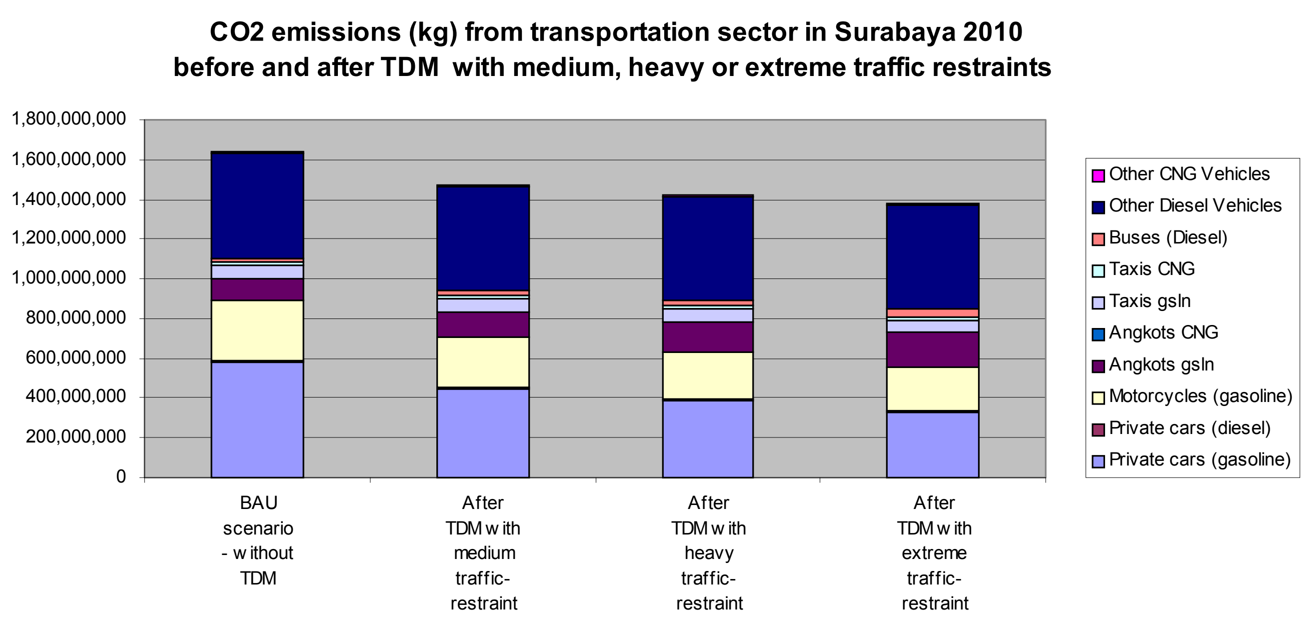
(g) Calculation results: CO_2 emissions by vehicle type 2010

The following table shows the estimated fuel consumption in 2010 for each TDM scenario (higher fuel consumption due to congestion effects already considered):

Fuel Consumption 2010 (in Liters)		BAU scenario - without TDM	After TDM with medium traffic-restraint	After TDM with heavy traffic-restraint	After TDM with extreme traffic-restraint
Private cars (gasoline)		249,141,690	191,126,595	166,342,431	141,558,267
Private cars (diesel)		4,692,402	3,900,543	3,394,743	2,888,944
Motorcycles (gasoline)		126,908,673	106,998,320	100,277,038	93,555,755
Public transport	Angkots gsln	49,757,184	56,354,160	65,474,310	74,594,460
	Angkots CNG	0	0	0	0
	Taxis gsln	27,649,440	27,649,440	27,649,440	27,649,440
	Taxis CNG	8,811,360	8,811,360	8,811,360	8,811,360
	Buses (Diesel)	7,710,300	9,100,000	11,414,000	13,702,000
Other Diesel Vehicles		199,871,679	199,871,679	199,871,679	199,871,679
Other CNG Vehicles		3,957,516	3,957,516	3,957,516	3,957,516

The following table and diagram summarize the reduction of CO_2 emissions by vehicle type before and after the TDM measures for the three scenarios with medium, heavy and extreme traffic-restraints. The CO_2 emissions were calculated directly from the fuel consumption using the fuel-specific conversion factors.

CO2 emissions 2010 (in kg)		BAU scenario - without TDM	After TDM with medium traffic-restraint	After TDM with heavy traffic-restraint	After TDM with extreme traffic-restraint
Private cars (gasoline)		580,500,137	445,324,967	387,577,865	329,830,763
Private cars (diesel)		12,294,092	10,219,422	8,894,228	7,569,034
Motorcycles (gasoline)		295,697,208	249,306,086	233,645,498	217,984,910
Public transport	Angkots gsln	115,934,239	131,305,193	152,555,143	173,805,092
	Angkots CNG	0	0	0	0
	Taxis gsln	64,423,195	64,423,195	64,423,195	64,423,195
	Taxis CNG	16,565,357	16,565,357	16,565,357	16,565,357
	Buses (Diesel)	20,200,986	23,842,000	29,904,680	35,899,240
Other Diesel Vehicles		523,663,799	523,663,799	523,663,799	523,663,799
Other CNG Vehicles		7,440,130	7,440,130	7,440,130	7,440,130
	Total	1,636,719,144	1,472,090,150	1,424,669,895	1,377,181,520



The calculated CO_2 emissions reduction through TDM measures would decrease from approximately 1,637 kilotons by 10%, 13% or 16%, respectively, depending on the intensity of the traffic restraints measures (medium, heavy or extreme).

4.6 IMPROVEMENTS FOR NON-MOTORIZED TRANSPORT

In the following calculations, the CO_2 emissions reduction potential of measures towards improvement of Non-Motorized Transport (NMT) is estimated. The improvements of NMT would encourage emissions-free transport modes for trips conducted on foot, by bike or by becak (rickshaw). The emission reduction effects can be achieved through substitution of motorized trips by non-motorized trips. Since NMT trips are, by nature, mostly conducted for short distances, it is highly expected that non-motorized ones will substitute only short-distance motorized trips. Therefore it is assumed that this substitution effect only applies to short-distance motorized trips, which here are defined as trips with an average length of 3 km. In reality, NMT improvements that mainly aim at short distance trips, do encourage longer non-motorized trips, too. But the effects on the longer trips are very limited, because most of the times they are significantly lower than the impacts affecting the short trips.

Furthermore, not all short motorized trips would be affected by NMT improvements. Short motorized trips, which are actually within reasonable distance to be conducted by NMT means, are currently conducted by motorized means due to impossibility, high insecurity or high level of detour, e.g. caused by lack of sidewalk or crossing facilities. This sort of trips are more likely to be substituted by non-motorized trips, than those motorized short trips, that are conducted mainly because of convenience reasons. Thus, improvements of NMT facilities will have significant effects. Given the poor conditions of NMT facilities, which are to be seen as the major constraint for NMT in Surabaya, and the fact that the urban mixed land-use pattern that is ideal for non-motorized trips, it is believed that the level of substitutable motorized trips is very high. In the center areas of city (e.g. Kedungdoro and Rungkut), is believed that more than 50% of the motorized trips are substitutable. For the purpose of that calculations here, the substitution rate is set lower to 30% citywide, which means that the improvement of NMT facilities would lead that 30% of short-motorized trips to be substituted by non-motorized trips.

Another assumption that is used in the following calculations is that the share of car in the extended modal split (that includes non-motorized trips) of short distance trips is believed to be very low, as indicated by a non-motorized traffic survey conducted by GTZ in cooperation with ITDP/LPIST in 2000. For the purpose of the calculations here, it is assumed that the car share is 1%. If around 30% of these short distance car trips can be substituted by non-motorized trips, then a total of 1,677 kiloliters gasoline and 34 kiloliters diesel can be saved.

The following table shows the modal split of short distance trips (average 3 km) based on the NMT surveys mentioned above. Since the calculation here is conducted on person.trip basis, and not like previous calculations, which were performed on vehicle-trip basis, the specific fuel consumption of angkot and motorcycle needs to be converted from vehicle.trip/liter to person.trip/liter. The specific fuel consumption of angkot is known to be 10 km per liter gasoline, and the specific fuel consumption of motorcycle is assumed to be 25 km per liter gasoline. Assuming the occupancy rate of angkot to be 8 passengers per angkot and the occupancy rate of motorcycle to be 1.1 persons per motorcycle, the calculated specific fuel consumption would be 0.04 liter gasoline per person per trip for angkot and 0.11 liter gasoline per person per trip. The specific fuel consumption of persons traveling by angkot and motorcycle is included in the last row of the table.

Mode	Modalsplit share	Fuel consumption (liter per person.trip)
walk	40%	-
becak	7%	-
bike	3%	-
angkot	17%	0.04
motorcycle	33%	0.11
Car	1%	0.58

Source: GTZ SUTP, Improving Conditions for Non-motorized Transport in Surabaya, 2000

The reduction of the gasoline consumption is calculated from the reduction of the angkot, motorcycle and car trips. In spite of the reduction of 30% person-trips by angkot in the short distance range, it is expected that there would be only a very small reduction of the number of angkot vehicle trips. If this reduction of angkot-passenger trips leads to a reduction of angkot-vehicle trips by 1%, then the total fuel consumption of angkots would decrease by approx. 570 kiloliters, to 56,959 kiloliters.

Furthermore, if one assumes that 30% of the total citywide motorcycle trips are short distance trips (in average of 3 km), and that these trips consume 15% of the total gasoline used by motorcycle[6], then the consumption for these short trips currently would amount to approximately 21,791 kiloliters (=15% * 145,277 kiloliters). If 30% of these short distance trips on motorcycle can be eliminated through NMT improvements, then a fuel saving of 6,500 kiloliters per year (= 30% * 15% * 145,277 kiloliters) can be reached.

If the NMT improvements citywide would lead to a reduction of short distance motorized trips by 30% as mentioned above, then it would lead to a following modal split:

Mode	Modalsplit share
walk	50%
becak	14%
bike	11%
angkot	12%
motorcycle	23%
Car	1%

This would reduce the fuel consumption of short trips by motorcycle, angkot and car proportionally by 8,800 kiloliters gasoline and 34 kiloliters diesel, which is in total equal to CO2 emissions of approximately 20 kilotons.

6 According to SITNP study report No. 7 1996, the average lengths of motorcycle trips are between 5 - 7 km depending on the trip purpose. Considering the normal distribution of the number of trips by trip length, it can be assumed that the first shortest 30% of all trips have an average of 3 km. Similar estimation approach it can be assumed that 30% of the shortest trips of all trips consume 15% of the total fuel consumption, and the rest of 70% of longest trips consume 85% of the total fuel consumption.

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